VOLUME ONE

MERRILL'S ATLAS of
RADIOGRAPHIC POSITIONS & RADIOLOGIC PROCEDURES

Tenth Edition

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Mosby
Vinita Merrill
1905-1977

Vinita Merrill had the foresight, talent, and knowledge to write the first edition of this atlas in 1949. The text she wrote became known as Merrill's Atlas in honor of the significant contribution she made to the profession of radiography and in acknowledgment of the benefit of her work to generations of students and practitioners.

Philip Ballinger is now Assistant Professor Emeritus in the Radiologic Technology Division of the School of Allied Medical Professions at The Ohio State University in Columbus, Ohio. In 1995, he retired after a 25-year career as Radiography Program Director at The Ohio State University. He continues to be involved in professional activities, such as speaking engagements at state, national, and international professional meetings. He began working on Merrill's Atlas in its fifth edition, which was published in 1982, and was the sole author for four editions. The tenth edition is Phil's second as co-author of the Atlas.

Eugene Frank recently retired after 31 years from his position as Assistant Professor of Radiology, Mayo Medical School and Director of the Mayo Radiography Program, Mayo Clinic/Foundation in Rochester, Minnesota. He continues to work in radiography education as Director of the Radiography Program at Riverland Community College, Austin, Minnesota. He frequently presents at professional gatherings throughout the world and has held leadership positions in state, national, and international professional organizations. The tenth edition is Gene's second as co-author of the Atlas.
This edition of Merrill's benefits from the expertise of a special advisory board. The following board members have provided professional input and advice and have helped the authors make decisions about atlas content throughout the preparation of the tenth edition:

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Welcome to the Tenth Edition of *Merrill’s Atlas of Radiographic Positions and Radiologic Procedures*. The tenth edition continues the tradition of excellence begun in 1949, when Vinita Merrill wrote the first edition of what has become a classic text. Over the last 55 years, *Merrill’s Atlas* has provided a strong foundation in anatomy and positioning for thousands of students who have gone on to successful careers as imaging technologists. *Merrill’s Atlas* is also a mainstay for everyday reference in imaging departments all over the world. As the co-authors of this Tenth Edition, we are honored to follow in Vinita Merrill’s footsteps.

**Learning and Perfecting Positioning Skills**

*Merrill’s Atlas* has an established tradition of helping students learn and perfect their positioning skills. After covering preliminary steps in radiography, radiation protection, and terminology in introductory chapters, *Merrill’s* then teaches anatomy and positioning in separate chapters for each bone group or organ system. The student learns to position the patient properly so that the resulting radiograph provides the information the physician needs to correctly diagnose the patient’s problem. The atlas presents this information for commonly requested projections, as well as those less commonly requested, making it the most comprehensive text and reference available.

The third volume of the atlas provides basic information about a variety of special imaging modalities, such as mobile, surgical, geriatrics, computed tomography, cardiac catheterization, magnetic resonance imaging, ultrasound, nuclear medicine technology, and radiation therapy. *Merrill’s Atlas* is not only a sound resource for students to learn from but also an indispensable reference as they move into the clinical environment and ultimately into their practice as imaging professionals.

**NEW ORTHOPEDIC PROJECTIONS**

New projections now commonly performed in imaging departments are presented for the first time in this edition. The new projections are the Folio Method of demonstrating the first metacarpophalangeal joint, the Apple Method of demonstrating loss of articular cartilage in the scapulohumeral joint, the Garth Method of imaging the shoulder for dislocations, bilateral standing AP ankles for joint evaluation, and a full description of the Judet Method of demonstrating the acetabulum for fractures.

**NEW SUMMARY OF PATHOLOGY**

New to this edition is a summary in each chapter of the primary pathology seen in the anatomical areas described in the chapter. These summaries serve as a study guide for students.

**NEW EXPOSURE TECHNIQUE CHARTS**

Each chapter contains a new exposure technique chart. The chart shows a sample technique for each essential projection described in the chapter. The kVp, mA, time, distance, AEC photocell, image receptor size, and dose are given. This new addition will help students learn the different exposure techniques required for each projection and appreciate the dose required for the projection.

**NEW CHAPTERS AND CONTENT**

An all new, well-illustrated chapter on trauma radiography (Chapter 13) provides the theoretic basis and the procedural information needed to perform the most common trauma projections. The chapter provides a description, positioning photo, and an actual trauma radiograph for the 13 most common trauma projections of the head, neck, thorax, abdomen, pelvis, and several limb projections.
Also new to this edition is a chapter on geriatric radiography (Chapter 29), which discusses all aspects of performing radiographic procedures on the elderly. As the age of the population increases, so does the number of imaging procedures performed on the elderly. A unique feature of this chapter is a section on the physiology of aging and its effects on the organ systems.

Another entirely new chapter on surgical radiography (Chapter 31) describes the most frequently performed procedures done in the surgical suite. The chapter includes an extensive introduction to surgical procedures and detailed instructions on how to perform the procedures. Specific descriptions of the 10 most common procedures done using the mobile C-arm fluoror unit, and the many procedures done using the mobile radiographic unit are described. A special feature of the chapter is a photograph of the procedure during an actual surgical procedure along with the actual surgical radiograph.

NEW METRIC FILM SIZES
Because most radiographic film can no longer be purchased in English sizes, metric measurements are now used to state most film sizes. For the past eight years both the English and metric film sizes have been stated in the atlas. Beginning with this edition all film sizes are now stated in metric. The only exceptions are for those few sizes that continue to be used in English. For those, both the English and metric in parentheses continue to be used.

NEW RADIOGRAPHIC MARKERS
The essential radiographs in each chapter now contain right (R) and/or left (L) markers correctly positioned on the radiographs. Students can more easily learn the correct placement of markers by studying the position of the R or L marker on the radiograph. Special projections such as bilateral body parts and decubitus positions also contain correct marker placement.

COMPUTED RADIOGRAPHY
Because of the rapid expansion and acceptance of computed radiography (CR), either selected positioning considerations and modifications or special instructions are indicated where necessary. A new icon $\hspace{1em}$ alerts the reader to CR notes. In addition, an updated chapter on CR (Chapter 34) assists the reader in understanding the principles.

ESSENTIAL PROJECTIONS
Essential projections are identified with the special icon shown here: $\hspace{1em}$

One new projection has been designated essential for this edition and that is the tangential projection of the intertubercular groove and the Fisk Modification of the projection. Essential projections are those most frequently performed and determined to be necessary for competency of entry-level practitioners. Of the over 400 projections described in this atlas, 191 have been identified as essential based on the results of two extensive surveys performed in the United States and Canada.1

OBSELETE PROJECTIONS DELETED
Projections identified as obsolete by the authors and the advisory board have been deleted. A summary is provided at the beginning of any chapter containing deleted projections so that the reader may refer to previous editions for information. Several projections have been deleted in this edition, most of them in the cranial chapters.

CHAPTERS DELETED
The chapters on Computer Fundamentals and Introduction to Quality Assurance have been deleted with this edition. Merrill's is primarily an anatomy, positioning, and radiographic projections and procedures text. The authors and the Advisory Board determined that these chapters are more appropriate for physics and imaging textbooks. Removing these physics-related chapters allowed room for the new clinically oriented surgical, trauma, and geriatrics radiology chapters.

Learning Aids for the Student
POCKET GUIDE TO RADIOGRAPHY
A new edition of Pocket Guide to Radiography complements the revision of Merrill’s Atlas. New to this edition is the addition of radiographs. In addition to instructions for positioning the patient and the body part for all the essential projections, the new pocket guide includes information on computed radiography (CR) and automatic exposure control (AEC). Space is provided for writing department techniques specific to the user.


RADIOGRAPHIC ANATOMY, POSITIONING, AND PROCEDURES WORKBOOK BY STEVEN G. HAYES, SR.

The new edition of this two-volume workbook retains most of the features of the previous editions: anatomy labeling exercises, positioning exercises, self-tests, and an answer key. The exercises include labeling of anatomy on drawings and radiographs, crossword puzzles, matching, short answers, and true/false. At the end of each chapter is a multiple-choice test to help students assess their comprehension of the whole chapter. New to this edition are more image evaluations to give students additional opportunities to evaluate radiographs for proper positioning and more positioning questions to complement the workbook’s strong anatomy review.

Teaching Aids for the Instructor
INSTRUCTOR’S CURRICULUM RESOURCE
This comprehensive resource provides valuable tools, such as teaching strategies and an electronic test bank, for teaching an anatomy and positioning class. The test bank includes 1400 questions, each coded by category and level of difficulty. Four exams are already compiled within the test bank to be used “as is” at the instructor’s discretion. The instructor also has the option of building new tests as often as desired by pulling questions from the pool or using a combination of questions from the test bank and questions that the instructor adds.

ELECTRONIC IMAGE COLLECTION
All the images, photographs, and line illustrations in Merrill’s Atlas are available on the Electronic Image Collection on CD-ROM.

More information about the Instructor’s Curriculum Resource and the Electronic Image Collection is available from an Elsevier sales representative.

EVOVE—ONLINE COURSE MANAGEMENT
Evolve is an interactive learning environment designed to work in coordination with Merrill’s Atlas. Instructors may use Evolve to provide an Internet-based course component that reinforces and expands on the concepts delivered in class.
Evolve may be used to publish the class syllabus, outlines, and lecture notes; set up "virtual office hours" and e-mail communication; share important dates and information through the online class Calendar; and encourage student participation through Chat Rooms and Discussion Boards. Evolve allows instructors to post exams and manage their grade books online. For more information, visit http://www.evolve.elsevier.com, or contact an Elsevier sales representative.

We hope you will find this edition of Merrill's Atlas of Radiographic Positions and Radiologic Procedures the best ever. Input from generations of readers has helped to keep the Atlas strong through nine editions, and we welcome your comments and suggestions. We are constantly striving to build on Vinita Merrill's work, and we trust that she would be proud and pleased to know that the work she began 55 years ago is still so appreciated and valued by the imaging sciences community.

Philip W. Ballinger
Eugene D. Frank
Advisory Board

In preparing for the tenth edition, our advisory board continually provided professional expertise and aid in decision making on the revision of this edition. The advisory board members are listed on page VI. We are most grateful for their input and contributions to this edition of the atlas.

Pathology Summary Research

The design and content of the new pathology summaries seen in each procedural chapter were completed by Rob Hughes, MSRS, RT(R). Mr. Hughes performed this work as a part of his Master's degree practicum for Midwestern State University, Wichita Falls, TX, Master's in Radiography program.

New Projections Research

The five new projections introduced for the first time in any radiography textbook were written by Catherine E. Hearty, MSRS, RT(R). Ms. Hearty performed this work as a part of her Master's degree practicum for Midwestern State University, Wichita Falls, TX, Master's in Radiography program.

Trauma Chapter Research

Research on the common trauma projections performed in the United States was completed by Thomas Wolfe, MSRS, RT(R). Mr. Wolfe performed this work as a part of his Master's degree practicum for Midwestern State University, Wichita Falls, TX, Master's in Radiography program.

Projections Research

Many of the existing projections in this edition of the atlas were carefully reviewed, edited, and simplified by Laura Carwile, MSRS, RT(R)(M)(QM). The more simplified descriptions of many projections enable students and practitioners to more easily understand how to perform the projection.

Reviewers

The group of radiography professionals listed below extensively reviewed this edition of the atlas and made many insightful suggestions for strengthening the atlas. We are most appreciative of their willingness to lend their expertise.

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P.W.B. and E.D.F.

Special Acknowledgments, P.W.B

The past twenty plus years have been some trip! Little did I know what was ahead when Mr. Don Ladig, then an Executive Editor at Mosby, contacted me and asked if I would be interested in doing a “little writing” following Miss Vinita Merrill’s death in 1977. Well, that “little writing” took far more time and effort than ever imagined. During the six editions in which I directed or participated, all photographic model illustrations were replaced, hundreds of radiographic images added, anatomic structures labeled, evaluation criteria added, changed from verse to bulleted statement format, full color illustrations added, plus numerous other changes. Many new chapters were added, and others deleted as our technology has evolved since the addition of the computer to radiology.

In my years of active involvement in revising six editions of this Atlas, I would be remiss not to again thank those who have helped me accomplish the major revisions commencing with the fifth edition. I thank Nina Kowalczyk, MS, RT(R), Alan J. Orth, BS, RT(R), and Elyse T. Massey, MS, RT(R) for their dedication and long hours. There were numerous times when we all asked why we were putting in such long hours, but the end product of an updated fifth edition of this Atlas was a goal for all of us. It was truly a team effort, and a great team of professionals. Many others helped, such as the photographers, models, and numerous reviewers. These individuals were thanked in the previous editions.

In preparing this tenth edition, I often called upon numerous individuals for an opinion regarding specific content areas. I often called upon, and obtained considerable support and constructive comments from Randall D. Dings, BS, RT(R) of Pima Community College in Tucson, Arizona. Thank you, Randy.
To the entire staff at Mosby Publishing, it has been my pleasure to work with concerned and caring individuals throughout the production of all editions. To Ms. Jeanne Wilke, Executive Editor, Health Professions of now Elsevier Science, thank you, Jeanne, for all of your support and understanding over the years. Appreciation is also extended to developmental editors Jennifer Genett Moorhead and Carolyn Kruse and project manager Melissa Lastarria for their work on this tenth edition.

To my step-mother, Ms. Ruth Hathaway, thank you and your family for welcoming our family into yours. I regret Dad is not with us to see this edition in print for he was always supportive and caring. To my parents, Mrs. Mildred Ballinger and my father, the very late Dwight W. Ballinger, your loving care and affection have always shown. Your support in the early days was always there, and thank you both for encouraging me to go back and get my college degree in the 1960's when the two-year hospital certificate program was about the only type of educational program available for the then "x-ray technologist." You were always there to support me and provide encouragement. I will always appreciate that support and love. To my sister, Ms. Sandra Jameson and her husband Tom, thank you for being there. You always gave me somebody to pick on!

To my son Eric, I have enjoyed our time together while you were growing up and now that you are a mature health care professional. I also appreciate your active involvement in the church and Habitat for Humanity. The use of your vacation time to serve as camp nurse also attests to your care and love for your patients. To my daughter, Monica and her husband Andy, we are proud of your accomplishments in life and wish you well in your careers and in turning your new house into a home. You already have the start for a loving and caring relationship. Your adopted puppies are bringing joy and fun to us all.

To my wife, Nancy, I was always calling you for something or I was asking you to run through some statements to ensure they were clear. Thank you, also, for your routine taxi service of driving me to and from the airport to go to some professional meeting. I recall one month I was in Ohio for only four days: I would come home, unpack, re-pack, and head back on the road. I enjoy the time since I now am "retired" because I have more time to travel. Thank you for being there with the children while they were growing up and I was too often out attending some other state's professional meeting. Yes, when home, we tried to attend band rehearsals, gymnastics meets, and the other parental activities. Thank you for always being there when I was working or out of town. I do love you and appreciate all of your support over these last 20+ years of living with "the book."

I am very grateful to have served for over twenty years as author of Merrill's Atlas. For six editions, I have directed the revision process, and I am very proud of the work of all the contributors and of my work. I am gratified by the recognition that the atlas has received from educators, practitioners, and especially students over so many years. As Gene Frank takes over, I wish him and all future authors of Merrill's the very best!

Philip W. Ballinger
9/2/2002

Special Acknowledgments, E.D.F.

Preparation of a comprehensive textbook such as Merrill's Atlas requires the support of numerous individuals. Phil Ballinger, MS, RT(R) FAERS, provided expert guidance for me throughout the revision process.

It is with great pleasure that I acknowledge the significant contributions of the following individuals. Lorrie L. Kelley, MS, RT(R)MR(CT), gave us permission to use many MR and CT images from her excellent textbook on cross-sectional anatomy.

Steven G. Hayes, MEd, RT(R), author of the accompanying workbook, played a significant role in suggesting items for revision and helping to standardize various aspects of the atlas.

I am greatly indebted to the Advisory Board members, Joyce Ortego, MS, RT(R), Valerie Palm RT(R), ACR, ID, Roger A. Preston, BS, RT(R), Mary Hagler, EdD, RT(R)TN, and Bettye Wilson, MA, RT(R)CT, RDMS, who assisted in the major decisions regarding new text, illustrations, critical editing, and new chapters. They tackled every challenge with enthusiasm and enjoyed every challenging query. Thanks to this highly talented and experienced group of radiography educators, this edition of the atlas is technically the best it can be.

Medical illustrator Jeanne Robertson did an excellent job of producing all the new line drawings in the atlas—a monumental task.

My wife, Jane Frank, and children, Matthew and Jillian Frank, supported and encouraged me as I worked many long hours preparing this edition.

Lastly, I extend special thanks to Jeanne Wilke, Executive Editor, who invited me to co-author the atlas. Once again I enjoyed working with all the associates at Elsevier who helped produce this edition. I continue to feel that whole group at Elsevier is highly dedicated, very professional, and "fun" to work with.

Carolyn Kruse was a pleasure to work with as she guided me through the final submissions and review process. Editorial assistant Paige Mosher was a great help with administrative and permissions tasks. Melissa Lastarria, project manager, did an excellent job of guiding the manuscript and illustrations through the review process in preparation for the printer, as did publishing services manager Trish Tannian, who coordinated the manufacturing. The excellent color and design work of Gail Hudson is evident throughout the atlas. Merrill's along with all the textbooks produced by the Elsevier radiography team are without a doubt the best designed radiography textbooks in the market. Jennifer Moorhead (formerly of Elsevier) played significant roles in producing the tenth edition of the atlas. My continued experience with the entire Elsevier editorial and production team continues to be very enjoyable and rewarding.

Eugene D. Frank
11/1/02

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Sufficient radiographic density is needed to make a diagnosis. **A,** Radiograph of the knee with insufficient density. It is too light to make a diagnosis and a repeat radiograph is needed. **B,** Radiograph of the knee with proper density. All bony aspects of the knee are seen, including soft tissue detail around the bone. **C,** Radiograph of the knee with too much density—diagnosis could not be made and a repeat radiograph is needed.

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**PRELIMINARY STEPS IN RADIOGRAPHY**

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Ethics on Radiologic Technology

Ethics is the term applied to a health professional’s moral responsibility and the science of appropriate conduct toward others. The work of the medical professional requires strict rules of conduct. The physician, who is responsible for the welfare of the patient, depends on the absolute honesty and integrity of all health care professionals to carry out orders and report mistakes.

The American Society of Radiologic Technologists (ASRT) developed the current code of ethics. The Canadian Association of Medical Radiation Technologists (CAMRT) has also adopted a similar code of ethics. All radiographers should familiarize themselves with these codes.

ASRT CODE OF ETHICS

1. The radiologic technologist conducts himself or herself in a professional manner, responds to patient needs, and supports colleagues and associates in providing quality patient care.

2. The radiologic technologist acts to advance the principal objective of the profession to provide services to humanity with full respect for the dignity of mankind.

3. The radiologic technologist delivers patient care and service unrestricted by concerns of personal attributes or the nature of the disease or illness, and without discrimination, regardless of gender, race, creed, religion, or socioeconomic status.

4. The radiologic technologist practices technology founded on theoretic knowledge and concepts, utilizes equipment and accessories consistent with the purpose for which they have been designed, and employs procedures and techniques appropriately.

5. The radiologic technologist assesses situations: exercises care, discretion, and judgment; assumes responsibility for professional decisions; and acts in the best interest of the patient.

6. The radiologic technologist acts as an agent through observation and communication to obtain pertinent information for the physician to aid in the diagnosis and treatment management of the patient, and recognizes that interpretation and diagnosis are outside the scope of practice for the profession.

7. The radiologic technologist utilizes equipment and accessories, employs techniques and procedures, performs services in accordance with an accepted standard of practice, and demonstrates expertise in minimizing the radiation exposure to the patient, self, and other members of the health care team.

8. The radiologic technologist practices ethical conduct appropriate to the profession and protects the patient’s right to quality radiologic technology care.

9. The radiologic technologist respects confidence entrusted in the course of professional practice, respects the patient’s right to privacy, and reveals confidential information only as required by law or to protect the welfare of the individual or the community.

10. The radiologic technologist continually strives to improve knowledge and skills by participating in educational and professional activities, sharing knowledge with colleagues, and investigating new and innovative aspects of professional practice. One means available to improve knowledge and skills is through professional continuing education.

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2 CAMRT. Personal communication. Apr 1997.
CAMRT CODE OF ETHICS
The CAMRT recognizes its obligation to identify and promote professional standards of conduct and performance. The execution of such standards is the personal responsibility of each member.

The code of ethics, adopted in June 1991, requires every member to do the following:

• Provide service with dignity and respect to all people regardless of race, national or ethnic origin, color, gender, religion, age, type of illness, mental, or physical challenges.

• Encourage the trust and confidence of the public through high standards of professional competence, conduct, and appearance.

• Conduct all technical procedures with due regard to current radiation safety standards.

• Practice only those procedures for which the necessary qualifications are held unless such procedures have been properly delegated by an appropriate medical authority and for which the technologist has received adequate training to an acceptable level of competence.

• Practice only those disciplines of medical radiation technology for which he or she has been certified by the CAMRT and is currently competent.

• Be mindful that patients must seek diagnostic information from their treating physician. In those instances where a discreet comment to the appropriate authority may assist diagnosis or treatment, the technologist may feel morally obliged to provide one.

• Preserve and protect the confidentiality of any information, either medical or personal, acquired through professional contact with the patient. An exception may be appropriate when the disclosure of such information is necessary to the treatment of the patient, the safety of other patients and health care providers, or is a legal requirement.

• Cooperate with other health care providers.

• Advance the art and science of medical radiation technology through ongoing professional development.

• Recognize that the participation and support of our association is a professional responsibility.

Image Receptor
In radiography the image receptor (IR) is the device that receives the energy of the x-ray beam and forms the image of the body part. In diagnostic radiology, the IR will be one of the following four devices:

1. Cassette with film—A device that contains special screens that glow when struck by x-rays and imprints the x-ray image on film. The use of a darkroom is required where the film is developed in a processor. Afterward the radiographic film image is ready for viewing on an illuminator (Fig. 1-1, A).

2. Image plate (IP)—A device similar to a cassette that contains special phosphorus that store the x-ray image. The IP is inserted into a reader device, which does not require a darkroom. The radiographic image is then converted to digital format and is viewed on a computer monitor or printed out on film (Fig. 1-1, B).

3. Direct radiography (DR)—Does not use a cassette or an IP. A flat panel detector built into the x-ray table or device captures the x-ray image and converts it into digital format. The image is then viewed on a computer monitor or printed out on film (Fig. 1-1, C).

4. Fluoroscopic screen—The x-rays strike a fluoroscopic screen where the image is formed and the body part is transmitted to a television monitor via a camera. This is a “real-time” device in which the body part is viewed live on a television (Fig. 1-1, D).
Radiograph

Each step in performing a radiographic procedure must be completed accurately to ensure that the maximal amount of information is recorded on the image. The information that results from performing the radiographic examination generally demonstrates the presence or absence of abnormality or trauma. This information assists in the diagnosis and treatment of the patient. Accuracy and attention to detail are essential in every radiologic examination.

The radiographer must be thoroughly familiar with the radiographic densities cast by normal anatomy structures. To develop the ability to analyze radiographs properly and to correct or prevent errors in performing the examination, the radiographer should study radiographs from the following standpoints:

1. Superimposition—The relationship of the anatomic superimposition to size, shape, position, and angulation must be reviewed.

2. Adjacent structures—Each anatomic structure must be compared with that of adjacent structures and reviewed to ensure that the structure is present and properly shown.

3. Optical density (OD)—Also known as the degree of film blackening, the optical density of the radiograph must be within a diagnostic range. If a radiograph is too light or dark, an accurate diagnosis becomes difficult or impossible (Fig. 1-2). If a change in technique is necessary, each of the following primary factors controlling density must be considered:
   - Milliamperage (mA)
   - Exposure time (second)
   - Milliampere-second (mAs)

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Fig. 1-1 Image receptors. A, Conventional radiographic cassette, opened and showing a sheet of x-ray film. B, Imaging plate. Contains a phosphor that stores the x-ray image. C, Direct radiography chest x-ray machine. A flat panel detector is located behind the unit (arrow) and stores the x-ray image. D, Fluoroscopic screen located under the fluoroscopic tower (arrow) transmits the x-ray image to a camera and then to a television for "real-time" viewing.
4. Contrast—The contrast, or the difference in density between any two areas on a radiograph, must be sufficient to allow radiographic distinction of adjacent structures with different tissue densities. A wide range of contrast levels is produced among the variety of radiographic examinations performed (Fig. 1-3). A low-contrast image displays many density levels, and a high-contrast image displays few density levels. The primary controlling factor of radiographic contrast is kilovoltage peak (kVp).

5. Recorded detail—The recorded detail, or the ability to visualize small structures, must be sufficient to clearly demonstrate the desired anatomic part (Fig. 1-4). Recorded detail is primarily controlled by the following:

- Geometry
- Film
- Distance
- Screen
- Focal spot size
- Motion

Fig. 1-2 Sufficient radiographic density is needed to make a diagnosis. A, Radiograph of the knee with insufficient density. It is too light to make a diagnosis and a repeat radiograph is needed. B, Radiograph of the knee with proper density. All bony aspects of the knee are seen, including soft tissue detail around the bone. C, Radiograph of the knee with too much density. Diagnosis could not be made and a repeat radiograph is needed.
6. Magnification—The magnification of the body part must be evaluated, taking into account the controlling factors of object-to-image receptor distance (OID), or how far the body part is from the IR, and source-to-image receptor distance (SID), or how far the x-ray tube is from the IR. All radiographs yield some degree of magnification because all body parts are three dimensional.

7. Shape Distortion—The shape distortion of the body part must be analyzed, and the following primary controlling factors must be studied:
- Alignment
- Central ray
- Anatomic part
- IR
- Angulation

An example of shape distortion is when a bone is projected longer or shorter than it actually is. Distortion is the misrepresentation of the size or shape of any anatomic structure.

A strong knowledge of anatomy and the ability to analyze radiographs correctly are paramount—especially to radiographers who work without a radiologist in constant attendance. In this situation the patient’s physician must be able to depend on the radiographer to perform the technical phase of examinations without assistance.

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Fig. 1-3: Sufficient contrast is needed to make a diagnosis. Two different scales of contrast are shown on the elbow. A, Long scale (low contrast). B, Short scale (high contrast).

Fig. 1-4: Different levels of recorded detail. A, Excellent recorded detail is seen throughout this radiograph of the arteries in the head. B, Poor recorded detail. Note the fuzzy edges of the arteries and bony structures in this image (arrows).
DISPLAY OF RADIOGRAPHS
Radiographs are generally displayed according to the preference of the interpreting physician. Because methods of displaying radiographic images have developed largely through custom, no fixed rules have been established. However, the radiologist, who is responsible for making a diagnosis based on the radiographic examination, and the radiographer, who performs the examination, follow traditional standards of practice regarding the placement of radiographs on the viewing device. In clinical practice, the viewing device is commonly called a viewbox, or illuminator.

ANATOMIC POSITION
Radiographs are usually placed on the illuminator and oriented so that the person looking at the image sees the body part placed in the anatomic position. The anatomic position refers to the patient standing erect with the face and eyes directed forward, arms extended by the sides with the palms of the hands facing forward, heels together, and toes pointing anteriorly (Fig. 1-5). When the radiograph is displayed in this manner, the patient’s left side is on the viewer’s right side and vice versa (Fig. 1-6). Professionals in medicine always describe the body, a body part, or a body movement as though it were in the anatomic position.

Fig. 1-5 Patient in the anatomic position. Many radiographs are placed on the illuminator with the body part matching this position.
Fig. 1-6 A radiologist interpreting a radiograph of a patient’s left shoulder. Note the radiograph is placed on the illuminator with the patient’s left side on the viewer’s right side. The radiologist spatially pictured the patient’s anatomy in the anatomic position and then placed the radiograph on the illuminator in that position.
Posteroanterior and anteroposterior

Fig. 1-7, A, illustrates the anterior (front) aspect of the patient’s chest placed closest to the IR for a posteroanterior (PA) projection. Fig. 1-7, B, illustrates the posterior (back) aspect of the patient’s chest placed closest to the IR for an anteroposterior (AP) projection. Regardless of whether the anterior or posterior body surface is closest to the IR, the radiograph is usually placed in the anatomic position (Fig. 1-8). (Positioning terminology is fully described in Chapter 3.)
Exceptions to these guidelines include the hands, wrists, feet, and toes. Hand and wrist radiographs are routinely displayed with the digits (fingers) pointed to the ceiling. Foot and toe radiographs are also placed on the illuminator with the toes pointing to the ceiling. Hand, wrist, toe, and foot radiographs are viewed from the perspective of the x-ray tube, or exactly as the anatomy was projected onto the IR (Figs. 1-9 and 1-10). This perspective means that the individual looking at the radiograph is in the position of the x-ray tube.

**Lateral radiographs**

Lateral radiographs are obtained with the patient’s right or left side placed against the IR. They are generally placed on the illuminator in the same orientation as if the viewer were looking at the patient from the perspective of the x-ray tube at the side where the x-rays first enter the patient—exactly like radiographs of the hands, wrists, feet, and toes. Another way to describe this is to display the radiograph so that the side of the patient closest to the IR during the procedure is also the side in the image closest to the illuminator. For example, a patient positioned for a left lateral chest radiograph is depicted in Fig. 1-11. The resulting left lateral chest radiograph is placed on the illuminator as shown in Fig. 1-12. A right lateral chest position and its accompanying radiograph would be positioned and displayed the opposite of that shown in Figs. 1-11 and 1-12.

**Fig. 1-9** Proper placement of patient and body part position for a posteroanterior (PA) projection of the left hand.

**Fig. 1-10**

A, Left hand positioned on IR. This view is from the perspective of the x-ray tube.

B, Radiograph of the left hand is placed on the illuminator in the same manner with the digits up.
Fig. 1-11  Proper patient position for a left lateral chest. Note the left side of the patient is placed against the image receptor.

Fig. 1-12  Left lateral chest radiograph placed on the illuminator with the anatomy seen from the perspective of the x-ray tube.
Oblique radiographs

Oblique radiographs are obtained when the patient’s body is rotated so that the projection obtained is not frontal, posterior, or lateral (Fig. 1-13). These radiographs are viewed with the patient’s anatomy placed in the anatomic position (Fig. 1-14).

Other radiographs

Many other less commonly performed radiographic projections are described throughout this book. The most common method of displaying the radiograph that is used in the radiology department and most clinical practice areas is generally either in the anatomic position or from the perspective of the x-ray tube; however, exceptions do occur. Some physicians prefer to view all radiographs from the perspective of the x-ray tube rather than in the anatomic position. A neurosurgeon, for example, operates on the posterior aspect of the body and therefore does not display spine radiographs in the anatomic position or from the perspective of the x-ray tube. The radiographs are displayed with the patient’s right side on the surgeon’s right side as though looking at the posterior aspect of the patient. What the surgeon sees on the radiograph is exactly what is seen in the open body part during the surgery.
Clinical History

The radiographer is responsible for performing radiographic examinations according to the standard department procedure except when contraindicated by the patient’s condition. The radiologist is a physician who is board certified to read, or interpret, x-ray examinations. As the demand for the radiologist’s time increases, less time is available to devote to the technical aspects of radiology. This situation makes the radiologist more dependent on the radiographer to perform the technical aspects of patient care. The additional responsibility makes it necessary for the radiographer to know the following:

- Normal anatomy and normal anatomic variations so that the patient can be accurately positioned
- The radiographic characteristics of numerous common abnormalities

Although the radiographer is not responsible for explaining the cause, diagnosis, or treatment of the disease, the radiographer’s professional responsibility is to produce an image that makes the abnormality evident.

When the physician does not see the patient, the radiographer is responsible for obtaining the necessary clinical history and observing any apparent abnormality that might affect the radiographic result. Examples include noting jaundice in gallbladder examinations, body surface masses possibly casting a density that could be mistaken for internal changes, tattoos that contain ferrous pigment, surface scars that may be visible radiographically, and some decorative or ornamental tee shirts. The physician should give specific instructions about what information is needed if the radiographer assumes this responsibility.

The requisition received by the radiographer should clearly identify the exact region to be radiographed and the suspected or existing diagnosis. The patient must be positioned and the exposure factors selected according to the region involved and the radiographic characteristics of the existent abnormality. Radiographers must understand the rationale behind the examination; otherwise, radiographs of diagnostic value cannot be produced. Having the information in advance prevents delay, inconvenience, and much more important, the unnecessary radiation exposure to the patient.

Initial Examination

The radiographs obtained for the initial examination of each body part are based on the anatomy or function of the part and the type of abnormality indicated by the clinical history. The radiographs obtained for the initial examination are usually the minimum required to detect any demonstrable abnormality in the region. Supplemental studies for further investigation are then made as needed. This method saves time, eliminates unnecessary radiographs, and reduces patient exposure to radiation.
Diagnosis and the Radiographer

A patient is naturally anxious about examination results and will ask questions. The radiographer should tactfully advise the patient that the referring physician will receive the report as soon as the radiographs have been interpreted by the radiologist. Referring physicians may also ask the radiographer questions, and they should be instructed to contact the interpreting radiologist.

Care of the Radiographic Examining Room

The radiographic examining room should be as scrupulously clean as any other room used for medical purposes. The mechanical parts of the x-ray machine such as the tablesides and the supporting structure and the collimator should be wiped with a clean, damp (not soaked) cloth every day. The metal parts of the machine should be periodically cleaned with a disinfectant. The overhead system, x-ray tube, and other parts that conduct electricity should be cleaned with alcohol or a clean, dry cloth. Water is never used to clean electrical parts.

The tabletop should be cleaned after each examination. Cones, collimators, compression devices, gonad shields, and other accessories should be cleaned daily and after any contact with a patient. Adhesive tape residue left on cassettes and cassette stands should be removed and the cassette disinfected. Cassettes should be protected from patients who are bleeding, and disposable protective covers should be manipulated so that they do not come in contact with ulcers or other discharging lesions. Use of stained or damaged cassettes is inexcusable and does not represent a professional atmosphere.

The radiographic room should be prepared for the examination before the patient arrives. The room should look clean and organized—not disarranged from the previous examination (Fig. 1-15). Fresh linen should be put on the table and pillow, and accessories needed during the examination should be placed nearby. Performing these preexamination steps requires only a few minutes but creates a positive, lasting impression on the patient; however, not performing these steps beforehand leaves a negative impression.

Fig. 1-15 A, The radiographic room should always be clean and straightened before beginning any examination begins. B, This room is not ready to receive a patient. Note devices stored on the floor and previous patient's gowns and towels laying on the table. Room does not present a welcoming sight for a patient.


**Standard Precautions**

Radiographers are engaged in caring for sick people and therefore should be thoroughly familiar with *standard precautions*. They should know the way to handle patients who are on isolation status without contaminating their hands, clothing, or apparatus, and radiographers must know the method of disinfecting these items when they become contaminated.

Hand washing is the easiest and most convenient method of preventing the spread of microorganisms (Fig. 1-16, A). Radiographers should wash their hands before and after each patient. Hands must always be washed, without exception, in the following specific situations:
- After examining patients with known communicable diseases
- After coming in contact with blood or body fluids
- Before beginning invasive procedures
- Before touching patients who are at risk of infections

As one of the first steps in aseptic technique, radiographers' hands should be kept smooth and free from roughness or chapping by the frequent use of soothing lotions. All abrasions should be protected by bandages to prevent the entrance of bacteria.

For the protection of radiographers' and patients' health, the laws of asepsis and prophylaxis must be obeyed. Radiographers should practice scrupulous cleanliness when handling all patients, whether the patients are known to have an infectious disease or not. If a radiographer is to examine the patient's head, face, or teeth, the patient should ideally see the radiographer perform hand washing. If this is not possible, the radiographer should perform hand washing and then enter the room drying the hands with a fresh towel. If the patient's face is to come in contact with the IR front or table, the patient should see the radiographer clean the device with a disinfectant or cover it with a clean drape.

A sufficient supply of gowns and disposable gloves should be kept in the radiographic room to be used to care for infectious patients. After examining infectious patients, radiographers must wash their hands in warm, running water and soapsuds and rinse and dry them thoroughly. If the sink is not equipped with a knee control for the water supply, the radiographer opens the valve of the faucet with a paper towel. After proper hand washing, the radiographer closes the valve of the faucet with a paper towel.

A folded sheet should be placed over the end of the stretcher or table to protect the IRs when a non-Bucky technique is used. The IR is then placed between the clean fold of the sheet, and with the hands between the clean fold, the radiographer can position the patient through the sheet. If the radiographer must handle the patient directly, an assistant should position the tube and operate the equipment to prevent contamination. If a patient has any moisture or body fluids on the body surface that could come in contact with the IR, a non-moisture-penetrable material must be used to cover the IR.

When the examination is finished, the contaminated linen should be folded with the clean side out and returned to the patient's room with the patient. There it will receive the special attention given to linen used for isolation unit patients or be disposed of according to the established policy of the institution. All radiographic tables must be cleaned after patients have touched it with their bare skin and after patients with communicable diseases have been on the table (Fig. 1-16, B).
Disinfectants and Antiseptics

Chemical substances that kill pathogenic bacteria are classified as *germicides* and *disinfectants* (e.g., dilute bleach is sometimes used as a disinfectant). Disinfection is the process of killing only those microorganisms that are pathogenic. The objection to the use of many chemical disinfectants is that to be effective, they must be used in solutions so strong that they damage the material being disinfected. Chemical substances that inhibit the growth of without necessarily killing pathogenic microorganisms are called *antiseptics*. Alcohol, which is commonly used for medical or practical asepsis in medical facilities, has antiseptic but not disinfectant properties. Sterilization, which is usually performed by means of heat or chemicals, is the destruction of all microorganisms.

Centers for Disease Control and Prevention

For the protection of health care workers, the Centers for Disease Control and Prevention (CDC)\(^1\) has issued recommendations for handling blood and other body fluids. According to the CDC, all human blood and certain body fluids should be treated as if they contain pathogenic microorganisms (Table 1-1). These precautions should apply to all contacts involving patients. Health care workers should wear gloves whenever they come into contact with blood, mucous membranes, wounds, and any surface or body fluid containing blood. For any procedure in which blood or other body fluids may be sprayed or splashed, the radiographer should wear a mask, protective eyewear (such as eye shields and goggles), and a gown.

Health care workers must be cautious to prevent needle stick injuries. Needles should never be recapped, bent, broken, or clipped. Instead, they should be placed in a puncture-proof container and properly discarded.

\(^1\)www.cdc.gov

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**TABLE 1-1**  
Body fluids that may contain pathogenic microorganisms

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Synovial fluid</th>
<th>Cerebrospinal fluid</th>
<th>Semen fluid</th>
<th>Vaginal fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Any fluid containing blood</td>
<td></td>
<td></td>
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<tr>
<td>Amniotic fluid</td>
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<tr>
<td>Pericardial fluid</td>
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<td></td>
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<tr>
<td>Pleural fluid</td>
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</tbody>
</table>

Operating Room

A radiographer who has not had extensive patient care education must exercise extreme caution to prevent contaminating sterile objects in the operating room. The radiographer should perform hand washing and wear scrub clothing, a scrub cap, and a mask and should survey the particular setup in the operating room before taking in the x-ray equipment. By taking this precaution, the radiographer can ensure that sufficient space is available to do the work without the danger of contamination. If necessary, the radiographer should ask the circulating nurse to move any sterile items. Because of the danger of contamination of the sterile field, sterile supplies, and persons scrubbed for the procedure, the radiographer should never approach the operative side of the surgical table unless directed to do so.

After checking the room setup, the radiographer should thoroughly wipe the x-ray equipment with a damp (not soaked) cloth before taking it into the operating room. The radiographer moves the mobile machine, or C-arm unit, to the free side of the operating table—the side opposite the surgeon, scrub nurse, and sterile layout. The machine should be maneuvered into a general position that will make the final adjustments easy when the surgeon is ready to proceed with the examination.

The IR is placed in a sterile covering, depending on the type of examination to be performed. The surgeon or one of the assistants holds the sterile case open while the radiographer gently drops the IR into it while being careful not to touch the sterile case. The radiographer may then give directions for positioning and securing the cassette for the exposure.
The radiographer should make the necessary arrangements with the operating room supervisor when performing work that requires the use of a tunnel or other special equipment. When an IR is being prepared for the patient, any tunnel or grid should be placed on the table with the tray opening to the side of the table opposite the sterile field. With the cooperation of the surgeon and operating room supervisor, a system can be developed for performing radiographic examinations accurately and quickly without moving the patient or endangering the sterile field (Fig. 1-17).

**Minor Surgical Procedures in the Radiology Department**

Procedures that require a rigid aseptic technique, such as cystography, intravenous urography, spinal punctures, angiography, and angiocardiography, are performed in the radiology department (Fig. 1-18). Although the physician needs the assistance of a nurse in certain procedures, the radiographer can make the necessary preparations and provide assistance in many procedures.

For procedures that do not require a nurse, the radiographer should know which surgical instruments and supplies are needed and the way to prepare and sterilize them. Radiographers may make arrangements with the surgical supervisor to acquire the education necessary to perform these procedures.

**Procedure Book**

A procedure or protocol book covering every examination performed in the radiology department is essential. Under the appropriate heading, each procedure should be outlined and state the staff required and duties of each member of the team. A listing of sterile and nonsterile items should also be included. A copy of the sterile instrument requirements should be given to the supervisor of the central sterile supply department to facilitate preparation of the trays for each procedure.

*Fig. 1-17* The radiographer must exercise extreme caution to prevent contaminating sterile objects in the operating room.

*Fig. 1-18* Many radiographic procedures require strict aseptic technique, such as seen in this procedure involving passing a catheter into the patient's femoral artery.
Bowel Preparation
Radiologic examinations involving the abdomen often require that the entire colon be cleansed before the examination so that diagnostic quality radiographs can be obtained. The patient's colon may be cleansed by one or any combination of the following:
• Limited diet
• Laxatives
• Enemas

The technique used to cleanse the patient's colon generally is selected by the medical facility or physician. The patient should be questioned about any bowel preparation that may have been completed before an abdominal procedure is begun. For additional information on bowel preparation, see Chapter 17, Volume 2.

Motion and Its Control
Patient motion plays a large role in radiography (Fig. 1-19). Because motion is the result of muscle action, the radiographer needs to know some information about the functions of various muscles. The radiographer should use this knowledge to eliminate or control motion for the exposure time necessary to complete a satisfactory examination. The three types of muscular tissue that affect motion are the following:
• Smooth (involuntary)
• Cardiac (involuntary)
• Striated (voluntary)

Involuntary muscles are composed of smooth muscular tissue and are controlled partially by the autonomic nervous system and the muscles' inherent characteristics of rhythmic contractility. By their rhythmic contraction and relaxation, these muscles perform the movement of the internal organs. The rhythmic action of the muscular tissue of the alimentary tract, called peristalsis, is normally more active in the stomach (about three or four waves per minute) and gradually diminishes along the intestine. The specialized cardiac muscular tissue functions by contracting the heart to pump blood into the arteries and expanding or relaxing to permit the heart to receive blood from the veins. The pulse rate of the heart varies with emotions, exercise, diet, size, age, and gender.

Involuntary motion is caused by the following:
• Heart pulsation
• Chill
• Peristalsis
• Tremor
• Spasm
• Pain

Fig. 1-19 A, Forearm radiograph of a patient who moved during the exposure. Note the fuzzy appearance of the edges of the bones. B, Radiograph of the patient without motion.
Involuntary muscle control
The primary method of reducing involuntary motion is to control the length of exposure time—the less exposure time to the patient, the better.

VOLUNTARY MUSCLES
The voluntary, or skeletal, muscles are composed of striated muscular tissue and are controlled by the central nervous system. These muscles perform the movements of the body initiated by the individual. In radiography the patient’s body must be positioned in such a way that the skeletal muscles are relaxed. The patient’s comfort level is a good guide to determine the success of the position.

Voluntary motion resulting from lack of control is caused by the following:
- Nervousness
- Discomfort
- Excitability
- Mental illness
- Fear
- Age
- Breathing

Voluntary muscle control
The radiographer can control voluntary patient motion by the following:
- Giving clear instructions
- Providing patient comfort
- Adjusting support devices
- Applying immobilization

Decreasing the length of exposure time is the best way to control voluntary motion that results from mental illness or the age of the patient. Immobilization for limb radiography can often be obtained for the duration of the exposure by having the patient phonate an mmm sound with the mouth closed or an ahhh sound with the mouth open. The radiographer should always be watching the patient during the exposure to ensure that the exposure is made during suspended respiration. Sponges and sandbags are commonly used as immobilization devices (Fig. 1-20).

Patient Instructions
When an examination requires preparation such as in kidney and gastrointestinal examinations, the radiographer must carefully instruct the patient. Although the particular examination or procedure may be repetitive to the radiographer, it is new to the patient. Frequently, what a radiographer interprets as patient stupidity results from lack of sufficiently explicit directions. The radiographer must be sure that the patient understands not only what to do but also why it has to be done. A patient is more likely to follow instructions correctly if the reason for the instructions is clear. If the instructions are complicated, they should be written out and verbally reviewed with the patient if necessary. For example, few patients know the way to give themselves an enema correctly, so the radiographer should question the patient and, when necessary, take the time to explain the correct procedure. This approach often saves film, time, and radiation exposure to the patient.

Fig. 1-20 Positioning sponges and sandbags are commonly used as immobilization devices.
Patient’s Attire, Ornaments, and Surgical Dressings

The patient should be dressed in a gown that allows exposure of limited body regions under examination. A patient is never exposed unnecessarily; a sheet should be used when appropriate. If a region of the body needs to be exposed to complete the examination, only the area under examination should be uncovered while the rest of the patient’s body is completely covered for warmth and privacy. When the radiographer is examining parts that must remain covered, disposable paper gowns or cotton cloth gowns without metal or plastic snaps are preferred (Fig. 1-21). If washable gowns are used, they should not be starched; starch is somewhat radiopaque, which means it cannot be penetrated easily by x-rays. Any folds in the cloth should be straightened to prevent confusing densities on the radiograph. The length of exposure should also be considered. Material that does not cast a density on a heavy exposure, such as that used on an adult abdomen, may show clearly on a light exposure, such as that used on a child’s abdomen.

Any radiopaque object should be removed from the region to be radiographed. Zippers, necklaces, snaps, thick elastic, and buttons should be removed when radiographs of the chest and abdomen are produced (Fig. 1-22). When radiographing the skull, the radiographer must make sure that dentures, removable bridgework, earrings, necklaces, and all hairpins are removed.

When the abdomen, pelvis, or hips of an infant are radiographed, the diaper should be removed. Because some diaper rash ointments are somewhat radiopaque, the area may need to be cleansed before the procedure.

Surgical dressings such as metallic salves and adhesive tape should be examined for radiopaque substances. If permission to remove the dressings has not been obtained or the radiographer does not know the way to remove them and the radiology department physician is not present, the surgeon or nurse should be asked to accompany the patient to the radiology department to remove the dressings. When dressings are removed, the radiographer should always make sure that a cover of sterile gauze adequately protects open wounds.

Fig. 1-21 A, A female patient wearing a disposable paper gown and positioned for a lateral projection of the lumbar spine. Private areas are completely covered. The gown is smoothed around the contour of the body for accurate positioning. B, The same patient wearing a traditional cloth hospital gown. The gown is positioned for maximal privacy.
Handling of Patients

Patients who are coherent and capable of understanding deserve an explanation of the procedure to be performed. Patients should understand exactly what is expected and be made comfortable. If patients are apprehensive about the examination, their fears should be alleviated. However, if the procedure will cause discomfort or be unpleasant, such as with cystoscopy and intravenous injections, the radiographer should calmly and truthfully explain the procedure. Patients should be told that it will cause some discomfort or be unpleasant, but because the procedure is a necessary part of the examination, full cooperation is needed. Patients usually respond favorably if they understand that all steps are being taken to alleviate discomfort.

Because the entire procedure may be a new experience, patients usually respond incorrectly when given more than one instruction at a time. For example, when instructed to get up on the table and lie on the abdomen, patients may get onto the table in the most awkward possible manner and lie on their backs. Instead of asking patients to get onto the table in a specific position, the radiographer should first have patients sit on the table and then give instructions on assuming the desired position. If patients sit on the table first, the position can be assumed with less strain and fewer awkward movements. The radiographer should never rush a patient. If patients feel hurried, they will be nervous and less able to cooperate. When moving and adjusting patients into position, the radiographer should manipulate the patients gently but firmly; a light touch can be as irritating as one that is too firm. Patients should be instructed and allowed to do as much of the moving as possible.

X-ray grids move under the radiographic table, and with floating or moving tabletops, patients may injure their fingers. To reduce the possibility of injury, the radiographer should inform patients to keep their fingers on top of the table at all times. Regardless of the part being examined, the patient’s entire body must be adjusted with resultant motion or rotation to prevent muscle pull in the area of interest. When patients are in an oblique (angled) position, the radiographer should use support devices and adjust the patients to relieve any strain. Immobilization devices and compression bands should be used whenever necessary but not to the point of discomfort. The radiographer should be cautious when releasing a compression band over the abdomen and should perform the procedure slowly.

In making final adjustments on a patient’s position, the radiographer should stand with the eyes in line with the position of the x-ray tube, visualize the internal structures, and adjust the part accordingly. Though there are few rules on positioning patients, many repeat examinations can be eliminated by following these guidelines. (See Chapters 28 and 29 for pediatric and geriatric patient handling instructions.)

Fig. 1-22 A, A necklace was left on for this chest radiograph. B, Keys were left in the pocket of a lightweight hospital robe during the examination of this patient’s pelvis. Both radiographs had to be repeated because the metal objects were not removed before the examination.
ILL OR INJURED PATIENTS

Great care must be exercised in handling trauma patients, particularly those with skull, spinal, and long bone injuries. A physician should perform any necessary manipulation to prevent the possibility of fragment displacement. The positioning technique should be adapted to each patient and necessitate as little movement as possible. If the tube-part-imaging plane relationship is maintained, the resultant projection will be the same regardless of the patient's position.

When a patient who is too sick to move alone must be moved, the following considerations should be kept in mind:

1. Move the patient as little as possible.
2. Never try to lift a helpless patient alone.
3. To prevent straining the back muscles when lifting a heavy patient, flex the knees, straighten the back, and bend from the hips.
4. When a patient's shoulders are lifted, the head should be supported. While holding the head with one hand, slide the opposite arm under the shoulders and grasp the axilla so that the head can rest on the bend of the elbow when the patient is raised.
5. When moving the patient's hips, first flex the patient's knees. In this position, patients may be able to raise themselves. If not, lifting the body when the patient's knees are bent is easier.
6. When helpless patients must be transferred to the radiographic table from a stretcher or bed, they should be moved on a sheet by at least four and preferably six people. The stretcher is placed parallel to and touching the table. Under ideal circumstances, at least three people should be stationed on the side of the stretcher and two on the far side of the radiographic table to grasp the sheet at the shoulder and hip levels. One person should support the patient's head and another the feet. When the signal is given, all six should smoothly and slowly lift and move the patient in unison (Fig. 1-23).

Many hospitals now have a specially equipped radiographic room adjoining the emergency department. These units often have special radiographic equipment and stretchers with radiolucent tops that allow severely injured patients to be examined on the stretcher and in the position in which they arrive. A mobile radiographic machine is often taken into the emergency department and radiographs are exposed there. Where this ideal emergency setup does not exist, trauma patients are often conveyed to the main radiology department. There they must be given precedence over nonemergency patients (see Chapters 13 and 30).

Fig. 1-23 Technique for a six-person transfer on a patient who is unable to move from a cart to the procedure table. Note the person holding and supporting the head.
Identification of Radiographs

All radiographs must include the following information (Fig. 1-24, A):

- Date
- Patient's name or identification number
- Right or left marker
- Institution identity

Correct identification is paramount and should always be confirmed. Identification is vital in comparison studies, on follow-up examinations, and in medicolegal and compensation cases. Radiographers should develop the habit of rechecking the identification marker just before placing it on the film. The CR systems introduced in recent years use a computer in the radiography room. The radiographer inputs the patient’s identification and other data directly on each radiograph via the computer (Fig. 1-24, B and C).

Other patient identification markings may include the patient’s age or date of birth, time of day, and the name of the radiographer or attending physician. For certain examinations, the radiograph should include such markings as cumulative time after introduction of contrast medium (e.g., 5 minute postinjection) and the level of the fulcrum (e.g., 9 cm) in tomography. Other radiographs are marked to indicate the position of the patient (e.g., upright, decubitus) or other markings specified by the institution.

Numerous methods of marking radiographs for identification are available. These methods include radiographing it along with the part, “flashing” it onto the film in the darkroom or examination room before development, writing it on the film after it has been processed, perforating the information on the film, or using the specialty IR-marking systems designed for accurate and efficient operation.
Fig. 1-25 A, AP projection of the abdomen showing a right (R) marker. B, AP projection of the left limb showing the left (L) marker on the outer margin of the image. C, AP projection of the right and left knees on one image showing both the R and L markers. D, AP projection of the chest performed in the left lateral decubitus position showing the R marker on the “upper” portion of the IR.
Anatomic Markers

Every radiograph must include an appropriate marker that clearly identifies the patient's right (R) or left (L) side. Medicolegal requirements mandate that these markers be present. Both radiographers and physicians must see them to determine the correct side of the patient or the correct limb. Markers are typically made of lead and placed directly on the IR. The marker is seen on the image along with the anatomical part (Fig. 1-25). It is unacceptable to hand-write the “R” or “L” on a radiograph after processing. The only exception may be for certain projections performed during surgical procedures. Often, and unfortunately, a radiograph that does not contain an accurate lead marker or patient identification will have to be repeated. Table 1-2 shows the specific rules of marker placement.

TABLE 1-2
Specific marker placement rules

1. For AP and PA projections that include both the R and L sides of the body (head, spine, chest, abdomen, and pelvis), a R marker is typically used.
2. For lateral projections of the head and trunk (head, spine, chest, abdomen, and pelvis), always mark the side closest to the IR. For example, if the left side is closest use a L marker. The marker is typically placed anterior to the anatomy.
3. For oblique projections that include both the R and L sides of the body (spine, chest, and abdomen) the side down, or nearest the IR is typically marked. For example, for a right posterior oblique (RPO) position, mark the R side.
4. For limb projections, use the appropriate R or L marker. The marker must be placed within the edge of the collimated x-ray beam.
5. For limb projections that are done with two images on one IR, only one of the projections needs to be marked.
6. For limb projections where both the R and L sides are imaged side-by-side on one IR (e.g., R and L AP knees), both the R and L markers must be used to clearly identify the two sides.
7. For AP, PA, or oblique chest projections, the marker is placed on the upper-outter corner so the thoracic anatomy is not obscured.
8. For decubitus positions of the chest and abdomen, the R or L marker should always be placed on the side up (opposite the side laid on) and away from the anatomy of interest.

NOTE: No matter which projection is performed, and no matter what position the patient is in, if a R marker is used it must be placed on the ‘right’ side of the patient’s body. If a L marker is used it must be placed on the ‘left’ side of the patient’s body.

Image Receptor Placement

The part to be examined is usually centered to the center point of the IR or to the position where the angulation of the central ray will project it to the center. The IR should be adjusted so that its long axis lies parallel with the long axis of the part being examined. Although a long bone angled across the radiograph does not impair the diagnostic value of the image, such an arrangement can be aesthetically distracting.

Even though the lesion may be known to be at the midbody (central portion) of a long bone, an IR large enough to include at least one joint should be used on all long bone studies. This method is the only means of determining the precise position of the part and localizing the lesion. Many institutions require that both joints be demonstrated when a long bone is initially radiographed. For tall patients, two exposures may be required, one for the long bone and joint closest to the area of concern and a second to demonstrate the joint at the opposite end.
An IR just large enough to cover the region under examination should always be used. In addition to being extravagant, large IRs include extraneous parts that detract from the appearance of the radiograph and, more important, cause unnecessary radiation exposure to the patient.

A standard rule in radiography is to place the object as close to the IR as possible. For example, when obtaining lateral images of the middle and ring fingers, the radiographer increases the OID so that the part lies parallel with the IR. In some situations this rule is modified. Although magnification is greater, less distortion occurs. The radiographer can increase the SID to compensate for the increase in OID, thus reducing magnification. In certain instances, intentional magnification is desirable. It is obtained by positioning and supporting the object between the IR and the focal spot of the tube. This procedure is known as magnification radiography.

For ease of comparison, bilateral examinations of small body parts may be placed on one IR. However, exact duplication of the location of the images on the film is difficult if the IR is not marked accurately. Many IRs have permanent markings on the edges to assist the radiographer in equally spacing multiple images on one IR. Depending on the size and shape of the body part being radiographed, the IR can be divided in half either transversely or longitudinally. In some instances, the IR may be divided into thirds or fourths (Fig. 1-26).

However, body parts must always be identified by right or left side and placed on the IR in the same manner, either facing or backing each other, according to established routines. The radiographer plans the exposures so that the image identification marker will not interfere with the part of interest.
Fig. 1-26 Examples of multiple exposures on one film. A, AP and lateral projections of the ankle radiographically exposed side by side on a 24 x 30 cm film. B, Four projections of the stomach directly imaged on a 35 x 43 cm film.
English-Metric Conversion and Film Sizes

Measures are the standards used to determine size. People in the United States and a few other countries use standards that belong to the customary, or English, system of measurement. Although this system was developed in England, people in nearly all other countries, including England, now use the metric system of measurement.

In the past couple of decades, efforts have been made to convert all English measurements to the world standard metric system. These efforts have not been particularly effective. Nevertheless, total conversion to the metric system most likely will occur in the future.

The following information is provided to assist the radiographer in converting measurements from the English system to the metric system and vice versa:
- 1 inch = 2.54 centimeters (cm)
- 1 cm = 0.3937 inch
- 40 inch SID = 1 meter (m) (approximately)

Radiographic film is manufactured in both English and metric sizes. Most sizes used in the United States have recently been converted to metric. (Table 1-3 lists the most common film sizes used in radiology departments in the United States along with their general usage.) However, 4 of the 11 common sizes continue to be manufactured in an English size. The 24 × 30 cm size has replaced the 10 × 12 inch size. However, the 10 × 12 inch size continues to be manufactured for use in grid cassettes. Very few if any English sizes are used outside the United States. Four of the former English film sizes are no longer manufactured. Several additional film sizes are used routinely in departments outside the United States, including the 30 × 40 cm and 40 × 40 cm sizes.

FILM SIZES IN THIS ATLAS

Film sizes recommended in the Atlas are for adults. These sizes are subject to modification as needed to fit the size of the body part. After eight years of identifying both English and metric film sizes in the atlas, only metric sizes will be used. The only exception is for the films that continue to be manufactured in English sizes.

TABLE 1-3

Most common radiology film sizes used in the United States*

<table>
<thead>
<tr>
<th>Current film sizes</th>
<th>Former film sizes†</th>
<th>Usage†</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 × 24 cm</td>
<td>9 × 9 inches</td>
<td>Mammography</td>
</tr>
<tr>
<td>8 × 10 inches</td>
<td></td>
<td>General examinations</td>
</tr>
<tr>
<td>24 × 24 cm</td>
<td></td>
<td>Fluoroscopic spots</td>
</tr>
<tr>
<td>24 × 30 cm</td>
<td>10 × 12 inches</td>
<td>General examinations and mammography</td>
</tr>
<tr>
<td>18 × 43 cm</td>
<td>7 × 17 inches</td>
<td>General examinations (grid cassettes)</td>
</tr>
<tr>
<td>30 × 35 cm</td>
<td>11 × 14 inches</td>
<td>Forearms, legs</td>
</tr>
<tr>
<td>35 × 35 cm</td>
<td></td>
<td>General examinations</td>
</tr>
<tr>
<td>35 × 43 cm</td>
<td>14 × 17 inches</td>
<td>Fluoroscopic spots</td>
</tr>
<tr>
<td>14 × 36 inches</td>
<td></td>
<td>General examinations</td>
</tr>
<tr>
<td>14 × 51 inches</td>
<td></td>
<td>Upright hip-to-ankle</td>
</tr>
</tbody>
</table>

*In order of the smallest to largest size.
†English sizes no longer in use.
‡Most common uses in the United States. Outside the United States, usage may differ.
Direction of Central Ray

The central or principal beam of rays, simply referred to as the central ray, is always centered to the IR unless receptor displacement is being used. The central ray is angled through the part of interest under the following conditions:

- When overlying or underlying structures must not be superimposed
- When a curved structure such as the sacrum or coccyx must not be stacked on itself
- When projection through angled joints such as the knee joint and lumbosacral junction is needed
- When projection through angled structures must be obtained without foreshortening or elongation, such as with a lateral image of the neck of the femur

The general goal is to place the central ray at right angles to the structure. Accurate positioning of the part and accurate centering of the central ray are of equal importance in obtaining a true structural projection.

Source-to-Image Receptor Distance

SID is the distance from the anode inside the x-ray tube to the IR (Fig. 1-27). SID is an important technical consideration in the production of radiographs of optimal quality. This distance is a critical component of each radiograph because it directly affects magnification of the body part and the recorded detail. The greater the SID, the less the body part is magnified and the greater the recorded detail will be. A SID of 40 inches (102 cm) traditionally has been used for most conventional examinations. In recent years, however, the SID has increased to 48 inches (122 cm) in some departments. Technically, a greater SID requires a longer exposure time because the x-ray tube is farther from the IR. This could prompt motion on the image. However, with the use of faster film-screen systems and the flexibility of technical factors when using CR systems, short exposure times are commonplace with SIDs up to 48 inches (122 cm). A SID must be established for each radiographic projection, and it also must be indicated on the technique chart.


For some radiographic projections an SID less than 40 inches (102 cm) is desirable. For example, in certain skull examinations such as that of the paranasal sinuses, a short SID of 32 to 36 inches (81 to 91 cm) is used to magnify the opposite side of the skull, thereby prompting an increase in the recorded detail of the side being examined.

Conversely, a longer than standard SID is used for some radiographic projections. In chest radiography a 72-inch (183-cm) SID is the minimum distance, and in many departments a distance up to 120 inches (305 cm) is used. These long distances are necessary to ensure that the lungs fit onto the 35-cm width of the IR (via reduced magnification of the body part) and, most importantly, to ensure that the heart is not technically enlarged for diagnoses of cardiac enlargement.

Fig. 1-27 A radiographic tube, patient, and table illustrates the SID and the SSD.
SOURCE-TO-IMAGE RECEPTOR DISTANCE IN THIS ATLAS

When a specific SID is necessary for optimal image quality, it is identified on the specific projection's page. The authors' recommendation for projections is to always use an SID of 48 inches (122 cm) unless otherwise indicated. The sample exposure technique charts in each chapter identify an SID of 48 inches (122 cm).

SOURCE-TO-SKIN DISTANCE

The distance between the radiography tube and the skin of the patient is termed the source-to-skin distance (SSD). See Figure 1-27. This distance affects the dose to the patient and is regulated by the National Council on Radiation Protection (NCRP). The current NCRP regulations state that the SSD shall not be less than 12 inches (30 cm) and should not be less than 15 inches (38 cm).¹


Collimation of X-Ray Beam

The beam of radiation must be narrow enough to irradiate only the area under examination. This restriction of the x-ray beam serves two purposes. First, it minimizes the amount of radiation to the patient and reduces the amount of scatter radiation that can reach the IR. Second, it produces radiographs that demonstrate excellent recorded detail and increased radiographic contrast by reducing scatter radiation, thereby producing a shorter scale of contrast, and preventing secondary radiation from unnecessarily exposing surrounding tissues, with resultant image fogging (Fig. 1-28).

The area of the beam of radiation is reduced to the required size by using an automatic collimator or a specifically shaped diaphragm constructed of lead or other metal with high radiation absorption capability. Because of beam restriction, the peripheral radiation strikes and is absorbed by the collimator metal and only those x-rays in the exit aperture are transmitted to the exposure field. Because their effectiveness depends on their proximity to the x-ray source, extension cones and diaphragms can be attached to the collimator.

Fig. 1-28 Radiographs of the hip joint and acetabulum. A, Collimator inadvertently opened to size 35 x 43 cm. Note that scatter and secondary radiation have reduced the radiographic contrast and a poor-quality image results. B, Collimator set correctly to 18 x 24 cm, improving radiographic contrast and the visibility of detail.
Gonad Shielding

The patient's gonads may be irradiated when radiographic examinations of the abdomen, pelvis, and hip areas are performed. When practical, gonad shielding should always be used to protect the patient. Contact, shadow, and large part area shields are used for radiography examinations (Figs. 1-29 through 1-31). The Center for Devices of Radiological Health has developed guidelines recommending gonad shielding in the following instances:

- If the gonads lie within or close to the primary x-ray field (about 5 cm from) despite proper beam limitation
- If the clinical objective of the examination is not compromised
- If the patient has a reasonable reproductive potential

In addition, gonad shielding is often appropriate when limbs are radiographed with the patient seated at the end of the radiographic table (see Fig. 1-8). Finally, gonad shielding must be considered and used when requested by the patient unless it is contraindicated (see Chapter 2). Gonad shielding is included in selected illustrations in this text. For additional information on the rationale of gonad shielding see Chapter 2.


Fig. 1-29 A, Contact shield placed over the gonads of this male patient. B, Contact shield placed over the gonads of this female patient.
Fig. 1-30  
A, Shadow shield used on male patient. The triangular lead device (arrow) is hung from the x-ray tube and positioned so its shadow falls on the gonads (double arrows).  
B, Shadow shield used on female baby. The cloverleaf shield was positioned under the collimator with magnets, so its shadow falls over the gonads (arrow).  
C, The cloverleaf-shaped shadow shield (arrow) positioned under the collimator with magnets.

Fig. 1-31  
A large piece of flexible lead (arrow) is draped over this patient's pelvis to protect the gonads during a mobile radiography examination of the chest.
Computed Radiography

Since the discovery of x-rays in 1895, computed radiography (CR) has prompted some of the most technically significant changes in the way radiographs are produced. Radiography departments worldwide are slowly converting to CR systems. In the future, all radiographs may eventually be done with CR or some other digital technology.

CR involves conventional radiographic projection radiography in which the latent image (the unseen image) is produced in digital format using computer technology. The CR system uses a conventional radiography machine and conventional positioning and technical factors. However, the image is acquired in a phosphor material plate inside a closed cassette rather than on a film in a light-tight cassette. After exposure the CR cassette is inserted into an image reader device (Fig. 1-32), where it is scanned by a laser beam and the final image appears on a computer monitor. The radiographer can either adjust the image for appropriate density and contrast and then print it on laser film or store the image in the computer to be read directly from the monitor by the radiologist (Fig. 1-33).

Fig. 1-32 Radiographer inserting an IR into an image reader unit. The unit scans the plate with a laser beam and places the digitized image of the body part in a computer for reading on a monitor or, if necessary, for printing on a laser film.

Fig. 1-33 A, The radiographer at the monitor uses the mouse to adjust the CR image of the body part to the proper size, density, and contrast before electronically sending the image for reading. B, The radiologist at the monitor is reading several CR images on one patient.
Attention to detail is paramount when the radiographer is using CR. The following sections address the technical considerations that are different from those used in conventional radiography. (A more detailed description of CR is presented in Chapter 34.)

KILOVOLTAGE
Because of the somewhat wider dynamic range of CR, a specific kVp setting is not as critical as in conventional radiography. A broader range of kVp settings may be acceptable for a specific radiography projection. However, not using a kVp that is significantly low or high is crucial. Slightly overpenetrating the body part is better than underpenetrating it. An optimum kVp range should be posted on the technique chart for all CR projections. In addition, for body parts that have different thicknesses of structures and densities but must be imaged on one projection (e.g., a femur), the thickest part must be well penetrated.

PART CENTERING
The body part that is being radiographed must always be placed in or near the center area of the CR cassette. If the central ray is directed to a body part that is positioned at the periphery of the cassette (e.g., a finger placed near the edge), the computer may not be able to form the image properly. This also depends on whether the computer is in the autoprocessing or manual-processing mode. Cassettes can be split in half and used for two separate exposures because the image reader will note the two areas of exposure.

SPLIT CASSETTES
If a CR cassette is divided in half and used for two separate exposures, the side not receiving the exposure must always be covered with a lead shield. Storage phosphors in the CR cassette are hypersensitive to small levels of exposure and may show on the image if not properly shielded. Covering the unused half prevents scatter radiation from reaching the unexposed side of the CR cassette. Although this technique is practiced in conventional radiography, it is more critical with CR. Depending on the specific technical factors used, the images may not appear at all, may contain artifacts, or may display other image-processing failures. In addition, technical factors for the two exposures must be relatively close to each other.

OVEREXPOSURE AND UNDEREXPOSURE
A light or dark image on the CR monitor may not indicate that the body part was underexposed or overexposed with x-rays as in conventional radiography. A wide array of computer-related factors can cause a light or dark image when using CR. CR images are displayed with numbers that indicate the amount of the exposure reaching the plate. The determination of overexposure or underexposure is made by evaluating this number for the exposure and not the lightness or darkness of the initial image on the monitor.

COLLIMATION
As with conventional radiology the body part being radiographed must be collimated cautiously. With CR a collimated area that exposes the cassette to noncollimated radiation (e.g., a lateral lumbar spine) produces an unacceptable image or one that is very dark or light.

OPEN CASSETTES
Once an exposure is made on a cassette, it can be opened momentarily and exposed to light without compromising the image—a 15-second exposure will start the erasure process. Exposing the phosphor starts the erasure process, but the process is slow. With CR cassettes the latent image remains stored in the phosphors. The cassette is not designed to be light tight. The plate is designed to protect the image storage phosphors from dust, scratches, and other damage. This is different from conventional radiography, in which the film inside the cassette is ruined even if momentarily exposed to light.

GRIDS
The phosphors in CR cassettes are much more sensitive to scatter radiation. Some projections may require a grid if the kVp is above a certain level. For example, one manufacturer requires that a grid be used for any exposure above 90 kVp. This consideration is particularly important in mobile radiography where many projections are done without a grid.
COMPUTED RADIOGRAPHY IN THIS ATLAS

For most radiographic examinations, radiographic positioning does not markedly change with CR. However, for some projections the part centering, central ray, collimation, and other technical factors may be slightly different. When this occurs, a comment will be made and indicated under the following:

COMPUTED RADIOGRAPHY

Foundation Exposure Techniques and Charts

An exposure technique chart should be placed in every radiographic room and on mobile machines including those that use AEC and computed radiography (CR). 1-3 The chart should be organized to display all the radiographic projections performed in the room. The specific exposure factors for each projection should also be indicated (Fig. 1-34).


Each chapter contains a sample exposure technique chart of the essential projections described in the chapter. This chart is a sample only and the exposure techniques listed should not be used unless all the technical parameters are exactly the same in the users department. However, the chart can be used to show typical manual and automatic exposure techniques, the difference between exposures for various body parts, and also as a baseline for developing accurate charts for a radiology department. The kVp values for each projection are approximate for the three-phase generator used for the charts and can be used for the body part as indicated.

A satisfactory technique chart can only be established by the radiographer’s familiarity with the characteristics of the particular equipment and accessories used and the radiologist’s preference in image quality. The following primary factors must be taken into account when the correct foundation technique is being established for each unit:

- Milliamperage (mA)
- Kilovolt (peak) (kVp)
- Exposure time (seconds)
- Automatic exposure controls (AEC)
- Source-to-image receptor distance (SID)
- Grid
- Film and screen speed number
- Electrical supply

With this information available, the exposure factors can be selected for each region of the body and balanced so that the best possible radiographic quality is obtained.

<table>
<thead>
<tr>
<th>Examination</th>
<th>Time</th>
<th>mA</th>
<th>kVp</th>
<th>mAs</th>
<th>SID</th>
<th>Cassette</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AP</td>
<td>.15</td>
<td>200</td>
<td>73</td>
<td>30.0</td>
<td>48*</td>
<td>24 x 30 cm</td>
</tr>
<tr>
<td>Towne</td>
<td>.15</td>
<td>200</td>
<td>78</td>
<td>30.0</td>
<td>48*</td>
<td>24 x 30 cm</td>
</tr>
<tr>
<td>Shoulder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder AP</td>
<td>.050</td>
<td>200</td>
<td>68</td>
<td>10.0</td>
<td>48*</td>
<td>24 x 30 cm</td>
</tr>
<tr>
<td>Neur View</td>
<td>.050</td>
<td>200</td>
<td>65</td>
<td>10.0</td>
<td>48*</td>
<td>24 x 30 cm</td>
</tr>
<tr>
<td>Axillary</td>
<td>.050</td>
<td>200</td>
<td>75</td>
<td>10.0</td>
<td>48*</td>
<td>10 x 12 in</td>
</tr>
<tr>
<td>Scapula AP &amp; LAT OBL</td>
<td>.080</td>
<td>200</td>
<td>75</td>
<td>16.0</td>
<td>48*</td>
<td>24 x 30 cm</td>
</tr>
<tr>
<td>Clavical</td>
<td>.050</td>
<td>200</td>
<td>72</td>
<td>10.0</td>
<td>48*</td>
<td>24 x 30 cm</td>
</tr>
<tr>
<td>Humerus</td>
<td>.500</td>
<td>200</td>
<td>78</td>
<td>10.0</td>
<td>48*</td>
<td>35 x 43 cm</td>
</tr>
<tr>
<td>West Point</td>
<td>.025</td>
<td>200</td>
<td>75</td>
<td>5.0</td>
<td>48*</td>
<td>24 x 30 cm</td>
</tr>
<tr>
<td>Dialysis Shoulder</td>
<td>.037</td>
<td>200</td>
<td>68</td>
<td>7.4</td>
<td>48*</td>
<td>24 x 30 cm</td>
</tr>
<tr>
<td>Stryker Notch 10°</td>
<td>.15</td>
<td>200</td>
<td>72</td>
<td>30.0</td>
<td>48*</td>
<td>8 x 10 in</td>
</tr>
</tbody>
</table>

Fig. 1-34 Radiographic exposure technique chart showing the manual technical factors for the examinations identified.
Adaptation of Exposure Technique to Patient

The radiographer's responsibility is to select the combination of exposure factors that produces the desired quality of radiographs for each region of the body and to standardize this quality. Once the radiographer establishes this standard quality, deviation from the exposure factors should be minimal. These foundation factors should be adjusted for every patient's size to maintain uniform quality. However, the same definition on all subjects cannot be achieved because of congenital and developmental factors and age and pathologic changes. Some patients have fine, distinct bony trabecular markings, whereas others do not. Individual differences must be considered when the quality of the radiograph is judged.

Certain pathologic conditions require the radiographer to compensate when establishing an exposure technique (Fig. 1-35). Selected conditions that require a decrease in technical factors include the following:
- Old age
- Pneumothorax
- Emphysema
- Emaciation
- Degenerative arthritis
- Atrophy

Some conditions require an increase in technical factors to penetrate the part to be examined, such as the following:
- Pneumonia
- Pleural effusion
- Hydrocephalus
- Enlarged heart
- Edema
- Ascites

Fig. 1-35 A, Right lateral decubitus chest radiograph showing a fluid level (arrows). The radiographic exposure technique had to be increased from the standard technique to demonstrate the fluid level. B, Left lateral decubitus chest radiograph showing an air-fluid level (arrows). The radiographic exposure technique had to be decreased from the standard technique to demonstrate the free air.
Preexposure Instructions
The radiographer should instruct the patient in breathing and have the patient practice until the needed actions are clearly understood. After the patient is in position but before the radiographer leaves to make the exposure, the radiographer should have the patient practice breathing once more. This step requires a few minutes, but it saves much time and the need for repeat radiographs.

Inspiration (inhalation) depresses the diaphragm and abdominal viscera, lengthens and expands the lung fields, elevates the sternum and pushes it anteriorly, and elevates the ribs and reduces their angle near the spine. Expiration (exhalation) elevates the diaphragm and abdominal viscera, shortens the lung fields, depresses the sternum, and lowers the ribs and increases their angle near the spine.

During trunk examinations the patient's phase of breathing is important. When exposures are to be made during shallow breathing, the patient should practice slow, even breathing, so that only the structures above the one being examined move. When lung motion and not rib motion is desired, the patient should practice slow, deep breathing after a compression band has been applied across the chest. (The correct respiration phase is printed in the positioning instructions for each projection in the text.)

Technical Factors
The variation in power delivered by the x-ray tube permits the radiographer to control several prime technical factors: milliamperage (mA), kilovolt peak (kVp), and exposure time (seconds). The radiographer selects the specific factors required to produce a quality radiograph using the generator's control panel after consulting a technique chart. Manual and automatic exposure control systems (AEC) are used to set the factors (Fig. 1-36).

Fig. 1-36 Shown is an x-ray generator control panel where exposure factors are set. Also note the exposure technique chart on the wall. The radiographer uses the chart to set the techniques for each projection performed.
Detailed aspects of each technical factor are presented in physics and imaging courses. Because of the variety of exposure factors and equipment used in clinical practice, specific technical factors are not presented in this atlas. However, the companion *Pocket Guide* is designed to allow students and radiographers to organize and write in the technical factors used in respective departments with the different equipment available (Fig. 1-37). However, each essential projection shows an approximate kVp and automatic exposure control (AEC) detector setting as described below. These two parameters will not vary from department to department. However, mA, exposure time, SID, screens, grids, CR, DR, etc. will be highly variable and therefore are not listed.

**KILOVOLTAGE IN THIS ATLAS**

The kVp setting is a critical factor that controls the energy and penetrating ability of the x-ray beam. A variety of kVp settings are used depending on the type of x-ray generators used, the type of grid used, and the contrast of the finish radiograph. For example, a 70-kVp technique with a three-phase generator requires 80 kVp with a single-phase generator to maintain the same contrast level. An approximate kVp value is shown for each essential projection for three-phase (3-0) generators. These are the kVp values that will ensure an adequate penetration of the body part and also appropriate dose control.


**AUTOMATIC EXPOSURE CONTROL IN THIS ATLAS**

X-ray generators contain AEC systems that are very complex and require several settings for each exposure—kVp, mA, backup timer, density control, screen setting, and sensor selection. A number of factors, including the type of examination, tabletop or Bucky technique, patient cooperation, and cassette size, determine which settings are used. For those projections that are performed using AEC, an approximate detector selection is shown in the text for each essential projection. The other AEC variables are not shown due to the wide range of settings used in radiology departments (Fig. 1-37).

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### Manual Factors

<table>
<thead>
<tr>
<th>Part Thickness (cm)</th>
<th>mA</th>
<th>kVp</th>
<th>Time</th>
<th>mAs</th>
<th>SID</th>
<th>Cassette Size</th>
<th>Image Receptor</th>
<th>Grid</th>
<th>10 or 30</th>
<th>Other</th>
</tr>
</thead>
<tbody>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

### AEC Factors

<table>
<thead>
<tr>
<th>Part Thickness (cm)</th>
<th>mA</th>
<th>kVp</th>
<th>AEC Detector</th>
<th>Density Comp.</th>
<th>SID</th>
<th>Cassette Size</th>
<th>Screen Comp.</th>
<th>Grid</th>
<th>10 or 30</th>
<th>Other</th>
</tr>
</thead>
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</tbody>
</table>

Notes: ______________________ Competency: ___ / ___ / ___

Instructor: ________________

*Fig. 1-37* The exposure technique page from the *Pocket Guide* showing how a specific department’s manual techniques and AEC techniques can be written-in for reference in setting optimal techniques.

(From Ballinger P, Frank E: *Pocket guide to radiography*, ed 5, St Louis, 2003, Mosby.)
Radiographs of the hip joint and acetabulum. **A**, Collimator inadvertently opened to size 35 × 43 cm. Note that scatter and secondary radiation have reduced the radiographic contrast and a poor-quality image results. **B**, Collimator set correctly to 18 × 24 cm, improving radiographic contrast and the visibility of detail.

**OUTLINE**
- Introduction, 40
- Radiation units, 42
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- Radiation protection guides, 45
- Medical radiation dose and exposure, 47
- Protection of the patient, 49
- Protection of the radiographer, 52
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Introduction

EARLY INJURIES

Perhaps no other event in our technologic history caused as much feverish scientific activity by so many as the accidental discovery of x-rays by Wilhelm Roentgen in November 1895. Because Roentgen was so thorough in his investigations, within a few short weeks he was able to characterize the nature of x-rays to nearly the same level of understanding as we have today. This early work earned him the first Nobel Prize in physics in 1901. Roentgen immediately recognized the potential diagnostic medical applications of his new “X-light.” He produced the first radiograph, which was of his wife’s hand.

One hundred years later, at the end of the twentieth century, the National Academy of Science named “imaging” as one of the twenty (number 14) great scientific and engineering feats of the century. The electrification of America was first.

Throughout 1896, the first year after Roentgen’s discovery, the world’s scientific literature was flooded with reports of experiments with x-rays. Very soon thereafter associated cases of radiodermatitis (reddening of the skin caused by exposure to ionizing radiation), in some instances severe enough to require surgery, were reported.

These reports had two immediate effects: (1) they accelerated the experimentation and application of x-rays in radiation therapy and (2) they suggested that radiation protection methods were necessary during diagnostic procedures to ensure the safety of both the operator and the patient. However, it took more than 30 years for even moderately consistent radiation protection measures to be universally applied.

By 1910 several hundred cases of severe x-ray burns, many leading to death, had been reported. To understand the magnitude of this tragedy among radiation pioneers, consider the case of Charles T. Dally, Thomas Edison’s friend and principal assistant. Within a few days after the announcement of the discovery of x-rays, Edison was deeply involved in his own investigations, using x-ray apparatus that he had assembled. Within months several of his assistants experienced radiodermatitis. Dally’s condition was mild at first, but, because of continued exposure, deteriorated rapidly and resulted in several amputations. He died in 1904 and is considered the first radiation fatality in the United States.

When Dally died, Edison discontinued his work with x-rays. He had already discovered calcium tungstate as an intensifying phosphor and developed the fluoroscope. Who knows what additional contributions Edison might have made to radiology had he continued his investigations.

Fig. 2-1 The sequence of events following radiation exposure.

(From Bushong SC: Radiologic science for technologists, ed 7, St Louis, 2002, Mosby.)
In the 1930s a consensus was reached on the need for radiation protection devices and procedures. These activities were principally in response to the reported radiation injuries to early radiologists.

In the 1950s scientific publications began to suggest that even the low levels of radiation exposure experienced in diagnostic radiology could be responsible for late radiation responses such as cancer and leukemia in patients. The sequence of events following radiation exposure leading to a radiation response are shown in Figure 2-1.

The first step in this process, ionization, is that which results in the unique potential hazard of x-rays and other ionizing radiations. Current radiation protection practices are prompted primarily by concern for late stochastic effects in patients and radiation workers. Recent use of high-dose fluoroscopy has resulted in an increasing incidence of deterministic effects in patients—skin burn.

### Deterministic Effects

After exposure to high doses of radiation, a number of early responses may appear. A whole-body radiation dose in excess of 200 rad (2 mGy) can result in death within weeks. Partial-body irradiation to any organ or tissue can cause atrophy (shrinking) and dysfunction (improper metabolism). A whole-body radiation dose as low as 25 rad (250 mGy) can produce measurable hematologic depression (reduction in the number of circulating blood cells), which may require months for recovery.

These early responses result from high doses of radiation rarely experienced in diagnostic radiology. Such effects are called deterministic; the severity of response is dose related and there is a dose threshold. Table 2-1 summarizes these effects.

![Table 2-1](image)

<table>
<thead>
<tr>
<th>Effect</th>
<th>Anatomic site</th>
<th>Minimum dose (rad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>Whole-body</td>
<td>100</td>
</tr>
<tr>
<td>Hematologic depression</td>
<td>Whole-body</td>
<td>25</td>
</tr>
<tr>
<td>Skin erythema</td>
<td>Small field</td>
<td>200</td>
</tr>
<tr>
<td>Epilation</td>
<td>Small field</td>
<td>300</td>
</tr>
<tr>
<td>Chromosome aberration</td>
<td>Whole-body</td>
<td>5</td>
</tr>
<tr>
<td>Gonadal dysfunction</td>
<td>Local tissue</td>
<td>10</td>
</tr>
</tbody>
</table>

### Stochastic Effects

Principal concern today is for the late effects of radiation exposure. These effects are called stochastic; the incidence of response is dose related and there is no dose threshold.

Such effects follow low-dose radiation exposures and may not occur for years. They fall into two categories: genetic effects and somatic effects. Genetic effects of radiation exposure are suspected; they have not been observed in humans. Somatic effects refer to all cells of the body except the genetic cells. The principal somatic effects are cancer and leukemia, which have been observed in humans. However, no individual has ever been identified as a radiation victim after low-dose radiation exposure. A low dose is generally considered to be a whole-body radiation dose of less than about 25 rad (250 mGy).
Such effects are detectable only when observations of thousands and even tens of thousands of irradiated individuals are made. Leukemia is more readily observed in an irradiated population than cancer because leukemia is relatively rare.

Because cancer is common, radiation-induced cancer is difficult to detect. The 1990 report of the BEIR Committee (Biologic Effects of Ionizing Radiation)—known as the BEIR-V Report—provides the most authoritative estimate of this radiation response. Although this report is exceedingly thorough, it can be summarized by the data in Table 2-2.

The BEIR committee postulated three scenarios. The first assumes a once-in-a-lifetime dose of 10 rad (100 mGy), simulating an accidental exposure. The second assumes an annual dose of 1000 mrad/yr (10 mGy/yr). The third assumes an annual exposure of 100 mrad/yr, approximating the dose we receive as occupational exposure.

Of 100,000 unirradiated persons, nearly 20,000 will die of malignant disease. After a single 10-rad (100-mGy) accidental dose, an additional 800 malignant deaths might occur. After an assumed exposure of 1000 mrad/yr, an additional 3000 may die of malignant disease. With an occupational exposure of 100 mrad/yr for a 40-year working period, an additional 600 cases of malignant disease may be expected.

### NEED FOR RADIATION PROTECTION

Radiographers receive approximately 50 mrem/yr (0.5 mSv/yr), nearly all during fluoroscopy and mobile radiography when protective apparel is worn. Consequently, exposures, although identified as whole body on the exposure report, are actually partial-body exposures. Although exposure levels are low and the possibility of a late effect is remote, it is prudent to keep radiation exposure to radiographers and patients ALARA (As Low As Reasonably Achievable).

A recent survey of nearly 150,000 radiographers yielded a large amount of statistical data about dose, demographics, and biologic effects. There was no indication that occupational radiation exposure caused any biologic effects. In fact, in all cases in which radiographers have been studied, no biologic effects have been observed. Nevertheless, late somatic effects are considered possible.

### Radiation Units

A special set of units is used to express the quantity of ionizing radiation. These units, the roentgen, the rad, and the rem, have been developed and defined over many years and are familiar to radiologic workers. However, those in educational programs and in professional practice must become familiar with a second set of radiation units derived from the International System (SI) of Units.

The SI units associated with classical radiation units and the appropriate conversions are shown in Table 2-3. Although they are referred to only superficially in this chapter, radiographers should be aware that they exist and should be prepared to implement them. At this time the United States is the only developed country that has yet to fully adopt SI radiation units as a system of measure.

#### TABLE 2-2

<table>
<thead>
<tr>
<th>Biologic Effects of Ionizing Radiation (BEIR) committee: estimated excess mortality from malignant disease, cases per 100,000 persons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal expectation</td>
</tr>
<tr>
<td>Excess cases</td>
</tr>
<tr>
<td>Single exposure to 10 rad</td>
</tr>
<tr>
<td>Continuous exposure to 1000 mrad/yr</td>
</tr>
<tr>
<td>Continuous exposure to 100 mrad/yr</td>
</tr>
</tbody>
</table>

#### TABLE 2-3

<table>
<thead>
<tr>
<th>Conventional radiation units, SI radiation units, and conversion factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Exposure</td>
</tr>
<tr>
<td>Air kerma</td>
</tr>
<tr>
<td>Absorbed dose</td>
</tr>
<tr>
<td>Dose equivalent</td>
</tr>
<tr>
<td>Activity</td>
</tr>
</tbody>
</table>

SI, International System of Units; C/kg, Coulomb per kilogram; rad, radiation absorbed dose; rem, roentgen equivalent; man. The use of Gy$_{v}$ and Gy, follows the proposal of Archer and Wagner.
UNIT OF EXPOSURE

When an x-ray tube is energized, x-rays are emitted in a collimated beam in the same way light is emitted from a flashlight. This useful beam of x-rays ionizes the air through which it passes. This effect is called exposure, and the unit of exposure is the roentgen (R).

The SI unit of radiation exposure has no special name: it is simply the C/kg. Because of many difficulties encountered with this unit, the radiologic community employs the gray (Gy) when expressing exposure in air. For our purposes we may assume that 1 R = 10 mGy.

UNIT OF RADIATION DOSE

When radiation exposure occurs, the resulting ionizations deposit energy in air. If an object such as a patient is present at the point of exposure, energy will be deposited in the patient. This deposition of energy by radiation exposure is called radiation absorbed dose, or simply absorbed dose, and it is measured in rad.

One rad is equivalent to depositing 100 erg of energy in each gram of tissue. The SI unit of absorbed dose is the gray and 1 Gy = 100 rad = 1 J/kg.

UNIT OF DOSE EQUIVALENT

If the irradiated object is a radiation worker or the public, then the radiation dose results in a radiation dose equivalent. The dose equivalent is measured in rem (radiation equivalent man), and 1 rem = 100 erg/g.

The SI unit of dose equivalent is the sievert (Sv), and 1 Sv = 1 J/kg.

Note that the rad and rem (gray and sievert) are expressed in similar units. The basic difference between the rem and other radiation units is that the rem is used only for radiation protection purposes; it is the unit of occupational exposure.

In diagnostic radiology 1 R can be considered equal to 1 rad and to 1 rem. This simplifying assumption is accurate to within about 15% and therefore is sufficiently precise for nearly all considerations of exposure and dose in diagnostic radiology.

APPLICATION OF RADIATION UNITS

Although roentgen, rad, and rem are used interchangeably in diagnostic radiology, such usage is incorrect because each unit has a precise application. Furthermore, 1 roentgen, 1 rad, and 1 rem are all rather large quantities. In practice, quantities 1000 times smaller are used: milliroentgen (mR), millirad (mrad), and millirem (mrem).

When a medical physicist evaluates the performance of an x-ray imaging system, the radiation intensity is expressed in mR or sometimes as mR/milliampere-seconds (mAs) at a given kilovolt (peak) (kVp).

When a patient is irradiated during an examination, the amount of radiation received by the patient is expressed in mrad. If a pregnant patient is irradiated, the fetal dose is also expressed in mrad.

Exposure received by radiographers is measured with an occupational radiation monitor. The source of such occupational exposure is nearly always scattered radiation from the patient (Fig. 2-2). The radiation monitor measures exposure; the radiation report indicates the dose equivalent in mrem.

The average occupational exposure received by a radiographer is approximately 50 mrem/yr. The mrem is reserved exclusively for use in radiation protection and therefore is a unit used not only to quantify occupational exposure but also sometimes to express the dose received by populations as the consequence of medical, industrial, and research applications of radiation.
Radation Sources and Levels

We are exposed to ionizing radiation in our daily lives from multiple sources. The largest source is natural background radiation, something over which we have no control. Other sources are medical diagnostic and therapeutic procedures and radiation applications associated with industry, research, and consumer products. To place in perspective the radiation exposures and risks associated with being a radiographer, we need to know something about the radiation levels associated with these other sources (Table 2-4).

NATURAL BACKGROUND

Humans have inhabited Earth for hundreds of thousands of years and have evolved in the presence of a constant radiation exposure called natural background radiation. Natural background radiation comes from three principal sources: (1) terrestrial radiation resulting from naturally occurring radionuclides in the earth, (2) cosmic radiation resulting from principally the sun but also sources outside our solar system and galaxy, and (3) internal exposure from radionuclides naturally deposited in the human body, principally potassium-40 ($^{40}$K). In the United States these sources produce a whole-body dose of 50 to 300 mrad/yr (0.5 to 3 mGy/yr), depending on location and diet.

### TABLE 2-4

Estimated average annual whole-body radiation dose (mrem) in the United States from various sources

<table>
<thead>
<tr>
<th>Radiation source</th>
<th>Annual dose (mrem)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Natural sources</strong></td>
<td></td>
</tr>
<tr>
<td>Internal radionuclides, principally $^{40}$K</td>
<td>39</td>
</tr>
<tr>
<td>Terrestrial radionuclides, principally $^{220}$R, $^{222}$Ra, $^{226}$Ra, $^{14}$C</td>
<td>29</td>
</tr>
<tr>
<td>Cosmic rays</td>
<td>29</td>
</tr>
<tr>
<td>Radon (dose to lungs only)</td>
<td>198</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>295</td>
</tr>
<tr>
<td><strong>Human sources</strong></td>
<td></td>
</tr>
<tr>
<td>Diagnostic x-rays</td>
<td>40</td>
</tr>
<tr>
<td>Nuclear medicine</td>
<td>14</td>
</tr>
<tr>
<td>Consumer products</td>
<td>10</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>65</td>
</tr>
<tr>
<td><strong>COMBINED TOTAL</strong></td>
<td>360</td>
</tr>
</tbody>
</table>

MEDICAL RADIATION EXPOSURE

Patients receive radiation exposure from radiographic examinations, fluoroscopic examinations, radioisotope studies, and radiation oncology procedures. By far, the largest amount of man-made radiation exposure is received from medical x-ray examinations. Approximately 65% of the U.S. population is exposed to such radiation each year. The radiation dose averaged over the entire population is approximately 55 mrem/yr (0.55 mSv/yr).

INDUSTRIAL, RESEARCH, AND CONSUMER APPLICATIONS

Industrial applications of ionizing radiation cover a wide range of activity including the mining, refining, and fabrication of nuclear fuel, industrial radiography, and the handling of radioisotopes for a large number of industrial applications.

Research applications of ionizing radiation include particle accelerators, x-ray diffraction units, electron microscopes, and radionuclides. Many research activities employ radionuclides, mostly low-energy, beta-emitting radionuclides such as $^3$H and $^{14}$C.

Many consumer products incorporate x-ray devices or radioactive material. Airport surveillance systems produce x-rays. Radioactive material is incorporated into various luminous products, such as instrument gauges, clocks, and exit signs. Radioactive material is also incorporated into such devices as check sources, static eliminators, and smoke detectors.

Collectively, these man-made sources contribute approximately 15 mrem/yr (150 μSv/yr) to the population dose.
Radiation Protection Guides

Much radiobiologic research dealing with experimental animals or observations of humans has been devoted to describing the relationship between radiation dose and biologic effect.

Such dose-response relationships have been described with great precision for deterministic effects, such as skin erythema, hematologic depression, and lethality. These responses exhibit a non-linear threshold-type dose-response relationship. Such a dose threshold indicates that there is a dose below which that response will not occur (Fig. 2-3).

This is not true for the stochastic effects and they are considered to have no dose threshold and increase in incidence with increasing dose (Fig. 2-4). This linear nonthreshold type of dose-response relationship suggests that no radiation dose, regardless how small, is safe.

**BASIS FOR RADIATION PROTECTION STANDARDS**

The basis for radiation protection standards is the linear, nonthreshold dose-response relationship. The stochastic effects of principal concern are leukemia and cancer, and they have been shown with reasonable accuracy to follow this dose-response model.

This basis for radiation protection guidance in the United States was first enunciated in 1932 when the National Council for Radiation Protection and Measurements (NCRP) recommended a whole-body dose limit of 50 rem/yr (500 mSv/yr). Over the years the dose limit has been revised downward several times and is now 5 rem/yr (50 mSv/yr).

It should be clear that any attempt to establish radiation dose-limits is highly subjective and requires value assessments beyond the realm of science. The present recommended dose limits have been in effect since 1987 and are considered safe levels when compared to other occupational hazards.

The current dose limits are considered to be an acceptable exposure for all radiation workers. Therefore it is that dose which, if received each year for a 40-year working lifetime, would not be expected to produce any significant effect. Nevertheless, radiation protection programs must be consistent with the ALARA concept, as previously defined.

---

**Fig. 2-3** The dose-response relationship for deterministic effects non-linear threshold.

(From Bushong SC: Radiologic science for technologists, ed 7, St Louis, 2002, Mosby.)

**Fig. 2-4** The dose-response relationship for stochastic effects is linear, non-threshold.
SPECIFIC RADIATION PROTECTION CONCEPTS

In addition to the specification of a whole-body dose limit for occupationally exposed persons and for the population at large, several tissues and organs of the body have been given special consideration because of their individual radiosensitivity. Specific types of individuals are likewise accorded attention in specifying a dose limit.

The NCRP recommended dose limits are summarized in Table 2-5. These dose limits have now been adopted by state and federal regulatory agencies and are law in all states. Note that only SI units are used and the units relate to limits of dose equivalent.

The concept of effective dose (E) is important. It is the sum of the weighted dose equivalents for irradiated tissues or organs. It takes into account the different mortality risks from cancer and the risk of severe hereditary effects in the first two generations associated with irradiation of different organs and tissues.

Effective dose is expressed symbolically as

$$\Sigma = \omega_T H_T$$

where \( \omega_T \) is the tissue-weighting factor representing the proportionate risk of tissue (T) and \( H_T \) is the average dose received by tissue (T). The tissue-weighting factor, \( \omega_T \), accounts for the relative radiosensitivity of various tissues and organs.

The concept of effective dose is particularly important in x-ray imaging. Radiologic technologists receive most of their occupational exposure during fluoroscopy and portable radiography when a protective apron reduces dose to the shielded portion of the body to near zero. Therefore the exposure recorded by a colar positioned monitor does not represent effective dose. The actual effective dose is only approximately 10% of that recorded by the occupational monitor.

The dose limit for the skin is 500 mSv/yr. During fluoroscopy it is often necessary for the hands or forearms of the radiologist to be near the useful beam. Usually these parts are protected by lead gloves. However, during certain procedures the use of such protective apparel is not possible. The dose limit for the hands is 500 mSv/yr. The dose limit for the lens of the eye is 150 mSv/yr.

The unborn child is known to be particularly sensitive to the effects of ionizing radiation; consequently, a dose limit of 5 mSv/9 mo is applied. In the case of the pregnant radiographer, it is unlikely that this fetal dose limit would ever be approached, much less exceeded, because of the use of protective apparel during fluoroscopy and portable radiography. Nevertheless, in recognizing this special concern, the NCRP has added the additional dose limit of 0.5 mSv/mo once the pregnancy is declared.

Under some circumstances students may be exposed to radiation during educational experiences. In such cases they are given a separate dose limit of 1 mSv/yr. This dose limit is directed particularly to high school and college students of any age but also to radiography students under age 18.

Even more changes in dose limits are on the way. The changes are not made because of fear that current limits are dangerous or even harmful; they are made in keeping with the principle of ALARA.

The changes also acknowledge that we can function efficiently, even with more restrictive dose limits. In 1991 the International Commission on Radiological Protection (ICRP) issued a number of recommendations, including an annual prospective effective dose equivalent of 2 mSv. Such a reduction is currently under consideration in the United States.

Fig. 2-5 summarizes the history of radiation protection dose limits over the past century.

**TABLE 2-5**

National Council for Radiation Protection and Measurements (NCRP): recommended dose limits

<table>
<thead>
<tr>
<th>Occupational exposure (annual)</th>
<th>Effective dose equivalent limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective dose equivalent limit (stochastic effects)</td>
<td>50 mSv (5000 mrem)</td>
</tr>
<tr>
<td>Dose equivalent limits for tissues and organs</td>
<td>150 mSv (15 mrem)</td>
</tr>
<tr>
<td>lens of eye</td>
<td>500 mSv (50 mrem)</td>
</tr>
<tr>
<td>All others (e.g., red bone marrow, breast, lung, gonads, thyroid skin and extremities)</td>
<td>10 mSv x N (1000 mrem x N)</td>
</tr>
<tr>
<td>Cumulative dose equivalent</td>
<td></td>
</tr>
<tr>
<td>Public exposure (annual)</td>
<td>1 mSv (100 mrem)</td>
</tr>
<tr>
<td>Education and training exposure (annual)</td>
<td>1 mSv (100 mrem)</td>
</tr>
<tr>
<td>Embryo-fetus exposure</td>
<td></td>
</tr>
<tr>
<td>Total dose equivalent limit</td>
<td>5 mSv (500 mrem)</td>
</tr>
<tr>
<td>Dose equivalent limit in a month</td>
<td>0.5 mSv (50 mrem)</td>
</tr>
</tbody>
</table>


N. Age of the worker.

Fig. 2-5 Dose limits have decreased over the past century.
Medical Radiation Dose and Exposure

The output x-ray intensity from any given radiographic or fluoroscopic imaging system can vary widely, depending on the type of equipment and technique employed. There may even be a sizable variation among x-ray imaging systems of the same manufacture and model when identical techniques are used.

The x-ray intensity, of course, determines the radiation dose to not only the patient but also to the radiographer. Consequently, several methods are used to determine x-ray output to estimate the dose to patient and radiographer. Approximate values are adequate to describe x-ray intensity; however, do not apply the following to any specific situation.

Patient dose during fluoroscopy is difficult to estimate because the x-ray beam is modulated and moves during the examination. Fluoroscopes have x-ray intensity limited by regulation to 10 R/min (100 mGy/min) at the tabletop. Experience has shown that, when operated at approximately 90 kVp, most fluoroscopes produce tabletop exposure of approximately 4 R/min (40 mGy/min).

Radiographic x-ray intensity varies directly with the mAs, with the square kVp and inversely as the square of the distance from the source. A good approximation of x-ray intensity during radiography is 5 mR/mAs at 80 cm source-to-skin distance (SSD).

PATIENT DOSE

The dose received by patients during diagnostic radiologic examinations is usually expressed in one of three ways: entrance skin exposure (ESE), organ dose, or fetal dose. Each has a specific application in assessing the risk to the patient, but ESE is the easiest to estimate.

Entrance skin exposure

The ESE of the patient during any radiographic examination can be measured directly or estimated by using the techniques previously described. ESE during fluoroscopy usually must be measured although it too can be estimated from a tabletop exposure measurement at the technique under investigation.

In recent years some government agencies have attempted to restrict patients’ radiation exposure during commonly performed radiographic examinations. It is also recognized that too low a radiation exposure can be just as hazardous as an excessive radiation exposure because an inadequate image is produced making diagnosis less precise and necessitating repeat radiologic examinations. Table 2-6 shows acceptable ranges for several radiographic examinations. These ranges are rather generous, reflecting the techniques and image receptors currently used.

<table>
<thead>
<tr>
<th>Examination</th>
<th>ESE per projection (mR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest (PA)</td>
<td>10 to 25</td>
</tr>
<tr>
<td>Skull (lateral)</td>
<td>105 to 240</td>
</tr>
<tr>
<td>Abdomen (AP)</td>
<td>375 to 700</td>
</tr>
<tr>
<td>Retrograde pyelogram</td>
<td>475 to 830</td>
</tr>
<tr>
<td>Cervical spine (AP)</td>
<td>35 to 165</td>
</tr>
<tr>
<td>Thoracic spine (AP)</td>
<td>295 to 485</td>
</tr>
<tr>
<td>Extremity</td>
<td>10 to 330</td>
</tr>
<tr>
<td>Dental (bite-wing and periapical)</td>
<td>230 to 425</td>
</tr>
</tbody>
</table>

PA, Posteroanterior; AP, anteroposterior.
Organ dose

Sometimes the radiation dose received by a specific organ or tissue is significant. Of course, organ dose usually cannot be measured directly but must be estimated. The breast, for example, is a tissue of primary concern because of the high utilization of x-ray mammography and the potential for radiation-induced breast cancer. Table 2-7 shows the approximate ESE and glandular dose received by the breast as a function of the type of examination. The glandular dose is that which is used to evaluate radiation carcinogenesis.

Another organ of particular concern is the bone marrow. Bone marrow dose is used to estimate the population mean marrow dose (MMD) as an index of the somatic effect of radiation exposure. Table 2-8 relates the MMD associated with various radiographic examinations. Each of these doses results from partial-body exposure and is averaged over the entire body.

Table 2-7 shows the approximate entrance skin exposure (ESE) and glandular dose received by the breast as a function of the type of examination. The glandular dose is that which is used to evaluate radiation carcinogenesis.

Table 2-8 indicates average bone marrow dose for selected radiographic examinations. The large difference between males and females results from the shielding of the ovaries by overlying tissue. The weighted average gonad dose to the general population is used to estimate the genetically significant dose (GSD).

Table 2-9 indicates average gonad doses received during various radiographic examinations. The large difference between males and females results from the shielding of the ovaries by overlying tissue. The weighted average gonad dose to the general population is used to estimate the genetically significant dose (GSD).
Fetal dose
Like most organ doses, fetal dose cannot be measured; it must be estimated. This estimate is usually obtained from phantom measurements or computer-generated calculations. Table 2-10 shows the results of an analysis by the U.S. Center for Devices and Radiological Health and reports fetal dose as a function of the normalized ESE. Before this table can be used, the ESE for the type of examination in question must be measured. The fetal dose is given in mrad/R ESE.

RADIOPHGRAPHER EXPOSURE
The radiographer receives most occupational exposure during fluoroscopy and portable radiography. However, because the radiographer wears protective apparel while performing these examinations, only part of the body is exposed.

During conventional radiography the radiographer is positioned behind a protective barrier, which often may be a secondary barrier. In this situation the useful beam is never directed at the radiographer and occupational radiation exposure is near zero.

A helpful way to estimate occupational radiation exposure to the radiographer during either fluoroscopy or radiography is to apply the 0.1% rule—the exposure 1 meter laterally from the patient is approximately 0.1% of the ESE. For example, in Fig. 2-2 the radiographer is positioned 2 meters from the patient. If the examination were of the chest, the ESE would be approximately 20 mR (200 µGy). The scatter radiation intensity 1 meter laterally would be 0.1% of the ESE or 0.02 mR (0.2 µGy). According to the inverse square law, at 2 meters the scatter radiation intensity would be 0.005 mR or 5 µR (0.05 µGy).

Protection of the Patient
The patient is protected from unnecessary radiation exposure during diagnostic x-ray examinations by certain design features of x-ray equipment, specially fabricated auxiliary apparatus and special attention to imaging technique.

EQUIPMENT AND APPARATUS DESIGN
Usually the features of radiographic and fluoroscopic equipment that are designed to reduce patient dose also reduce exposure to the radiographer. This aspect of radiation control should be kept in mind when patient protection is considered.

Filtration
A minimum of 2.5 mm aluminum equivalent total filtration is required on all fluoroscopic x-ray tubes and for radiographic tubes operating above 70 kVp. The patient couch is considered part of the fluoroscopic filtration. The purpose of filtration is to reduce the intensity of low-energy x-rays, which do not contribute to the image, from reaching the patient.

<table>
<thead>
<tr>
<th>Examination</th>
<th>Fetal dose (mrad/R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Cervical spine</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Full-mouth dental</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Chest</td>
<td>2</td>
</tr>
<tr>
<td>Stomach and upper gastrointestinal tract</td>
<td>25</td>
</tr>
<tr>
<td>Gallbladder</td>
<td>3</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>250</td>
</tr>
<tr>
<td>Intravenous urography</td>
<td>265</td>
</tr>
<tr>
<td>Abdomen</td>
<td>265</td>
</tr>
<tr>
<td>Pelvis</td>
<td>265</td>
</tr>
<tr>
<td>Extremity</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

TABLE 2-10
Approximate fetal dose as a function of entrance skin exposure (ESE)
**Collimation**

Collimation is the restriction of the useful x-ray beam to the anatomy being examined. This spares adjacent tissue from unnecessary radiation exposure.

Restricting the x-ray beam by collimation reduces not only the volume of tissue irradiated but also the absolute dose at any point because of the accompanying reduction in scatter radiation. Reduction of scatter radiation also improves image quality by improving image contrast.

**Specific area shielding**

Often part of the useful x-ray beam needs to be shielded during the examination. Thus those tissues of the body that lie in or near the useful beam but do not need to be imaged can be shielded. Gonad shielding is a good example of such specific area shielding and can be applied with either shadow or contact shields.

Gonad shields should be used in the following situations: (1) when a patient is of reproductive age, (2) when the gonads lie in or near the useful beam, and (3) when the use of such shielding will not compromise the required diagnostic information. The use of gonad shields reduces the gonad dose to near zero.

**Image receptors**

The speed of an image receptor greatly influences patient dose. Rare-earth screens developed in conjunction with matched photographic emulsions show relative speeds of up to 12 times those of older calcium tungstate screen-film combinations.

Today’s fluoroscopic image intensifiers also incorporate more efficient input phosphors that reduce patient dose significantly. Digital fluoroscopy incorporating pulsed x-ray beams and image-hold techniques can also result in a reduction in patient dose.

Solid state image receptors have the potential for reducing the patient dose and are replacing film-screen image receptors in many applications. Use of these newer imaging modalities is increasing and promises additional reduction in patient dose.

**Radiographic technique**

Radiographic technique is not only important in the production of a quality image but also greatly influences patient dose. Ideally, the higher the kVp, the lower the patient dose, because a small increase in kVp is compensated with a large reduction in mAs.

However, as kVp is raised, image contrast is reduced, and for some examinations this reduction in contrast may be unacceptable. For example, mammography could be performed at a far lower patient dose if the kVp were increased. However, the radiographic contrast would be very poor and the image would contain less diagnostic information.

Radiographic technique should be optimized to the body part in order to produce a quality image at low dose.
ADMINISTRATIVE PROCEDURES

Patient selection and examination selection are two areas in which radiologic technologists can contribute to reducing unnecessary patient dose.

Pregnancy

Safeguards against accidental fetal irradiation are particularly critical during the first 2 months of pregnancy. In those early weeks, a pregnancy may not be suspected and the fetus could be exposed unknowingly.

The radiographer should never knowingly conduct a radiologic examination on a pregnant patient unless a documented decision has been made to do so. When such an examination does proceed, all of the previously discussed techniques for minimizing patient dose should be employed.

The risk of injury following irradiation in utero is small and the usual benefit is so great that if the examination is clinically indicated, it should be performed. Many studies have shown that delay in scheduling such an examination is more harmful to the patient than the x-ray exposure.

Fetal doses during radiographic exposure rarely exceed a few hundred millirad. However, if the examination is a high-dose procedure of the pelvis, such as computed tomography or a fluoroscopic examination, special attention may be appropriate if the patient suspects pregnancy.

Radiographers fulfill their responsibility to potentially pregnant patients by posting caution signs in the waiting room and in each examining room. Such signs warn patients about the importance of informing the radiographer or radiologist that pregnancy is a possibility. Fig. 2-6 shows a helpful poster available from the National Center for Devices and Radiological Health that provides this message.

Patient and examination selection

Precautions against unnecessary patient radiation exposure are generally the responsibility of the radiologist, not the radiographer. Patient selection and examination selection are two such situations.

Patients selected for x-ray examination fall into two categories: those who have symptoms and those who do not. Patients with symptoms require x-ray examination to provide the physician with information to plan the patient’s future clinical management.

Patients without symptoms usually are referred for x-ray examination to provide baseline information for possible future problems or to satisfy certain legal, insurance, or employment requirements. Screening mammography is one such example.

Fig. 2-6 Signs like this one alert patients to the possibility that radiation can harm an unknown pregnancy.
Selection of patients without symptoms for an x-ray examination involves mass screening with selected routine procedures, many of which may not be medically justified. Routine x-ray examinations should not be performed when there is no precise medical indication.

Substantial evidence shows that some such examinations are of little benefit because the disease detection rate is very low. Examples of such unacceptable screening programs follow:

1. Tuberculosis—Mass screening has not been found effective; better methods of tuberculosis testing are now available.
2. Hospital admissions—Chest x-ray examination for routine hospital admission should not be performed on patients with no clinical indication of chest disease.
3. Preemployment physicals—Chest and lower back x-ray examinations are not justified because little knowledge is gained about previous injury or disease.
4. Periodic health examinations—Many physicians debate the frequency of a general physical examination as a preventive medicine protocol. Certainly, the physical evaluation of an asymptomatic patient should not include x-ray examination, especially fluoroscopy.
5. Whole-body CT—This examination is currently promoted by some as a general health head-to-toe screening tool. It should not be done. The radiation dose is too high and the disease detection rate too low.

TABLE 2-11
X-ray attenuation values for the common lead (Pb) equivalent thicknesses of protective aprons

<table>
<thead>
<tr>
<th>Equivalent thickness (mm Pb)</th>
<th>60 kVp</th>
<th>80 kVp</th>
<th>100 kVp</th>
<th>120 kVp</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>99</td>
<td>97</td>
<td>94</td>
<td>92</td>
</tr>
<tr>
<td>0.5</td>
<td>99</td>
<td>99</td>
<td>96</td>
<td>95</td>
</tr>
<tr>
<td>1.0</td>
<td>99</td>
<td>99</td>
<td>98</td>
<td>97</td>
</tr>
</tbody>
</table>

For the radiographer, occupational radiation exposure is most likely to occur during fluoroscopy (Fig. 2-7) or mobile radiography. Consequently, particular care and attention should be exercised during these examinations.

Protective apparel should always be worn for both fluoroscopic and mobile radiographic procedures. Table 2-11 shows the degree of protection provided by the principal sizes of the available protective lead aprons. Most radiographers find the 0.5-mm lead apron perfectly adequate. Thicker aprons may be too heavy for some radiographers engaged in a heavy fluoroscopy schedule. Each mobile x-ray unit should have a protective apron assigned to it, and the apron should remain with the unit at all times.

Fig. 2-7 Scatter radiation during mobile fluoroscopy is low when the x-ray tube is under the table (A) and more intense when the x-ray tube is over the patient (B).
ADMINISTRATIVE PROCEDURES

Every radiographer should be familiar with the cardinal principles of radiation protection—time, distance, and shielding; and with ALARA:

1. The *time* of exposure to a radiation source should be kept to a minimum.
2. The *distance* between the radiation source and the radiographer should be as great as possible.
3. When appropriate and practicable, protective *shielding* should be positioned between the radiation source and the radiographer.
4. Maintain radiation exposure as *low as reasonably achievable*.

A prime example of these principles occurs during fluoroscopy. As shown in Fig. 2-8, the maximum exposure rate in a fluoroscopic examination exists in the area adjacent to the table. Because the primary beam is emitted by the under-table tube and intercepts the patient, the patient becomes the radiation source due to scatter radiation.

The radiologist must minimize the exposure time by activating the foot or hand control intermittently for minimum x-ray beam on-time. The radiographer can help by making certain that the 5-minute fluoroscopic reset timer is functioning and is used sparingly.

The radiographer can *minimize occupational exposure* by taking one step back from the edge of the fluoroscopic table when it is not absolutely essential to remain there. During fluoroscopy the radiologist and radiographer must wear *protective apparel*, which is the most effective method for reducing occupational radiation exposure.

---

Fig. 2-8 Isointensity profiles adjacent to a fluoroscope.

Occupational radiation
Perhaps the single most important aspect of a radiation control program in diagnostic radiology is a properly designed occupational radiation monitoring program. Four types of radiation measuring devices are used as occupational radiation monitors: pocket ionization chambers, film badges, thermoluminescent dosimetry badges and optically stimulated luminescence (OSL) badges.

Pocket ionization chambers can be used for occupational radiation monitoring, although they seldom are used in diagnostic radiology. The advantage to these devices is that they can be evaluated daily. Photographic film in the form of a film badge has been the principal occupational radiation monitor for years. The design of the film badge has undergone many refinements, such as metal filters that enable it to measure not only the quantity of radiation but also the type of radiation, approximate energy, and direction.

Thermoluminescent dosimetry (TLD) badges are used as occupational radiation monitors and have many of the same performance characteristics as film badges. The sensitive material of the TLD is reusable and can be used for lengths of time exceeding the monthly interval limits placed on film badges.

Optically stimulated luminescence (OSL) badges are the newest addition to occupational radiation monitors. They are sensitive, accurate and can be worn for periods up to one year.

Under some circumstances it is not only permissible but advisable to monitor x-ray workers for calendar-quarter intervals rather than monthly or biweekly intervals. The principal advantage to this mode of radiation monitoring is the reduced record keeping that is required.

Radiographers receive most of their occupational exposure during fluoroscopy and portable radiography, but they wear protective apparel for these procedures. The monitor should be worn unshielded (outside the protective apron) at the collar region. This region of the body will receive at least 10 times the radiation exposure of the protected trunk of the body. Therefore it is prudent to monitor the collar region because this provides a way to estimate thyroid and eye lens dose.

The orientation of the monitor is also important. The front of the monitor must face the radiation source. If the orientation of the monitor is reversed, the filters in the monitor will not be in the correct position and the analysis will be false.

A personnel monitoring program is not complete unless proper documentation is provided. Most commercial vendors of occupational radiation monitors will provide the user with a periodic computer-generated report containing all of the required information. For this report to be complete, all of the requested information on each individual must be supplied, including name, social security number, date of birth, gender, and previous radiation exposure.

Pregnant radiographers
Special administrative procedures are required for pregnant radiographers. It is the responsibility of each female radiographer to inform her supervisor when she discovers or suspects that she is pregnant. This situation then becomes a declared pregnancy and new rules take effect. The supervisor should then consult with the pregnant radiographer and review completely the onsite radiation control program.

Under normal circumstances a radiographer receives less than 5 mSv (500 mrem) annually, as recorded by the occupational radiation monitor. The exposure under the protective apron should not exceed 0.5 mSv (50 mrem) annually, and the resulting fetal dose should not exceed 0.25 mSv (25 mrem). Because the dose limitation to the fetus is 5 mSv for the gestation period, under most circumstances additional or special radiation protective measures are not necessary.

To comply with current NCRP recommendations, management must deliberately review each radiation monitoring report to ensure that the occupational fetal dose does not exceed 0.5 mSv in any month. The collar-positioned monitor can be used to estimate fetal dose by multiplying the reported result by 0.1. Better yet, a second monitor may be positioned at waist level under the protective apron.

When a second monitor is provided, the two monitors must consistently be worn at the assigned positions. To avoid confusion, the second monitor should be labeled "baby badge" or "fetal monitor" with the label colored a "baby" blue or yellow "belly."
Summary of Procedures

For radiographers, nearly all occupational radiation exposure occurs during fluoroscopy and mobile radiography. The following procedures will help to reduce this occupational exposure:

- During radiography, always remain behind the operating console barrier.
- Never participate in a fluoroscopic or mobile radiographic procedure without a protective apron.
- Always position your occupational radiation monitor on your collar.
- Review your monthly occupational radiation monitoring report.
- Wear a protective apron during mobile radiography, and stand on the opposite side of the operating console from the patient.
- During C-arm fluoroscopy, be sure the x-ray tube is below the patient.
- If you become pregnant, inform your supervisor so that additional radiation protection procedures can be implemented.

The following procedures will help to reduce patient radiation dose. However, remember that a quality image is more important than reduced patient radiation dose.

- Use high kVp technique for radiography.
- Record the fluoroscopic x-ray beam on-time if it exceeds 20 minutes.
- Use gonad shields when such use will not interfere with the examination.
- Make sure the patient is properly prepared so that repeat examination is not necessary.
- If the patient thinks she may be pregnant, consult the radiologist before continuing the examination.

Observing these essentials of radiation protection will ensure that your exposure and that of your patient is ALARA—as low as reasonably achievable (Fig 2-9).

![Image of a patient and a radiographer with a diagram of a medical examination]

**Fig. 2-9** What is wrong with this scene?

1. Radiation monitor is positioned improperly
2. Protective apron is not worn properly
3. There is too much x-ray beam on-time
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3
3

GENERAL ANATOMY AND RADIOGRAPHIC POSITIONING TERMINOLOGY

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A, Radiograph of 6-year-old child. Epiphysis and epiphyseal plate shown on a knee radiograph (arrows). B, Radiograph of the same area in a 21-year-old individual. Full ossification has occurred, and only subtle epiphyseal lines are seen (arrows).
General Anatomy

Radiographers must possess a thorough knowledge of anatomy, physiology, and osteology to obtain radiographs that demonstrate the desired body part. Anatomy is the term applied to the science of the structure of the body. Physiology is the study of the function of the body organs. Osteology is the detailed study of the body of knowledge relating to the bones of the body.

Radiographers also must have a general understanding of all body systems and their functions. Particular attention must be given to thoroughly understanding the skeletal system and the surface landmarks used to locate different body parts. The radiographer must be able to mentally visualize the internal structures that are to be radiographed. By using external landmarks, the radiographer should properly position body parts to obtain the best diagnostic radiographs possible.

BODY PLANES

The full dimension of the human body as viewed in the anatomic position (see Chapter 1) can be effectively subdivided through the use of imaginary body planes. These planes slice through the body at designated levels from all directions. The following four fundamental body planes referred to in radiography are illustrated in Fig. 3-1, A:

- Sagittal
- Coronal
- Horizontal
- Oblique

Sagittal plane

A sagittal plane divides the entire body or a body part into right and left segments. The plane passes vertically through the body from front to back (Fig. 3-1, A and B). The midsagittal plane is a specific sagittal plane that passes through the midline of the body and divides it into equal right and left halves (Fig. 3-1, C).

Coronal plane

A coronal plane divides the entire body or a body part into anterior and posterior segments. The plane passes through the body vertically from one side to the other (see Fig. 3-1, A and B). The midcoronal plane is a specific coronal plane that passes through the midline of the body, dividing it into equal anterior and posterior halves (see Fig. 3-1, C). This plane is often referred to as the midaxillary plane.

Horizontal plane

A horizontal plane passes crosswise through the body or a body part at right angles to the longitudinal axis. It is positioned at a right angle to the sagittal and coronal planes. This plane divides the body into superior and inferior portions. Often it is referred to as a transverse or axial plane (Fig. 3-1, A).
**Oblique plane**

An oblique plane can pass through a body part at any angle between the three planes discussed earlier (see Fig. 3-1, A and B). Planes are used in radiographic positioning to center a body part to the image receptor (IR) or central ray and to ensure that the body part is properly oriented and aligned with the IR. For example, the mid-sagittal plane may be centered and perpendicular to the IR with the long axis of the IR parallel to the same plane. Planes can also be used to guide projections of the central ray. The central ray for an anteroposterior (AP) projection, for example, passes through the body part parallel to the sagittal plane and perpendicular to the coronal plane. Quality imaging requires attention to all relationships among body planes, the IR, and the central ray.

Body planes are used in computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound (US) to identify the orientation of anatomic cuts or slices demonstrated in the procedure. Imaging in several planes is often used to demonstrate a body part (Fig. 3-2).

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**Fig. 3-2** Magnetic resonance images of the knee in four planes. A, Sagittal. B, Coronal. C, Horizontal. D, Oblique, 45 degrees.
SPECIAL PLANES

Two special planes are used in radiographic positioning. These planes are localized to a specific area of the body only.

Interiliac plane
The interiliac plane transects the pelvis at the top of the iliac crests at the level of the fourth lumbar spinous process (Fig. 3-3, A). It is used in positioning the lumbar spine, sacrum, and coccyx.

Occlusal plane
The occlusal plane is formed by the biting surfaces of the upper and lower teeth with the jaws closed (Fig. 3-3, B). It is used in positioning the odontoid process and some head projections.

BODY CAVITIES

The two great cavities of the torso are the thoracic and abdominal cavities (Fig. 3-4). The thoracic cavity is subdivided into a pericardial segment and two pleural portions. Although the abdominal cavity has no intervening partition, the lower portion is called the pelvic cavity. Some anatomists combine the abdominal and pelvic cavities and refer to them as the abdominopelvic cavity. The principal structures located in the cavities follow.

Thoracic cavity
- Pleural membranes
- Lungs
- Trachea
- Esophagus
- Pericardium
- Heart and great vessels

Abdominal cavity
- Peritoneum
- Liver
- Gallbladder
- Pancreas
- Spleen
- Stomach
- Intestines
- Kidneys
- Ureters
- Major blood vessels
- Pelvic portion: rectum, urinary bladder, and parts of the reproductive system

Fig. 3-3 Special planes. A, Interiliac plane transecting the trunk at the tops of the iliac crests. B, Occlusal plane formed by the biting surfaces of the teeth.

Fig. 3-4 Anterior view of the torso showing the two great cavities: thoracic and abdominal.
DIVISIONS OF THE ABDOMEN

The abdomen is the portion of the trunk that is bordered superiorly by the diaphragm and inferiorly by the superior pelvic aperture (pelvic inlet). The location of organs or an anatomic area can be described by dividing the abdomen according to one of two methods: four quadrants or nine regions.

Quadrants

The abdomen is often divided into four clinical divisions called quadrants (Fig. 3-5). The midsagittal plane and a horizontal plane intersect at the umbilicus and create the boundaries. The quadrants are named as follows:

• Right upper quadrant (RUQ)
• Right lower quadrant (RLQ)
• Left upper quadrant (LUQ)
• Left lower quadrant (LLQ)

Dividing the abdomen into four quadrants is useful for describing the location of the various abdominal organs. For example, the spleen can be described as being located in the left upper quadrant.

Regions

Some anatomists divide the abdomen into nine regions by using four planes (Fig. 3-6). These anatomic divisions are not used as often as quadrants in clinical practice. The nine regions of the body, divided into three groups, are named as follows.

Superior

• Right hypochondrium
• Epigastrium
• Left hypochondrium

Middle

• Right lateral
• Umbilical
• Left lateral

In the clinical setting a patient could be described as having “epigastric” pain. A patient with discomfort in the right lower abdomen could be described as having “RLQ” pain. Sometimes a quadrant term is used and sometimes a region term.

Fig. 3-5 Four quadrants of the abdomen.

Fig. 3-6 Nine regions of the abdomen.
TABLE 3-1
External landmarks related to body structures at the same level

<table>
<thead>
<tr>
<th>Body structures</th>
<th>External landmarks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cervical area (see Fig. 3-6)</strong></td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>Mastoid tip</td>
</tr>
<tr>
<td>C2, C3</td>
<td>Gonion (angle of mandible)</td>
</tr>
<tr>
<td>C3, C4</td>
<td>Hyoid bone</td>
</tr>
<tr>
<td>C5</td>
<td>Thyroid cartilage</td>
</tr>
<tr>
<td>C7, T1</td>
<td>Vertebra prominens</td>
</tr>
<tr>
<td><strong>Thoracic area</strong></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>Approximately 2 in (5 cm) above level of jugular notch</td>
</tr>
<tr>
<td>T2, T3</td>
<td>Level of jugular notch</td>
</tr>
<tr>
<td>T4, T5</td>
<td>Level of sternal angle</td>
</tr>
<tr>
<td>T7</td>
<td>Level of inferior angles of scapulae</td>
</tr>
<tr>
<td>T9, T10</td>
<td>Level of xiphoid process</td>
</tr>
<tr>
<td><strong>Lumbar area</strong></td>
<td></td>
</tr>
<tr>
<td>L2, L3</td>
<td>Inferior costal margin</td>
</tr>
<tr>
<td>L4, L5</td>
<td>Level of most superior aspect of iliac crests.</td>
</tr>
<tr>
<td><strong>Sacrum and pelvic area</strong></td>
<td></td>
</tr>
<tr>
<td>S1, S2</td>
<td>Level of anterior superior iliac spines (ASS)</td>
</tr>
<tr>
<td>Coccyx</td>
<td>Level of pubic symphysis and greater trochanters</td>
</tr>
</tbody>
</table>

**SURFACE LANDMARKS**

Most anatomic structures cannot be visualized directly; therefore the radiographer must use various protuberances, tuberosities, and other external indicators to accurately position the patient. These surface landmarks enable the radiographer to consistently obtain radiographs of optimal quality for a wide variety of body types. If surface landmarks are not used for radiographic positioning or if they are used incorrectly, the chance of having to repeat the radiograph greatly increases.

Many of the commonly used landmarks are listed in Table 3-1 and diagrammed in Fig. 3-7. However, these landmarks are accepted averages for the majority of patients and should be used only as guidelines. Variations in anatomic build or pathologic conditions may warrant positioning compensation on an individual basis. The ability to compensate is gained through experience.
BODY HABITUS

The common variations in the shape of the human body are termed the body habitus. Mills determined the primary classifications of body habitus based on his study of 1000 patients. The specific type of body habitus is important in radiography because it determines the size, shape, and position of the organs of the thoracic and abdominal cavities.

Body habitus directly affects the location of the following:
- Heart
- Lungs
- Diaphragm
- Stomach
- Colon
- Gallbladder

An organ such as the gallbladder may vary in position by as much as 8 inches, depending on the body habitus. The stomach may be positioned horizontally, high, and in the center of the abdomen for one type of habitus and positioned vertically, low, and to the side of the midline in another type. Fig. 3-8 shows an example of the placement, shape, and size of the lungs, heart, and diaphragm in patients with four different body habitus types.

Body habitus and the placement of the thoracic and abdominal organs are also important in the determination of technical and exposure factors for the appropriate radiographic density and contrast and the radiation doses. For example, contrast medium in the gallbladder may affect the automatic exposure control detector. For one type of habitus the gallbladder may lie directly over the detector (which is not desirable); for another it may not even be near the detector. The standard placement and size of the IR may have to be changed because of body habitus. The selection of kilovolt (peak) and milliamperesecond exposure factors may also be affected by the type of habitus because of wide variations in physical tissue density. These technical considerations are described in greater detail in radiography physics and imaging texts.

Fig. 3-8 Placement, shape, and size of the lungs, heart, and diaphragm in patients with four different body habitus types. A, Sthenic. B, Hyposthenic. C, Asthenic. D, Hypersthenic.
Table 3-2 describes specific characteristics of the four types of body habitus and outlines their general shapes and variations. The four major types of body habitus and their approximate frequency in the population are identified below:

- Sthenic, 50%
- Hyposthenic, 35%
- Asthenic, 10%
- Hypersthenic, 5%

More than 85% of the population has either a sthenic or hyposthenic body habitus. The sthenic type is considered the dominant type of habitus. The relative shape of patients with a sthenic or hyposthenic body habitus and the position of their organs are referred to in clinical practice as ordinary or average. All standard radiographic positioning and exposure techniques are based on these two groups. Therefore radiographers must become thoroughly familiar with the characteristics and organ placements of these two body types.

Radiographers must also become familiar with the two extreme habitus types: asthenic and hypersthenic. In these two small groups (15% of the population), the placement and size of the organs significantly affect positioning and the selection of exposure factors. Consequently, radiography of these patients can be challenging. Experience and professional judgment enable the radiographer to determine the correct body habitus and to judge the specific location of the organs.

### TABLE 3-2
Four types of body habitus: prevalence, organ placement, and characteristics*

<table>
<thead>
<tr>
<th>Sthenic, 50%</th>
<th>Organs</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart: moderately transverse</td>
<td>Build: moderately heavy</td>
<td></td>
</tr>
<tr>
<td>Lungs: moderate length</td>
<td>Abdomen: moderately long</td>
<td></td>
</tr>
<tr>
<td>Diaphragm: moderately high</td>
<td>Thorax: moderately short, broad, and deep</td>
<td></td>
</tr>
<tr>
<td>Stomach: high, upper left</td>
<td>Pelvis: relatively small</td>
<td></td>
</tr>
<tr>
<td>Colon: spread evenly; slight dip in transverse colon</td>
<td>Gallbladder: centered on right side, upper abdomen</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hyposthenic, 35%</th>
<th>Organs</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart: nearly vertical and at midline</td>
<td>Build: frail</td>
<td></td>
</tr>
<tr>
<td>Lungs: long, apices above clavicles, may be broader above base</td>
<td>Abdomen: short</td>
<td></td>
</tr>
<tr>
<td>Diaphragm: low</td>
<td>Thorax: long, shallow</td>
<td></td>
</tr>
<tr>
<td>Stomach: low and medial, in the pelvis when standing</td>
<td>Pelvis: wide</td>
<td></td>
</tr>
<tr>
<td>Colon: low, folds on itself</td>
<td>Gallbladder: centered on right side</td>
<td></td>
</tr>
<tr>
<td>Gallbladder: centered on right side</td>
<td>Gallbladder: low and nearer the midline</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Asthenic, 10%</th>
<th>Organs</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart: nearly vertical and at midline</td>
<td>Build: frail</td>
<td></td>
</tr>
<tr>
<td>Lungs: long, apices above clavicles, may be broader above base</td>
<td>Abdomen: short</td>
<td></td>
</tr>
<tr>
<td>Diaphragm: low</td>
<td>Thorax: long, shallow</td>
<td></td>
</tr>
<tr>
<td>Stomach: low and medial, in the pelvis when standing</td>
<td>Pelvis: wide</td>
<td></td>
</tr>
<tr>
<td>Colon: low, folds on itself</td>
<td>Gallbladder: centered on right side</td>
<td></td>
</tr>
<tr>
<td>Gallbladder: centered on right side</td>
<td>Gallbladder: low and nearer the midline</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hypersthenic, 5%</th>
<th>Organs</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart: axis nearly transverse</td>
<td>Build: massive</td>
<td></td>
</tr>
<tr>
<td>Lungs: short, apices at or near clavicles</td>
<td>Abdomen: long</td>
<td></td>
</tr>
<tr>
<td>Diaphragm: high</td>
<td>Thorax: short, broad, deep</td>
<td></td>
</tr>
<tr>
<td>Stomach: high, transverse, and in the middle</td>
<td>Pelvis: narrow</td>
<td></td>
</tr>
<tr>
<td>Colon: around periphery of abdomen</td>
<td>Gallbladder: high, outside, lies more parallel</td>
<td></td>
</tr>
</tbody>
</table>

The organs and characteristics for this habitus are intermediate between the sthenic and asthenic body habitus types. This habitus is the most difficult to classify.

*Note the significant differences between the two extreme habitus types (i.e., sthenic and hypersthenic). The differences between the sthenic and hyposthenic types are less distinct.*
Body habitus is not an indication of disease or other abnormality, and it is not determined by the body fat or physical condition of the patient. Habitus is simply a classification of the four general shapes of the trunk of the human body. The radiographer should, when positioning patients, be conscious that habitus is not necessarily associated with height or weight. Four patients of equal height could have four different trunk shapes (Fig. 3-9).

Fig. 3-9 Different trunks are shown for the asthenic and hypersthenic habitus, the two extremes. Note the abdomen is the same length in both patients (diaphragm to pubic symphysis). The abdominal organs are in completely different positions. Art is based on actual autopsy findings by R. Walter Mills, MD.
TABLE 3-3
Axial skeleton: 80 bones

<table>
<thead>
<tr>
<th>Area</th>
<th>Bones</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skull Cranial</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Facial</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Auditory ossicles*</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Neck Hyoid</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Thorax Sternum</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Ribs</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Vertebral column Thoracic</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Lumbar</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Sacrum</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Coccyx</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

*Auditory ossicles are small bones in the ears. They are not considered official bones of the axial skeleton but are placed here for convenience.

TABLE 3-4
Appendicular skeleton: 126 bones

<table>
<thead>
<tr>
<th>Area</th>
<th>Bones</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder Clavicles</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>girdle Scapulae</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Upper limbs Humeri</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Ulnae</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Radii</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Carpals</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Metacarpals</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Phalanges</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Lower limbs Femora</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Tibias</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Fibulae</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Patellae</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Tarsals</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Metatarsals</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Phalanges</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Pelvic girdle Hip bones</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Osteology

The adult human skeleton is composed of 206 primary bones. Ligaments unite the bones of the skeleton. Bones provide the following:

- Attachment for muscles
- Mechanical basis for movement
- Protection of internal organs
- A frame to support the body
- Storage for calcium, phosphorus, and other salts
- Production of red and white blood cells

The 206 bones of the body are divided into two main groups:

- Axial skeleton
- Appendicular skeleton

The axial skeleton supports and protects the head and trunk with 80 bones (Table 3-3). The appendicular skeleton allows the body to move in various positions and from place to place with its 126 bones (Table 3-4). Fig. 3-10 identifies these two skeletal areas.

GENERAL BONE FEATURES

The general features of most bones are shown in Fig. 3-11. All bones are composed of a strong, dense outer layer called the compact bone and an inner portion of less dense spongy bone. The hard outer compact bone protects the bone and gives it strength for supporting the body. The softer spongy bone contains a speculated network of interconnecting spaces called the trabeculae (Fig. 3-12). The trabeculae are filled with red and yellow marrow. Red marrow produces red and white blood cells, and yellow marrow stores adipose (fat) cells. Long bones have a central cavity called the medullary cavity, which contains trabeculae filled with yellow marrow. In long bones the red marrow is concentrated at the ends of the bone and not in the medullary cavity.

A tough, fibrous connective tissue called the periosteum covers all bony surfaces except the articular surfaces, which are covered by the articular cartilage. The tissue lining the medullary cavity of bones is called the endosteum. Bones contain various knoblike projections called tubercles and tuberosities, which are covered by the periosteum. Muscles, tendons, and ligaments attach to the periosteum at these projections. Blood vessels and nerves enter and exit the bone through the periosteum.
Fig. 3-10 Two main groups of bones. A, Axial skeleton. B, Appendicular skeleton.

Fig. 3-11 General bone features and anatomic parts.

Fig. 3-12 Radiograph of the distal femur and condyles showing the bony trabeculae within the entire bone.
BONE VESSELS AND NERVES

Bones are live organs and must receive a blood supply for nourishment or they will die. Bones also contain a supply of nerves. Blood vessels and nerves enter and exit the bone at the same point, through openings called the foramina. Near the center of all long bones is an opening in the periosteum called the nutrient foramen. The nutrient artery of the bone passes into this opening and supplies the cancellous bone and marrow. The epiphyseal artery separately enters the ends of long bones to supply the area, and periosteal arteries enter at numerous points to supply the compact bone. Veins exiting the bones carry blood cells to the body (Fig. 3-13).

BONE DEVELOPMENT

Ossification is the term given to the development and formation of bones. Bones begin to develop in the second month of embryonic life. Ossification occurs separately by two distinct processes: intermembranous ossification and endochondral ossification.

Intermembranous ossification

Bones that develop from fibrous membranes in the embryo produce the flat bones such as those of the skull, clavicles, mandible, and sternum. Before birth these bones are not joined. As flat bones grow after birth, they join and form sutures. Other bones in this category merge together and create the various joints of the skeleton.

Endochondral ossification

Bones created by endochondral ossification develop from hyaline cartilage in the embryo and produce the short, irregular, and long bones. Endochondral ossification occurs from two distinct centers of development called the primary and secondary centers of ossification.

Primary ossification

Primary ossification begins before birth and forms the entire bulk of the short and irregular bones. This process forms the long central shaft in long bones. During development only, the long shaft of the bone is called the diaphysis (Fig. 3-14, A).

Secondary ossification

Secondary ossification occurs after birth when a separate bone begins to develop at both ends of every long bone. Each end is called the epiphysis (Fig. 3-14, B). At first the diaphysis and epiphysis are distinctly separate. As growth occurs, a plate of cartilage called the epiphyseal plate develops between the two areas (Fig. 3-14, C). This plate is seen on the long-bone radiographs of all pediatric patients (Fig. 3-15, A). The epiphyseal plate is important radiographically because it is a common site of fractures in pediatric patients. Near the age of 21, full ossification occurs and the two areas become completely joined; only a moderately visible epiphyseal line appears on the bone (Fig. 3-15, B).

CLASSIFICATION OF BONES

Bones are classified by shape, as follows (Fig. 3-16):

- Long
- Short
- Flat
- Irregular
- Sesamoid

Long bones

Long bones are found only in the limbs. They consist primarily of a long cylindrical shaft called the body and two enlarged, rounded ends that contain a smooth, slippery articular surface. A layer of articular cartilage covers this surface. The ends of these bones all articulate with other long bones. The femur and humerus are typical long bones. The phalanges of the fingers and toes are also considered long bones. A primary function of long bones is to provide support.

Short bones

Short bones consist mainly of cancellous bone containing red marrow and have a thin outer layer of compact bone. The carpal bones of the wrist and the tarsal bones of the ankles are the only short bones. They are varied in shape and allow minimum flexibility of motion in a short distance.
Flat bones
Flat bones consist largely of two tables of compact bone. The narrow space between the inner and outer tables contains cancellous bone and red marrow, or diploe as it is called in flat bones. The bones of the cranium, sternum, and scapula are examples of flat bones. The flat surfaces of these bones provide protection, and their broad surfaces allow muscle attachment.

Irregular bones
Irregular bones are so termed because their peculiar shapes and variety of forms do not place them in any other category. The vertebrae and the bones in the pelvis and face fall into this category. Like other bones, they have compact bone on the exterior and cancellous bone containing red marrow in the interior. Their shape serves many functions, including attachment for muscles, tendons, and ligaments, or they attach to other bones to create joints.

Fig. 3-15 A, Radiograph of 6-year-old child. Epiphysis and epiphyseal plate shown on a knee radiograph (arrows). B, Radiograph of the same area in a 21-year-old individual. Full ossification has occurred, and only subtle epiphyseal lines are seen (arrows).

Fig. 3-16 Bones are classified by shape. A, The humerus is a long bone. B, The carpals of the wrist are short bones. C, The sternum is a flat bone. D, The vertebra is an irregular bone. E, The patella is a sesamoid bone.
TABLE 3-5
Structural classification of joints

<table>
<thead>
<tr>
<th>Connective tissue</th>
<th>Classification</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibrous</td>
<td>1. Syndesmosis</td>
<td>Slightly movable</td>
</tr>
<tr>
<td></td>
<td>2. Suture</td>
<td>Immovable</td>
</tr>
<tr>
<td></td>
<td>3. Gomphosis</td>
<td>Immovable</td>
</tr>
<tr>
<td>Cartilaginous</td>
<td>4. Symphysis</td>
<td>Slightly movable</td>
</tr>
<tr>
<td></td>
<td>5. Synchondrosis</td>
<td>Immovable</td>
</tr>
<tr>
<td>Synovial</td>
<td>6. Gliding</td>
<td>Freely movable</td>
</tr>
<tr>
<td></td>
<td>7. Hinge</td>
<td>Freely movable</td>
</tr>
<tr>
<td></td>
<td>8. Pivot</td>
<td>Freely movable</td>
</tr>
<tr>
<td></td>
<td>9. Ellipsoid</td>
<td>Freely movable</td>
</tr>
<tr>
<td></td>
<td>10. Saddle</td>
<td>Freely movable</td>
</tr>
<tr>
<td></td>
<td>11. Ball and socket</td>
<td>Freely movable</td>
</tr>
</tbody>
</table>

Sesamoid bones
Sesamoid bones are very small and oval. They develop inside and beside tendons. Their function is to protect the tendon from excessive wear. The largest sesamoid bone is the patella, or the kneecap. Other sesamoids are located beneath the first metatarsal of the foot and adjacent to the metacarpals of the hand. Two small but prominent sesamoids are located beneath the base of the large toe. Like all other bones, they can be fractured.

Arthrology
Arthrology is the study of the joints, or articulations between bones. Joints make it possible for bones to support the body, protect internal organs, and create movement. A variety of specialized articulations are needed for these functions to occur.

Fig. 3-17 Examples of the three types of fibrous joints. A, Syndesmosis: inferior tibiofibular joint. B, Suture: sutures of the skull. C, Gomphosis: roots of the teeth in the alveolus.
The two classifications of joints described in anatomy books are functional and structural. Studying both classifications can be confusing. The most widely used and primary classification is the structural classification, which will be used to describe all the joints in this atlas. This is also the classification recognized by Nomina Anatomica. However, for academic interest a brief description of the functional classification is also provided.

**FUNCTIONAL CLASSIFICATION**

When joints are classified as functional, they are broken down into three classifications. These classifications are based on the mobility of the joint as follows:
- Synarthroses: immovable joints
- Amphiarthroses: slightly movable
- Diarthroses: freely movable

**STRUCTURAL CLASSIFICATION**

The structural classification of joints is based on the type of tissue that unite or bind the articulating bones. A thorough study of this classification will be easier if radiographers first become familiar with the terminology and breakdown of the structural classification identified in Table 3-5.

**Fibrous joints**

Fibrous joints do not have a joint cavity. They are united by various fibrous and connective tissues or ligaments. These are the strongest joints in the body because they are virtually immovable. The three types of fibrous joints follow:

1. **Syndesmosis**: an immovable joint or very slightly movable joint united by sheets of fibrous tissue. The inferior tibiofibular joint is an example (Fig. 3-17, A).
2. **Suture**: an immovable joint occurring only in the skull. In this joint the interlocking bones are held tightly together by strong connective tissues. The sutures of the skull are an example (Fig. 3-17, B).
3. **Gomphosis**: an immovable joint occurring only in the roots of the teeth. The roots of the teeth that lie in the alveolar sockets are held in place by fibrous periodontal ligaments (Fig. 3-17, C).

**Cartilaginous joints**

Cartilaginous joints are similar to fibrous joints in two ways: (1) they do not have a joint cavity, and (2) they are virtually immovable. Hyaline cartilage or fibrocartilage unites these joints. The two types of cartilaginous joints follow:

4. **Symphysis**: a slightly movable joint. The bones in this joint are separated by a pad of fibrocartilage. The ends of the bones contain hyaline cartilage. A symphysis joint is designed for strength and shock absorbency. The joint between the two pubic bones (pubic symphysis) is an example of a symphysis joint (Fig. 3-18, A). Another example of a symphysis joint is the joint between each vertebral body. These joints all contain a fibrocartilaginous pad or disk.
5. **Synchondrosis**: an immovable joint. This joint contains a rigid cartilage that unites two bones. An example is the epiphyseal plate found between the epiphysis and diaphysis of a growing long bone (Fig. 3-18, B). Before adulthood these joints consist of rigid hyaline cartilage that unites two bones. When growth stops, the cartilage ossifies, thus making this type of joint a temporary joint.
Synovial joints

Synovial joints permit a wide range of motion, and therefore they are all freely movable. These joints are the most complex joints in the body. Their distinguishing features are shown in Fig. 3-19.

An articular capsule completely surrounds and enfolds all synovial joints to join the separate bones together. The outer layer of the capsule is called the fibrous capsule, and its fibrous tissue connects the capsule to the periosteum of the two bones. The synovial membrane, which is the inner layer, surrounds the entire joint to create the joint cavity. The membrane produces a thick, yellow, viscous fluid called synovial fluid. Synovial fluid lubricates the joint space to reduce friction between skin and bones, tendons and bones, and muscles and bones. The menisci, bursae, and other joint structures can be visualized radiographically by injecting iodine-based contrast medium or air directly into the synovial cavity. This procedure, called arthrography, is detailed in Chapter 13.

The six synovial joints complete the structural classification. They are listed in order of increasing movement. The most common name of each joint is identified, and the less frequently used name is given in parentheses.

1. **Gliding (plane):** uniaxial movement. This is the simplest synovial joint. Joints of this type permit very slight movement. They have flattened or slightly curved surfaces, and most glide slightly in only one axis. The intercarpal and intertarsal joints of the wrist and foot are examples of the gliding joint (Fig. 3-20, A).

2. **Hinge (ginglymus):** uniaxial movement. A hinge joint permits only flexion and extension. The motion is similar to that of a door. The elbow, knee, and ankle are examples of this type of joint (Fig. 3-20, B).

3. **Pivot (trochoid):** uniaxial movement. These joints allow only rotation around a single axis. A rounded or pointed surface of one bone articulates within a ring formed partially by the other bone. An example of this joint is the articulation of the atlas and axis of the cervical spine. The atlas rotates around the dens of the axis and allows the head to rotate to either side (Fig. 3-20, C).

4. **Ellipsoid (condyloid):** biaxial movement, primary. An ellipsoid joint permits movement in two directions at right angles to each other. The radiocarpal joint of the wrist is an example. Flexion and extension occur along with abduction and adduction. Circumduction, a combination of both movements, can also occur (Fig. 3-20, D).

5. **Saddle (sellar):** biaxial movement. This joint permits movement in two axes, very similar to the ellipsoid joint. The joint is so named because the articular surface of one bone is saddle shaped and the articular surface of the other bone is shaped like a rider sitting in a saddle. The carpo-metacarpal joint between the trapezium and the first metacarpal is the only saddle joint in the body. The face of each bone end has a concave and a convex aspect. The opposing bones are shaped in a manner that allows side-to-side and up-and-down movement (Fig. 3-20, E).

6. **Ball and socket (spheroid):** multi-axial movement. This joint permits movement in many axes: flexion and extension, abduction and adduction, circumduction, and rotation. In a ball-and-socket joint the round head of one bone rests within the cup-shaped depression of the other bone. The hip and shoulder are examples (Fig. 3-20, F).
Bone Markings and Features

The following anatomic terms are used to describe either processes or depressions on bones.

**PROCESSES OR PROJECTIONS**

Processes or projections extend beyond or project out from the main body of a bone and are designated by the following terms:

- **condyle**: Rounded process at an articular extremity
- **coracoid or coronoid**: Beaklike or crownlike process
- **crest**: Ridge-like process
- **epicondyle**: Projection above a condyle
- **facet**: Small, smooth-surfaced process for articulation
- **hamulus**: Hook-shaped process
- **head**: Expanded end of a long bone
- **horn**: Horn-like process on a bone
- **line**: Less prominent ridge than a crest; a linear elevation
- **malleolus**: Club-shaped process
- **protuberance**: Projecting part or prominence
- **spine**: Sharp process
- **styloid**: Long, pointed process
- **tubercle**: Small, rounded, and elevated process
- **tuberosity**: Large, rounded, and elevated process

**DEPRESSIONS**

Depressions are hollow or depressed areas and are described by the following terms:

- **fissure**: Cleft or deep groove
- **foramen**: Hole in a bone for transmission of blood vessels and nerves
- **fossa**: Pit, fovea, or hollow space
- **groove**: Shallow linear channel
- **meatus**: Tubelike passageway running within a bone
- **notch**: Indentation into the border of a bone
- **sinus**: Recess, groove, cavity, or hollow space such as (1) a recess or groove in bone, as used to designate a channel for venous blood on inner surface of cranium, (2) an air cavity in bone or a hollow space in other tissue (used to designate a hollow space within a bone as in paranasal sinuses), or (3) a fistula or suppurating channel in soft tissues
- **sulcus**: Furrow, trench, or fissure-like depression

**Fractures**

A fracture is a break in the bone. Fractures are classified according to the nature of the break. Several general terms can pertain to them:

- **closed**: Fracture that does not break through the skin
- **open**: Serious fracture in which the broken bone or bones project through the skin
- **nondisplaced**: Fracture in which the bone retains its normal alignment
- **displaced**: More serious fracture in which the bones are not in anatomic alignment

Some of the common classifications of fractures are listed below and identified in Fig. 3-21.

- Compression
- Open or compound
- Simple
- Greenstick
- Transverse
- Spiral or oblique
- Comminuted
- Impacted

Many fractures fall into more than one category. For example, a fracture could be spiral, closed, and nondisplaced.
Anatomic Relationship Terms

Various terms are used to describe the relationship of parts of the body in the anatomic position. Radiographers should be thoroughly familiar with these terms, which are commonly used in clinical practice. Most of the following positioning and anatomic terms are paired as opposites. Fig. 3-22 illustrates two commonly used sets of terms.

- **anterior (ventral)** refers to forward or front part of the body or forward part of an organ.
- **posterior (dorsal)** refers to back part of a body or organ. (Note, however, that the superior surface of the foot is referred to as the dorsal surface.)
- **caudad** refers to parts away from the head of the body.
- **cephalad** refers to parts toward the head of the body.
- **superior** refers to nearer the head or situated above.
- **inferior** refers to nearer the feet or situated below.
- **central** refers to midarea or main part of an organ.
- **proximal** refers to parts nearer the point of attachment, point of reference, origin, or beginning; toward the center of the body.
- **distal** refers to parts farthest from the point of attachment, point of reference, origin, or beginning; away from center of body.
- **external** refers to parts outside an organ or on the outside of the body.
- **internal** refers to parts within or on the inside of an organ.
- **parietal** refers to the wall or lining of a body cavity.
- **visceral** refers to the covering of an organ.
- **ipsilateral** refers to a part or parts on the same side of the body.
- **contralateral** refers to a part or parts on the opposite side of the body.
- **palmar** refers to the palm of the hand.
- **plantar** refers to sole of the foot.
- **dorsum** refers to the top or anterior surface of the foot, or to the back or posterior surface of the hand.

Radiographic Positioning Terminology

Radiography is the process of recording an image of a body part using one or more types of image receptors (IRs) (cassette/fil, cassette/phosphor plate, or fluoroscopic screen/TV). The terminology used to position the patient and to obtain the radiograph was developed through convention. Attempts to analyze the usage often lead to confusion because the manner in which the terms are used does not follow one specific rule. During the preparation of this chapter, contact was maintained with the American Registry of Radiologic Technologists (ARRT) and the Canadian Association of Medical Radiation Technologists (CAMRT). The ARRT first distributed the “Standard Terminology for Positioning and Projection” in 1978; it has not been substantially revised since initial distribution. Despite its title, the ARRT document did not actually define selected positioning terms. Terms not defined by the ARRT are defined in this text.

Approval of Canadian positioning terminology is the responsibility of the CAMRT Radiography Council on Education. This council provided information for the development of this chapter and clearly identified the terminology differences between the United States and Canada.

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1. ARRT Educator’s handbook. ed 3. 1990. ARRT.
2. ARRT. Conventions specific to the radiographic examinations. 1993. ARRT.
3. ARRT. Personal communication and permission. May 1993.
The terminology used by the ARRT and CAMRT is consistent overall with that used in this text. The only difference is that the term view is commonly used in Canada for some projections and positions.

The following are the four positioning terms most commonly used in radiology:
- Projection
- Position
- View
- Method

**PROJECTION**

The term *projection* is defined as the path of the central ray as it exits the x-ray tube and goes through the patient to the IR. Most projections are defined by the entrance and exit points in the body and are based on the anatomic position. For example, when the central ray enters anywhere in the front (anterior) surface of the body and exits the back (posterior), an *anteroposterior* (AP) projection is obtained. Regardless of which body position the patient is in (e.g., supine, prone, upright, etc.), if the central ray enters the anterior body surface and exits the posterior body surface, the projection is termed an AP projection (Fig. 3-23).

Projections can also be defined by the relationship formed between the central ray and the body as the central ray passes through the entire body or body part. Examples include the *axial* and *tangential projections.*

All radiographic examinations described in this text are standardized and titled by their x-ray projection. It is the x-ray projection that accurately and concisely defines each image produced in radiography. A complete listing of the projection terms used in radiography is provided in Table 3-6. The essential radiographic projections follow.

**AP projection**

In Fig. 3-24 a perpendicular central ray enters the anterior body surface and exits the posterior body surface. This is an AP projection. The patient is shown in the supine or dorsal recumbent body position. AP projections can also be achieved with upright, seated, or lateral decubitus positions.

**PA projection**

In Fig. 3-25 a perpendicular central ray is shown entering the posterior body surface and exiting the anterior body surface. This illustrates a *posteroanterior* (PA) projection with the patient in the upright body position. PA projections can also be achieved with seated, prone (ventral recumbent), and lateral decubitus positions.

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**TABLE 3-6**

Primary x-ray projections

<table>
<thead>
<tr>
<th>Projections</th>
<th>Positions</th>
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<tbody>
<tr>
<td>Anteroposterior (AP)</td>
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<tr>
<td>Posteroanterior (PA)</td>
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<td>Trendelenburg</td>
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<td>AP axial oblique</td>
<td>Radiographic body positions</td>
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<td>Right</td>
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<tr>
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<td>Left</td>
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<td>Oblique</td>
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<td>Left posterior</td>
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<td>(RPO)</td>
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<td>(LPO)</td>
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<td>(RAO)</td>
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<td>(LAO)</td>
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<td>Parieto-orbital</td>
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</table>

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Upright
Supine
Lateral decubitus

Fig. 3-23. Patient’s head placed in upright, supine, and lateral decubitus positions for a radiograph. All three body positions produce an AP projection of the skull.
Axial projection

In an axial projection (Fig. 3-26), there is longitudinal angulation of the central ray with the long axis of the body or a specific body part. This angulation is based on the anatomic position and is most often produced by angling the central ray cephalad or caudad. The longitudinal angulation in some examinations is achieved by angling the entire body or body part while maintaining the central ray perpendicular to the IR.

The term axial, as used in this text, refers to all projections in which the longitudinal angulation between the central ray and the long axis of the body part is 10 degrees or more. When a range of central ray angles, such as 5 to 15 degrees, is recommended for a given projection, the term axial is used because the angulation could exceed 10 degrees. Axial projections are used in a wide variety of examinations and can be obtained with the patient in virtually any body position.

Tangential projection

Occasionally the central ray is directed toward the outer margin of a curved body surface to profile a body part just under the surface and project it free of superimposition. This is called a tangential projection because of the tangential relationship formed between the central ray and the entire body or body part (Fig. 3-27).
Lateral projection
For a lateral projection, a perpendicular central ray enters one side of the body or body part, passes transversely along the coronal plane, and exits on the opposite side. Lateral projections can enter from either side of the body or body part as needed for the examination. This can be determined by the patient’s condition or ordered by the physician. When a lateral projection is used for head, chest, or abdominal radiography, the direction of the central ray is described with reference to the associated radiographic position. A left lateral position or right lateral position specifies the side of the body closest to the IR and corresponds with the side exited by the central ray (Fig. 3-28). Lateral projections of the limbs are further clarified by the terms lateromedial or mediolateral to indicate the sides entered and exited by the central ray (Fig. 3-29). The transsthoracic projection is a unique lateral projection used for shoulder radiography and is described in Chapter 5 of this atlas.

Oblique projection
During an oblique projection the central ray enters the body or body part from a side angle following an oblique plane. Oblique projections may enter from either side of the body and from anterior or posterior surfaces. If the central ray enters the anterior surface and exits the opposite posterior surface, it is an AP oblique projection; if it enters the posterior surface and exits anteriorly, it is a PA oblique projection (Fig. 3-30).

Most oblique projections are achieved by rotating the patient with the central ray perpendicular to the IR. As in the lateral projection the direction of the central ray for oblique projections is described with reference to the associated radiographic position. A right posterior oblique position, for example, places the right posterior surface of the body closest to the IR and corresponds with an AP oblique projection exiting through the same side. This relationship is discussed later. Oblique projections can also be achieved for some examinations by angling the central ray diagonally along the horizontal plane rather than rotating the patient.

Complex projections
For additional clarity, projections may be defined by entrance and exit points and by the central ray relationship to the body at the same time. For example, in the PA axial projection the central ray enters the posterior body surface and exits the anterior body surface following an axial or angled trajectory relative to the entire body or body part. Axiolateral projections also use angulations of the central ray, but the ray enters and exits through lateral surfaces of the entire body or body part.

Fig. 3-28 Lateral projection of chest. The patient is placed in the right lateral position. The right side of chest is touching the image receptor. The central ray enters the left or opposite side of body.

Fig. 3-29 Lateromedial projection of the forearm. The central ray enters the lateral aspect of the forearm and exits the medial aspect.
**True projections**

The term *true* (true AP, true PA, and true lateral) is often used in clinical practice. True is used to specifically indicate that the body part must be placed exactly in the anatomic position.

A true AP or PA projection is obtained when the central ray is perpendicular to the coronal plane and parallel to the sagittal plane. A true lateral projection is obtained when the central ray is parallel to the normal plane and perpendicular to the sagittal plane. When a body part is rotated for an AP or PA oblique projection, a true AP or PA cannot be obtained. In this atlas the term true is used only when the body part is placed in the anatomic position.


**POSITION**

The term *position* is used in two ways in radiology. One way identifies the overall posture of the patient or the general body position. The patient may, for example, be described as upright, seated, or supine. The other use of *position* refers to the specific placement of the body part in relation to the radiographic table or IR during imaging. This is the radiographic position and may be a right lateral, left anterior oblique, or other position depending on the examination and anatomy of interest. A listing of all general body positions and radiographic positions is provided in Table 3-6.

During radiography, general body positions are combined with radiographic positions to produce the appropriate image. For clarification of the positioning for an examination, it is often necessary to include references to both because a particular radiographic position such as right lateral can be achieved in several general body positions (upright, supine, lateral recumbent, etc.) with differing image outcomes. Specific descriptions of general body positions and radiographic positions follow.

---

![PA oblique projection of the chest](image-url)
Fig. 3-31  Supine position of the body, also termed the dorsal recumbent position. The patient’s knees are flexed for comfort.

Fig. 3-32  Prone position of the body. It can also be termed the ventral recumbent position.

Fig. 3-33  Recumbent position of the body, specifically a right lateral recumbent position.

Fig. 3-34  Trendelenburg’s position of the body. The feet are higher than the head.

General body positions
The following list describes the general body positions. All are commonly used in radiography practice.

upright  Erect or marked by a vertical position (see Fig. 3-25)
seated  Upright position in which the patient is sitting on a chair or stool
recumbent  General term referring to lying down in any position, such as dorsal recumbent (Fig. 3-31), ventral recumbent (Fig. 3-32), or lateral recumbent (Fig. 3-33)
supine  Lying on the back (see Fig. 3-31)
prone  Lying face down (see Fig. 3-32)
Trendelenburg’s position  Supine position with the head tilted downward (Fig. 3-34)
Fowler’s position  Supine position with the head higher than the feet (Fig. 3-35)
Sim’s position  A recumbent position with the patient lying on the left anterior side (semi-prone) with the left leg extended and the right knee and thigh partially flexed (Fig. 3-36)
Lithotomy position  A supine position with the knees and hip flexed and thighs abducted and rotated externally, supported by ankle supports (Fig. 3-37)
**Lateral position**

Lateral radiographic positions are always named according to the side of the patient that is placed closest to the IR (Figs. 3-38 and 3-39). In this text, the right or left lateral positions are indicated as subheadings for all lateral x-ray projections of the head, chest, and abdomen in which either the left or right side of the patient is placed adjacent to the IR. The specific side selected depends on the condition of the patient, the anatomic structure of clinical interest, and the purpose of the examination. Note that in Figs. 3-38 and 3-39 the x-ray projection for the positions indicated is lateral projection.

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**Fig. 3-35** Fowler’s position of the body. The head is higher than the feet.

**Fig. 3-36** Sim’s position of the body. Patient is on the left side in a recumbent oblique position.

**Fig. 3-37** Lithotomy position of the body. Knees and hips are flexed and thighs abducted and rotated laterally.

**Fig. 3-38** Left lateral radiographic position of the chest results in a lateral projection.

**Fig. 3-39** Right lateral radiographic position of the chest results in a lateral projection.
Oblique position

An oblique radiographic position is achieved when the entire body or body part is rotated so that the coronal plane is not parallel with the radiographic table or IR. The angle of oblique rotation varies with the examination and structures to be demonstrated. In this atlas an angle is specified for each oblique position (e.g., rotated 45 degrees from the prone position).

Oblique positions, like lateral positions, are always named according to the side of the patient that is placed closest to the IR. In Fig. 3-40 the patient is rotated with the right anterior body surface in contact with the radiographic table. This is a right anterior oblique (RAO) position because the right side of the anterior body surface is closest to the IR. Fig. 3-41 shows the patient placed in a left anterior oblique (LAO) position.
The relationship between oblique position and oblique projection can be summarized simply. Anterior oblique positions result in PA oblique projections as shown in Figs. 3-40 and 3-41. Similarly, posterior oblique positions result in AP oblique projections as illustrated in Figs. 3-42 and 3-43.

The oblique positioning terminology used in this atlas has been standardized using the RAO and LAO or RPO and LPO positions along with the appropriate PA or AP oblique projection. For oblique positions of the limbs, the terms *medial rotation* and *lateral rotation* have been standardized to designate the direction in which the limbs have been turned from the anatomic position (Fig. 3-44).
Decubitus position

In radiographic positioning terminology, the term *decubitus* indicates that the patient is lying down and that the central ray is horizontal and parallel with the floor. Three primary decubitus positions are named according to the body surface on which the patient is lying: *lateral decubitus* (left or right), *dorsal decubitus*, and *ventral decubitus*. Of these, the lateral decubitus position is most often used to demonstrate the presence of air-fluid levels or free air in the chest and abdomen.

In Fig. 3-45 the patient is placed in the left lateral decubitus radiographic position with the back (posterior surface) closest to the IR. In this position, a horizontal central ray provides an AP projection. Thus Fig. 3-45 is accurately described as an AP projection with the body in the left lateral decubitus position. Alternatively, the patient may be placed with the front of the body (anterior surface) facing the IR, resulting in a PA projection. This would be correctly described as a PA projection of the body in the left lateral decubitus position. Right lateral decubitus positions may be necessary with AP or PA projections, depending on the examination.

In Fig. 3-46 the patient is shown in a dorsal decubitus radiographic position with one side of the body next to the IR. The horizontal central ray provides a lateral projection. This is correctly described as a lateral projection with the patient placed in the dorsal decubitus position. Either side may face the IR, depending on the examination or the patient’s condition.

The ventral decubitus radiographic position (Fig. 3-47) also places a side of the body adjacent to the IR, resulting in a lateral projection. Similar to the earlier examples, the accurate terminology is lateral projection with the patient in the ventral decubitus position. Once again, either side may face the IR.

Lordotic position

The lordotic position is achieved by having the patient lean backward while in the upright body position so that only the shoulders are in contact with the IR (Fig. 3-48). An angulation forms between the central ray and the long axis of the upper body, producing an AP axial projection. This position is used for the visualization of pulmonary apices (see Chapter 10) and clavicles (see Chapter 5).
Note to educators, students, and clinicians

In clinical practice the terms *position* and *projection* are interchangeably and incorrectly used. Incorrect use leads to confusion for the student who is attempting to learn the correct terminology of the profession. Educators and clinicians are encouraged to generally use the term *projection* when describing any examination performed. The word *projection* is the only term that accurately describes how the body part is being examined. The term *position* should be used only when referring to the placement of the patient’s body. These are two distinct terms that should not be interchanged. A correct example is “We are going to perform a PA projection of the chest with the patient in the upright position.”

**VIEW**

The term *view* is used to describe the body part as seen by the IR. Use of this term is restricted to the discussion of a finished radiograph or image. *View* and *projection* are exact opposites. The shadows cast on an IR by the x-rays projected through a body part are viewed on the resulting image from the opposite direction. Simply stated, the image “looks back” into the body from the side that was closest to the IR. For many years *view* and *projection* were often used interchangeably, which led to confusion. In the United States *projection* has replaced *view* as the preferred terminology for describing radiographic images. In Canada *view* remains an acceptable positioning term. For consistency, the atlas refers to all views as *images* or *radiographs*.

**METHOD**

Some radiographic projections and procedures are named after individuals (e.g., Waters or Towne) in recognition of their development of a method to demonstrate a specific anatomic part. Method, which was first described in the fifth edition of this atlas, describes the specific radiographic projection that the individual developed. The method specifies the x-ray projection and body position, and it may include specific items such as IR and central ray position. In this atlas, standard projection terminology is used first and a named method is listed secondarily (e.g., PA axial projection; Towne method). The ARRT and CAMRT use the standard anatomic projection terminology and list the originator in parentheses.
Body Movement Terminology

The following terms are used to describe movement related to the limbs. These terms are often used in positioning descriptions and in the patient history provided to the radiographer by the referring physician. They must, therefore, be studied thoroughly.

**abduct or abduction** Movement of a part away from the central axis of the body or body part

**adduct or adduction** Movement of a part toward the central axis of the body or body part (Fig. 3-49)

**extension** Straightening of a joint; When both elements of the joint are in the anatomic position; the normal position of a joint (Fig. 3-50).

**flexion** Act of bending a joint; the opposite of extension (Fig. 3-50)

**hyperextension** Forced or excessive extension of a limb or joints

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**Fig. 3-49** Abduction and adduction of the arm.

**Fig. 3-50** Extension of the arm (anatomic position) and flexion (bending).

**Fig. 3-51** Hyperextension, extension, and hyperflexion of the neck.

**Fig. 3-52** Inversion and eversion of the foot at the ankle joint.
**hyperflexion** Forced overflexion of a limb or joints (Fig. 3-51)

**evert/eversion** Outward turning of the foot at the ankle

**invert/inversion** Inward turning of the foot at the ankle (Fig. 3-52)

**pronate/pronation** Rotation of the forearm so that the palm is down

**supinate/supination** Rotation of the forearm so that the palm is up (in the anatomic position) (Fig. 3-53)

**rotate/rotation** Turning or rotating of the body or a body part around its axis (Fig 3-54. A). Rotation of a limb will be either **medial** (toward the midline of the body from the anatomic position; Fig. 3-54, B) or **lateral** (away from the midline of the body from the anatomic position; Fig. 3-54, C)

**circumduction** Circular movement of a limb (Fig. 3-55)

**tilt** Tipping or slanting a body part slightly. The tilt is in relation to the long axis of the body (Fig. 3-56)

**deviation** A turning away from the regular standard or course (Fig. 3-57).

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**Fig. 3-53** Pronation and supination of the forearm.

**Fig. 3-54** A, Rotation of the chest and abdomen. The patient's arm and knee are flexed for comfort. B, Medial rotation of the left leg. C, Lateral rotation of the left leg.

**Fig. 3-55** Circumduction of the arm.

**Fig. 3-56** Tilt of the skull is 15 degrees from the long axis.

**Fig. 3-57** Radial deviation of the hand (turned to the radial side) and ulnar deviation (turned to the ulnar side).
### TABLE 3-7

Greek and Latin nouns: common singular and plural forms

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<thead>
<tr>
<th>Singular</th>
<th>Plural</th>
<th>Examples: singular—plural</th>
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<tbody>
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<td>-ces</td>
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### TABLE 3-8

Frequently misused single and plural word forms

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**Medical Terminology**

Single and plural word endings for common Greek and Latin nouns are presented in Table 3-7. Single and plural word forms are often confused. Examples of commonly misused word forms are listed in Table 3-8. Generally the singular form is used when the plural form is intended.
PA hand showing complete fracture and dislocation of the third proximal phalanx. Note overall hand was placed in correct position despite trauma. This gives the physician accurate information about displacement of the bone.
### SUMMARY OF PROJECTIONS

#### PROJECTIONS, POSITIONS & METHODS

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<th>Anatomy</th>
<th>Projection</th>
<th>Position &amp; Method</th>
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<td>Wrist: trapezium</td>
<td>PA oblique</td>
<td>RAFERT-LONG</td>
</tr>
<tr>
<td>135</td>
<td>▲</td>
<td>Carpal bridge</td>
<td>Tangential</td>
<td>CLEMENTS-NAKAYAMA</td>
</tr>
<tr>
<td>136</td>
<td>▲</td>
<td>Carpal canal</td>
<td>Tangential</td>
<td>GAYNOR-HART</td>
</tr>
<tr>
<td>138</td>
<td>▲</td>
<td>Forearm</td>
<td>AP</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>▲</td>
<td>Forearm</td>
<td>Lateral</td>
<td></td>
</tr>
<tr>
<td>141</td>
<td>▲</td>
<td>Elbow</td>
<td>AP</td>
<td></td>
</tr>
<tr>
<td>142</td>
<td>▲</td>
<td>Elbow</td>
<td>Lateral</td>
<td></td>
</tr>
<tr>
<td>144</td>
<td>▲</td>
<td>Elbow</td>
<td>AP oblique</td>
<td>Medial rotation</td>
</tr>
<tr>
<td>145</td>
<td>▲</td>
<td>Elbow</td>
<td>AP oblique</td>
<td>Lateral rotation</td>
</tr>
<tr>
<td>146</td>
<td>▲</td>
<td>Elbow: distal humerus</td>
<td>AP</td>
<td>Partial flexion</td>
</tr>
<tr>
<td>147</td>
<td>▲</td>
<td>Elbow: proximal forearm</td>
<td>AP</td>
<td>Partial flexion</td>
</tr>
<tr>
<td>148</td>
<td>▲</td>
<td>Elbow: distal humerus</td>
<td>AP</td>
<td>Acute flexion</td>
</tr>
<tr>
<td>149</td>
<td>▲</td>
<td>Elbow: proximal forearm</td>
<td>PA</td>
<td>Acute flexion</td>
</tr>
<tr>
<td>150</td>
<td>▲</td>
<td>Elbow: radial head</td>
<td>Lateral</td>
<td></td>
</tr>
<tr>
<td>152</td>
<td>▲</td>
<td>Distal humerus</td>
<td>PA axial</td>
<td></td>
</tr>
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<td>153</td>
<td>▲</td>
<td>Olecranon process</td>
<td>PA axial</td>
<td></td>
</tr>
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<td>154</td>
<td>▲</td>
<td>Humerus</td>
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<td>156</td>
<td>▲</td>
<td>Humerus</td>
<td>AP</td>
<td>Recumbent</td>
</tr>
<tr>
<td>157</td>
<td>▲</td>
<td>Humerus</td>
<td>Lateral</td>
<td>Recumbent</td>
</tr>
<tr>
<td>158</td>
<td>▲</td>
<td>Humerus</td>
<td>Lateral</td>
<td>Recumbent, lateral recumbent</td>
</tr>
</tbody>
</table>

The icons in the Essential column indicate projections frequently performed in the United States and Canada. Students should demonstrate competence in these projections.
Anatomists divide the bones of the upper limbs, or extremities, into the following main groups:

- Hand
- Forearm
- Arm
- Shoulder girdle

The proximal arm and shoulder girdle are discussed in Chapter 5.

**Hand**

The hand consists of 27 bones, which are subdivided into the following groups:

- Phalanges: bones of the digits (fingers and thumb)
- Metacarpals: bones of the palm
- Carpal: bones of the wrist (Fig. 4-1)

**DIGITS**

The digits are described by numbers and names; however, description by number is the more correct practice. Beginning at the lateral, or thumb, side of the hand the numbers and names are as follows:

- First digit (thumb)
- Second digit (index finger)
- Third digit (middle finger)
- Fourth digit (ring finger)
- Fifth digit (small finger)

The digits contain a total of 14 phalanges (phalanx, singular), which are long bones that consist of a cylindric body and articular ends. Nine digits have two articular ends. The first digit has two phalanges—the proximal and distal. The other digits have three phalanges—the proximal, middle, and distal. The proximal phalanges are the closest to the palm, and the distal phalanges are the farthest from the palm. The distal phalanges are small and flattened, with a roughened rim around their distal anterior end; this gives them a spatulalike appearance.

**CARPAL TERMINOLOGY CONVERSION**

<table>
<thead>
<tr>
<th>Preferred</th>
<th>Synonyms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal row:</td>
<td></td>
</tr>
<tr>
<td>Scaphoid</td>
<td>Navicular</td>
</tr>
<tr>
<td>Lunate</td>
<td>Semilunar</td>
</tr>
<tr>
<td>Triquetrum</td>
<td>Triquetral, cuneiform, or triangular</td>
</tr>
<tr>
<td>Pisiform</td>
<td>(none)</td>
</tr>
<tr>
<td>Distal row:</td>
<td></td>
</tr>
<tr>
<td>Trapezium</td>
<td>Greater multangular</td>
</tr>
<tr>
<td>Trapezoid</td>
<td>Lesser multangular</td>
</tr>
<tr>
<td>Capitate</td>
<td>Os magnum</td>
</tr>
<tr>
<td>Capitate</td>
<td>Unciform</td>
</tr>
</tbody>
</table>

**METACARPALS**

Five metacarpals, which are cylindric in shape and slightly concave anteriorly, form the palm of the hand (see Fig. 4-1). They are long bones consisting of a body and two articular ends, the head distally and the base proximally. The metacarpal heads, commonly known as the knuckles, are located on the dorsal hand. The metacarpals are numbered one to five, beginning from the lateral side of the hand.

**WRIST**

The wrist has eight carpal bones, which are fitted closely together and arranged in two horizontal rows (see Fig. 4-1). The carpals are classified as short bones and are composed largely of cancellous tissue with an outer layer of compact bony tissue. These bones, with one exception, have two or three names; this book uses the preferred terms (see box). The proximal row of carpals, which is nearest the forearm, contains the scaphoid, lunate, triquetrum, and pisiform. The distal row includes the trapezium, trapezoid, capitate, and hamate.
Each carpal contains identifying characteristics. Beginning the proximal row of carpals on the lateral side, the scaphoid, the largest bone in the proximal carpal row, has a tubercle on the anterior and lateral aspect for muscle attachment and is palpable near the base of the thumb. The lunate articulates with the radius proximally and is easy to recognize because of its crescent shape. The trapezium is roughly pyramidal and articulates anteriorly with the hamate. The pisiform is a pea-shaped bone situated anterior to the triquetrum and is easily palpated.

Beginning the distal row of carpals on the lateral side, the trapezium has a tubercle and groove on the anterior surface. The tubercles of the trapezium and scaphoid comprise the lateral margin of the carpal groove. The trapezoid has a smaller surface anteriorly than posteriorly. The capitate articulates with the base of the third metacarpal and is the largest and most centrally located carpal. The wedge-shaped hamate exhibits the prominent hook of hamate, which is located on the anterior surface. The hamate and the pisiform form the medial margin of the carpal groove.

A triangular depression is located on the posterior surface of the wrist and is visible when the thumb is abducted and extended. This depression, known as the anatomic snuffbox, is formed by the tendons of the two major muscles of the thumb. The anatomic snuffbox overlies the scaphoid bone and the radial artery, which carries blood to the dorsum of the hand. Tenderness in the snuffbox area is a clinical sign suggesting fracture of the scaphoid—the most commonly fractured carpal bone.

CARPAL SULCUS

The anterior or palmar surface of the wrist is concave from side to side and forms the carpal sulcus (Figs. 4-2 and 4-3). The flexor retinaculum, a strong fibrous band, attaches medially to the pisiform and hook of hamate and laterally to the tubercles of the scaphoid and trapezium. The carpal tunnel is the passageway created between the carpal sulcus and flexor retinaculum. The median nerve and the flexor tendons pass through the carpal canal. Carpal tunnel syndrome results from compression of the median nerve inside the carpal tunnel.

Fig. 4-2 Axial MRI of the wrist. Bones in same position as Fig. 4-3. Note position of the carpal bones and the carpal sulcus protecting the tendons of the fingers and the median nerve (mn). The flexor retinaculum (fr) is also seen.

(From Kelley L, Peterson C: Sectional anatomy. St Louis, 1997, Mosby.)

Fig. 4-3 Carpal sulcus.
Forearm

The *forearm* contains two bones that lie parallel to each other—the *radius* and *ulna*. Like other long bones, they have of a body and two articular extremities. The radius is located on the lateral side of the forearm, and the ulna is on the medial side (Figs. 4-4 and 4-5).

ULNA

The *body* of the ulna is long and slender and tapers inferiorly. The upper portion of the ulna is large and presents two beaklike processes and concave depressions (Fig. 4-6). The proximal process, or *olecranon process*,concaves anteriorly and slightly inferiorly and forms the proximal portion of the *trochlear notch*. The more distal *coronoid process* projects anteriorly from the anterior surface of the body and curves slightly superiorly. The process is triangular and forms the lower portion of the trochlear notch. A depression called the *radial notch* is located on the lateral aspect of the coronoid process.

The distal end of the ulna includes a rounded process on its lateral side called the *head* and a narrower conic projection on the posteromedial side called the *ulnar styloid process*. An articular disk separates the head of the ulna from the wrist joint.

RADIUS

The proximal end of the radius is small and presents a flat disklike *head* above a constricted area called the *neck*. Just inferior to the neck on the medial side of the *body* of the radius is a roughened process called the *radial tuberosity*. The distal end of the radius is broad and flattened and has a conic projection on its lateral surface called the *radial styloid process*.

---

**Fig. 4-4** Anterior aspect of left radius and ulna.

**Fig. 4-5** Lateral aspect of left radius and ulna.

**Fig. 4-6** Radial aspect of left proximal ulna.
The arm has one bone called the humerus, which consists of a body and two articular ends (Figs. 4-7 and 4-8). The proximal part of the humerus articulates with the shoulder girdle and is described further in Chapter 5. The distal humerus is broad and flattened and presents numerous processes and depressions.

The distal end of the humerus is called the humeral condyle and includes two smooth elevations for articulation with the bones of the forearm—the trochlea on the medial side and the capitulum on the lateral side. The medial and lateral epicondyles are superior to the condyle and easily palpated. On the anterior surface superior to the trochlea, a shallow depression called the coronoid fossa receives the coronoid process when the elbow is flexed. The relatively small radial fossa, which receives the radial head when the elbow is flexed, is located lateral to the coronoid fossa and proximal to the capitulum. The olecranon fossa is a deep depression found immediately behind the coronoid fossa on the posterior surface and accommodates the olecranon process when the elbow is extended.

The proximal end of the humerus contains the head, which is large, smooth, and rounded and lies in an oblique plane on the superomedial side. Just below the head, lying in the same oblique plane, is the narrow, constricted anatomic neck. The constriction of the body just below the tubercles is called the surgical neck, which is the site of many fractures.

The lesser tubercle is situated on the anterior surface of the bone immediately below the anatomic neck. The tendon of the subscapularis muscle inserts at the lesser tubercle. The greater tubercle is located on the lateral surface of the bone just below the anatomic neck and is separated from the lesser tubercle by a deep depression called the intertubercular groove.
**Upper Limb Articulations**

Table 4-1 contains a summary of the joints of the upper limb. A detailed description of the upper limb articulations follows.

The interphalangeal articulations between the phalanges are synovial hinge type and allow only flexion and extension. The interphalangeal joints are named by location and are differentiated as either proximal interphalangeal (PIP) or distal interphalangeal (DIP), by the digit number, and by right or left hand (e.g., the PIP articulation of the fourth digit of the left hand) (Fig. 4-9, A). Because the first digit has only two phalanges, the joint between the two phalanges is simply called the interphalangeal joint.

### Table 4-1

**Joints of the upper limb**

<table>
<thead>
<tr>
<th>Joint</th>
<th>Structural classification</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interphalangeal</td>
<td>Synovial</td>
<td>Hinge</td>
</tr>
<tr>
<td>Metacarpophalangeal</td>
<td>Synovial</td>
<td>Ellipsoidal</td>
</tr>
<tr>
<td>Carpometacarpal:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First digit</td>
<td>Synovial</td>
<td>Saddle</td>
</tr>
<tr>
<td>Second to fifth digits</td>
<td>Synovial</td>
<td>Gliding</td>
</tr>
<tr>
<td>Intercarpal</td>
<td>Synovial</td>
<td>Gliding</td>
</tr>
<tr>
<td>Radiocarpal</td>
<td>Synovial</td>
<td>Ellipsoidal</td>
</tr>
<tr>
<td>Radioulnar:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximal</td>
<td>Synovial</td>
<td>Pivot</td>
</tr>
<tr>
<td>Distal</td>
<td>Synovial</td>
<td>Pivot</td>
</tr>
<tr>
<td>Humeroulnar</td>
<td>Synovial</td>
<td>Hinge</td>
</tr>
<tr>
<td>Humeroradial</td>
<td>Synovial</td>
<td>Hinge</td>
</tr>
</tbody>
</table>
The metacarpals articulate with the phalanges at their distal ends and the carpals at their proximal ends. The metacarpophalangeal (MCP) articulations are synovial ellipsoidal joints and have the movements of flexion, extension, abduction, adduction, and circumduction. Because of the less convex and wider surface of the MCP joint of the thumb, only limited abduction and adduction are possible.

The carpals articulate with each other, the metacarpals, and the radius of the forearm. In the carpometacarpal (CMC) articulations the first metacarpal and trapezium form a synovial saddle joint, which permits the thumb to oppose the fingers (touch the fingertips). The articulations between the second, third, fourth, and fifth metacarpals and the trapezoid, capitare, and hamate form synovial gliding joints. The intercarpal articulations are also synovial gliding joints. The articulations between the lunate and scaphoid form a gliding joint. The radiocarpal articulation is a synovial ellipsoidal type. This joint is formed by the articulation of the scaphoid, lunate, and triquetrum, with the radius and the articular disk just distal to the ulna (Fig. 4-9, C).

Fig. 4-9 A, Articulations of the hand and wrist. B, Radiocarpal articulation formed by the scaphoid, lunate, and triquetrum with the radius. C, Coronal MRI of the wrist demonstrating the various joints of the wrist.
The distal and proximal radioulnar articulations are synovial pivot joints. The distal ulna articulates with the ulnar notch of the distal radius. The proximal head of the radius articulates with the radial notch of the ulna at the medial side. The movements of supination and pronation of the forearm and hand largely result from the combined rotary action of these two joints. In pronation the radius turns medially and crosses over the ulna at its upper third and the ulna makes a slight counter-rotation that rotates the humerus medially.

The elbow joint proper includes the proximal radioulnar articulation and the articulations between the humerus and the radius and ulna. The three joints are enclosed in a common capsule. The trochlea of the humerus articulates with the ulna at the trochlear notch. The capitulum of the humerus articulates with the flattened head of the radius. The humeroulnar and humeroradial articulations form a synovial hinge joint and allow only flexion and extension movement (Figs. 4-10 and 4-11, A). The proximal humerus and its articulations are described with the shoulder girdle in Chapter 5.

Fat Pads

The three areas of fat\(^2\) associated with the elbow joint can be visualized only in the lateral projection (Fig. 4-11, B). The posterior fat pad covers the largest area and lies within the olecranon fossa of the posterior humerus. The superimposed coronoid and radial fat pads, which lie in the coronoid and radial fossae of the anterior humerus, form the anterior fat pad. The supinator fat pad is positioned anterior to and parallel with the anterior aspect of the proximal radius.

When the elbow is flexed 90 degrees for the lateral projection, only the anterior and supinator fat pads are visible and the posterior fat pad is depressed within the olecranon fossa. In a negative elbow the anterior fat pad somewhat resembles a teardrop and the supinator fat pad appears as shown in Fig. 4-11, B. The fat pads become significant radiographically when an elbow injury causes effusion and displaces the fat pads or alters their shape. Visualization of the posterior fat pad is a reliable indicator of elbow pathology. Exposure factors designed to demonstrate soft tissues are extremely important on lateral elbow radiographs because visualization of the fat pads may be the only evidence of injury.


**Fig. 4-10** Anterior aspect of left elbow joint.

### SUMMARY OF ANATOMY TERMS

<table>
<thead>
<tr>
<th>Hand</th>
<th>Radius</th>
<th>Articulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>phalanges (bones of digits)</td>
<td>head</td>
<td>interphalangeal</td>
</tr>
<tr>
<td>digits</td>
<td>neck</td>
<td>metacarpophalangeal</td>
</tr>
<tr>
<td>metacarpals</td>
<td>body</td>
<td>carpalometacarpal</td>
</tr>
<tr>
<td>carpals</td>
<td>radial tuberosity</td>
<td>ulnoulnar</td>
</tr>
<tr>
<td></td>
<td>radial styloid process</td>
<td>humeralcondyle</td>
</tr>
<tr>
<td>Metacarpals</td>
<td></td>
<td>capitulum</td>
</tr>
<tr>
<td>first to fifth metacarpals</td>
<td></td>
<td>medial epicondyle</td>
</tr>
<tr>
<td>body</td>
<td></td>
<td>lateral epicondyle</td>
</tr>
<tr>
<td>head</td>
<td></td>
<td>coronoid fossa</td>
</tr>
<tr>
<td>base</td>
<td></td>
<td>olecranon fossa</td>
</tr>
<tr>
<td>Wrist</td>
<td></td>
<td>olecranon process</td>
</tr>
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<td>trochlear notch</td>
</tr>
<tr>
<td>lunate</td>
<td></td>
<td>radial notch</td>
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<td>head</td>
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<td>ulnar styloid process</td>
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<td></td>
</tr>
<tr>
<td>trapezoid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>capitate</td>
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- **See Addendum at the end of the volume for a summary of the changes in the anatomic terms used in this edition.**

### EXPOSURE TECHNIQUE CHART ESSENTIAL PROJECTIONS

#### UPPER LIMB

<table>
<thead>
<tr>
<th>Part</th>
<th>cm</th>
<th>kVp*</th>
<th>tm</th>
<th>mA</th>
<th>mAs</th>
<th>AEC</th>
<th>SID</th>
<th>IR</th>
<th>Dose (mrads)</th>
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<tbody>
<tr>
<td>Digits</td>
<td>Ave</td>
<td>54</td>
<td>.01</td>
<td>200s</td>
<td>2</td>
<td>48*</td>
<td>8 x 10 in-2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Hand-PA</td>
<td>Ave</td>
<td>54</td>
<td>.01</td>
<td>200s</td>
<td>2</td>
<td>48*</td>
<td>24 x 30 cm-2</td>
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<tr>
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<td>57</td>
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<td>200s</td>
<td>2</td>
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<td>7</td>
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</tr>
<tr>
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<td>Ave</td>
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<td>.01</td>
<td>200s</td>
<td>2</td>
<td>48*</td>
<td>24 x 30 cm-2</td>
<td>11</td>
<td></td>
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<td>Ave</td>
<td>54</td>
<td>.01</td>
<td>200s</td>
<td>2</td>
<td>48*</td>
<td>24 x 30 cm-2</td>
<td>11</td>
<td></td>
</tr>
<tr>
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<td>Ave</td>
<td>60</td>
<td>.01</td>
<td>200s</td>
<td>2</td>
<td>48*</td>
<td>8 x 10 in</td>
<td>18</td>
<td></td>
</tr>
<tr>
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<td>Ave</td>
<td>65</td>
<td>.01</td>
<td>200s</td>
<td>2</td>
<td>48*</td>
<td>24 x 30 cm-2</td>
<td>18</td>
<td></td>
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<tr>
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<td>Ave</td>
<td>60</td>
<td>.02</td>
<td>200s</td>
<td>4</td>
<td>48*</td>
<td>8 x 10 in</td>
<td>18</td>
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<td>Ave</td>
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<td>.01</td>
<td>200s</td>
<td>2</td>
<td>48*</td>
<td>24 x 30 cm-2</td>
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<tr>
<td>Elbow-Distal Humerus</td>
<td>Ave</td>
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<td>.01</td>
<td>200s</td>
<td>2</td>
<td>48*</td>
<td>24 x 30 cm-2</td>
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<td></td>
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<td>Elbow-Proximal Forearm</td>
<td>Ave</td>
<td>65</td>
<td>.01</td>
<td>200s</td>
<td>2</td>
<td>48*</td>
<td>8 x 10 in</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Humerus-AP, Latera</td>
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<td>.01</td>
<td>200s</td>
<td>2</td>
<td>48*</td>
<td>35 x 43 cm</td>
<td>28</td>
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<td>Humerus-Lateral Recumbent</td>
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<td>2</td>
<td>48*</td>
<td>30 x 35 cm</td>
<td>5</td>
<td></td>
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</tbody>
</table>

* s. Small focal spot.
* kVp values are for a 3-phase 12-pulse generator.
* Relative doses for comparison use. All doses are skin entrance for average adult at cm indicated.
* Tabletop extremity IR. Screen/Film speed 100.
* Tabletop, standard IR. Screen/Film Speed 300.
* 16:1 grid. Screen/Film Speed 300.
* Gratals P. Turner GW. Burns CB. Using the same exposure factors for wet and dry casts.

# SUMMARY OF PATHOLOGY*

<table>
<thead>
<tr>
<th>Condition</th>
<th>Radiographic Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone Cyst</td>
<td>Fluid filled cyst with a wall of fibrous tissue</td>
</tr>
<tr>
<td>Bursitis</td>
<td>Inflammation of the bursa</td>
</tr>
<tr>
<td>Dislocation</td>
<td>Displacement of a bone from the joint space</td>
</tr>
<tr>
<td>Fracture</td>
<td>Disruption in the continuity of bone</td>
</tr>
<tr>
<td>Bennett’s</td>
<td>Fracture at the base of the first metacarpal</td>
</tr>
<tr>
<td>Boxer’s</td>
<td>Fracture at the base of the fifth metacarpal</td>
</tr>
<tr>
<td>Colle’s</td>
<td>Fracture of the distal radius and ulnar styloid with posterior displacement</td>
</tr>
<tr>
<td>Smith’s</td>
<td>Fracture of the distal radius and ulnar styloid with anterior displacement</td>
</tr>
<tr>
<td>Torus or Buckle</td>
<td>Impacted fracture with bulging of the periosteum</td>
</tr>
<tr>
<td>Gout</td>
<td>Hereditary form of arthritis where uric acid is deposited in joints</td>
</tr>
<tr>
<td>Joint Effusion</td>
<td>Accumulation of fluid in the joint associated with an underlying condition</td>
</tr>
<tr>
<td>Metastases</td>
<td>Transfer of a cancerous lesion from one area to another</td>
</tr>
<tr>
<td>Osteoarthritis or</td>
<td>Form of arthritis marked by progressive cartilage deterioration in synovial joints and</td>
</tr>
<tr>
<td>Degenerative Joint Disease</td>
<td>vertebral</td>
</tr>
<tr>
<td>Osteomyelitis</td>
<td>Inflammation of bone due to a pyogenic infection</td>
</tr>
<tr>
<td>Osteopetrosis</td>
<td>Increased density of atypically soft bone</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>Loss of bone density</td>
</tr>
<tr>
<td>Rheumatoid Arthritis</td>
<td>Chronic, systemic, inflammatory collagen disease</td>
</tr>
<tr>
<td>Tumor</td>
<td>New tissue growth where cell proliferation is uncontrolled</td>
</tr>
<tr>
<td>Chondrosarcoma</td>
<td>Malignant tumor arising from cartilage cells</td>
</tr>
<tr>
<td>Enchondroma</td>
<td>Benign tumor consisting of cartilage</td>
</tr>
<tr>
<td>Ewing’s Sarcoma</td>
<td>Malignant tumor of bone arising in medullary tissue</td>
</tr>
<tr>
<td>Osteosarcoma</td>
<td>Malignant, primary tumor of bone with bone or cartilage formation</td>
</tr>
</tbody>
</table>

*Rob Hughes, MS, RT(R), contributed the new pathology terms and definitions for each chapter of this edition of the atlas.
General Procedures
When the upper limb is radiographed, the following steps should be initiated:

- Remove rings, watches, and other radiopaque objects, and place them in secure storage during the procedure.
- Seat the patient at the side or end of the table to avoid a strained or uncomfortable position.
- Place the IR at a location and angle that allows the patient to be in the most comfortable position. Because the degree of immobilization (particularly of the hand and digits) is limited, the patient must be comfortable to promote relaxation and cooperation in maintaining the desired position.
- Unless otherwise specified, direct the central ray at a right angle to the midpoint of the IR. Because the joint spaces of the limbs are narrow, accurate centering is essential to avoid obscuring the joint spaces.
- Radiograph each side separately when performing a bilateral examination of the hands or wrists. This prevents distortion, particularly of the joint spaces.
- Shield gonads from scattered radiation with a sheet of lead-impregnated rubber or a lead apron placed over the patient’s pelvis (Fig. 4-12).
- Use close collimation. This technique is recommended for all upper limb radiographs.
- Placing multiple exposures on one IR is a common practice. The side of the unexposed IR should always be covered with lead, especially when the new computed radiography IRs are used.
- Use right or left markers and all other vital identification markers when appropriate.

Digits (Second Through Fifth)

**PA PROJECTIONS**

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise or crosswise for two or more images on one IR

**Position of patient**
- Seat the patient at the end of the radiographic table.

**Position of part**
When radiographing individual digits (except the first), take the following steps:
- Place the extended digit with the palmar surface down on the unmasked portion of the IR.
- Separate the digits slightly, and center the digit under examination to the midline portion of the IR.
- Center the PIP joint to the IR (Figs. 4-13 to 4-15).
- Shield gonads.

![Fig. 4-12 Properly shielded patient.](image)
![Fig. 4-13 A, PA second digit. B, PA third digit.](image)
![Fig. 4-14 PA fourth digit.](image)
![Fig. 4-15 PA fifth digit.](image)
Central ray
- Perpendicular to the PIP joint of the affected digit.
- Collimate to the digit under examination.

**COMPUTED RADIOGRAPHY**

The digit must be placed in the central area of the IR for all finger projections. Two or more images can be projected on one IR; however, the finger must be placed in the central area, and the exposed and unexposed areas must be covered with lead.

**Structures shown**
A PA projection of the appropriate digit is visualized (Figs. 4-16 through 4-19).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- No rotation of the digit:
  - Concavity of the phalangeal shafts and an equal amount of soft tissue on both sides of the phalanges
  - Fingernail, if visualized and normal, centered over the distal phalanx
  - Entire digit from fingertip to distal portion of the adjoining metacarpal
  - No soft tissue overlap from adjacent digits
  - Open interphalangeal and MCP joint spaces without overlap of bones
  - Soft tissue and bony trabeculation

**NOTE:** Digits that cannot be extended can be examined in small sections with dental films. When joint injury is suspected, an AP projection is recommended instead of a PA projection.

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![Fig. 4-16 PA second digit.](image)

![Fig. 4-17 PA third digit.](image)

![Fig. 4-18 PA fourth digit.](image)

![Fig. 4-19 Fractured fifth digit (arrow).](image)
**LATERAL PROJECTION**

Lateromedial or mediolateral

**Image receptor:** 8 x 10 inch (18 x 24 cm) lengthwise or crosswise for two or more images on one IR

**Position of patient**
- Seat the patient at the end of the radiographic table.

**Position of part**
- Because lateral digit positions are difficult to hold, tell the patient how the digit is adjusted on the IR, and demonstrate with your own finger. Let the patient assume the most comfortable arm position.
- Ask the patient to extend the digit to be examined. Close the rest of the digits into a fist, and hold them in complete flexion with the thumb.
- Support the elbow on sandbags or provide other suitable support when the elbow must be elevated to bring the digit into position.
- With the digit under examination extended and other digits folded into a fist, have the patient’s hand rest on the lateral, or radial, surface for the second or third digit (Figs. 4-20 and 4-21) or on the medial, or ulnar, surface for the fourth or fifth digit (Figs. 4-22 and 4-23).
- Before making the final adjustment of the digit position, place the IR so that the midline of its unmasked portion is parallel with the long axis of the digit. Center the IR to the PIP joint.
- Rest the second and fifth digits directly on the IR, but for an accurate image of the bones and joints, elevate the third and fourth digits and place their long axes parallel with the plane of the IR. A radiolucent sponge may be used to support the digits.
- Immobilize the extended digit by placing a strip of adhesive tape, a tongue depressor, or other support against its palmar surface. The patient can hold the support with the opposite hand.
- Adjust the anterior or posterior rotation of the hand to obtain a true lateral position of the digit.
- Shield gonads.
Central ray
- Perpendicular to the PIP joint of the affected digit.
- Collimate to the digit being examined.

Structures shown
A lateral projection of the affected digit is shown (Figs. 4-24 through 4-27).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Entire digit in a true lateral position:
  - Fingernail in profile, if visualized and normal
  - Concave, anterior surfaces of the phalanges
  - No rotation of the phalanges
- No obstruction of the proximal phalanx or MCP joint by adjacent digits
- Open interphalangeal joint spaces
- Soft tissue and bony trabeculation

Fig. 4-24 Lateral digit showing a chip fracture (arrow) and dislocation involving the distal interphalangeal joint of second digit (arrow).

Fig. 4-25 Lateral third digit.
Fig. 4-26 Lateral fourth digit.
Fig. 4-27 Lateral fifth digit.
PA OBLIQUE PROJECTION

Lateral rotation

Image receptor: 8 × 10 inch (18 × 24 cm) lengthwise or crosswise for two or more images on one IR

Position of patient
- Seat the patient at the end of the radiographic table.

Position of part
- Place the patient’s forearm on the table with the hand pronated and the palm resting on the IR.
- Center the IR at the level of the PIP joint.
- Rotate the hand externally until the digits are separated and supported on a 45-degree foam wedge. The wedge supports the digits in a position parallel with the IR plane (Figs. 4-28 through 4-31) so that the interphalangeal joint spaces are open.
- Shield gonads.

Central ray
- Perpendicular to the PIP joint of the affected digit.
- Collimate to the digit being examined.

Structures shown
The resultant image shows a PA oblique projection of the bones and soft tissue of the affected digit (Figs. 4-32 through 4-35).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Entire digit rotated at a 45-degree angle, including the distal portion of the adjoining metacarpal
- No superimposition of the adjacent digits over the proximal phalanx or MCP joint
- Open interphalangeal and MCP joint spaces
- Soft tissue and bony trabeculation

OPTION: Some radiographers rotate the second digit medially from the prone position (Fig. 4-36). The advantage of medially rotating the digit is that the part is closer to the IR for improved recorded detail and increased ability to see certain fractures.1

Fig. 4-32 PA oblique second digit.

Fig. 4-33 PA oblique third digit.

Fig. 4-34 PA oblique fourth digit.

Fig. 4-35 PA oblique fifth digit.

Fig. 4-36 PA oblique second digit (alternative method, medial rotation).
First Digit (Thumb)

AP, PA, LATERAL, AND PA OBLIQUE PROJECTIONS

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise or crosswise for two or more images on one IR

### AP PROJECTION

**Position of patient**
- Seat the patient at the end of the radiographic table with the arm internally rotated.

**Position of part**
- Demonstrate how to avoid motion or rotation with the hand. By adjusting the body position on the chair, the patient can place the hand in the correct position with the least amount of strain on the arm.
- Put the patient’s hand in a position of extreme internal rotation. Have the patient hold the extended digits back with tape or the opposite hand. Rest the thumb on the IR. If the elbow is elevated, place a support under it and have the patient rest the opposite forearm against the table for support (Fig. 4-37).
- Center the long axis of the thumb parallel with the long axis of the IR. Adjust the position of the hand to ensure a true AP projection of the thumb. Place the fifth metacarpal back far enough to avoid superimposition.
- Lewis suggested directing the central ray 10 to 15 degrees along the long axis of the thumb toward the wrist to demonstrate the first metacarpal free of the soft tissue of the palm.
- Shield gonads.

### PA PROJECTION

**Position of patient**
- Seat the patient at the end of the radiographic table with the hand resting on its medial surface.

**Position of part**
- If a PA projection of the first CMC joint and first digit is to be performed, place the hand in the lateral position. Rest the elevated and abducted thumb on a radiographic support, or hold it up with a radiolucent stick. Adjust the hand to place the dorsal surface of the digit parallel with the IR. This position magnifies the part (Fig. 4-38).
- Center the MCP joint to the center of the IR.
- Shield gonads.

### LATERAL PROJECTION

**Position of patient**
- Seat the patient at the end of the radiographic table with the relaxed hand placed on the IR.

**Position of part**
- Place the hand in its natural arched position with the palmar surface down and fingers flexed or resting on a sponge.
- Place the midline of the IR parallel with the long axis of the digit. Center the IR to the MCP joint.
- Adjust the arching of the hand until a true lateral position of the thumb is obtained (Fig. 4-39).

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Fig. 4-37 AP first digit.

Fig. 4-38 PA first digit (cotton swab).

Fig. 4-39 Lateral first digit.

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First Digit (Thumb)

PA OBLIQUE PROJECTION

Position of patient
- Seat the patient at the end of the radiographic table with the palm of the hand resting on the IR.

Position of part
- With the thumb abducted, place the palmar surface of the hand in contact with the IR. Ulnar deviate the hand slightly. This relatively normal placement positions the thumb in the oblique position.
- Align the longitudinal axis of the thumb with the long axis of the IR. Center the IR to the MCP joint (Fig. 4-40).
- Shield gonads.

Central ray
- Perpendicular to the MCP joint for the AP, PA, lateral, and oblique projections.
- Collimate to include entire first digit.

Structures shown
AP, PA, lateral, and PA oblique projections of the thumb are demonstrated (Figs. 4-41 through 4-44).

EVALUATION CRITERIA

AP and PA thumb
The following should be clearly demonstrated:
- No rotation:
  - Concavity of the phalangeal and metacarpal shafts
  - Equal amount of soft tissue on both sides of the phalanges
  - Thumbnail, if visualized, in the center of the distal thumb
- Area from the distal tip of the thumb to the trapezium
- Open interphalangeal and MCP joint spaces
- Soft tissue and bony trabeculation

Lateral thumb
The following should be clearly demonstrated:
- First digit in a true lateral projection:
  - Thumbnail, if visualized and normal, in profile
  - Concave, anterior surface of the proximal phalanx
  - No rotation of the phalanges
- Area from the distal tip of the thumb to the trapezium
- Open interphalangeal and MCP joint spaces
- Soft tissue and bony trabeculation

Oblique thumb
The following should be clearly demonstrated:
- Proper rotation of phalanges, soft tissue, and first metacarpal
- Area from the distal tip of the thumb to the trapezium
- Open interphalangeal and MCP joint spaces
- Soft tissue and bony trabeculation
First Digit (Thumb)

First Carpometacarpal Joint

**AP PROJECTION**

**ROBERT METHOD**

Robert first described the radiographic projection of the first CMC joint in 1936. Lewis modified the central ray for this projection in 1988, and Long and Rafert further modified the central ray in 1995. This projection is commonly performed to demonstrate arthritic changes, fractures, displacement of the first CMC joint, and the Bennett's fracture. The Robert method does not replace the initial AP or PA thumb projection.

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise


**Position of patient**

- Seat the patient sideways at the end of the radiographic table. The patient should be positioned low enough to place the shoulder, elbow, and wrist on the same plane. The entire limb must be on the same plane to prevent elevation of the carpal bones and closing of the first CMC joint (Fig. 4-45, A).

**Position of part**

- Extend the limb straight out on the radiographic table.
- Rotate the arm internally to place the posterior aspect of the thumb on the IR with the thumbnail down (Fig. 4-45, B).
- Place the thumb in the center of the IR.
- Hyperextend the hand so that the soft tissue over the ulnar aspect does not obscure the first CMC joint (Fig. 4-46). Ensure that the thumb is not oblique.
- Long and Rafert state that the patient may hold the fingers back with the other hand.
- Steady the hand on a sponge if necessary.
- Shield gonads.


![Fig. 4-45 A](image)

Patient in position for AP thumb to demonstrate the first carpometacarpal joint: Robert method. The patient leans forward to place the entire arm on the same plane and for ease of maximum internal arm rotation. B, Thumb, hand, and wrist in correct position for AP of first carpometacarpal joint. Note the specific area of the wrist where the joint is located (arrow).

![Fig. 4-46](image)

Hyperextended hand and thumb position for AP projection of first carpometacarpal joint: Robert method. The soft tissue of the palm (arrow) is positioned out of the way so that the joint will be clearly shown. Inset: the first carpometacarpal joint is a saddle joint; the articular surfaces are shown.
First Digit (Thumb)

Central ray (Fig. 4-47)

Robert method
• Perpendicular entering at the first CMC joint

Long and Ratert modification
• Angled 15 degrees proximally along the long axis of the thumb and entering the first CMC joint.
• Collimate to include the entire thumb.

Lewis modification
• Angled 10 to 15 degrees proximally along the long axis of the thumb and entering the first MCP joint

NOTE: Angulation of the central ray serves two purposes: (1) it may help project the soft tissue of the hand away from the first CMC joint, and (2) it can help open the joint space when the space is not shown with a perpendicular central ray.

Structures shown
This projection demonstrates the first CMC joint free of superimposition of the soft tissues of the hand (Fig. 4-48, A).

EVALUATION CRITERIA
The following should be clearly demonstrated:
• First CMC joint free of superimposition of the hand or other bony elements
• First metacarpal with the base in convex profile
• Trapezium

Fig. 4-47 Central ray angulation choices for demonstration of the first carpometacarpal joint. A, Robert method. 0 degrees to carpometacarpal joint. B, Long-Rafert modification. 15 degrees cephalad to carpometacarpal joint. C, Lewis modification. 10 to 15 degrees cephalad to the metacarpophalangeal joint.

Fig. 4-48 A, Optimal radiograph of an AP first carpometacarpal joint (arrow): Robert method. B, Example of a typical repeat radiograph. Soft tissue of the palm (arrows) obscured first carpometacarpal joint. The Long-Rafert or Lewis modification of the central ray would help demonstrate the joint on this patient.
First Carpometacarpal Joint

AP PROJECTION
BURMAN METHOD

When hyperextension of the wrist is not contraindicated, Burman stated that this projection provides a clearer image of the first CMC joint than the standard AP projection.

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise

**SID:** The recommended distance is 18 inches. This produces a magnified image that creates a greater field of view of the concavoconvex aspect of this joint.

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**Position of patient**
- Seat the patient at the end of the radiographic table so that the forearm can be adjusted to lie approximately parallel with the long axis of the IR.

**Position of part**
- Place the IR under the wrist, and center the first CMC joint to the center of the IR.
- Hyperextend the hand, and have the patient hold the position with the opposite hand or with a bandage looped around the digits.
- Rotate the hand internally, and abduct the thumb so that it is flat on the IR (Fig. 4-49).
- Shield gonads.

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*Fig. 4-49* Hyperextended hand and abducted thumb position for AP of the first carpometacarpal joint: Burman method.
Central ray
• Through the first CMC joint at a 45-degree angle toward the elbow

Structures shown
This image shows a magnified concavo-convex outline of the first CMC joint (Fig. 4-50).

EVALUATION CRITERIA
The following should be clearly demonstrated:
• First metacarpal
• Trapezium in concave profile
• Base of the first metacarpal in convex profile
• First CMC joint, unobscured by adjacent carpals

Fig. 4-50  AP thumb to demonstrate the first carpometacarpal joint: Burman method.
(Courtesy Michael Burman)
First Digit (Thumb)

First Metacarpophalangeal Joint

PA PROJECTION

FOLIO METHOD

This projection is useful for the diagnosis of ulnar collateral ligament (UCL) rupture in the MCP joint of the thumb, also known as “skier’s thumb.”

**Image Receptor:** 8 x 10 inch (18 x 24 cm) crosswise

**Position of patient**
- Seat the patient at the end of the radiographic table.


**Position of part**
- Place the patient’s hands on the cassette resting them on their medial aspects.
- Tightly wrap a rubber band around the distal portion of both thumbs and place a roll of medical tape between the bodies of the first metacarpals.
- Ensure the thumbs remain in the PA plane by keeping the thumbnails parallel to the cassette (Fig. 4-51).
- Prior to exposure instruct the patient to pull their thumbs apart and hold.
- *Shield gonads.*

**Central ray**
- Perpendicular to a point midway between both hands at the level of the MCP joint.

**Structures shown**
This projection demonstrates the MCP joints and metacarpal phalangeal angles bilaterally (Fig. 4-52).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- No rotation of the thumbs
- First metacarpals
- Diagnostic image of the first MCP joint
- Rubber band and medical tape in correct position
- Thumbs centered to the center of the image

**RESEARCH:** Catherine E. Hearty, MS, RT(R), performed the research and provided this new projection for this edition of the atlas.

![Fig. 4-51 Hands and thumbs in position for PA first metacarpophalangeal joints, Folio method. Note roll of tape between thumbs.](image-url)
Fig. 4-52 First metacarpophalangeal joint, Folsom method. A, Normal thumbs with acceptable metacarpal phalangeal joints bilaterally. The roll of tape is visible between the metacarpals, as well as the rubber band holding the distal aspects of the thumbs. B, Increased angulation of the left MCP joint with a 13 degree difference compared to the right MCP joint. The partially torn left UCL measures 20 degrees between the long axis of the first metacarpal and proximal phalanx, while the uninjured side measures 7 degrees.
Hand

**PA PROJECTION**

**Image receptor:** 8 x 10 inch (18 x 24 cm) for hand of average size or 24 x 30 cm crosswise for two images.

**Position of patient**
- Seat the patient at the end of the radiographic table.
- Adjust the patient’s height so that the forearm is resting on the table (Fig. 4-53, A).

**Position of part**
- Rest the patient’s forearm on the table, and place the hand with the palmar surface down on the IR.
- Center the IR to the MCP joints, and adjust the long axis of the IR parallel with the long axis of the hand and forearm.
- Spread the fingers slightly (Fig. 4-53, B).
- Ask the patient to relax the hand to avoid motion. Prevent involuntary movement with the use of adhesive tape or positioning sponges. A sandbag may be placed over the distal forearm.
- Shield gonads.

**Central ray**
- Perpendicular to the third MCP joint.

**Structures shown**
PA projections of the carpals, metacarpals, phalanges (except the thumb), interarticularations of the hand, and distal radius and ulna are shown in Fig. 4-54. This image also demonstrates a PA oblique projection of the first digit.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- No rotation of the hand:
  - Equal concavity of the metacarpal and phalangeal shafts on both sides
  - Equal amount of soft tissue on both sides of the phalanges
  - Fingernails, if visualized, in the center of each distal phalanx
- Open MCP and interphalangeal joints, indicating that the hand is placed flat on the IR
- Slightly separate digits with no soft tissue overlap
- All anatomy distal to the radius and ulna
- Soft tissue and bony trabeculation

**NOTE:** When the MCP joints are under examination and the patient cannot extend the hand enough to place its palmar surface in contact with the IR, the position of the hand can be reversed for an AP projection. This position is also used for the metacarpals when the hand cannot be extended because of an injury, a pathologic condition, or the use of dressings.

**SPECIAL TECHNIQUE:** Clements and Nakayama describe a special exposure technique for imaging early rheumatoid arthritis.1


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*Fig. 4-53 A,* Properly shielded patient in position for a PA hand. *B,* PA hand.
Fig. 4-54  A, PA hand  B, PA hand showing complete fracture and dislocation of the third proximal phalanx. Note overall hand was placed in correct position despite trauma. This gives the physician accurate information about displacement of the bone.
PA OBLIQUE PROJECTION
Lateral rotation

Image receptor: 8 x 10 inch (18 x 24 cm) lengthwise or 24 x 30 cm crosswise for two images

Position of patient
- Seat the patient at the end of the radiographic table.
- Adjust the patient’s height to rest the forearm on the table.

Position of part
- Rest the patient’s forearm on the table with the hand pronated and the palm resting on the IR.
- Adjust the obliquity of the hand so that the MCP joints form an angle of approximately 45 degrees with the IR plane.
- Use a 45-degree foam wedge to support the fingers in the extended position to demonstrate the interphalangeal joints (Figs. 4-55 and 4-56).
- When examining the metacarpals, obtain a PA oblique projection of the hand by rotating the patient’s hand laterally (externally) from the pronated position until the fingertips touch the IR (Fig. 4-57).
- If it is not possible to obtain the correct position with all fingertips resting on the IR, elevate the index finger and thumb on a suitable radiolucent material (see Fig. 4-56). Elevation opens the joint spaces and reduces the degree of foreshortening of the phalanges.
- For either approach, center the IR to the MCP joints and adjust the midline to be parallel with the long axis of the hand and forearm.
- Shield gonads.
Central ray
- Perpendicular to the third MCP joint.

Structures shown
The resulting image shows a PA oblique projection of the bones and soft tissues of the hand (Fig. 4-58). This supplemental position is used for investigating fractures and pathologic conditions.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Minimal overlap of the third-fourth and fourth-fifth metacarpal shafts
- Slight overlap of the metacarpal bases and heads
- Separation of the second and third metacarpals
- Open interphalangeal and MCP joints
- Digits separated slightly with no overlap of their soft tissues
- All anatomy distal to the distal radius and ulna
- Soft tissue and bony trabeculation

NOTE: Lane, Kennedy, and Kuschner recommend the inclusion of a reverse oblique projection to better demonstrate severe metacarpal deformities or fractures. This projection is accomplished by having the patient rotate the hand 45 degrees medially (internally) from the palm-down position.

Kallen recommended using a tangential oblique projection to demonstrate metacarpal head fractures. From the PA hand position, the MCP joints are flexed 75 to 80 degrees with the dorsum of the digits resting on the IR. The hand is rotated 40 to 45 degrees toward the ulnar surface. Then the hand is rotated 40 to 45 degrees forward until the affected MCP joint is projected beyond its proximal phalanx. The perpendicular central ray is directed tangentially to enter the MCP joint of interest. Variations of rotation are described to demonstrate the second metacarpal head free of superimposition.


Fig. 4-58 A, PA oblique hand with digits on sponge to demonstrate open joints B, PA oblique hand without support sponge, showing the fracture (arrow). Note that the interphalangeal joints (arrows) are not entirely open, and phalanges are foreshortened.
Hand

**LATERAL PROJECTION**

Mediolateral or lateromedial

**Extension and fan lateral**

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise for hand of average size or 24 × 30 cm crosswise for two images

**Position of patient**

- Seat the patient at the end of the radiographic table with the forearm in contact with the table and the hand in the lateral position with the ulnar aspect down (Fig. 4-59).
- Alternatively, place the radial side of the wrist against the IR (Fig. 4-60). However, this position is more difficult for the patient to assume.
- If the elbow is elevated, support it with sandbags.

**Position of part**

- Extend the patient’s digits and adjust the first digit at a right angle to the palm.
- Place the palmar surface perpendicular to the IR.
- Center the IR to the MCP joints, and adjust the midline to be parallel with the long axis of the hand and forearm. If the hand is resting on the ulnar surface, immobilization of the thumb may be necessary.
- The two extended digit positions result in superimposition of the phalanges. A modification of the lateral hand is the **fan lateral position**, which eliminates superimposition of all but the proximal phalanges. For the fan lateral position, place the digits on a sponge wedge. Abduct the thumb and place it on the radiolucent sponge for support (Fig. 4-61).
- Shield gonads.

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Fig. 4-59 Lateral hand with ulnar surface to IR: lateromedial.

Fig. 4-60 Lateral hand with radial surface to IR: mediolateral.

Fig. 4-61 Fan lateral hand.
Central ray

- Perpendicular to the second digit MCP joint

Structures shown

This image, which shows a lateral projection of the hand in extension (Fig. 4-62), is the customary position for localizing foreign bodies and metacarpal fracture displacement. The exposure technique depends on the foreign body.

The fan lateral superimposes the metacarpals but demonstrates almost all of the individual phalanges. The most proximal portions of the proximal phalanges remain superimposed (Fig. 4-63).

EVALUATION CRITERIA

The following should be clearly demonstrated:

- Hand in a true lateral position if the following are seen:
  - Superimposed phalanges (individually demonstrated on fan lateral)
  - Superimposed metacarpals
  - Superimposed distal radius and ulna
  - Extended digits
  - Thumb free of motion and superimposition
  - Each bone outlined through the superimposed shadows of the other metacarpals

NOTE: To better demonstrate fractures of the fifth metacarpal, Lewis' recommended rotating the hand 5 degrees posteriorly from the true lateral position. This positioning removes the superimposition of the second through fourth metacarpals. The thumb is extended as much as possible, and the hand is allowed to become hollow by relaxation. The central ray is angled so that it passes parallel to the extended thumb and enters the midshaft of the fifth metacarpal.

LATERAL PROJECTION
Lateromedial in flexion

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise

**Position of patient**
- Seat the patient at the end of the radiographic table.
- Ask the patient to rest the forearm on the table, and place the hand on the IR with the ulnar aspect down.

**Position of part**
- Center the IR to the MCP joints, and adjust it so that its midline is parallel with the long axis of the hand and forearm.
- With the patient relaxing the digits to maintain the natural arch of the hand, arrange the digits so that they are perfectly superimposed (Fig. 4-64).
- Have the patient hold the thumb parallel with the IR, or if necessary immobilize the thumb with tape or a sponge.
- Shield gonads.

**Central ray**
- Perpendicular to the MCP joints, entering MCP joint of the second digit

**Structures shown**
This projection produces a lateral image of the bony structures and soft tissues of the hand in their normally flexed position (Fig. 4-65). It also demonstrates anterior or posterior displacement in fractures of the metacarpals.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Superimposed phalanges and metacarpals
- Superimposed distal radius and ulna
- Flexed digits
- No motion or superimposition of the first digit
- Radiographic density similar to frontal and oblique hand images, which requires increased exposure factors to compensate for greater hand thickness
- Clear outline of each bone through the superimposed shadows of the other metacarpals

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AP OBLIQUE PROJECTION
NORGAARD METHOD

**Medial rotation**
The Norgaard method, sometimes referred to as the *ball-catcher's position*, assists in detecting early radiologic changes needed to diagnose rheumatoid arthritis. Norgaard reported that it is often possible to make an early diagnosis of rheumatoid arthritis by using this position before laboratory tests are positive. He also stated that extremely fine-grain intensifying screens should be used to demonstrate high resolution. Low kilovoltage peak (60 to 65) is recommended to obtain necessary contrast.

In a more recent article, Stapczynski recommended this projection for the demonstration of fractures of the base of the fifth metacarpal.

**Image receptor:** 24 × 30 cm (10 × 12 inch) crosswise

**Position of patient**
- Seat the patient at the end of the radiographic table. Norgaard recommended that both hands be radiographed in the half-supinate position for comparison.

**Position of part**
- Have the patient place the palms of both hands together. Center the MCP joints on the medial aspect of both hands to the IR. Both hands should be in the lateral position.
- Place two 45-degree radiolucent sponges against the posterior aspect of each hand.
- Rotate the patient’s hands to a half-supinate position until the dorsal surface of each hand rests against each 45-degree sponge support (Fig. 4-66).
- Extend the patient’s fingers, and abduct the thumbs slightly to avoid superimposition over the fingers.

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• The original method of positioning the hands is often modified. The patient is positioned similar to the method described except that the fingers are not extended. Instead the fingers are cupped as if the patient were going to catch a ball (Fig. 4-67). Comparable diagnostic information is demonstrated using either position.
  • Shield gonads.

Central ray
• Perpendicular to a point midway between both hands at the level of the MCP joints for either of the two patient positions.

Structures shown
The resulting image shows an AP 45-degree oblique projection of both hands (Fig. 4-68). The early radiologic change significant in making the diagnosis of rheumatoid arthritis is a symmetric, very slight, indistinct outline of the bone corresponding to the insertion of the joint capsule dorsoradial on the proximal end of the first phalanx of the four fingers. In addition, associated demineralization of the bone structure is always present in the area directly below the contour defect.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Both hands from the carpal area to the tips of the digits
- Metacarpal heads free of superimposition
- Useful level of density over the heads of the metacarpals

Fig. 4-66 AP oblique hands, semi-supinated position.
Fig. 4-67 Ball-catcher's position.

Fig. 4-68 A, AP oblique hands, ball-catcher's position, showing where indistinct area occurs (arrow). B, Ball-catcher's position.
**Wrist**

**PA PROJECTION**

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise or crosswise for two or more images on one IR

**Position of patient**
- Seat the patient low enough to place the axilla in contact with the table, or elevate the limb to shoulder level on a suitable support. This position places the shoulder, elbow, and wrist joints in the same plane to permit right-angle rotation of the ulna and radius for the lateral position.

**Position of part**
- Have the patient rest the forearm on the table, and center the wrist to the IR area.
- When it is difficult to determine the exact location of the carpal because of a swollen wrist, ask the patient to flex the wrist slightly and center the IR to the point of flexion. When the wrist is in a cast or splint, the exact point of centering can be determined by comparison with the opposite side.
- Adjust the hand and forearm to lie parallel with the long axis of the IR.
- Slightly arch the hand at the MCP joints by flexing the digits to place the wrist in close contact with the IR (Fig. 4-69).
- When necessary, place a support under the digits to immobilize them.
- Shield gonads.

**Central ray**
- Perpendicular to the midcarpal area

**Structures shown**
A PA projection of the carpals, distal radius and ulna, and proximal metacarpals is shown (Fig. 4-70). The projection gives a slightly oblique rotation to the ulna. When the ulna is under examination, an AP projection should be taken.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Distal radius and ulna, carpals, and proximal half of metacarpals
- No rotation in carpals, metacarpals, or radius
- Soft tissue and bony trabeculation
- No excessive flexion to overlap and obscure metacarpals with digits

**NOTE:** To better demonstrate the scaphoid and capitate, Daifner, Emmerling, and Buterbaugh\(^1\) recommended angling the central ray when the patient is positioned for a PA radiograph. A central ray angle of 30 degrees toward the elbow elongates the scaphoid and capitate, whereas an angle of 30 degrees toward the fingertips only elongates the capitate


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Fig. 4-69 A, PA wrist. (S, Scaphoid; L, lunate; T, triquetrum; P, pisiform; G, trapezium; M, trapezoid; C, capitate; and H, hamate.) B, PA wrist showing fracture of the distal radius (arrow).
**AP PROJECTION**

**Image receptor:** 8 x 10 inch (18 x 24 cm) lengthwise or crosswise for two or more images on one IR

**Position of patient**
- Seat the patient at the end of the radiographic table.

**Position of part**
- Have the patient rest the forearm on the table, with the arm and hand supinated.
- Place the IR under the wrist, and center it to the carpal.
- Elevate the digits on a suitable support to place the wrist in close contact with the IR.
- Have the patient lean laterally to prevent rotation of the wrist (Fig. 4-71).
- Shield gonads.

**Central ray**
- Perpendicular to the midcarpal area

**Structures shown**
The *carpal interspaces* are better demonstrated in the AP image than the PA image. Because of the oblique direction of the interspaces, they are more closely parallel with the divergence of the x-ray beam (Fig. 4-72).

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**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Distal radius and ulna, carpals, and proximal half of the metacarpals
- No rotation of the carpals, metacarpals, radius, and ulna
- Well-demonstrated soft tissue and bony trabeculation
- No overlapping or obscuring of the metacarpals as a result of excessive flexion

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**Fig. 4-71** AP wrist.

**Fig. 4-72** A, AP wrist. (S, Scaphoid; L, lunate; T, triquetrum; P, pisiform; G, trapezium; M, trapezoid; C, capitate; and H, hamate.) B, AP wrist showing complete dislocation of the lunate (black arrow) and fracture of the ulnar styloid process (white arrow).
**LATERAL PROJECTION**

**Lateromedial**

**Image receptor:** 8 x 10 inch (18 x 24 cm) lengthwise or crosswise for two images.

**Position of patient**
- Seat the patient at the end of the radiographic table.
- Have the patient rest the arm and forearm on the table to ensure that the wrist is in a lateral position.

**Position of part**
- Have the patient flex the elbow 90 degrees to rotate the ulna to the lateral position.
- Center the IR to the carpals, and adjust the forearm and hand so that the wrist is in a true lateral position (Fig. 4-73).
- **Shield gonads.**

**Central ray**
- Perpendicular to the wrist joint.

**Structures shown**
This image shows a lateral projection of the proximal metacarpals, carpals, and distal radius and ulna (Fig. 4-74). An image obtained with the radial surface against the IR (Fig. 4-75) is shown for comparison. This position can also be used to demonstrate anterior or posterior displacement in fractures.

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**Fig. 4-73** Lateral wrist with ulnar surface to IR.

**Fig. 4-74 A, B** Lateral wrist with ulnar surface to IR. B, Lateral with fracture (arrow). This is the same patient as in Fig. 4-70, B.
EVALUATION CRITERIA

The following should be clearly demonstrated:
- Distal radius and ulna, carpals, and proximal half of metacarpals
- Superimposed distal radius and ulna
- Superimposed metacarpals
- Radiographic density similar to PA or AP and oblique radiographs, which requires increased exposure factors to compensate for greater part thickness

NOTE: Burman et al suggested that the lateral position of the scaphoid should be obtained with the wrist in palmar flexion because this action rotates the bone anteriorly into a dorsopalmar position (Fig. 4-76, A). This position, however, is valuable only when sufficient flexion is permitted.

Fiole2,3 was the first to describe a small bony growth occurring on the dorsal surface of the third CMC joint. He termed the condition carpe bossu (carpal boss) and found that it is demonstrated best in a lateral position with the wrist in palmar flexion (Fig. 4-76, B).

1Burman MS et al: Fractures of the radial and ulnar axes, AJR 51:455, 1944.

Fig. 4-75 Lateral wrist with radial surface to IR.

Fig. 4-76 A, Lateral wrist showing an obvious complete anterior dislocation of the lunate bone. Same patient as Fig. 4-72, B. B, Lateral wrist with palmar flexion of wrist, showing carpal boss (arrow).
PA OBLIQUE PROJECTION

Lateral rotation

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise or crosswise for two images on one IR

**Position of patient**
- Seat the patient at the end of the radiographic table, placing the axilla in contact with the table.

**Position of part**
- Rest the palmar surface of the wrist on the IR.
- Adjust the IR so that its center point is under the scaphoid when the wrist is rotated from the pronated position.
- From the pronated position, rotate the wrist laterally (externally) until it forms an angle of approximately 45 degrees with the plane of the IR. For exact positioning and to ensure duplication in follow-up examinations, place a 45-degree foam wedge under the elevated side of the wrist.
- Extend the wrist slightly, and if the digits do not touch the table, support them in place (Fig. 4-77).
- When the scaphoid is under examination, adjust the wrist in ulnar deviation. Place a sandbag across the forearm.
- Shield gonads.

**Central ray**
- Perpendicular to the midcarpal area. It enters just distal to the radius.

**Structures shown**
This projection demonstrates the carpals on the lateral side of the wrist, particularly the trapezium and the scaphoid. The scaphoid is superimposed on itself in the direct PA projection (Figs. 4-78 and 4-79).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- A well demonstrated scaphoid and trapezium;
- Distal radius and ulna, carpals and proximal half of metacarpals
- Usually, adequate amount of obliquity in the following circumstances:
  - Slight interosseus space between the third-fourth and fourth-fifth metacarpal shafts
  - Slight overlap of the distal radius and ulna
- Soft tissue and bony trabeculation
Wrist

AP OBLIQUE PROJECTION

Medial rotation

**Image receptor:** 8 x 10 inch (18 x 24 cm) lengthwise or crosswise for two images on one IR

**Position of patient**
- Seat the patient at the end of the radiographic table.
- Have the patient rest the forearm on the table in the supine position.

**Position of part**
- Place the IR under the wrist and center it at the dorsal surface of the wrist.
- Rotate the wrist medially (internally) until it forms a semisupinated position of approximately 45 degrees to the IR (Fig. 4-80).
- Shield gonads.

**Central ray**
- Perpendicular to the midcarpal area. It enters the anterior surface of the wrist midway between its medial and lateral borders.

**Structures shown**
This position separates the pisiform from the adjacent carpal bones. It also gives a more distinct radiograph of the triquetrum and hamate (compare Figs. 4-81 and 4-82).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Carpals on medial side of wrist
- Triquetrum, hamate, and pisiform free of superimposition and in profile
- Distal radius and ulna, carpals and proximal half of metacarpals
- Radiographic quality soft tissue and bony trabeculation

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Fig. 4-80 AP oblique wrist: medial rotation.

Fig. 4-81 AP oblique wrist.

Fig. 4-82 AP oblique wrist.

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**Wrist**

**PA PROJECTION**

**Ulnar deviation**

*Image receptor:* 8 × 10 inch (18 × 24 cm) lengthwise or crosswise for two images

*Position of patient*
- Seat the patient at the end of the radiographic table with the arm and forearm resting on the table.

*Position of part*
- Position the wrist on the IR for a PA projection.
- With one hand cupped over the joint to hold it in position, move the elbow away from the patient’s body and then turn the hand outward until the wrist is in extreme ulnar deviation (Fig. 4-83).
- *Shield gonads.*

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**Central ray**
- Perpendicular to the scaphoid.
- Clear delineation sometimes requires a central ray angulation of 10 to 15 degrees proximally or distally.

**Structures shown**
This position corrects foreshortening of the scaphoid, which occurs with a perpendicular central ray. It also opens the spaces between the adjacent carpals (Fig. 4-84).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Scaphoid with adjacent articulations open
- No rotation of wrist
- Extreme ulnar deviation, as revealed by the angle formed between longitudinal axes of the forearm compared with the longitudinal axes of the metacarpals
- Soft tissue and bony trabeculation

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*Fig. 4-83* PA wrist in ulnar deviation.

*Fig. 4-84* A, PA wrist in ulnar deviation. (S, Scaphoid; L, lunate; T, triquetrum; P, pisiform; G, trapezium; M, trapezoid; C, capitate; and H, hamate.) B, Wrist in ulnar deviation.
Wrist

PA PROJECTION
Radial deviation

Image receptor: 8 × 10 inch (18 × 24 cm) lengthwise or crosswise for two images.

Position of patient
- Seat the patient at the end of the radiographic table.

Position of part
- Position the wrist on the IR for a PA projection.
- Cup one hand over the wrist joint to hold it in position. Then move the elbow toward the patient’s body and turn the hand medially until the wrist is in extreme radial deviation (Fig. 4-85).
- Shield gonads.

Central ray
- Perpendicular to the midcarpal area.

Structures shown
Radial deviation opens the interspaces between the carpals on the medial side of the wrist (Fig. 4-86).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Carpals and their articulations on the medial side of the wrist.
- No rotation of wrist.
- Extreme radial deviation, as revealed by the angle formed between longitudinal axes of forearm compared to the longitudinal axes of the metacarpals.
- Soft tissue and bony trabeculation.


Fig. 4-85 PA wrist in radial deviation.

Fig. 4-86 A, PA wrist in radial deviation. (S, Scaphoid; L, Lunate; T, Triquetrum; P, Pisiform; G, Trapezium; M, Trapezoid; C, Capitate; and H, Hamate.) B, Wrist in radial deviation.
Scaphoid

PA AXIAL PROJECTION
STECHER METHOD

Image receptor: 8 x 10 inch (18 x 24 cm) lengthwise

Position of patient
- Seat the patient at the end of the radiographic table with the arm and axilla in contact with the table.
- Rest the forearm on the table.

Position of part
- Place one end of the IR on a support and adjust the IR so that the finger end of the IR is elevated 20 degrees (Fig. 4-87).
- Adjust the wrist on the IR for a PA projection, and center the wrist to the IR.
- Bridgman suggested positioning the wrist in ulnar deviation for this radiograph.
- Shield gonads.

Central ray
- Perpendicular to the table and directed to enter the scaphoid

Structures shown
The 20-degree angulation of the wrist places the scaphoid at right angles to the central ray so that it is projected without self-superimposition (Figs. 4-88 and 4-89).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Scaphoid
- No rotation of carpals, metacarpals, radius, or ulna
- Distal radius and ulna, carpals, and proximal half of the metacarpals
- Soft tissue and bony trabeculation

1Stecher WR: Roentgenography of the carpal navicular bone, AJR 37:704, 1937.
VARIATIONS

Stecher recommended the previous method as preferable; however, a similar position can be obtained by placing the IR and wrist horizontally and directing the central ray 20 degrees toward the elbow (Fig. 4-90).

To demonstrate a fracture line that angles superoinferiorly, these positions may be reversed. In other words, the wrist may be angled inferiorly, or from the horizontal position the central ray may be angled toward the digits.

A third method recommended by Stecher is to have the patient clench the fist. This elevates the distal end of the scaphoid so that it lies parallel with the IR; it also widens the fracture line. The wrist is positioned as for the PA projection, and no central ray angulation is used.

Fig. 4-90 A, PA axial wrist for scaphoid: Stecher method, angulation of central ray. B, PA axial wrist: Stecher method.
Scaphoid Series
PA AND PA AXIAL PROJECTIONS
RAFERT-LONG METHOD

Ulnar deviation
Scaphoid fractures account for 60% of all carpal bone injuries. In 1991, Rafert and Long described this method of diagnosing scaphoid fractures using a four-image, multiple-angle central ray series. The series is performed after routine wrist radiographs do not identify a fracture.

Image receptor: 8 x 10 inch (18 x 24 cm) crosswise for two images


Position of patient
- Seat the patient at the end of the radiographic table with the arm and forearm resting on the table.

Position of part
- Position the wrist on the IR for a PA projection.
- Without moving the forearm, turn the hand outward until the wrist is in extreme ulnar deviation (Fig. 4-91).
- Shield gonads.

Central ray
- Perpendicular and with multiple cephalad angles. With the hand and wrist in the same position for each projection, four separate exposures are made at 0, 10, 20, and 30 degrees cephalad.
- The central ray should directly enter the scaphoid bone.
- Collimation should be close to improve image quality.

Structures shown
The scaphoid is demonstrated with minimal superimposition (Fig. 4-92).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- No rotation of the wrist
- Scaphoid with adjacent articular areas open
- Extreme ulnar deviation

Fig. 4-91 PA wrist in ulnar deviation.
Fig. 4-92: PA and PA axial wrist in ulnar deviation for Rafert-Long method scaphoid series. Radiographs are all from the same patient. 

**A**, PA wrist with 0-degree central ray angle. 

**B**, PA axial wrist with 10-degree cephalad angle. 

**C**, PA axial wrist with 20-degree cephalad angle. 

**D**, PA axial wrist with 30-degree cephalad angle. 

Fractures of the trapezium are rare; however, if undiagnosed, these fractures can lead to functional difficulties. In certain cases the articular surfaces of the trapezium should be evaluated to treat the osteoarthritic patient.

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise

**Position of patient**
- With the patient seated at the end of the radiographic table, place the hand on the IR in the lateral position.

**Position of part**
- Place the wrist in the lateral position, resting on the ulnar surface over the center of the IR.
- Place a 45-degree sponge wedge against the anterior surface, and rotate the hand to come in contact with the sponge.
- If the patient is able to achieve ulnar deviation, adjust the IR so that the long axis of the IR and the forearm align with the central ray (Fig. 4-93).
- If the patient is unable to comfortably achieve ulnar deviation, align the straight wrist to the IR and rotate the elbow end of the IR and arm 20 degrees away from the central ray (Fig. 4-94).
- Shield gonads.

**Central ray**
- Angled 45 degrees distally to enter the anatomic snuffbox of the wrist and pass through the trapezium

**Structures shown**
The image clearly demonstrates the trapezium and its articulations with the adjacent carpal bones (Fig. 4-95). The articulation of the trapezium and scaphoid is not demonstrated on this image.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Trapezium projected free of the other carpal bones with the exception of the articulation with the scaphoid.
**Carpal Bridge**

**TANGENTIAL PROJECTION**

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise

**Position of patient**
- Seat or stand the patient at the side of the radiographic table to permit the required manipulation of the arm or x-ray tube.

**Position of part**
- The originators of this projection recommended that the hand lie palm upward on the IR with the hand at right angle to the forearm (Fig. 4-96).

- When the wrist is too painful to be adjusted in the position just described, a similar image can be obtained by elevating the forearm on sandbags or other suitable support. Then with the wrist flexed in right-angle position, place the IR in the vertical position (Fig. 4-97).

**Central ray**
- Directed to a point about 1½ inches (3.8 cm) proximal to the wrist joint at a caudal angle of 45 degrees

**Structures shown**
The carpal bridge is demonstrated on the image in Figs. 4-98 and 4-99. The originators recommended this procedure for demonstration of fractures of the scaphoid, lunate dislocations, calcifications and foreign bodies in the dorsum of the wrist, and chip fractures of the dorsal aspect of the carpal bones.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Dorsal aspect of the wrist
- Carpals
- Dorsal surface of the carpals free of superimposition by the metacarpal bases

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The carpal canal contains the tendons of the flexors of the fingers and the median nerve. Compression of the median nerve results in pain. Radiography is performed to identify abnormality of the bones or soft tissue of the canal.

Fractures of the hook of hamate, pisiform, and trapezium are increasingly seen in athletes. The tangential projection is helpful in identifying fractures of these carpal bones. This projection was added as an essential projection based on the 1997 survey performed by Bontrager.2

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise

**Inferosuperior**

**Position of patient**
- Seat the patient at the end of the radiographic table so that the forearm can be adjusted to lie parallel with the long axis of the table.
- Hyperextend the wrist, and center the IR to the joint at the level of the radial styloid process.
- For support, place a radiolucent pad approximately ½ inch (1.9 cm) thick under the lower forearm.
- Adjust the position of the hand to make its long axis as vertical as possible.
- To prevent superimposition of the shadows of the hamate and pisiform bones, rotate the hand slightly toward the radial side.
- Have the patient grasp the digits with the opposite hand, or use a suitable device to hold the wrist in the extended position (Fig. 4-100).
- Shield gonads.

**Central ray**
- Directed to the palm of the hand at a point approximately 1 inch (2.5 cm) distal to the base of the third metacarpal and at an angle of 25 to 30 degrees to the long axis of the hand.

**Structures shown**
This image of the carpal canal (carpal tunnel) shows the palmar aspect of the trapezium, the tubercle of the trapezium, and the scaphoid, capitane, hook of hamate, triquetrum, and entire pisiform (Fig. 4-101).

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**Fig. 4-100** Tangential (inferosuperior) carpal canal: Gaynor-Hart method.

**Fig. 4-101** Tangential (inferosuperior) carpal canal: Gaynor-Hart method.
Carpal Canal

Superoinferior

Position of patient
- When the patient cannot assume or maintain the previously described wrist position, a similar image may be obtained.
- Have the patient dorsiflex the wrist as much as is tolerable and lean forward to place the carpal canal tangent to the IR (Fig. 4-102). The canal is easily palpable on the palmar aspect of the wrist as the concavity between the trapezium laterally and hook of hamate and pisiform medially.

Position of part
- When dorsiflexion of the wrist is limited, Marshall suggested placing a 45-degree angle sponge under the palmar surface of the hand. This slightly elevates the wrist to place the carpal canal tangent to the central ray. A slight degree of magnification exists because of the increased object-to-image receptor distance (OID) (Fig. 4-103).

Central ray
- Tangential to the carpal canal at the level of the midpoint of the wrist
- Angled toward the hand approximately 20 to 35 degrees from the long axis of the forearm

EVALUATION CRITERIA

With either approach, the following should be clearly demonstrated:
- Carpals in an arch arrangement
- Pisiform in profile and free of superimposition
- Hamulus of hamate
- All carpals

Fig. 4-102 Tangential (inferosuperior) carpal canal.

Fig. 4-103 Tangential (inferosuperior) carpal canal.
**AP PROJECTION**

The IR should be long enough to include the entire forearm from the olecranon process of the ulna to the styloid process of the radius. Both images of the forearm may be taken on one IR by alternately covering one half of the IR with a lead mask. Space should be allowed for the patient identification marker so that no part of the radiographic image is cut off.

**Image receptor:** Lengthwise—18 × 43 cm single; 35 × 43 cm divided

**Position of patient**
- Seat the patient close to the radiographic table and low enough to place the entire limb in the same plane.

**Position of part**
- Supinate the hand, extend the elbow, and center the unmasked half of the IR to the forearm. Ensure that the joint of interest is included.
- Adjust the IR so that the long axis is parallel with the forearm.
- Have the patient lean laterally until the forearm is in a true supinated position (Fig. 4-104).
- Because the proximal forearm is commonly rotated in this position, palpate and adjust the humeral epicondyles to be equidistant from the IR.
- Ensure that the hand is supinated (Fig. 4-105). Pronation of the hand crosses the radius over the ulna at its proximal third and rotates the humerus medially, resulting in an oblique projection of the forearm (Fig. 4-106).
- Shield gonads.

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**Fig. 4-104** AP forearm.

**Fig. 4-105** AP forearm with hand supinated.

**Fig. 4-106** AP forearm with hand pronated—incorrect.
Central ray
• Perpendicular to the midpoint of the forearm

Structures shown
An AP projection of the forearm demonstrates the elbow joint, the radius and ulna, and the proximal row of slightly distorted carpal bones (Fig. 4-107).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Wrist and distal humerus
- Slight superimposition of the radial head, neck, tuberosity over the proximal ulna
- No elongation or foreshortening of the humeral epicondyles
- Partially open elbow joint if the shoulder was placed in the same plane as the forearm
- Similar radiographic densities of the proximal and distal forearm

Fig. 4-107 A, AP forearm with fractured radius and ulna (arrows). B, AP forearm showing both joints.
**LATERAL PROJECTION**

**Lateromedial**

**Image receptor:** Lengthwise—18 × 43 cm single; 35 × 43 cm divided

**Position of patient**
Seat the patient close to the radiographic table and low enough that the humerus, shoulder joint, and elbow lie in the same plane.

**Position of part**
- Flex the elbow 90 degrees, and center the forearm over the unmasked half of the IR and parallel with the long axis of the forearm.
- Make sure that the entire joint of interest is included.
- Adjust the limb in a true lateral position. The thumb side of the hand must be up (Fig. 4-108).
- *Shield gonads.*

**Central ray**
- Perpendicular to the midpoint of the forearm

**Structures shown**
The lateral projection demonstrates the bones of the forearm, the elbow joint, and the proximal row of carpal bones (Fig. 4-109).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Wrist and distal humerus
- Superimposition of the radius and ulna at their distal end
- Superimposition by the radial head over the coronoid process
- Radial tuberosity facing anteriorly
- Superimposed humeral epicondyles
- Elbow flexed 90 degrees
- Soft tissue and bony trabeculation along the entire length of the radial and ulnar shafts
AP PROJECTION

Image receptor: 8 × 10 inch (18 × 24 cm) single or 24 × 30 cm divided

Position of patient
• Seat the patient near the radiographic table and low enough to place the shoulder joint, humerus, and elbow joint in the same plane.

Position of part
• Extend the elbow, supinate the hand, and center the IR to the elbow joint.
• Adjust the IR to make it parallel with the long axis of the part (Fig. 4-110).
• Have the patient lean laterally until the humeral epicondyles and anterior surface of the elbow are parallel with the plane of the IR.
• Supinate the hand to prevent rotation of the bones of the forearm.
• Shield gonads.

Central ray
• Perpendicular to the elbow joint

Structures shown
An AP projection of the elbow joint, digital arm, and proximal forearm is presented (Fig. 4-111).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Radial head, neck, and tuberosity slightly superimposed over the proximal ulna
- Elbow joint open and centered to the central ray
- No rotation of humeral epicondyles
- Soft tissue and bony trabeculation

Fig. 4-110 AP elbow.

Fig. 4-111 A, AP elbow with wide latitude exposure technique for soft tissue detail. B, AP elbow with normal exposure technique.
**LATERAL PROJECTION**

*Lateromedial*

Griswold¹ gave two reasons for the importance of flexing the elbow 90 degrees: (1) the olecranon process can be seen in profile, and (2) the elbow fat pads are the least compressed. It must be realized that in partial or complete extension the olecranon process elevates the posterior elbow fat pad and simulates joint pathology.

*Image receptor:* 8 × 10 inch (18 × 24 cm) single or 24 × 30 cm divided

**Position of patient**

- Seat the patient at the end of the radiographic table low enough to place the humerus and elbow joint in the same plane.

**Position of part**

- From the supine position, flex the elbow 90 degrees and place the humerus and forearm in contact with the table.
- Center the IR to the elbow joint. Adjust the elbow joint so that its long axis is parallel with the long axis of the forearm (Figs. 4-112 and 4-113). On patients with muscular forearms, elevate the wrist to place the forearm parallel with the IR.
- Adjust the IR diagonally to include more of the arm and forearm (Fig. 4-114).
- To obtain a lateral projection of the elbow, adjust the hand in the lateral position and ensure that the humeral epicondyles are perpendicular to the plane of the IR.
- *Shield gonads.*

**Central ray**

- Perpendicular to the elbow joint, regardless of its location on the IR.

---

Structures shown
The lateral projection demonstrates the elbow joint, distal arm, and proximal forearm (see Figs. 4-113 and 4-114).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Open elbow joint centered to the central ray
- Elbow flexed 90 degrees
- Superimposed humeral epicondyles
- Radial tuberosity facing anteriorly
- Radial head partially superimposing the coronoid process
- Olecranon process seen in profile
- Bony trabeculation and any elevated fat pads in the soft tissue at the anterior and posterior distal humerus and the anterior proximal forearm

NOTE: When injury to the soft tissue around the elbow is suspected, the joint should be flexed only 30 or 35 degrees (Fig. 4-115). This partial flexion does not compress or stretch the soft structures as does the full 90-degree lateral flexion.

Fig. 4-114 Lateral elbow.

Fig. 4-115 A, Lateral elbow in partial flexion position for soft tissue image. B, Lateral elbow of patient who fell from a tree resulting in an impacted fracture (arrows) of the distal humerus.
AP OBLIQUE PROJECTION
Medial rotation

Image receptor: 8 × 10 inch (18 × 24 cm) single or 24 × 30 cm divided

Position of patient
• Seat the patient at the end of the radiographic table with the arm extended and in contact with the table.

Position of part
• Extend the limb in position for an AP projection, and center the midpoint of the IR to the elbow joint (Fig. 4-116).
• Medially (internally) rotate or pronate the hand, and adjust the elbow to place its anterior surface at an angle of 45 degrees. This degree of obliquity usually clears the coronoid process of the radial head.
• Shield gonads.

Central ray
• Perpendicular to the elbow joint

Structures shown
The image shows an oblique projection of the elbow with the coronoid process projected free of superimposition (Fig. 4-117).

EVALUATION CRITERIA
The following should be clearly demonstrated:
■ Coronoid process in profile
■ Elongated medial humeral epicondyle
■ Ulna superimposed by the radial head and neck
■ Olecranon process within the olecranon fossa
■ Soft tissue and bony trabeculation

Fig. 4-116 AP oblique elbow: medial rotation.

Fig. 4-117 AP oblique elbow.
**Elbow**

AP OBLIQUE PROJECTION

Lateral rotation

Image receptor: 8 × 10 inch (18 × 24 cm) single or 24 × 30 cm divided

Position of patient

- Seat the patient at the end of the radiographic table with the arm extended and in contact with the table.

Position of part

- Extend the patient’s arm in position for an AP projection and center the midpoint of the IR to the elbow joint.
- Rotate the hand laterally (externally) to place the posterior surface of the elbow at a 45-degree angle (Fig. 4-118). When proper lateral rotation is achieved, the patient’s first and second digits should touch the table.
- Shield gonads.

Central ray

- Perpendicular to the elbow joint

**Structures shown**

The image shows an oblique projection of the elbow with the radial head and neck projected free of superimposition of the ulna (Fig. 4-119).

**EVALUATION CRITERIA**

The following should be clearly demonstrated:

- Radial head, neck, and tuberosity projected free of the ulna
- Open elbow joint
- Soft tissue and bony trabeculation
**Distal Humerus**

**AP PROJECTION**

**Partial flexion**

When the patient cannot completely extend the elbow, the lateral position is easily performed; however, two AP projections must be obtained to avoid distortion. A separate AP projection of the distal humerus and proximal forearm is required.

**Image receptor:** Both exposures can be made on one 8 x 10 inch (18 x 24 cm) IR or on one IR placed crosswise by alternately covering one half of the IR with a lead mask.

**Position of patient**

- Seat the patient low enough to place the entire humerus in the same plane. Support the elevated forearm.

**Position of part**

- If possible, supinate the hand. Place the IR under the elbow, and center it to the condyloid area of the humerus (Fig. 4-120).
- Shield gonads.

**Central ray**

- Perpendicular to the humerus, traversing the elbow joint.
- Depending on the degree of flexion, angle the central ray distally into the joint.

**Structures shown**

This projection shows the distal humerus when the elbow cannot be fully extended (Figs. 4-121 and 4-122).

**EVALUATION CRITERIA**

The following should be clearly demonstrated:

- Distal humerus without rotation or distortion
- Proximal radius superimposed over the ulna
- Closed elbow joint
- Greatly foreshortened proximal forearm
- Trabecular detail on the distal humerus

---

**Fig. 4-120** AP elbow, partially flexed.

**Fig. 4-121** AP elbow, partially flexed, demonstrating distal humerus.

**Fig. 4-122** AP elbow, partially flexed, demonstrating distal humerus. White proximal radius and ulna is the result of overlap of an anterior dislocated elbow (see Fig. 4-125).
Proximal Forearm

AP PROJECTION
Partial flexion

**Image receptor:** 8 × 10 inch (18 × 24 cm)

**Position of patient**
Seat the patient at the end of the radiographic table with the hand supinated.

**Position of part**
- Seat the patient high enough to permit the dorsal surface of the forearm to rest on the table (Fig. 4-123). If this position is not possible, elevate the limb on a support, adjust the limb in the lateral position, place the IR in the vertical position behind the upper end of the forearm, and direct the central ray horizontally.
- **Shield gonads.**

**Central ray**
- Perpendicular to the elbow joint and long axis of the forearm.
- Adjust the IR so that the central ray passes to its midpoint.

**Structures shown**
This projection demonstrates the proximal forearm when the elbow cannot be fully extended (Figs. 4-124 and 4-125).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:

- Proximal radius and ulna without rotation or distortion
- Radial head, neck, and tuberosity slightly superimposed over the proximal ulna
- Partially open elbow joint
- Foreshortened distal humerus
- Trabecular detail on the proximal forearm

**NOTE:** Holly\(^1\) described a method of obtaining the AP projection of the radial head. The patient is positioned as described for the distal humerus. The elbow is extended as much as possible, and the forearm is supported. The forearm should be supinated enough to place the horizontal plane of the wrist at an angle of 30 degrees from horizontal.

Distal Humerus
AP PROJECTION
Acute flexion
When fractures around the elbow are being treated using the Jones orthopedic technique (complete flexion), the lateral position offers little difficulty, but the frontal projection must be made through the superimposed bones of the AP arm and PA forearm.

Image receptor: 8 × 10 inch (18 × 24 cm); may be divided for two images on one IR

Position of patient
• Seat the patient at the end of the radiographic table with the elbow fully flexed (unless contraindicated).

Position of part
• Center the IR proximal to the epicondylar area of the humerus. The long axis of the arm and forearm should be parallel with the long axis of the IR (Figs. 4-126 and 4-127).
• Adjust the arm or the radiographic tube and IR to prevent rotation.
• Shield gonads.

Central ray
• Perpendicular to the humerus approximately 2 inches (5 cm) superior to the olecranon process

Structures shown
This position superimposes the bones of the forearm and arm. The olecranon process should be clearly demonstrated (Fig. 4-128).

EVALUATION CRITERIA
The following should be clearly demonstrated:
■ Forearm and humerus superimposed
■ No rotation
■ Olecranon process and distal humerus
■ Soft tissue outside the olecranon process

Fig. 4-126 AP distal humerus: acute flexion of elbow.
Fig. 4-127 AP distal humerus: acute flexion of elbow.
Fig. 4-128 AP distal humerus: acute flexion of elbow.
Proximal Forearm

PA PROJECTION

Acute flexion

Image receptor: 8 × 10 inch (18 × 24 cm)

Position of patient
- Seat the patient at the end of the radiographic table with the elbow fully flexed.

Position of part
- Center the flexed elbow joint to the center of the IR. The long axis of the superimposed forearm and arm should be parallel with the long axis of the IR (Figs. 4-129 and 4-130).
- Move the IR toward the shoulder so that the central ray will pass to the midpoint.
- Shield gonads.

Central ray
- Perpendicular to the flexed forearm, entering approximately 2 inches (5 cm) distal to the olecranon process

Structures shown
The superimposed bones of the arm and forearm are outlined (Fig. 4-131). The elbow joint should be more open than for projections of the distal humerus.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Forearm and humerus superimposed
- No rotation
- Proximal radius and ulna
Radial Head
LATERAL PROJECTION
Lateromedial
Four-position series
Place the IR in position, and cover the unused section with a sheet of lead. For demonstration of the entire circumference of the radial head free of superimposition, four projections with varying positions of the hand are performed.

Image receptor: $8 \times 10$ inch ($18 \times 24$ cm) single or $24 \times 30$ cm divided

---

Position of patient
- Seat the patient low enough to place the entire arm in the same horizontal plane.

Position of part
- Flex the elbow 90 degrees, center the joint to the unmasked IR, and place the joint in the lateral position.
- Make the first exposure with the hand supinated as much as is possible (Fig. 4-132).
- Shift the IR and make the second exposure with the hand in the lateral position, that is, with the thumb surface up (Fig. 4-133).
- Shift the IR, and make the third exposure with the hand pronated (Fig. 4-134).
- Shift the IR, and make the fourth exposure with the hand in extreme internal rotation, that is, resting on the thumb surface (Fig. 4-135).
- Shield gonads.

---

Fig. 4-132 Lateral elbow, radius with hand supinated as much as possible.

Fig. 4-133 Lateral elbow, radius with hand lateral.

Fig. 4-134 Lateral elbow, radius with hand pronated.

Fig. 4-135 Lateral elbow, radius with hand internally rotated.
Elbow

Central ray
• Perpendicular to the elbow joint

Structures shown
The radial head is projected in varying degrees of rotation (Figs. 4-136 to 4-139).

EVALUATION CRITERIA
The following should be clearly demonstrated:

- Radial tuberosity facing anteriorly for the first and second images and posteriorly for the third and fourth images (see Figs. 4-136 to 4-139)
- Elbow flexed 90 degrees
- Radial head partially superimposing the coronoid process but seen in all images

NOTE: Greenspan and Norman¹ reported that the radial head can be projected more clearly with reduced superimposition by directing the central ray 45 degrees medially (toward the shoulder) when the structure is positioned as in Figs. 4-132 to 4-135. The resulting radiograph is shown in Fig. 4-140.


Fig. 4-136 Lateral elbow, radius with hand supinated.
Fig. 4-137 Lateral elbow, radius with hand lateral.
Fig. 4-138 Lateral elbow, radius with hand pronated (radial tuberosity, arrow).
Fig. 4-139 Lateral elbow, radius with hand internally rotated.
Fig. 4-140 Lateral elbow, radial head with central ray angled 45 degrees medially as described by Greenspan and Norman.
PA AXIAL PROJECTION

**Image receptor:** 8 x 10 inch (18 x 24 cm) for one or two images on one IR

**Position of patient**
- Seat the patient high enough to enable the forearm to rest on the radiographic table with the arm in the vertical position. The patient must be seated so that the forearm can be adjusted parallel with the long axis of the table.

**Position of part**
- Ask the patient to rest the forearm on the table, and then adjust the forearm so that its long axis is parallel with the table.
- Center a point midway between the epicondyles and the center of the IR.
- Flex the patient’s elbow to place the arm in a nearly vertical position so that the humerus forms an angle of approximately 75 degrees from the forearm (approximately 15 degrees between the central ray and the long axis of the humerus).
- Confirm that the patient is not leaning anteriorly or posteriorly.
- Supinate the hand to prevent rotation of the humerus and ulna, and have the patient immobilize it with the opposite hand (Fig. 4-141).
- **Shield gonads.**

**Central ray**
- Perpendicular to the ulnar sulcus, entering at a point just medial to the olecranon process

**Structures shown**
This projection demonstrates the epicondyles, trochlea, ulnar sulcus (groove between the medial epicondyle and the trochlea), and olecranon fossa (Fig. 4-142). The projection is used in radiohumeral bursitis (tennis elbow) to detect otherwise obscured calcifications located in the ulnar sulcus.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Outline of the ulnar sulcus (groove)
- Soft tissue outside the distal humerus
- Forearm and humerus superimposed
- No rotation
Olecranon Process

PA AXIAL PROJECTION

**Image receptor:** 8 × 10 inch (18 × 24 cm)

**Position of patient**
- Seat the patient at the end of the radiographic table, high enough that the forearm can rest flat on the IR.

**Position of part**
- Adjust the arm at an angle of 45 to 50 degrees from the vertical position and ensure that the patient is not leaning anteriorly or posteriorly.
- Supinate the hand and have the patient immobilize it with the opposite hand.
- Center a point midway between the epicondyles and the center of the IR.
- Shield gonads.

**Central ray**
- Perpendicular to the olecranon process to demonstrate the dorsum of the olecranon process and at a 20-degree angle toward the wrist to demonstrate the curved extremity and articular margin of the olecranon process (Fig. 4-143).

**Structures shown**
The projection demonstrates the olecranon process and the articular margin of the olecranon and humerus (Figs. 4-144 to 4-146).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Olecranon process in profile
- Soft tissue outside the olecranon process
- Forearm and humerus superimposed
- No rotation

![Fig. 4-143 PA axial olecranon process with central ray angled 20 degrees.](image1)

![Fig. 4-144 PA axial olecranon process.](image2)

![Fig. 4-145 PA axial olecranon process with central ray angulation of 0 degrees.](image3)

![Fig. 4-146 PA axial olecranon process with central ray angulation of 20 degrees.](image4)
Humerus

**AP PROJECTION**

**Upright**

Shoulder and arm abnormalities, whether traumatic or pathologic in origin, are extremely painful. For this reason an upright position, either standing or seated, should be used whenever possible. With rotation of the patient's body as required, the arm can be positioned quickly and accurately with minimal discomfort to the patient.

**Image receptor:** Lengthwise—18 × 43 cm; 35 × 43 cm

**Position of patient**
- Place the patient in a seated-upright or standing position facing the x-ray tube.
- Fig. 4-147 illustrates the body position used for an AP projection of the freely movable arm. The body position, whether oblique or facing toward or away from the IR, is unimportant as long as a true frontal radiograph of the arm is obtained.

**Position of part**
- Adjust the height of the IR to place its upper margin about 1/2 inches (3.8 cm) above the head of the humerus.
- Abduct the arm slightly, and supinate the hand.
- A coronal plane passing through the epicondyles should be parallel with the IR plane for the AP (or PA) projection (see Fig. 4-147).
- Shield gonads.
- **Respiration:** Suspend.

**Central ray**
- Perpendicular to the midportion of the humerus and the center of the IR

**Structures shown**
The AP projection demonstrates the entire length of the humerus. The accuracy of the position is shown by the epicondyles (Fig. 4-148).

---

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Elbow and shoulder joints
- Maximal visibility of epicondyles without rotation
- Humeral head and greater tubercle in profile
- Outline of the lesser tubercle, located between the humeral head and the greater tubercle
- Beam divergence possibly partially closing the elbow joint
- No great variation in radiographic densities of the proximal and distal humerus
Humerus

LATERAL PROJECTION
Lateromedial
Upright

Image receptor: 18 × 43 cm; 35 × 43 cm

Position of patient
• Place the patient in a seated-upright or standing position facing the x-ray tube. The body position, whether oblique or facing toward or away from the IR, is not critical as long as a true projection of the lateral arm is obtained.

Position of part
• Place the top margin of the IR approximately 1 1/2 inches (3.8 cm) above the level of the head of the humerus.
• Unless contraindicated by possible fracture, internally rotate the arm, flex the elbow approximately 90 degrees, and place the patient’s anterior hand on the hip. This will place the humerus in lateral position. A coronal plane passing through the epicondyles should be perpendicular with the IR plane (Fig. 4-149).
• Shield gonads.
• Respiration: Suspend.

Central ray
• Perpendicular to the midportion of the humerus and the center of the IR

Structures shown
The lateral projection demonstrates the entire length of the humerus. A true lateral image is confirmed by superimposed epicondyles (Fig. 4-150).

EVALUATION CRITERIA
The following should be clearly demonstrated:
■ Elbow and shoulder joints
■ Superimposed epicondyles
■ Lesser tubercle in profile
■ Greater tubercle superimposed over the humeral head
■ Beam divergence possibly partially closing the elbow joint
■ No great variation in radiographic densities of the proximal and distal humerus

Fig. 4-149 Upright position for lateral humerus. Note the hand placement on the hip.

Fig. 4-150 Upright lateral humerus.
Humerus

AP PROJECTION
Recumbent
The IR size selected should be long enough to include the entire humerus.

Image receptor: Lengthwise—18 × 43 cm; 35 × 43 cm

Position of patient
• With the patient in the supine position, adjust the IR to include the entire length of the humerus.

Position of part
• Place the upper margin of the IR approximately 1 1/2 inches (3.8 cm) above the humeral head.
• Elevate the opposite shoulder on a sandbag to place the affected arm in contact with the IR or elevate the arm and IR on sandbags.
• Unless contraindicated, supinate the hand and adjust the limb to place the epicondyles parallel with the plane of the IR (Fig. 4-151).
• Shield gonads.
• Respiration: Suspend.

Central ray
• Perpendicular to the midportion of the humerus and the center of the IR

Fig. 4-151 Recumbent position for AP humerus. Note that the hand is supinated.
**Humerus**

**LATERAL PROJECTION**

*Lateromedial*

*Recumbent*

**Position of patient**
Place the patient in the supine position with the humerus centered to the IR, or use a Bucky tray.

**Position of part**
- Adjust the top of the IR to be approximately 1½ inches (3.8 cm) above the level of the head of the humerus.
- Unless contraindicated by possible fracture, abduct the arm somewhat and center the IR under it.
- Rotate the forearm medially to place the epicondyles perpendicular to the plane of the IR, and rest the *posterior aspect* of the hand against the patient’s side. This movement turns the epicondyles in the lateral position without flexing the elbow (see Fig. 4-149). (The elbow may be flexed slightly for comfort.)
- Adjust the position of the IR to include the entire length of the humerus (Fig. 4-152).

![Fig. 4-152 Recumbent position for lateral humerus. Note the posterior aspect of patient's hand against thigh.](image-url)
LATERAL PROJECTION

Lateromedial
Recumbent or lateral recumbent
• When a known or suspected fracture exists, position the patient in the recumbent or lateral recumbent position, place the IR close to the axilla, and center the humerus to the IR’s midline.
• Unless contraindicated, flex the elbow, turn the thumb surface of the hand up, and rest the humerus on a suitable support (Fig. 4-153).
• Adjust the position of the body to place the lateral surface of the humerus perpendicular to the central ray.
• Shield gonads.
• Respiration: Suspend.

Central ray
Recumbent
• Horizontal and perpendicular to the midportion of the humerus and the center of the IR.
Lateral recumbent
• Directed to the center of the IR, which exposes only the distal humerus (see Fig. 4-153)

Structures shown
The lateral projection demonstrates the distal humerus (Fig. 4-154).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Distal humerus
- Superimposed epicondyles
AP axial, 25 degree caudal projection, demonstrating calcareous peritendinitis.
# SUMMARY OF PROJECTIONS

## PROJECTIONS, POSITIONS & METHODS

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The icons in the Essential column indicate projections frequently performed in the United States and Canada. Students should become competent in these projections.
Shoulder Girdle

The shoulder girdle is formed by two bones, the clavicle and scapula. Their function is to connect the upper limb to the trunk. Although the alignment of these two bones is considered a girdle, it is incomplete both in front and in back. The girdle is completed in front by the sternum, which articulates with the medial end of the clavicle. The scapulae are widely separated in the back. The proximal portion of the humerus is part of the upper limb and not the shoulder girdle proper; however, because the proximal humerus is included in the shoulder joint, its anatomy is considered with that of the shoulder girdle (Fig. 5-1).

Clavicle

The clavicle, classified as a long bone, has a body and two articular extremities (Fig. 5-2). The clavicle lies in a horizontal oblique plane just above the first rib and forms the anterior part of the shoulder girdle. The lateral aspect is termed the acromial extremity, and it articulates with the acromion process of the scapula. The medial aspect, termed the sternal extremity, articulates with the manubrium of the sternum and the first costal cartilage. The clavicle, which serves as a fulcrum for the movements of the arm, is doubly curved for strength. The curvature is more acute in males than in females.
Scapula

The scapula, classified as a flat bone, forms the posterior part of the shoulder girdle (Figs. 5-3 and 5-4). Triangular in shape, the scapula has two surfaces, three borders, and three angles. Lying on the superoposterior thorax between the second and seventh ribs, the scapula’s medial border runs parallel with the vertebral column. The body of the bone is arched from top to bottom for greater strength, and its surfaces serve as the attachment sites of numerous muscles.

The costal (anterior) surface of the scapula is slightly concave and contains the subscapular fossa. It is filled almost entirely by the attachment of the subscapularis muscle. The anterior serratus muscle attaches to the medial border of the costal surface from the superior angle to the inferior angle.

The dorsal (posterior) surface is divided into two portions by a prominent spinous process. The crest of spine arises at the superior third of the medial border from a smooth, triangular area and runs obliquely superior to end in a flattened, ovoid projection called the acromion. The area above the spine is called the supraspinous fossa and gives origin to the supraspinatus muscle. The infraspinatus muscle arises from the portion below the spine, which is called the infraspinous fossa. The teres minor muscle arises from the superior two thirds of the lateral border of the dorsal surface and the teres major from the distal third and the inferior angle. The dorsal surface of the medial border affords attachment of the levator muscles of the scapulae, greater rhomboid muscle, and lesser rhomboid muscle.

The superior border extends from the superior angle to the coracoid process and at its lateral end has a deep depression, the scapular notch. The medial border extends from the superior to the inferior angles. The lateral border extends from the glenoid cavity to the inferior angle.
The superior angle is formed by the junction of the superior and medial borders. The inferior angle is formed by the junction of the medial (vertebral) and lateral borders and lies over the seventh rib. The lateral angle, the thickest part of the body of the scapula, ends in a shallow, oval depression called the glenoid cavity. The constricted region around the glenoid cavity is called the neck of the scapula. The coracoid process arises from a thick base that extends from the scapular notch to the superior portion of the neck of the scapula. This process projects first anteriorly and medially and then curves on itself to project laterally. The coracoid process can be palpated just distal and slightly medial to the acromioclavicular articulation.

**Humerus**

The proximal end of the humerus consists of a head, an anatomic neck, two prominent processes called the greater and lesser tubercles, and the surgical neck (Fig. 5-5). The head is large, smooth, and rounded, and it lies in an oblique plane on the superomedial side of the humerus. Just below the head, lying in the same oblique plane, is the narrow, constricted anatomic neck. The constriction of the body just below the tubercles is called the surgical neck, which is the site of many fractures.

The lesser tubercle is situated on the anterior surface of the bone, immediately below the anatomic neck (see Figs. 5-5 to 5-7). The tendon of the subscapular muscle inserts at the lesser tubercle. The greater tubercle is located on the lateral surface of the bone, just below the anatomic neck, and is separated from the lesser tubercle by a deep depression called the intertubercular (bicipital) groove. The superior surface of the greater tubercle slopes posteriorly at an angle of approximately 25 degrees and has three flattened impressions for muscle insertions. The anterior impression is the highest of the three and affords attachment to the tendon of the supraspinatus muscle. The middle impression is the point of insertion of the infraspinatus muscle. The tendon of the upper fibers of the teres minor muscle inserts at the posterior impression (the lower fibers insert into the body of the bone immediately below this point).

**Fig. 5-5** Anterior aspect of right proximal humerus.

**Fig. 5-6** Superior aspect of humerus.

**Fig. 5-7** Horizontal section through the scapulohumeral joint showing normal anatomic relationships.
Bursae are small synovial fluid-filled sacs that relieve pressure and reduce friction in tissue. They are often found between the bones and the skin, and they allow the skin to move easily when the joint is moved. Bursae are found also between bones and ligaments, muscles, or tendons. One of the largest bursae of the shoulder is the subacromial bursa (Fig. 5-8). It is located under the acromion process and lies between the deltoid muscle and the shoulder joint capsule. It does not normally communicate with the joint. Other bursae of the shoulder are found superior to the acromion, between the coracoid process and the joint capsule, and between the capsule and the tendon of the subscapular muscle. Bursae become important radiographically when injury or age causes the deposition of calcium.

### Shoulder Girdle Articulations

A summary of the three joints of the shoulder girdle is contained in Table 5-1, and a detailed description follows.

#### SCAPULOHUMERAL ARTICULATION

The scapulohumeral articulation between the glenoid cavity and the head of the humerus forms a synovial ball-and-socket joint, allowing movement in all directions (Figs. 5-9 and 5-10). Although many muscles connect with, support, and enter into the function of the shoulder joint, radiographers are chiefly concerned with the insertion points of the short rotator cuff muscles (Figs. 5-11 and 5-12). The insertion points of these muscles—the subscapular, supraspinatus, infraspinatus, and teres minor—have already been described.
Fig. 5-9 Articulations of the scapula and humerus.

Fig. 5-10 A, Coronal MRI of the shoulder. Note articular cartilage around humeral head and muscles closely surrounding the bone. B, Axial CT of the shoulder, midjoint. Note position of the bones relative to each other and articular cartilage in the glenoid cavity.

h, Humerus; gc, glenoid cavity; sn, scapular neck.

An articular capsule completely encloses the shoulder joint. The tendon of the long head of the biceps brachii muscle, which arises from the superior margin of the glenoid cavity, passes through the capsule of the shoulder joint, between its fibrous and synovial layers, arches over the head of the humerus, and descends through the intertubercular (bicipital) groove. The short head of the biceps arises from the coracoid process and, with the long head of the muscle, inserts in the radial tuberosity. Because it crosses with both the shoulder and elbow joints, the biceps help synchronize their action.

The interaction of movement between the wrist, elbow, and shoulder joints makes the position of the hand important in radiography of the upper limb. Any rotation of the hand also rotates the joints. The best approach to the study of the mechanics of joint and muscle action is to perform all movements ascribed to each joint and carefully note the reaction in remote parts.
**ACROMIOCLAVICULAR ARTICULATION**

The acromioclavicular articulation between the acromion process of the scapula and the acromial extremity of the clavicle forms a synovial gliding joint (see Fig. 5-9). It permits both gliding and rotary (elevation, depression, protraction, and retraction) movement. Because the end of the clavicle rides higher than the adjacent surface of the acromion, the slope of the surfaces tends to favor displacement of the acromion downward and under the clavicle.

**STERNOClavicular ARTICULATION**

The sternoclavicular articulation is formed by the sternal extremity of the clavicle with two bones: the manubrium and the first rib cartilage (see Fig. 5-9). The union of the clavicle with the manubrium of the sternum is the only bony union between the upper limb and trunk. This articulation is a synovial double-gliding joint. However, the joint is adapted by a fibrocartilaginous disk to provide movements similar to a ball-and-socket joint: circumduction, elevation, depression, and forward and backward movements. The clavicle carries the scapula with it through any movement.

**SUMMARY OF ANATOMY TERMS**

<table>
<thead>
<tr>
<th>Shoulder girdle</th>
<th>crest of spine</th>
<th>intertubercular groove</th>
<th>greater tubercles</th>
</tr>
</thead>
<tbody>
<tr>
<td>clavicle</td>
<td>acromion</td>
<td>lesser tubercles</td>
<td>body</td>
</tr>
<tr>
<td>scapula</td>
<td>supraspinous fossa</td>
<td>bursae</td>
<td>subacromial bursa</td>
</tr>
<tr>
<td>Clavicle</td>
<td>infraspinous fossa</td>
<td>Shoulder articulations</td>
<td>scapulohumeral</td>
</tr>
<tr>
<td>body</td>
<td>superior border</td>
<td>acromioclavicular</td>
<td>acromiohumeral</td>
</tr>
<tr>
<td>acromial extremity</td>
<td>coracoid process</td>
<td>sternoclavicular</td>
<td></td>
</tr>
<tr>
<td>sternal extremity</td>
<td>scapular notch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scapula</td>
<td>lateral border</td>
<td></td>
<td></td>
</tr>
<tr>
<td>medial border</td>
<td>glenoid cavity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>body</td>
<td>lateral angle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>costal surface</td>
<td>neck</td>
<td></td>
<td></td>
</tr>
<tr>
<td>subscapular fossa</td>
<td>Humerus (proximal aspect)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>superior angle</td>
<td>head</td>
<td></td>
<td></td>
</tr>
<tr>
<td>inferior angle</td>
<td>anatomic neck</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dorsal surface</td>
<td>surgical neck</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*See Addendum at the end of the volume for a summary of the changes in the anatomic terms used in this edition.
SUMMARY OF PATHOLOGY

<table>
<thead>
<tr>
<th>Condition</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bursitis</td>
<td>Inflammation of the bursa</td>
</tr>
<tr>
<td>Dislocation</td>
<td>Displacement of a bone from the joint space</td>
</tr>
<tr>
<td>Fracture</td>
<td>Disruption in the continuity of bone</td>
</tr>
<tr>
<td>Hills-Sachs Defect</td>
<td>Impacted fracture of the posterolateral aspect of the humeral head with dislocation</td>
</tr>
<tr>
<td>Metastases</td>
<td>Transfer of a cancerous lesion from one area to another</td>
</tr>
<tr>
<td>Osteoarthritis or Degenerative Joint Disease</td>
<td>Form of arthritis marked by progressive cartilage deterioration in synovial joints and vertebrae</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>Loss of bone density</td>
</tr>
<tr>
<td>Rheumatoid Arthritis</td>
<td>Chronic, systemic, inflammatory collagen disease</td>
</tr>
<tr>
<td>Tendonitis</td>
<td>Inflammation of the tendon and tendon-muscle attachment</td>
</tr>
<tr>
<td>Tumor</td>
<td>New tissue growth where cell proliferation is uncontrolled</td>
</tr>
<tr>
<td>Chondrosarcoma</td>
<td>Malignant tumor arising from cartilage cells</td>
</tr>
</tbody>
</table>

EXPOSURE TECHNIQUE CHART ESSENTIAL PROJECTIONS

**SHOULDER GIRDLE**

<table>
<thead>
<tr>
<th>Part</th>
<th>cm</th>
<th>kVp</th>
<th>tm</th>
<th>mA</th>
<th>mAs</th>
<th>AEC</th>
<th>SID</th>
<th>IR</th>
<th>Dose^1 (mrad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder-AP^2</td>
<td>18</td>
<td>75</td>
<td>200s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder-Transsthoracic Lateral^2</td>
<td>40</td>
<td>80</td>
<td>200s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder-Axillary^4</td>
<td>18</td>
<td>75</td>
<td>.08</td>
<td>200s</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder-PA Oblique Scapular Y^4</td>
<td>24</td>
<td>85</td>
<td>.08</td>
<td>200s</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intertubercular Gr.^3</td>
<td>3</td>
<td>55</td>
<td>.01</td>
<td>200s</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A-C Articulation-AP^6</td>
<td>14</td>
<td>70</td>
<td>.15</td>
<td>200s</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clavicle-AP, PA^1</td>
<td>16</td>
<td>70</td>
<td>.06</td>
<td>200s</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scapula-AP^8</td>
<td>18</td>
<td>75</td>
<td>200s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scapula-Lateral^8</td>
<td>24</td>
<td>85</td>
<td>.08</td>
<td>200s</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

^1 kVp values are for a 3-phase 12-pulse generator.
^2 Relative doses for comparison use. All doses are skin entrance for average adult at cm indicated.
^3 Bucky, 1:1 Grid, Screen/Film Speed 300.
^4 Tabletop, 8:1 Grid, Screen/Film Speed 300.
^5 Tabletop, Standard R. Screen/Film Speed 300.
Radiation Protection

Protection of the patient from unnecessary radiation is a professional responsibility of the radiographer (see Chapters 1 and 2 for specific guidelines). In this chapter, the Shield gonads statement at the end of the Position of part section indicates that the patient is to be protected from unnecessary radiation by using proper collimation and placing lead shielding between the gonads and the radiation source to restrict the radiation beam.

Shoulder Projection Removed

The following projection has been removed from the Atlas. The projection may be reviewed in its entirety in the ninth edition and all previous editions.

Shoulder joint

- Axial Projection with Rolled Film: Cleaves Method

Shoulder

AP PROJECTION
External, Neutral, Internal rotation humerus

NOTE: Do not have the patient rotate the arm if fracture or dislocation is suspected.

Image receptor: 24 × 30 cm cross-wise

Position of patient

- Examine the patient in the upright or the supine position. Shoulder and arm lesions, whether traumatic or pathologic in origin, are extremely sensitive to movement and pressure. For this reason the upright position should be used whenever possible.

Position of part

- Center the shoulder joint to the midline of the grid.
- Adjust the position of the IR so that its center is 1 inch (2.5 cm) inferior to the coracoid process.
- If necessary to overcome the curve of the back and the resultant obliquity of the shoulder structures, slightly rotate the patient enough to place the body of the scapula parallel with the plane of the IR.
- If the patient is in the supine position, support the elevated (nonradiographed) shoulder and hip on sandbags.
### TABLE 5-2
The hand position and its effect on the proximal humerus

<table>
<thead>
<tr>
<th>Description</th>
<th>Hand position</th>
<th>Proximal humerus position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supinating the hand will position the humerus in <em>external rotation</em>.</td>
<td></td>
<td>[AP image of shoulder with external rotation, arrow pointing to greater tubercle]</td>
</tr>
<tr>
<td>The palm of the hand placed against the hip will position the humerus in <em>neutral rotation</em>.</td>
<td></td>
<td>[AP image of shoulder with neutral rotation, arrow pointing to greater tubercle]</td>
</tr>
<tr>
<td>The posterior aspect of the hand placed against the hip will position the humerus in <em>internal rotation</em>.</td>
<td></td>
<td>[AP image of shoulder with internal rotation, arrow pointing to greater tubercle]</td>
</tr>
</tbody>
</table>
Shoulder

External rotation humerus:
- Ask the patient to supinate the hand, unless contraindicated (Table 5-2).
- Abduct the arm slightly, and rotate it so that the epicondyles are parallel with the plane of the IR. Externally rotating the entire arm from the neutral position places the shoulder and entire humerus in the true anatomic position (Fig. 5-13).

Neutral rotation humerus:
- Ask the patient to rest the palm of the hand against the thigh (see Table 5-3). This position of the arm rolls the humerus slightly internal into a neutral position, placing the epicondyles at an angle of about 45 degrees with the plane of the IR.

Internal rotation humerus:
- Ask the patient to flex the elbow somewhat, rotate the arm internally, and rest the back of the hand on the hip (see Table 5-3).
- Adjust the arm to place the epicondyles perpendicular to the plane of the IR.
- Shield gonads.
- Respiration: Suspend.

Central ray
- Perpendicular to a point 1 inch (2.5 cm) inferior to the coracoid process

COMPUTED RADIOGRAPHY

Both dense and nondense body areas will be exposed. The kilovolt (peak) kVp must be sufficient to penetrate the dense area. Collimation must be very close to keep unnecessary radiation from reaching the IR phosphor.
Shoulder

Structures shown

The resulting image shows the bony and soft structures of the shoulder and proximal humerus in the anatomic position (Figs. 5-14 to 5-16). The scapulohumeral joint relationship and the region of the subacromial bursa are seen.

External rotation:
The greater tubercle of the humerus and the site of insertion of the supraspinatus tendon are visualized (Fig. 5-14).

Neutral rotation:
The posterior part of the supraspinatus insertion, which sometimes profiles small calcific deposits not otherwise visualized (Fig. 5-15).

Internal rotation:
The proximal humerus is seen in a true lateral position. When the arm can be abducted enough to clear the lesser tubercle of the head of the scapula, a profile image of the site of the insertion of the subscapular tendon is seen (Fig. 5-16).

Fig. 5-14 AP shoulder, external rotation humerus: greater tubercle (arrow).

Fig. 5-15 AP shoulder, neutral rotation humerus: greater tubercle (arrow).
EVALUATION CRITERIA

The following should be clearly demonstrated:

- Superior scapula, lateral half of the clavicle, and proximal humerus
- Soft tissue around the shoulder, along with bony trabecular detail

**External rotation:**
- Humeral head in profile
- Greater tubercle in profile on the lateral aspect of the humerus
- Scapulohumeral joint visualized with slight overlap of humeral head on glenoid cavity
- Outline of lesser tubercle between the humeral head and greater tubercle

**Neutral rotation:**
- Greater tubercle partially superimposing the humeral head
- Humeral head in partial profile
- Slight overlap of the humeral head on the glenoid cavity

**Internal rotation:**
- Lesser tubercle in profile and pointing medially
- Outline of the greater tubercle superimposing the humeral head
- Greater amount of humeral overlap of the glenoid cavity than in the external and neutral positions

Fig. 5-16 AP shoulder, internal rotation humerus: greater tubercle (arrow); lesser tubercle in profile (arrowhead).
**TRANSTHORACIC LATERAL PROJECTION**

**LAWRENCE METHOD**

**R or L position**

The Lawrence method is used when trauma exists and the arm cannot be rotated or abducted because of an injury.

**Image receptor:** 24 x 30 cm lengthwise

**Position of patient**

- Although this position can be carried out with the patient in the upright or the supine position, the upright position is much easier on the trauma patient. It also facilitates accurate adjustment of the shoulder.
- For upright positioning, seat or stand the patient in the lateral position before a vertical grid device (Fig. 5-17).
- If an upright position is not possible, place the patient in a recumbent position on the table with radiolucent pads elevating the head and shoulders (Fig. 5-18).

**Position of part**

- Have the patient raise the uninjured arm, rest the forearm on the head, and elevate the shoulder as much as possible (see Fig. 5-17). Elevation of the uninjured shoulder drops the injured side, separating the shoulders to prevent superimposition. Ensure that the midcoronal plane is perpendicular to the IR.
- No attempt should be made to rotate or otherwise move the injured arm.
- Center the IR to the surgical neck area of the affected humerus.
- **Shield gonads.**
- **Respiration:** Full inspiration. Having the lungs full of air improves the contrast and decreases the exposure necessary to penetrate the body.
- If the patient can be sufficiently immobilized to prevent voluntary motion, a breathing technique can be utilized. In this case, instruct the patient to practice slow, deep breathing. A minimum exposure time of 3 seconds (4 to 5 seconds is desirable) will give excellent results when a low milliamperage is used.

**Central ray**

- Perpendicular to the IR, entering the midcoronal plane at the level of the surgical neck.
- If the patient cannot elevate the unaffected shoulder, angle the central ray 10 to 15 degrees cephalad to obtain a comparable radiograph.

---

Shoulder

Structures shown
A lateral image of the shoulder and proximal humerus is projected through the thorax (Figs. 5-19 and 5-20).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Proximal humerus
- Scapula, clavicle, and humerus seen through the lung field
- Scapula superimposed over the thoracic spine
- Unaffected clavicle and humerus projected above the shoulder closest to the IR

Fig. 5-19 Transthoracic lateral shoulder: Lawrence method.

Fig. 5-20 Transthoracic lateral shoulder (patient breathing): Lawrence method.
Shoulder Joint

**INFEROSUPERIOR AXIAL PROJECTION**

**LAWRENCE METHOD**

**INFEROSUPERIOR AXIAL PROJECTION**

**RAFERT ET AL**

Image receptor: 10 × 12 inch (24 × 30 cm) Grid crosswise, placed in the vertical position in contact with the superior surface of the shoulder

Position of patient

- With the patient in the supine position, elevate the head, shoulders, and elbow about 3 inches (7.6 cm).

Position of part

- As much as possible, abduct the arm of the affected side at right angles to the long axis of the body.
- Keep the humerus in external rotation, and adjust the forearm and hand in a comfortable position, grasping a vertical support or extended on sandbags or a firm pillow. Support may be needed under the forearm and hand. Provide patient with an extension board for the arm.
- Have the patient turn the head away from the side being examined so that the IR can be placed against the neck.
- Place the IR on edge against the shoulder and as close as possible to the neck.
- Support the IR in position with sandbags, or use a vertical IR holder (Fig. 5-21).

**RAFERT MODIFICATION**

- Anterior dislocation of the humeral head can result in a wedge-shaped compression fracture of the articular surface of the humeral head, called the Hill-Sachs defect. The fracture will be located on the posterolateral humeral head. An exaggerated external rotation of the arm may be required to see the defect.
- With the patient in position exactly as for the Lawrence method, externally rotate the extended arm until the hand forms a 45-degree oblique. The thumb will be pointing downward (Fig. 5-22).
- Assist the patient in rotating the arm to avoid overstressing the shoulder joint.
- Shield gonads.
- Respiration: Suspend.

Fig. 5-21 Inferosuperior axial shoulder joint: Lawrence method.

Fig. 5-22 Inferosuperior axial shoulder joint: Rafert modification. Note the exaggerated external rotation of arm and thumb pointing downward. If present, a Hill-Sachs defect would show as a wedge-shaped depression on the posterior aspect of the articulating surface of the humeral head (arrow).


1Lawrence WS: New position in radiographing the shoulder joint, AJR (2)728, 1915.


Shoulder Joint

Central ray

Lawrence method

- Horizontally through the axilla to the region of the acromioclavicular articulation. The degree of medial angulation of the central ray depends on the degree of abduction of the arm. The degree of medial angulation is often between 15 and 30 degrees. The greater the abduction, the greater the angle.

Rafert modification

- Horizontal and angled approximately 15 degrees medially, entering the axilla and passing through the acromioclavicular joint.

Structures shown

An inferosuperior axial image shows the proximal humerus, the scapulohumeral joint, the lateral portion of the coracoid process, and the acromioclavicular articulation. The insertion site of the subscapular tendon on the lesser tubercle of the humerus and the point of insertion of the teres minor tendon on the greater tubercle of the humerus are also shown. A Hill-Sachs compression fracture on the posterolateral humeral head may be seen using the Rafert modification (Figs. 5-23 and 5-24).

EVALUATION CRITERIA

The following should be clearly demonstrated:
- Scapulohumeral joint with slight overlap
- Coracoid process, pointing anteriorly
- Lesser tubercle in profile and directed anteriorly
- Acromioclavicular joint, acromion, and acromial end of clavicle projected through the humeral head
- Soft tissue in the axilla with bony trabecular detail
- Axillary structures

Fig. 5-23  A, Inferosuperior axial shoulder joint: Lawrence method. B, Inferosuperior axial shoulder joint: Rafert modification showing a Hill-Sachs defect (arrows).


Fig. 5-24  Inferosuperior axial shoulder joint: Lawrence method showing comminuted fracture of the humerus. Patient came into ER with arm extended out.
**Fig. 5-25** Inferosuperior axial shoulder joint: West Point method.

**Fig. 5-26** West Point method with anterior and medial central ray angulation.

**INFEROSUPERIOR AXIAL PROJECTION**

**WEST POINT METHOD**

**Image receptor:** 8 × 10 inch (18 × 24 cm) crosswise placed in the vertical position in contact with the superior surface of the shoulder.

**Position of patient**
- Adjust the patient in the prone position with approximately a 3-inch (7.6-cm) pad under the shoulder being examined.
- Turn the patient's head away from the side being examined.

**Position of part**
- Abduct the arm of the affected side 90 degrees, and rotate so that the forearm rests over the edge of the table or a Bucky tray, which may be used for support. (Figs. 5-25 and 5-26).
- Place a vertically supported IR against the superior aspect of the shoulder with the edge of the IR in contact with the neck.
- Support the IR with sandbags or a vertical IR holder.
- Shield gonads.
- Respiration: Suspend.

Central ray
- Directed at a dual angle of 25 degrees anteriorly from the horizontal and 25 degrees medially. The central ray enters approximately 5 inches (13 cm) inferior and 1½ inch (3.8 cm) medial to the acromial edge and exits the glenoid cavity.

Structures shown
The resulting image shows bony abnormalities of the anterior inferior rim of the glenoid in patients with instability of the shoulder (Fig. 5-27).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Humeral head projected free of the coracoid process
- Articulation between the head of the humerus and the glenoid cavity
- Acromion superimposed over the posterior portion of the humeral head
- Shoulder joint

Fig. 5-27 Inferosuperior axial shoulder joint: West Point method.
INFEROSUPERIOR AXIAL PROJECTION
CLEMENTS MODIFICATION

**Image receptor:** 8 × 10 inch (18 × 24 cm) placed in the vertical position in contact with the superior surface of the shoulder.

**Position of patient**
- When the prone or supine position is not possible, Clements suggested that the patient be radiographed in the lateral recumbent position lying, on the unaffected side.
- Flex the patient’s hips and knees.

**Position of part**
- Abduct the affected arm 90 degrees, and point it toward the ceiling.
- Place the IR against the superior aspect of the patient’s shoulder, holding it in place with the unaffected arm or by securing it appropriately (Fig. 5-28, A).
- **Shield gonads.**
- **Respiration:** Suspend.

**Central ray**
- Horizontal to the midcoronal plane, passing through the midaxillary region of the shoulder.
- Angled 5 to 15 degrees medially when the patient cannot abduct the arm a full 90 degrees (Fig. 5-28, B). The resulting radiograph is seen in Fig. 5-29.

---

Fig. 5-28  Inferosuperior axial shoulder joint: Clements modification. A, Arm abducted 90 degrees. B, Arm partially abducted.

Fig. 5-29  Inferosuperior axial shoulder joint: Clements modification.
**SUPEROINFERIOR AXIAL PROJECTION**

**Image receptor:** 8 × 10 inch (18 × 24 cm) placed lengthwise for accurate centering to the shoulder joint.

**Position of patient**
- Seat the patient at the end of the table on a stool or chair high enough to enable extension of the shoulder under examination well over the IR.

**Position of part**
- Place the IR near the end of the table and parallel with its long axis.
- Have the patient lean laterally over the IR until the shoulder joint is over the midpoint of the IR.
- Bring the elbow to rest on the table.
- Flex the patient’s elbow 90 degrees, and place the hand in the prone position (Fig. 5-30).
- Have the patient tilt the head toward the unaffected shoulder.
- To obtain direct lateral positioning of the head of the humerus, adjust any anterior or posterior leaning of the body to place the humeral epicondyles in the vertical position.
- Shield gonads.
- **Respiration:** Suspend.
Shoulder Joint

Central ray
• Angled 5 to 15 degrees through the shoulder joint and toward the elbow

Structures shown
A superoinferior axial image shows the joint relationship of the proximal end of the humerus and the glenoid cavity (Fig. 5-31). The acromioclavicular articulation, the outer portion of the coracoid process, and the points of insertion of the subscapularis muscle (at body of scapula) and teres minor muscle (at inferior axillary border) are demonstrated.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Open scapulohumeral joint (not open on patients with limited flexibility)
- Coracoid process projected above the clavicle
- Lesser tubercle in profile
- Acromioclavicular joint through the humeral head

Fig. 5-31 Superoinferior axial shoulder joint.
Shoulder Joint

**AP AXIAL PROJECTION**

**Image receptor:** $8 \times 10$ inch $(18 \times 24 \text{ cm})$ crosswise

**Position of patient**
- Position the patient in the upright or supine body position.

**Position of part**
- Center the scapulohumeral joint of the shoulder being examined to the midline of the grid (Fig. 5-32).
- Shield gonads.
- *Respiration:* Suspend.

**Central ray**
- Directed through the scapulohumeral joint at a cephalic angle of 35 degrees

**Structures shown**
The axial image shows the relationship of the head of the humerus to the glenoid cavity. This is useful in diagnosing cases of posterior dislocation (Fig. 5-33).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Scapulohumeral joint
- Proximal humerus
- Clavicle projected above superior angle of scapula

![Fig. 5-32 AP axial shoulder joint.](image1)

![Fig. 5-33 AP axial shoulder joint.](image2)
Shoulder Joint

Scapular Y

PA OBLIQUE PROJECTION

RAO or LAO position

This projection, described by Rubin, Gray, and Green, obtained its name as a result of the appearance of the scapula. The body of the scapula forms the vertical component of the Y, and the acromion and coracoid processes form the upper limbs. The projection is useful in the evaluation of suspected shoulder dislocations.

Image receptor: 24 × 30 cm

Position of patient

- Radiograph the patient in the upright or recumbent body position; the upright position is preferred.
- When the patient is severely injured, modify the anterior oblique position by placing the patient in the posterior oblique position.

Position of part

- Position the anterior surface of the shoulder being examined against the upright table.
- Rotate the patient so that the midcoronal plane forms an angle of 45 to 60 degrees to the IR. The position of the arm is not critical because it does not alter the relationship of the humeral head to the glenoid cavity (Fig. 5-34). Palpate the scapula, and place its flat surface perpendicular to the IR.
- Position the center of the IR at the level of the scapulohumeral joint.
- Shield gonads.
- Respiration: Suspend.

COMPUTED RADIOGRAPHY

Collimation must be very close to prevent unnecessary radiation from reaching the IR phosphor.


Fig. 5-34 PA oblique shoulder joint.
Shoulder Joint

Central ray
- Perpendicular to the scapulohumeral joint (Table 5-3)

Structures shown
The scapular Y is demonstrated on an oblique image of the shoulder. In the normal shoulder the humeral head is directly superimposed over the junction of the Y (Fig. 5-35). In anterior (subcoracoid) dislocations, the humeral head is beneath the coracoid process (Fig. 5-36); in posterior (subacromial) dislocations, it is projected beneath the acromion process. An AP shoulder projection is shown for comparison (Fig. 5-37).

TABLE 5-3
Similar shoulder projections

<table>
<thead>
<tr>
<th>Name</th>
<th>Body rotation</th>
<th>Scapula relationship to IR</th>
<th>Central ray angle*</th>
<th>Central ray entrance point*</th>
<th>Arm position*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acromioclavicular articulation: Alexander method</td>
<td>45 to 60 degrees</td>
<td>Perpendicular</td>
<td>15 degrees caudad</td>
<td>Acromioclavicular joint</td>
<td>Across chest</td>
</tr>
<tr>
<td>Shoulder joint: Neer method</td>
<td>45 to 60 degrees</td>
<td>Perpendicular</td>
<td>10 to 15 degrees border caudad</td>
<td>Superior humeral</td>
<td>At side</td>
</tr>
<tr>
<td>Shoulder joint: scapular Y</td>
<td>45 to 60 degrees</td>
<td>Perpendicular</td>
<td>0 degrees</td>
<td>Scapulohumeral joint</td>
<td>At side</td>
</tr>
<tr>
<td>Scapula lateral</td>
<td>45 to 60 degrees</td>
<td>Perpendicular</td>
<td>0 degrees</td>
<td>Center of medial border of scapula</td>
<td>Variable</td>
</tr>
</tbody>
</table>

*The central ray angles and entrance points and the arm positions are the only differences among these four projections.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- No superimposition of the scapular body over the bony thorax
- Acromion projected laterally and free of superimposition
- Coracoid possibly superimposed or projected below the clavicle
- Scapula in lateral profile
Shoulder Joint

Fig. 5-35  PA oblique shoulder joint. Note the scapular Y components—body, acromion, and coracoid.

Fig. 5-36  PA oblique shoulder joint showing anterior dislocation (humeral head projected beneath coracoid process).

Fig. 5-37  AP shoulder (same patient as in Fig. 5-36).
Shoulder Joint

Glenoid Cavity

**AP OBLIQUE PROJECTION**
 **GRASHEY METHOD**
RPO or LPO position

**Image receptor:** 8 x 10 inch (18 x 24 cm) crosswise

**Position of patient**
- Achieve this position with the patient in the supine or upright position. The upright position is more comfortable for the patient and facilitates accurate adjustment of the part.

**Position of part**
- Center the IR to the scapulohumeral joint.
- Rotate the body approximately 35 to 45 degrees toward the affected side (Fig. 5-38).
- Adjust the degree of rotation to place the scapula parallel with the plane of the IR. This allows the head of the humerus to be in contact with the IR.
- If the patient is in the supine position, the body may need to be rotated more than 45 degrees to place the scapula parallel to the IR.
- In addition, support the elevated shoulder and hip on sandbags (Fig. 5-39).
- Abduct the arm slightly in internal rotation, and place palm of the hand on the abdomen.
- **Shield gonads.**
- **Respiration:** Suspend.

---

**Fig. 5-38** Upright AP oblique glenoid cavity: Grashey method.

**Fig. 5-39** Recumbent AP oblique glenoid cavity: Grashey method.
Shoulder Joint

Central ray
- Perpendicular to the glenoid cavity at a point 2 inches (5 cm) medial and 2 inches (5 cm) inferior to the superolateral border of the shoulder

Structures shown
The joint space between the humeral head and the glenoid cavity (scapulohumeral joint) is shown (Figs. 5-40 and 5-41).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Open joint space between the humeral head and glenoid cavity
- Glenoid cavity in profile
- Soft tissue at the scapulohumeral joint along with trabecular detail on the glenoid and humeral head

NOTE: Kornguth and Salazar\(^1\) reported a projection similar to the 45-degree AP oblique shoulder just described. For the apical oblique projection, the central ray enters the coracoid process with a caudal angulation of 45 degrees. The patient remains in a 45-degree oblique position with the affected shoulder against the IR.


Fig. 5-40 AP oblique glenoid cavity: Grashey method.

Fig. 5-41 AP oblique glenoid cavity: Grashey method showing moderate deterioration of the scapulohumeral joint.
Supraspinatus "Outlet" TANGENTIAL PROJECTION
NEER METHOD

RAO or LAO position

This radiographic projection is useful to demonstrate tangentially the coracoacromial arch or outlet to diagnose shoulder impingement. The tangential image is obtained by projecting the X-ray beam under the acromion and acromioclavicular joint, which defines the superior border of the coracoacromial outlet.

Image receptor: 8 × 10 inch (18 × 24 cm) lengthwise

Position of patient
- Place the patient in a seated or standing position facing the vertical grid device.

Position of part
- With the patient’s affected shoulder centered and in contact with the IR, rotate the patient’s unaffected side away from the IR. Palpate the flat aspect of the affected scapula and place it perpendicular to the IR. The degree of patient obliquity varies from patient to patient. The average degree of patient rotation varies from 45 to 60 degrees from the plane of the IR (Fig. 5-42).
- Place the patient’s arm at the patient’s side.
- Shield gonads.
- Respiration: Suspend.

Central ray
- Angled 10 to 15 degrees caudad, entering the superior aspect of the humeral head (see Table 5-3)

Structures shown
The tangential outlet image demonstrates the posterior surface of the acromion and the acromioclavicular joint identified as the superior border of the coracoacromial outlet (Figs. 5-43 and 5-44).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Humeral head projected below the acromioclavicular joint
- Humeral head and acromioclavicular joint with bony detail
- Humerus and scapular body, generally parallel
Shoulder Joint

Proximal Humerus
AP AXIAL PROJECTION
STRYKER "NOTCH" METHOD

Dislocations of the shoulder are frequently caused by posterior defects involving the posterolateral head of the humerus. Such defects, called Hill-Sachs defects, are often not demonstrated using conventional radiographic positions. Hall, Isaac, and Booth described the notch projection, from ideas expressed by Cm. W. S. Stryker U.S.N., as being useful in identifying the cause of shoulder dislocation.

Image receptor: 24 × 30 cm

Position of patient
- Place the patient on the radiographic table in the supine position.

Position of part
- With the coracoid process of the affected shoulder centered to the table, ask the patient to flex the arm slightly beyond 90 degrees and place the palm of the hand on top of the head with fingertips resting on the head. (This hand position places the humerus in a slight internal rotation position.) The body of the humerus is adjusted to be vertical so that it is parallel to the midsagittal plane of the body (Fig. 5-45).
- Shield gonads.
- Respiration: Suspend.

Central ray
- Angled 10 degrees cephalad, entering the coracoid process

Structures shown
The resulting image will show the posterolateral and posterosuperior areas of the humeral head (Figs. 5-46 and 5-47).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Overlapping of coracoid process and clavicle
- Long axis of the humerus aligned with the long axis of the patient’s body
- Bony trabeculation of the head of the humerus

Fig. 5-45 AP axial humeral notch: Stryker notch method.

Fig. 5-46 AP axial humeral notch: Stryker notch method.

Fig. 5-47 Same projection in a patient with a small Hill-Sachs defect (arrow).
Glenoid Cavity
AP OBLIQUE PROJECTION
APPLE METHOD
RPO or LPO position
This projection is similar to the Grashey Method but uses weighted abduction to demonstrate a loss of articular cartilage in the scapulohumeral joint.

**Image receptor:** 24 × 30 cm crosswise

**Position of patient**
- Achieve this position with the patient seated or upright.

---


**Position of part**
- Center the IR to the scapulohumeral joint.
- Rotate the body approximately 35 degrees to 45 degrees toward the affected side.
- The posterior surface of affected side is closest to the IR.
- The scapula should be positioned parallel to the plane of the IR.
- The patient should hold a 1 pound weight in his or her hand on the same side as the affected shoulder in a neutral position.
- While holding the weight have the patient abduct the arm 90 degrees from the midline of the body (Fig. 5-48).
- Shield gonads.
- Respiration: Suspend.

---

Fig. 5-48 Axial oblique projection: Apple method.
Shoulder Joint

Central ray
- Perpendicular to the IR at the level of the coracoid process

NOTE: To avoid motion, have the correct technical factors set on the generator and be ready to make the exposure before the patient abducts the arm.

Structures shown
The scapulohumeral joint (Fig. 5-49).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Open joint space between the humeral head and the glenoid cavity
- Glenoid cavity in profile
- Soft tissue at the scapulohumeral joint along with trabecular detail on the glenoid and the humeral head
- The arm in a 90 degree position

RESEARCH: Catherine E. Hearty, MS, RT(R), performed the research and provided this new projection for this edition of the atlas.

Fig. 5-49 A, AP oblique projection: Grashey method, of the shoulder showing a normal scapulohumeral joint space. B, AP oblique projection: Grashey method, with weighted abduction showing loss of articular cartilage (arrow).
Glenoid Cavity

AP AXIAL OBLIQUE PROJECTION

GARTH METHOD

RPO or LPO position

This projection is recommended for acute shoulder trauma and for identifying posterior scapulohumeral dislocations, glenoid fractures, Hill-Sachs lesions, and soft-tissue calcifications.

**Image receptor:** 24 × 30 cm lengthwise

**Position of patient**

- Achieve this position with the patient in the supine, seated or upright position.

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Fig. 5-50, **A**, AP axial oblique: Garth method. RPO position. Note 45 degree CR. **B**, Top view of same position as A. Note 45 degree patient position.
Position of part
- Center the IR to the glenohumeral joint.
- Rotate the body approximately 45 degrees toward the affected side.
- The posterior surface of the affected side is closest to the IR.
- Flex the elbow of the affected arm and place arm across the chest (Fig. 5-50).
- Shield gonads.
- Respiration: Suspend.

Central ray
- Angled 45 degrees caudad through the scapulohumeral joint

Structures shown
The scapulohumeral joint, humeral head, coracoid process, and scapular head and neck are shown (Fig. 5-51).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- The scapulohumeral joint, humeral head, and scapular head and neck free of superimposition
- The coracoid process should be well visualized
- Posterior dislocations will project the humeral head superiorly from the glenoid cavity and anterior dislocations project inferiorly.

RESEARCH: Catherine E. Hearty, MS, RT(R), performed the research and provided this new projection for this edition of the atlas.

Fig. 5-51 AP axial oblique: Garth method demonstrates an anterior dislocation of the proximal humerus. The humeral head is shown below the coracoid process, a common appearance with anterior dislocation.

(Courtesy of Bruce W. Long, MS, RT(R); CV and John A. Rafter, MS, RT(R))
Proximal Humerus

**Intertubercular Groove**

**TANGENTIAL PROJECTION**

**FISK MODIFICATION**

In recent years, various modifications of the intertubercular groove image have been devised. In all cases the central ray is aligned to be tangential to the intertubercular groove, which lies on the anterior surface of the humerus.

The x-ray tube head assembly may limit the performance of this examination. Some radiographic units have large collimators and/or handles that limit flexibility in positioning. A mobile radiographic unit may be used to reduce this difficulty.

**Image receptor:** 8 × 10 inch (18 × 24 cm)

---

**Position of patient**

- Place the patient in the supine, seated, or standing position.
- To improve centering, extend the chin or rotate the head away from the affected side.

**Position of part**

- With the patient supine, palpate the anterior surface of the shoulder to locate the intertubercular groove.
- With the patient's hand in the supinated position, place the IR against the superior surface of the shoulder and immobilize the IR as shown in Fig. 5-52.
- Shield gonads.
- Respiration: Suspend.

---

**Fisk Modification**

Fisk first described this position with the patient standing at the end of the radiographic table. This employs a greater OID. The following steps are then taken with Fisk's technique:

- Instruct the patient to flex the elbow and lean forward far enough to place the posterior surface of the forearm on the table. The patient supports and grasps the IR as depicted in Fig. 5-53.
- For radiation protection and to reduce backscatter to the film from the forearm, place a lead shielding between the IR and the forearm.
- Place a sandbag under the hand to place the IR horizontal.
- Have the patient lean forward or backward as required to place the vertical humerus at an angle of 10 to 15 degrees.

---

Central ray
- Angled 10 to 15 degrees posterior (downward from horizontal) to the long axis of the humerus for the supine position (see Fig. 5-52)

Fisk Modification
- Perpendicular to the IR when the patient is leaning forward and the vertical humerus is positioned 10 to 15 degrees (see Fig. 5-53)

Structures shown
The tangential image profiles the intertubercular groove free from superimposition of the surrounding shoulder structures (Figs. 5-54 and 5-55).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Intertubercular groove in profile
- Soft tissue along with enhanced visibility of the intertubercular groove

![Fig. 5-54 Supine tangential intertubercular groove.](image)

![Fig. 5-55 Standing tangential intertubercular groove: Fisk modification.](image)
Proximal Humerus

Teres Minor Insertion
PA PROJECTION
BLACKETT-HEALY METHOD

Image receptor: 8 x 10 inch (18 x 24 cm) crosswise

Position of patient
• Adjust the patient in the prone position, with the arms along the sides of the body and the head resting on the cheek of the affected side.
• Place support under the ankles for the patient's comfort.

Position of part
• Place the IR under the shoulder, and center it to a point about 1 inch (2.5 cm) below the coracoid process.
• Turn the arm to a position of extreme internal rotation. If possible, flex the elbow and place the hand on the patient's back (Figs. 5-56 and 5-57).
• Shield gonads.
• Respiration: Suspend at the end of exhalation for a more uniform density.

Central ray
• Perpendicular to the head of the humerus

Structures shown
This position rotates the head of the humerus so that the greater tubercle is brought anteriorly, giving a tangential image of the insertion of the teres minor at the outer edge of the bone just below the articular surface of the head (Fig. 5-58).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Outline of the greater tubercle superimposing the humeral head
- Lesser tubercle in profile and pointing medially
- Soft tissue around the humerus along with trabecular detail on the humeral head

Fig. 5-56 PA proximal humerus for teres minor insertion.

Fig. 5-57 PA proximal humerus for teres minor insertion.

Fig. 5-58 PA proximal humerus for teres minor insertion.
**Proximal Humerus**

**Subscapular Insertion**

**AP PROJECTION**

**BLACKETT-HEALY METHOD**

*Image receptor:* 8 x 10 inch (18 x 24 cm)

**Position of patient**

- Place the patient in the supine position, with the arms resting along the sides of the body.

**Position of part**

- Align the patient's body so that the affected shoulder joint is centered to the midline of the table.
- The opposite shoulder may be elevated approximately 15 degrees and supported with a sandbag.

- Abduct the affected arm to the long axis of the body, flex the elbow, and rotate the arm internally by pronating the hand (Figs. 5-59 and 5-60).
- Place one sandbag under the hand and another on top, if necessary, for immobilization.
- Shield gonads.
- Respiration: Suspend.

**Central ray**

- Perpendicular to the shoulder joint, entering the coracoid process

**Structures shown**

This method provides an image of the insertion of the subscapularis at the lesser tubercle (Fig. 5-61).

**EVALUATION CRITERIA**

The following should be clearly demonstrated:

- Lesser tubercle in profile and pointing inferiorly
- Outline of the greater tubercle superimposing the humeral head
- Soft tissue around the humerus along with trabecular detail on the humeral head

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![Fig. 5-59 AP proximal humerus for subscapularis insertion.](image1)

![Fig. 5-60 AP proximal humerus for subscapularis insertion.](image2)

![Fig. 5-61 AP proximal humerus for subscapularis insertion.](image3)
**Acromioclavicular Articulations**

**Infraspinatus Insertion**

**AP AXIAL PROJECTION**

Place the patient in the supine position with the affected arm by the patient’s side. Turn the arm in external rotation to open the subacromial space (Fig. 5-62, A). Rotate the arm to the neutral position (Fig. 5-62, B) and then in complete internal rotation (Fig. 5-62, C) to allow full evaluation of the humeral head. Direct the central ray to enter the coracoid process at an angle of 25 degrees caudad. The image profiles the greater tubercle, the site of insertion of the infraspinatus tendon, and opens the subacromial space.

**Acromioclavicular Articulations**

**AP PROJECTION**

**Bilateral PEARSON METHOD**

**Image receptor:** 18 × 43 cm or two 8 × 10 inch (18 × 24 cm), as needed to fit the patient

**SID:** 72 inches (183 cm). A longer SID reduces magnification, which enables both joints to be included on one image. It also reduces the distortion of the joint space resulting from central ray divergence.

**Position of patient**

- Place patient in an upright body position, either seated or standing, because dislocation of the acromioclavicular joint tends to reduce itself in the recumbent position. The positioning is easily modified to obtain a PA projection.

**Position of part**

- Place the patient in the upright position before a vertical grid device, and adjust the height of the IR so that the midpoint of the IR lies at the same level as the acromioclavicular joints (Fig. 5-63).
- Center the midline of the body to the midline of the grid.
- Ensure that the weight of the body is equally distributed on the feet to avoid rotation.
- With the patient’s arms hanging by the sides, adjust the shoulders to lie in the same horizontal plane. It is important that the arms hang unsupported.
- Make two exposures: one in which the patient is standing upright without weights attached, and a second in which the patient has equal weights (5 to 8 lb) affixed to each wrist.\(^1\,2\)
- After the first exposure, slowly affix the weights to the patient’s wrist using a band or strap.
- Instruct the patient not to favor (tense up) the injured shoulder.
- Avoid having the patient hold weights in each hand; this tends to make the shoulder muscles contract, thus reducing the possibility of demonstrating a small acromioclavicular separation.
- Shield gonads. Also use a thyroid collar, because the thyroid gland is exposed to the primary beam.
- Respiration: Suspend.

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Fig. 5-62. AP axial, 25-degree caudal angulation, demonstrating calcareous peritendinitis (arrows). **A,** External rotation. **B,** Neutral position. **C,** Internal rotation.
Acromioclavicular Articulations

Central ray
- Perpendicular to the midline of the body at the level of the acromioclavicular joints for a single projection; directed at each respective acromioclavicular joint when two separate exposures are needed for each shoulder in broad-shouldered patients

COMPUTED RADIOGRAPHY
Collimation must be very close to keep unnecessary radiation from reaching the IR phosphor.

Structures shown
Bilateral images of the acromioclavicular joints are demonstrated (Figs. 5-64 and 5-65). This projection is used to demonstrate dislocation, separation, and function of the joints.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Acromioclavicular joints visualized with some soft tissue and without excessive density
- Both acromioclavicular joints, with and without weights, entirely included on one or two single radiographs
- No rotation or leaning by the patient
- Right or left and weight or nonweight markers
- Separation, if done, clearly seen on the images with weights

Fig. 5-63 Bilateral AP acromioclavicular articulations.

Fig. 5-64 Bilateral AP acromioclavicular joints demonstrating normal left joint and separation of right joint (arrow).

Fig. 5-65 Normal acromioclavicular joints requiring two separate radiographs.
Acromioclavicular Articulations

AP AXIAL PROJECTION
ALEXANDER METHOD

Alexander suggested that both AP and PA axial oblique projections be used in cases of suspected acromioclavicular subluxation or dislocation. Each side is examined separately.

**Image receptor:** 8 x 10 inch (18 x 24 cm) lengthwise

**Position of patient**
- Have the patient place the back against the vertical grid device and sit or stand upright.
- Center the affected shoulder under examination to the grid.
- Adjust the height of the IR so that the midpoint of the film is at the level of the acromioclavicular joint.
- Adjust the patient’s position to center the coracoid process to the IR (Fig. 5-66).
- **Shield gonads.**
- **Respiration:** Suspend.

**Central ray**
- Directed to the coracoid process at a cephalic angle of 15 degrees (Fig. 5-67). This angulation projects the acromioclavicular joint above the acromion.

---

Acromioclavicular Articulations

Structures shown
The resulting image will show the acromioclavicular joint projected slightly superiorly compared with an AP projection (Fig. 5-68).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Acromioclavicular joint and clavicle projected above the acromion
- Acromioclavicular joint visualized with some soft tissue and without excessive density

Fig. 5-68 AP axial acromioclavicular articulation: Alexander method.
Acromioclavicular Articulations

PA AXIAL OBLIQUE PROJECTION
ALEXANDER METHOD
RAO or LAO position

Image receptor: 8 x 10 inch (18 x 24 cm) lengthwise


Position of part
• Stand or sit the patient facing the IR, and place the hand of the affected side under the opposite axilla.
• Rotate the patient so the midcoronal plane forms an angle of 45 to 60 degrees from the IR to place the scapula perpendicular to the IR.
• Adjust the patient's position to center the acromioclavicular joint to the midline of the grid (Fig. 5-69).

Just before making the exposure, have the patient lean the shoulder being examined against the IR stand with the arm pulled firmly across the chest. Placing the arm across the chest draws the scapula laterally and forward. Although the projection can be done with the arm at the side, pulling the arm across the chest places the joint as close as possible to the IR. The scapula and acromioclavicular joint are thus placed in the lateral position.
• Shield gonads.
• Respiration: Suspend.

Central ray
• Directed through the acromioclavicular joint at an angle of 15 degrees caudad (see Table 5-3)

Structures shown
The PA axial oblique image demonstrates the acromioclavicular joint and the relationship of the bones of the shoulder (Fig. 5-70).

EVALUATION CRITERIA
The following should be clearly demonstrated:
• Acromioclavicular articulation in profile
• Acromioclavicular joint visualized with some soft tissue without excessive density

Fig. 5-69 PA axial oblique acromioclavicular articulation.

Fig. 5-70 PA axial oblique acromioclavicular articulation.
AP PROJECTION

**Image receptor:** 24 × 30 cm cross-wise

**Position of patient**
- Place the patient in the supine or upright position.
- If the clavicle is being examined for a fracture or a destructive disease or if the patient cannot be placed in the upright position, use the supine position to reduce the possibility of fragment displacement or additional injury.

**Position of part**
- Adjust the body to center the clavicle to the midline of the table or vertical grid device.
- Place the arms along the sides of the body, and adjust the shoulders to lie in the same horizontal plane.
- Center the clavicle to the IR (Fig. 5-71).
- **Shield gonads.**
- **Respiration:** Suspend at the end of exhalation to obtain a more uniform density image.

**Central ray**
- Perpendicular to the midshaft of the clavicle

**COMPUTED RADIOGRAPHY**
Collimation must be very close to keep unnecessary radiation from reaching the IR phosphor.

**Structures shown**
This projection demonstrates a frontal image of the clavicle (Fig. 5-72).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Entire clavicle centered on the image
- Uniform density
- Lateral half of the clavicle above the scapula, with the medial half superimposing the thorax
PA PROJECTION

The PA projection is generally well accepted by the patient who is able to stand, and it is most useful when improved recorded detail is desired. The advantage of the PA projection is that the clavicle is closer to the image receptor, thus reducing the OID. Positioning is similar to that of the AP projection. The differences are as follows:

- The patient is standing upright (back toward the x-ray tube) or prone (Fig. 5-73).
- The perpendicular central ray exits midshaft of the clavicle (Fig. 5-74).

Structures shown and evaluation criteria are the same as for the AP projection.

COMPUTED RADIOGRAPHY

Collimation must be very close to keep unnecessary radiation from reaching the IR phosphor.
**AP AXIAL PROJECTION**

**Lordotic position**

**NOTE:** If the patient is injured or unable to assume the lordotic position, a slightly distorted image results when the tube is angled. An optional approach for improved recorded detail is the PA axial projection.

**Image receptor:** 24 × 30 cm crosswise

**Position of patient**
- Stand or seat the patient 1 foot in front of the vertical IR device, with the patient facing the x-ray tube.
- Alternatively, if the patient is unable to stand and assume the lordotic position, place the patient supine on the table.

**Position of part**

**Standing lordotic position**
- Temporarily support the patient in the lordotic position to estimate the required central ray angulation, and have the patient reassume the upright position while the equipment is adjusted.
- Have the patient lean backward in a position of extreme lordosis, and rest the neck and shoulder against the vertical grid device. The neck will be in extreme flexion (Figs. 5-75 and 5-76).
- Center the clavicle to the center of the IR (see Fig. 5-76).

**Supine position**
- Center the IR to the clavicle.
- Shield gonads.
- Respiration: Suspend at the end of full inspiration to further elevate and angle the clavicle.

**Central ray**
- Directed to enter the midshaft of the clavicle.
- Cephalic central ray angulation can vary from the long axis of the torso. Thinner patients require more angulation to project the clavicle off the scapula and ribs.
- For the standing lordotic position, 0 to 15 degrees is recommended (see Fig. 5-75).
- For the supine position, 15 to 30 degrees is recommended (see Fig. 5-76).

**COMPUTED RADIOGRAPHY**

Collimation must be very close to keep unnecessary radiation from reaching the IR phosphor.

**Structures shown**
An axial image of the clavicle is projected above the ribs (Fig. 5-77).

**EVALUATION CRITERIA**

The following should be clearly demonstrated:
- Most of the clavicle projected above the ribs and scapula with the medial end overlapping the first or second rib
- Clavicle in a horizontal placement
- Entire clavicle along with the acromioclavicular and sternoclavicular joints

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Fig. 5-75 AP axial clavicle, lordotic position.

Fig. 5-76 AP axial clavicle.

Fig. 5-77 AP axial clavicle of 3-year-old child, showing fracture (arrow). This is the same patient as Fig. 5-74.
PA AXIAL PROJECTION
Positioning of the PA axillary clavicle is similar to the AP axial projection just described. The differences are as follows:
- The patient is prone or standing, facing the vertical grid device.
- The central ray is angled 15 to 30 degrees caudad (Fig. 5-78).
Structures shown and evaluation criteria are the same as for the AP axial projection described previously.

COMPUTED RADIOGRAPHY
Collimation must be very close to keep unnecessary radiation from reaching the IR phosphor.

TANGENTIAL PROJECTION
The tangential projection is similar to the AP axial projection described previously. However, the increased angulation of the central ray required for this approach places the central ray nearly parallel with the rib cage. The clavicle is thus projected free of the chest wall.

Image receptor: 8 x 10 inch (18 x 24 cm) crosswise

Position of patient
- With the patient in the supine position, place the arms along the sides of the body.

Position of part
- If possible, depress the shoulder to place the clavicle in a horizontal plane.
- Have the patient turn the head away from the side being examined.
- Place the IR on edge at the top of the shoulder and support it in position. The IR should be as close to the neck as possible (Figs. 5-79 and 5-80).
- Shield gonads.
- Respiration: Suspend.

Fig. 5-78 PA axillary clavicle.
Clavicle

Central ray
- Angled so that the central ray will pass between the clavicle and the chest wall, perpendicular to the plane of the IR. The angulation will be about 25 to 40 degrees from the horizontal.
- If the medial third of the clavicle is in question, it is also necessary to angle the central ray laterally; 15 to 25 degrees is usually sufficient.

Structures shown
An inferosuperior image of the clavicle is demonstrated, projected free of superimposition (Fig. 5-81).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Midclavicle without superimposition
- Acromial and sternal ends superimposed
- Entire clavicle along with the acromioclavicular and sternoclavicular joints

Fig. 5-79 Tangential clavicle.

Fig. 5-80 Tangential alignment for clavicle.

Fig. 5-81 Tangential clavicle.
Clavicle

**TANGENTIAL PROJECTION**

**TARRANT METHOD**¹

The Tarrant method is particularly useful with patients who have multiple injuries or who cannot assume the lordotic or recumbent position.

**Image receptor:** 24 × 30 cm crosswise

**Position of patient**
- Place the patient in a seated position.

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**Position of part**
- Adjust a sheet of leaded rubber over the gonad area. A folded pillow or blankets may be placed on the patient’s lap to support the horizontally placed IR if needed.
- Using the collimator light as the indicator, center the IR to the projected clavicle area, and have the patient hold the IR in position.
- Ask the patient to lean slightly forward (Fig. 5-82).
- Shield gonads.
- Respiration: Suspend.

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Fig. 5-82 Tangential clavicle: Tarrant method.
Central ray
- Directed anterior and inferior to the midshaft of the clavicle at a 25- to 35-degree angle. It should pass perpendicular to the longitudinal axis of the clavicle.
- Because of the considerable OID, an increased SID is recommended to reduce magnification.

Structures shown
The clavicle above the thoracic cage is demonstrated (Fig. 5-83).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Most of the clavicle above the ribs and scapula with the medial end overlapping the first or second ribs
- Clavicle in a horizontal orientation
- Entire clavicle along with the acromioclavicular and sternoclavicular joints

Fig. 5-83 Tangential clavicle: Tarrant method.
AP PROJECTION

Image receptor: 24 × 30 cm lengthwise

Position of patient
• Place the patient in the upright or supine position. The upright position is preferred if the shoulder is tender.

Position of part
• Adjust the patient’s body, and center the affected scapula to the midline of the grid.
• Abduct the arm to a right angle with the body to draw the scapula laterally. Then flex the elbow, and support the hand in a comfortable position.
• For this projection, do not rotate the body toward the affected side because the resultant obliquity would offset the effect of drawing the scapula laterally (Fig. 5-84).
• Position the top of the IR 2 inches (5 cm) above the top of the shoulder.
• Shield gonads.
• Respiration: Make this exposure during slow breathing to obliterate lung detail.

Fig. 5-84 AP scapula.
Scapula

Central ray
- Perpendicular to the midscapular area at a point approximately 2 inches (5 cm) inferior to the coracoid process

Structures shown
An AP projection of the scapula is demonstrated (Fig. 5-85).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Lateral portion of the scapula free of superimposition from the ribs
- Scapula horizontal and not obliqued
- Scapular detail through the superimposed lung and ribs (Shallow breathing should help obliterate lung detail.)
- Acromion process and inferior angle

Fig. 5-85 A, AP scapula. B, AP scapula showing fracture of the scapula through the glenoid cavity and extending inferiorly (arrows).
**Scapula**

**LATERAL PROJECTION**

**RAO or LAO body position**

- **Image receptor:** 24 × 30 cm lengthwise

**Position of patient**

- Place the patient in the upright position, standing or seated, facing a vertical grid device.
- The prone position can be used, but the projection will be more difficult to perform. The supine position can also be used; however, the scapula will be magnified.

**Position of part**

- Adjust the patient in an RAO or LAO position, with the affected scapula centered to the grid. The average patient requires a 45- to 60-degree rotation from the plane of the IR.
- Place the arm in one of two positions according to the area of the scapula to be demonstrated:
  - For delineation of the acromion and coracoid processes of the scapula, have the patient flex the elbow and place the back of the hand on the posterior thorax at a level sufficient to prevent the humerus from overlapping the scapula (Figs. 5-86 and 5-87). Mazujian suggested that the patient place the arm across the upper chest by grasping the opposite shoulder as shown in Fig. 5-88.
  - For demonstration of the body of the scapula, ask the patient to extend the arm upward and rest the forearm on the head or across the upper chest by grasping the opposite shoulder. (Figs. 5-88 and 5-89).

- After placing the arm in any of the above positions, grasp the lateral and medial borders of the scapula between the thumb and index fingers of one hand. Make a final adjustment of the body rotation, placing the body of the scapula perpendicular to the plane of the IR.
- **Shield gonads.**
- **Respiration:** Suspend.

**Central ray**

- Perpendicular to the midmedial border of the protruding scapula (see Table 5-3).

**COMPUTED RADIOGRAPHY**

Collimation must be very close to keep unnecessary radiation from reaching the IR phosphor.

**Structures shown**

A lateral image of the scapula is demonstrated by this projection. The placement of the arm determines the portion of the superior scapula that is superimposed over the humerus.

**EVALUATION CRITERIA**

The following should be clearly demonstrated:

- Lateral and medial borders superimposed
- No superimposition of the scapular body on the ribs
- No superimposition of the humerus on the area of interest
- Inclusion of the acromion process and inferior angle
- Lateral thickness of scapula with proper density

---

Fig. 5-87 Lateral scapula with arm on posterior chest.

Fig. 5-88 Lateral scapula with arm across upper anterior thorax.

Fig. 5-89 Lateral scapula with arm extended above head.
Scapula

**PA OBLIQUE PROJECTION**
**LORENZ AND LILIENFELD METHODS**
**RAO or LAO position**

**Image receptor:** 24 × 30 cm length-wise

**Position of patient**
- Place the patient in the upright or lateral recumbent position.
- When the shoulder is painful, use the upright position if possible.

**Fig. 5-90** PA oblique scapula: Lorenz method.

**Fig. 5-91** PA oblique scapula: Lilienfeld method.

**Fig. 5-92** Lorenz method with scapula showing fracture (arrow).
Scapula

Position of part

- With the patient in the lateral position, upright or recumbent, align the body and center the scapula to the midline of the grid device.
- Adjust the arm according to the projection desired.

Lorenz method

- Adjust the arm of the affected side at a right angle to the long axis of the body, flex the elbow, and rest the hand against the patient's head.
- Rotate the body slightly forward, and have the patient grasp the side of the table or the stand for support (Fig. 5-90).

Lilienfeld method

- Extend the arm of the affected side obliquely upward, and have the patient rest the hand on his or her head.
- Rotate the body slightly forward, and have the patient grasp the side of the table or the stand for support (Fig. 5-91).

Both methods

- Grasp the lateral and medial borders of the scapula between the thumb and index fingers of one hand, and adjust the rotation of the body so that the scapula will be projected free of the rib cage.
- Shield gonads.
- Respiration: Suspend.

Central ray

- Perpendicular to the IR, between the chest wall and the midarea of the protruding scapula

Structures shown

An oblique image of the scapula is shown. The degree of obliquity depends on the position of the arm. The delineation of the different parts of the bone in the two oblique projections are shown in Figs. 5-92 and 5-93.

EVALUATION CRITERIA

The following should be clearly demonstrated:
- Oblique scapula
- Medial border adjacent to the ribs
- Acromion process and inferior angle

Fig. 5-93 PA oblique scapula: Lilienfeld method.
Scapula

**AP OBLIQUE PROJECTION**

**RPO or LPO position**

**Image receptor:** 24 × 30 cm length-wise

**Position of patient**

- Place the patient in the supine or upright position.
- Use the upright position when the shoulder is painful unless contraindicated.

**Position of part**

- Align the body and center the affected scapula to the midline of the grid.
- For moderate AP oblique projection, ask the patient to extend the arm superiorly, flex the elbow, and place the supinated hand under the head or have the patient extend the affected arm across the anterior chest.
- Have the patient turn away from the affected side enough to rotate the shoulder 15 to 25 degrees (Fig. 5-94).
- For a steeper oblique projection, ask the patient to extend the arm, rest the flexed elbow on the forehead, and rotate the body away from the affected side 25 to 35 degrees (Fig. 5-95).
- Grasp the lateral and medial borders of the scapula between the thumb and index fingers of one hand, and adjust the rotation of the body to project the scapula free of the rib cage.
- For a direct lateral projection of the scapula using this position, draw the arm across the chest, and adjust the body rotation to place the scapula perpendicular to the plane of the IR as previously described and shown in Figs. 5-86 to 5-89.
- Shield gonads.
- **Respiration:** Suspend.

**Central ray**

- Perpendicular to the lateral border of the rib cage at the midscapular area

**Structures shown**

This projection shows oblique images of the scapula, projected free or nearly free of rib superimposition (Figs. 5-96 to 5-97).

**EVALUATION CRITERIA**

The following should be clearly demonstrated:
- Oblique scapula
- Lateral border adjacent to the ribs
- Acromion process and inferior angle
Fig. 5-96 AP oblique scapula, 15- to 25-degree body rotation.

Fig. 5-97 AP oblique scapula, 25- to 30-degree body rotation.
Coracoid Process

**AP AXIAL PROJECTION**

**Image receptor:** 24 × 30 cm crosswise

**Position of patient**
- Place the patient in the supine position with the arms along the sides of the body.

**Position of part**
- Adjust the position of the body, and center the affected coracoid process to the midline of the grid.
- Position the IR so that the midpoint of the IR will coincide with the central ray.
- Adjust the shoulders to lie in the same horizontal plane.
- Abduct the arm of the affected side slightly, and supinate the hand, immobilizing it with a sandbag across the palm (Fig. 5-98).
- Shield gonads.
- **Respiration:** Suspend at the end of exhalation for a more uniform density.

**Central ray**
- Directed to enter the coracoid process at an angle of 15 to 45 degrees cephalad. Kwak, Espiniella, and Kattan recommend 30 degrees. The degree of angulation depends on the shape of the patient's back. Round-shouldered patients require a greater angulation than those with a straight back (Fig. 5-99).

**Structures shown**
A slightly elongated inferosuperior image of the coracoid process is illustrated (Fig. 5-100). Because the coracoid is curved on itself, it casts a small, oval shadow in the direct AP projection of the shoulder.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Coracoid process with minimal self-superimposition
- Clavicle slightly superimposing the coracoid process

---

Scapula

Fig. 5-100  AP axial coracoid process.
Scapular Spine

TANGENTIAL PROJECTION
LAQUERRIÈRE-PIERQUIN METHOD

Image receptor: 8 x 10 inch (18 x 24 cm) crosswise

Position of patient
• As described by Laquerrière and Pierquin,1 place the patient in the supine position.

Position of part
• Center the shoulder to the midline of the grid.
• Adjust the patient’s rotation to place the body of the scapula in a horizontal position. When this requires elevation of the opposite shoulder, support it on sandbags or radiolucent sponges.
• Turn the head away from the shoulder being examined enough to prevent superimposition (Fig. 5-101).
• Funke2 found that in the examination of patients with small breasts, clavicular superimposition can be prevented by using a 15-degree radiolucent wedge to angle the shoulder caudally.
• Shield gonads.
• Respiration: Suspend.

1Laquerrière and Pierquin: De la nécessité d'employer une technique radiographique spéciale pour obtenir certains détails squelettiques, J Radiol Electr 3:145, 1918.
Scapular Spine

Central ray
- Directed through the posterosuperior region of the shoulder at an angle of 45 degrees caudad. A 35-degree angulation suffices for obese and round-shouldered patients.
- After adjusting the x-ray tube, position the IR so that it is centered to the central ray.

Structures shown
The spine of the scapula is shown in profile and is free of bony superimposition, except for the lateral end of the clavicle (Figs. 5-102 and 5-103).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Scapular spine superior to the scapular body
- Scapular spine with some soft tissue around it and without excessive density

NOTE: When the shoulder is too painful to tolerate the supine position, this projection can be obtained with the patient in the prone or upright position, as described on the following page.

Fig. 5-102 Tangential scapular spine image with 45-degree central ray angulation.

Fig. 5-103 Tangential scapular spine image with 30-degree central ray angulation.
Scapular Spine

TANGENTIAL PROJECTION
Prone position

**Image receptor:** 8 × 10 inch (18 × 24 cm) crosswise

**Position of part**
- Place the patient in the prone position, and center the shoulder to the midline of the grid.
- Place the arms along the sides of the body, and adjust the shoulders to lie in the same horizontal plane.
- Take care to prevent lateral rotation of the scapula.
- Have the patient rest the head on the chin or the cheek of the affected side.
- Supinate the hand of the affected side (Fig. 5-104).
- Adjust a radiolucent wedge under the side of the shoulder and upper arm to place the scapula in the horizontal position.
- **Shield gonads.**
- **Respiration:** Suspend.

Fig. 5-104 Prone tangential scapular spine.

Fig. 5-105 Upright tangential scapular spine.
Scapular Spine

Central ray
- Direct through the scapular spine at an angle of 45 degrees cephalad. The central ray exits at the anterosuperior aspect of the shoulder.

Upright position
An increased SID is recommended because of the greater OID.

Position of part
- Seat the patient with his or her back toward and resting against the end of the table.
- Place the IR on the table, center it in line with the shoulder, and adjust the IR on a support to place it at an angle of 45 degrees (Fig. 5-105).
- Shield gonads.
- Respiration: Suspend.

Central ray
- Directed through the anterosuperior aspect of the shoulder at a posteroinferior angle of 45 degrees
- Perpendicular to the plane of the IR

Structures shown
The tangential image shows the scapular spine in profile and free of superimposition of the scapular body (Figs. 5-106 and 5-107).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Scapular spine above the scapular wing
- Scapular spine with some soft tissue around it and without excessive density

Fig. 5-106 Prone tangential scapular spine.

Fig. 5-107 Upright tangential scapular spine.
AP knee on a 15 year old. Arrow pointing to benign lesion.
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The icons in the Essential column indicate projections that are frequently performed in the United States and Canada. Students should be competent in these projections.
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The lower limb, or extremity, and its girdle (considered in Chapter 7) are studied in four parts: (1) foot, (2) leg, (3) thigh, and (4) hip. The bones are composed, shaped, and placed so that they can carry the body in the upright position and transmit its weight to the ground with a minimal amount of stress to the individual parts.

**Foot**

The foot consists of 26 bones (Figs. 6-1 and 6-2):
- 14 phalanges (bones of the toes)
- 5 metatarsals (bones of the instep)
- 7 tarsals (bones of the ankle)

The bones of the foot are similar to those in the hand. The structural differences, however, permit walking and support of the body's weight. For descriptive purposes the foot is sometimes divided into the forefoot, midfoot, and hindfoot. The forefoot includes the metatarsals and toes. The midfoot includes five tarsals—the cuneiforms, navicular, and cuboid bones. The hindfoot includes the talus and calcaneus. The bones of the foot are shaped and joined together to form a series of longitudinal and transverse arches. The longitudinal arch functions as a shock absorber to distribute the weight of the body in all directions, which permits smooth walking (see Fig. 6-2). The transverse arch runs from side to side and assists in supporting the longitudinal arch. The superior surface of the foot is termed the *dorsum* or *dorsal surface*, and the inferior, or posterior, aspect of the foot is termed the *plantar surface*.

**Phalanges**

Each foot has 14 phalanges—two in the great toe and three in each of the other toes. The phalanges of the great toe are termed the *distal* and *proximal phalanges*. Those of the other toes are termed the *proximal, middle, and distal phalanges*. Each phalanx is composed of a body and two expanded articular ends—the proximal *base* and the distal *head*.

---

![Fig. 6-1 Dorsal (superior) aspect of right foot.](image1)

![Fig. 6-2 Right foot. A, Medial aspect. B, Lateral aspect. C, Coronal section near base of metatarsals. Transverse arch shown.](image2)
METATARSALS
The five metatarsals are numbered one to five beginning at the medial or great toe side of the foot. The metatarsals consist of a body and two articular ends. The expanded proximal end is called the base, and the small, rounded distal end is termed the head. The five heads form the “ball” of the foot. The first metatarsal is the shortest and thickest. The second metatarsal is the longest. The base of the fifth metatarsal contains a prominent tuberosity, which is a common site of fractures.

TARSALS
The proximal foot contains seven tarsals (see Fig. 6-1):
- Calcaneus
- Talus
- Navicular bone
- Cuboid
- Medial cuneiform
- Intermediate cuneiform
- Lateral cuneiform

Beginning at the medial side of the foot, the cuneiforms are described as medial, intermediate, and lateral.

The calcaneus is the largest and strongest tarsal bone (Fig. 6-3). It projects posteriorly and medially at the distal part of the foot. The long axis of the calcaneus is directed inferiorly and forms an angle of approximately 30 degrees. The posterior and inferior portions of the calcaneus contain the posterior tuberosity for attachment of the Achilles tendon. Superiorly, three articular facets join with the talus. They are called the anterior, middle, and posterior facets. Between the middle and posterior talar articular facets is a groove, the calcaneal sulcus, which corresponds to a similar groove on the inferior surface of the talus. Collectively these sulci comprise the sinus tarsi. The medial aspect of the calcaneus extends outward as a shelflike overhang and is termed the sustentaculum tali. The lateral surface of the calcaneus contains the trochlea.

The talus, irregular in form and occupying the most superior position of the foot, is the second largest of the tarsal bones (see Figs. 6-1, 6-2, and 6-3). The talus articulates with four bones—the tibia, fibula, calcaneus, and navicular bone. The superior surface, the trochlear surface, articulates with the tibia. The head of the talus is directed anteriorly and has articular surfaces that join the navicular bone and calcaneus. On the inferior surface is a groove, the sulcus tali, that forms the roof of the sinus tarsi. Posterior to the sinus tali is the posterior articular surface for articulation with the calcaneus.

The cuboid bone lies on the lateral side of the foot between the calcaneus and the fourth and fifth metatarsals (see Fig. 6-1). The navicular bone lies on the medial side of the foot between the talus and the three cuneiforms. The cuneiforms lie at the central and medial aspect of the foot between the navicular bone and the first, second, and third metatarsals. The medial cuneiform is the largest of the three cuneiform bones, and the intermediate is the smallest.

The seven tarsals can be remembered using the following mnemonic:

Chubby
Twisted,
Never
Could
Cha
Cha
Cha

Calcaneus
Talus
Navicular
Cuboid
Cuneiform—medial
Cuneiform—intermediate
Cuneiform—lateral

Fig. 6-3 A, Articular surfaces of left calcaneus. B, Photograph of superior aspect of right calcaneus. Note the three articular facet surfaces.
**SESAMOID BONES**

Beneath the head of the first metatarsal are two small bones called *sesamoid* bones. They are detached from the foot and embedded within two tendons. These bones are seen on most adult foot radiographs. They are a common site of fractures and must be demonstrated radiographically (see Fig. 6-2).

**Leg**

The leg has two bones: the *tibia* and *fibula*. The tibia, the second largest bone in the body, is situated on the medial side of the leg. Slightly posterior to the tibia on the lateral side of the leg is the fibula.

**Tibia**

The *tibia* (Fig. 6-4) is the larger of the two bones of the leg and consists of one body and two expanded extremities. The proximal end of the tibia has two prominent processes—the *medial* and *lateral condyles*. The superior surfaces of the condyles form smooth facets for articulation with the condyles of the femur. These two flatlike superior surfaces are called the *tibial plateaus*, and they slope posteriorly about 10 to 20 degrees. Between the two articular surfaces is a sharp projection, the *intercondylar eminence*, which terminates in two peaklike processes called the medial and lateral *intercondylar tubercles*. The lateral condyle has a facet at its distal posterior surface for articulation with the *head* of the fibula. On the anterior surface of the tibia, just below the condyles, is a prominent process called the *tibial tuberosity*, to which the ligamentum patellae attaches. Extending along the anterior surface of the tibial body, beginning at the tuberosity, is a sharp ridge called the *anterior crest*.

![Fig. 6-4](image-url) Right tibia and fibula. A, Anterior aspect. B, Posterior aspect. C, Lateral aspect. D, Proximal end of the tibia and fibula showing angle of the tibial plateau.
The distal end of the tibia (Fig. 6-5) is broad, and its medial surface is prolonged into a large process called the medial malleolus. Its anterolateral surface contains the anterior tubercle, which overlays the fibula. The lateral surface is flattened and contains the triangular fibular notch for articulation with the fibula. The surface under the distal tibia is smooth and shaped for articulation with the talus.

**FIBULA**
The fibula is slender in comparison to its length and consists of one body and two articular extremities. The proximal end of the fibula is expanded into a head, which articulates with the lateral condyle of the tibia. At the lateroposterior aspect of the head is a conical projection called the apex. The enlarged distal end of the fibula is the lateral malleolus. The lateral malleolus is pyramidal and marked by several depressions at its inferior and posterior surfaces. Viewed axially, the lateral malleolus lies approximately 15 degrees to 20 degrees more posterior than the medial malleolus (Fig. 6-5, C).

**Fig. 6-5** Right distal tibia and fibula in true anatomic position. **A,** Mortise joint and surrounding anatomy. Note the slight overlap of the anterior tubercle of the tibia and the superolateral talus over the fibula. **B,** Lateral aspect showing fibula positioned slightly posterior to the tibia. **C,** MRI axial plane of the lateral and medial malleoli and talus. Note lateral malleolus lies more posterior than medial malleolus. **D,** MRI coronal plane of the ankle clearly showing the ankle mortise joint (arrows).
Femur

The femur is the longest, strongest, and heaviest bone in the body (Figs. 6-6 and 6-7). This bone consists of one body and two articular extremities. The body is cylindrical, slightly convex anteriorly, and slants medially from 5 to 15 degrees (see Fig. 6-6, A). The extent of medial inclination depends on the breadth of the pelvic girdle. When the femur is vertical, the medial condyle is lower than the lateral condyle (see Fig. 6-6, C). About a 5- to 7-degree difference exists between the two condyles. Because of this difference, on lateral radiographs of the knee the central ray is angled 5 to 7 degrees cephalad to "open" the joint space of the knee. The superior portion of the femur articulates with the acetabulum of the hip joint (considered with the pelvic girdle in Chapter 7.)
The distal end of the femur is broadened and has two large eminences: the larger medial condyle and the smaller lateral condyle. Anteriorly the condyles are separated by the patellar surface, a shallow, triangular depression. Posteriorly the condyles are separated by a deep depression called the intercondylar fossa. A slight prominence above and within the curve of each condyle forms the medial and lateral epicondyles. The medial condyle contains the adductor tubercle, which is located on the posterolateral aspect. The tubercle is a raised bony area that receives the tendon of the adductor muscle. This tubercle is important to identify on lateral knee radiographs because it assists in identifying overrotation or underrotation. The triangular area superior to the intercondylar fossa on the posterior femur is the popliteal surface, over which the popliteal blood vessels and nerves pass.

Patella
The patella, or knee cap (Fig. 6-8), is the largest and most constant sesamoid bone in the body (see Chapter 3). The patella is a flat, triangular bone situated at the distal anterior surface of the femur. The patella develops in the tendon of the quadriceps femoris muscle between the ages of 3 and 5 years. The apex, or tip, is directed inferi orly, lies ½ inch (1.3 cm) above the joint space of the knee, and is attached to the tuberosity of the tibia by the patellar ligament. Interestingly, the superior border of the patella is called the base.

Fig. 6-8 Anterior and lateral aspects of patella.
Knee Joint

The knee joint is one of the most complex joints in the human body. The femur, tibia, fibula, and patella are held together by a complex group of ligaments. These ligaments work together to provide stability for the knee joint. Although radiographers do not produce images of these ligaments, they need to have a basic understanding of their positions and interrelationship.

Many patients with knee injuries do not have fractures, but they may have torn one or more of these ligaments, which can cause great pain and may alter the position of the bones. Fig. 6-9 shows the following important ligaments of the knee:

- Posterior cruciate ligament
- Anterior cruciate ligament
- Tibial collateral ligament
- Fibular collateral ligament

Fig. 6-9 Knee joint. A, Anterior aspect with femur flexed. B, Posterior aspect. C, Superior surface of tibia. D, Sagittal section.
The knee joint contains two fibrocartilage disks called the lateral and medial meniscus (see Figs. 6-9 and 6-10). The circular menisci lie on the tibial plateaus. They are thick at the outer margin of the joint and taper off toward the center of the tibial plateau. The center of the tibial plateau contains cartilage that articulates directly with the condyles of the knee. The menisci provide stability for the knee and also act as a shock absorber. The menisci are commonly torn during injury. Either a knee arthrogram or a magnetic resonance imaging (MRI) scan must be performed to visualize a meniscal tear.

Fig. 6-10 A, MRI coronal plane. B, MRI sagittal plane.
Lower Limb Articulations

The joints of the lower limb are summarized in Table 6-1. Beginning with the most distal portion of the lower limb, the articulations are as follows.

The interphalangeal articulations, between the phalanges, are synovial hinges that allow only flexion and extension (Fig. 6-11, A). The joints between the distal and middle phalanges are the distal interphalangeal (DIP) joints. Articulations between the middle and proximal phalanges are the proximal interphalangeal (PIP) joints. With only two phalanges in the great toe, the joint is known simply as the interphalangeal joint.

**TABLE 6-1**

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<tr>
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<th>Structural classification</th>
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*The mortise joint can be divided specifically into the talofibular and tibiotalar joints (superior and medial aspects). The joint includes the medial malleolar, lateral malleolar, and superior aspects of the talus.*
Fig. 6-11 A, and B, Joints of the right foot. C, MRI sagittal plane of the anterior foot. D, MRI sagittal plane of posterior foot and ankle. Joint spaces and articular surfaces are clearly shown using MRI.
The distal heads of the metatarsals articulate with the proximal ends of the phalanges at the metatarsophalangeal articulations to form synovial ellipsoidal joints, which have movements of flexion, extension, and slight adduction and abduction. The proximal bases of the metatarsals articulate with one another (intermetatarsal articulations) and with the tarsals (tarsometatarsal articulations) to form synovial gliding joints, which permit flexion, extension, adduction, and abduction movements.

The intertarsal articulations allow only slight gliding movements between the bones and are classified as synovial gliding or synovial ball-and-socket joints (see Table 6-1). The joint spaces are narrow and obliquely situated. Those lying in the horizontal plane slant inferiorly and posteriorly at a vertical angle of approximately 15 degrees. When the joint surfaces of these bones are in question, it is necessary to angle the x-ray tube or adjust the foot to place the joint spaces parallel with the central ray.

The calcaneus supports the talus and articulates with it by an irregularly shaped, three-faceted joint surface, forming the subtalar joint. This joint is classified as synovial gliding. Anteriorly the calcaneus articulates with the cuboid at the calcaneocuboid joint. This joint is a synovial gliding joint. The talus rests on top of the calcaneus (see Fig. 6-11). It articulates with the navicular bone anteriorly, supports the malleoli of the tibia and fibula at its sides.

Each of the three parts of the subtalar joint is formed by reciprocally shaped facets on the inferior surface of the talus and the superior surface of the calcaneus. Study of the superior and medial aspects of the calcaneus (see Fig. 6-3) will help the radiographer to better understand the problems involved in radiography of this joint.

The ankle joint is commonly called the ankle mortise, or mortise joint. It is formed by the articulations between the lateral malleolus of the fibula and the inferior surface and medial malleolus of the tibia (Fig. 6-12). These form a socket type of structure that articulates with the superior portion of the talus. The talus fits inside the mortise. The articulation is a synovial hinge type of joint. The primary action of the ankle joint is dorsiflexion (flexion) and plantar flexion (extension); however, in full plantar flexion a small amount of rotation and abduction-adduction is permitted. Other movements at the ankle largely depend on the gliding movements of the intertarsal joints, particularly the one between the talus and calcaneus.

The fibula articulates with the tibia at both its distal and proximal ends. The distal tibiofibular joint is a fibrous syndesmosis joint allowing slight movement. The head of the fibula articulates with the posteroinferior surface of the lateral condyle of the tibia, which forms the proximal tibiofibular joint, which is a synovial gliding joint (Fig. 6-12).

The patella articulates with the patellar surface of the femur and protects the front of the knee joint. This articulation is called the patellofemoral joint, when the knee is extended and relaxed, the patella is freely movable over the patellar surface of the femur. When the knee is flexed, which is also a synovial gliding joint, the patella is locked in position in front of the patellar surface. The knee joint, or femorotibial joint, is the largest joint in the body. It is called a synovial modified hinge joint. In addition to flexion and extension, the knee joint allows slight medial and lateral rotation in the flexed position. The joint is enclosed in an articular capsule and held together by numerous ligaments (Fig. 6-13).

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**SUMMARY OF ANATOMY**

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<th>Metatarsals (5)</th>
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*See Addendum at the end of the volume for a summary of changes in the anatomic terms used in this edition.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Definition</th>
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<tr>
<td>Bone Cyst</td>
<td>Fluid filled cyst with a wall of fibrous tissue</td>
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<tr>
<td>Congenital Clubfoot</td>
<td>Abnormal twisting of the foot, usually inward and downward</td>
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<tr>
<td>Dislocation</td>
<td>Displacement of a bone from the joint space</td>
</tr>
<tr>
<td>Fracture</td>
<td>Disruption in the continuity of bone</td>
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<tr>
<td>Pott’s</td>
<td>Avulsion fracture of the medial malleolus with loss of the ankle mortise</td>
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<tr>
<td>Gout</td>
<td>Hereditary form of arthritis where uric acid is deposited in joints</td>
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<td>Metastases</td>
<td>Transfer of a cancerous lesion from one area to another</td>
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<td>Osgood-Schlatter Disease</td>
<td>Incomplete separation or avulsion of the tibial tuberosity</td>
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<td>Osteoarthritis or Degenerative Joint Disease</td>
<td>Form of arthritis marked by progressive cartilage deterioration in synovial joints and vertebrae</td>
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<td>Softening of the bones due to a vitamin D deficiency</td>
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<td>Osteomyelitis</td>
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<td>Osteopetrosis</td>
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<td>Osteoporosis</td>
<td>Loss of bone density</td>
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<tr>
<td>Paget’s Disease</td>
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<td>Tumor</td>
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<td>Chondrosarcoma</td>
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<tr>
<td>Enchondroma</td>
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<td>Ewing’s Sarcoma</td>
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<td>Osteochondroma or Exostosis</td>
<td>Benign bone tumor projection with a cartilaginous cap</td>
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<td>Osteoclastoma or Giant Cell Tumor</td>
<td>Lucent lesion in the metaphysis, usually at the distal femur</td>
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<td>Osteoid Osteoma</td>
<td>A benign lesion of cortical bone</td>
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<tr>
<td>Osteosarcoma</td>
<td>Malignant, primary tumor of bone with bone or cartilage formation</td>
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## EXPOSURE TECHNIQUE CHART ESSENTIAL PROJECTIONS

### LOWER LIMB

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<th>Part</th>
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<th>tm</th>
<th>mA</th>
<th>mAs</th>
<th>AEC</th>
<th>SID</th>
<th>IR</th>
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1. Small focal spot.
2. kVp values are for a 3-phase 12-pulse generator.
3. Relative doses for comparison use. All doses are skin entrance for average adult at cm indicated.
4. Tabletop, Extremity IR. Screen/Film speed 100.
5. Tabletop, Standard IR. Screen/Film speed 300.
6. Bucky, 16:1 grid. Screen/Film speed 300.
Radiation Protection

Protecting the patient from unnecessary radiation is a professional responsibility of the radiographer (see Chapter 1 for specific guidelines). In this chapter, the *Shield gonads* statement at the end of the *Position of part* sections indicates that the patient is to be protected from unnecessary radiation by restricting the radiation beam, using proper collimation, and placing lead shielding between the gonads and the radiation source.

Toes

**AP OR AP AXIAL PROJECTIONS**

Because of the natural curve of the toes, the interphalangeal joint spaces are not best demonstrated on the AP projection. When demonstration of these joint spaces is not critical, an AP projection may be performed (Figs. 6-14 and 6-15). An AP axial projection is recommended to open the joint spaces and reduce foreshortening (Figs. 6-16 and 6-17).

**Image receptor:** 8 x 10 inch (18 x 24 cm) crosswise for two images on one IR

**Position of patient**
- Have the patient seated or placed supine on the radiographic table.

**Position of part**
- With the patient in the supine or seated position, flex the knees, separate the feet about 6 inches (15 cm), and touch the knees together for immobilization.
- Center the toes directly over one half of the IR (see Figs. 6-14 and 6-16), or place a 15-degree foam wedge well under the foot and rest the toes near the elevated base of the wedge (Fig. 6-18).
- Adjust the IR half with its midline parallel to the long axis of the foot, and center it to the third metatarsophalangeal joint.
- *Shield gonads.*

**Central ray**
- Perpendicular through the third metatarsophalangeal joint (see Fig. 6-14) when demonstration of the joint spaces is not critical. To open the joint spaces, either direct the central ray 15 degrees posteriorly through the third metatarsophalangeal joint (see Fig. 6-16), or if the 15-degree foam wedge is used, direct the central ray perpendicularly (Fig. 6-19).

**Structures shown**
The images demonstrate the 14 phalanges of the toes; the distal portions of the metatarsals; and, on the axial projections, the interphalangeal joints.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- No rotation of phalanges
- Open interphalangeal and metatarsophalangeal joint spaces on the axial projections
- Toes separated from each other
- Distal ends of the metatarsals
- Soft tissues and bony trabecular detail

**NOTE:** Some institutions may demonstrate the entire foot, whereas others radiograph only the toe(s) of interest.
Toes

Fig. 6-14 AP toes, perpendicular central ray.

Fig. 6-15 AP toes, perpendicular central ray.

Fig. 6-16 AP axial toes, central ray angulation of 15 degrees.

Fig. 6-17 AP axial toes, central ray angulation of 15 degrees.

Fig. 6-18 AP axial, 15-degree foam wedge.

Fig. 6-19 AP axial, toes on 15-degree wedge.
**PA PROJECTION**

**Image receptor:** 8 × 10 inch (18 × 24 cm) crosswise for two images on one IR

**Position of patient**
- Have patient lie prone on the radiographic table because this position naturally turns the foot over so that the dorsal aspect is in contact with the IR.

**Position of part**
- Place the toes in the appropriate position by elevating them on one or two small sandbags and adjusting the support to place the toes horizontal.
- Place the IR half under the toes with the midline of the side used parallel with the long axis of the foot, and center it to the third metatarsophalangeal joint (Fig. 6-20).

**Central ray**
- Perpendicular to the midpoint of the IR entering the third metatarsophalangeal joint (see Fig. 6-20). The interphalangeal joint spaces are shown well because the natural divergence of the x-ray beam coincides closely with the position of the toes (Fig. 6-21).

**Structures shown**
- This projection will demonstrate the 14 phalanges of the toes, the interphalangeal joints, and the distal portions of the metatarsals.

**EVALUATION CRITERIA**

The following should be clearly demonstrated:
- No rotation of phalanges
- Open interphalangeal and metatarsophalangeal joint spaces
- Toes separated from each other
- Distal ends of the metatarsals
- Soft tissues and bony trabecular detail
Toes

AP OBLIQUE PROJECTION

Medial rotation

**Image receptor:** 8 × 10 inch (18 × 24 cm) crosswise for two images on one IR

**Position of patient**
- Place the patient in the supine or seated position on the radiographic table.
- Flex the knee of the affected side enough to have the sole of the foot resting firmly on the table.

**Position of part**
- Position the IR half under the toes.
- Medially rotate the lower leg and foot, and adjust the plantar surface of the foot to form a 30- to 45-degree angle from the plane of the IR (Fig. 6-22).
- Center the toes to the IR.
- Shield gonads.

**Central ray**
- Perpendicular and entering the third metatarsophalangeal joint

**NOTE:** Oblique projections of individual toes may be obtained by centering the affected toe to the portion of the IR being used and collimating closely. The foot may be placed in a medial oblique position for the first and second toes and in a lateral oblique position for the fourth and fifth toes. Either oblique position is adequate for the third (middle) toe.

**Structures shown**
An AP oblique projection of the phalanges shows the toes and the distal portion of the metatarsals rotated medially (Fig. 6-23).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- All phalanges
- Oblique toes
- Open interphalangeal and second through fifth metatarsophalangeal joint spaces
- First metatarsophalangeal joint (not always opened)
- Toes separated from each other
- Distal ends of the metatarsals
- Soft tissue and bony trabecular detail

![Fig. 6-22 AP oblique toes, medial rotation.](image)

![Fig. 6-23 AP oblique toes.](image)
PA OBLIQUE PROJECTION

Medial rotation

**Image receptor:** 8 × 10 inch (18 × 24 cm) crosswise for two exposures on one IR

**Position of patient**
- Have the patient lie in the lateral recumbent position on the affected side.

**Position of part**
- Adjust the affected limb in a partially extended position.
- Have the patient turn toward the prone position until the ball of the foot forms an angle of approximately 30 degrees to the horizontal, or have the patient rest the foot against a foam wedge or sandbag (Fig. 6-24).
- Center the IR half to the third metatarsophalangeal joint, and adjust it so that its midline is parallel with the long axis of the foot.
- **Shield gonads.**

**Central ray**
- Perpendicular to the third metatarsophalangeal joint

**Structures shown**
A PA oblique projection of the phalanges shows the toes and the distal portion of the metatarsals rotated laterally (Fig. 6-25).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- All phalanges
- Oblique toes
- Open interphalangeal and second through fifth metatarsophalangeal joint spaces
- First metatarsophalangeal joint (not always opened)
- Toes separated from each other
- Distal ends of the metatarsals
- Soft tissue and bony trabecular detail

---

Fig. 6-24 PA oblique toes, medial rotation.

Fig. 6-25 PA oblique toes.
**Toes**

**LATERAL PROJECTIONS**

**Mediolateral or lateromedial**

*Image receptor: 8 × 10 inch (18 × 24 cm) crosswise for multiple exposures on one IR*

**Position of patient**
- Have the patient lie in the lateral recumbent position on the *unaffected* side.
- Support the affected limb on sandbags, and adjust it in a comfortable position.
- To prevent superimposition, tape the toes above the one being examined into a flexed position; a 4 × 4 inch gauze pad also may be used to separate the toes.

**Position of part**

*Great toe, second toe*
- Place an 8 × 10 inch (18 × 24 cm) IR under the toe, and center it to the proximal phalanx.
- Grasp the patient’s limb by the heel and knee, and adjust its position to place the toe in a true lateral position.
- Adjust the long axis of the IR so that it is parallel with the long axis of the toe (Figs. 6-26, 6-27, and 6-28).

---

*Fig. 6-26 Lateral great toe.*

*Fig. 6-27 Lateral second toe.*

*Fig. 6-28 Lateral second toe using occlusal film.*
Toes

Fig. 6-29 Lateral third toe.

Fig. 6-30 Lateral fourth toe.

Fig. 6-31 Lateral fifth toe.

Fig. 6-32 Lateral great toe.

Third, fourth, fifth toes
• Place the patient on the affected side for these three toes.
• Select an 8 x 10 inch (18 x 24 cm) IR or an occlusal film.
• If the occlusal film is used, place it with the pebbled surface up between the toe being examined and the subadjacent toe.
• Adjust the position of the limb to place the toe of interest and the IR or film in a parallel position, placing the toe as close to the IR or film as possible.
• Support the elevated heel on a sandbag or sponge for immobilization (Figs. 6-29, 6-30, and 6-31).
• Shield gonads.
Central ray
- Perpendicular to the plane of the IR or film, entering the metatarsophalangeal joint of the great toe or the proximal interphalangeal joint of the lesser toes

Structures shown
The resulting images show a lateral projection of the phalanges of the toe and the interphalangeal articulations projected free of the other toes (Figs. 6-32 through 6-36).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Phalanges in profile (toenail should appear lateral).
- Phalanx, without superimposition of adjacent toes. When superimposition cannot be avoided, the proximal phalanx must be demonstrated.
- Open interphalangeal joint spaces. The metatarsophalangeal joints will be overlapped but may be seen in some patients.
- Soft tissue and bony trabecular detail.

Fig. 6-33 A, Lateral second toe. B, Lateral second toe showing the metatarsophalangeal joint (arrow).

Fig. 6-34 Lateral third toe.

Fig. 6-35 Lateral fourth toe.

Fig. 6-36 A, Lateral fifth toe. B, Lateral fifth toe showing the metatarsophalangeal joint (arrow). Note, distal interphalangeal joint is fused.
Sesamoids

TANGENTIAL PROJECTION
LEWIS\(^1\) AND HOLLY\(^2\) METHODS

Image receptor: 8 × 10 inch (18 × 24 cm) crosswise for multiple exposures on one IR


Position of patient
- Place the patient in the prone position.
- Elevate the ankle of the affected side on sandbags for stability, if needed. A folded towel may be placed under the knee for comfort.

Position of part
- Rest the great toe on the table in a position of dorsiflexion, and adjust it to place the ball of the foot perpendicular to the horizontal plane.
- Center the IR to the second metatarsal (Fig. 6-37).
- Shield gonads.

Central ray
- Perpendicular and tangential to the first metatarsophalangeal joint

Structures shown
The resulting image shows a tangential projection of the metatarsal head in profile and the sesamoids (Fig. 6-38).

Fig. 6-37 Tangential sesamoids: Lewis method.

Fig. 6-38 Tangential sesamoids: Lewis method with toes against IR.
EVALUATION CRITERIA

The following should be clearly demonstrated:

- Sesamoids free of any portion of the first metatarsal
- Metatarsal heads

NOTE: Holly described a position that he believed was more comfortable for the patient. With the patient seated on the table, the foot is adjusted so that the medial border is vertical and the plantar surface is at an angle of 75 degrees with the plane of the IR. The patient holds the toes in a flexed position with a strip of gauze bandage. The central ray is directed perpendicular to the head of the first metatarsal bone (Figs. 6-39 and 6-40).


Fig. 6-39 Tangential sesamoids: Holly method.

Fig. 6-40 A, Tangential sesamoids: Holly method with heel against IR. B, Sesamoid with fracture (arrow).
**Sesamoids**

**TANGENTIAL PROJECTION**  
**CAUSTON METHOD**

**Image receptor:** 8 × 10 inch (18 × 24 cm)

**Position of patient**
- Place the patient in the lateral recumbent position on the unaffected side, and flex the knees.

**Position of part**
- Partially extend the limb being examined and put sandbags under the knee and foot.
- Adjust the height of a sandbag under the knee to place the foot in the lateral position, with the first metatarsophalangeal joint perpendicular to the horizontal plane of the IR.
- Place the IR under the distal metatarsal region, and adjust it so that the midpoint will coincide with the central ray (Figs. 6-41 and 6-42).
- Shield gonads.

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![Fig. 6-41: Tangential sesamoids.](image1)

![Fig. 6-42: Tangential sesamoids using occlusal film.](image2)

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(Causton J: Projection of sesamoid bones in the region of the first metatarsophalangeal joint, Radiology 9:39, 1943.)
Sesamoids

Central ray
• Directed to the prominence of the first metatarsophalangeal joint at an angle of 40 degrees toward the heel

Structures shown
The tangential image shows the sesamoid bones projected axiolaterally with a slight overlap (Fig 6-43).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- First metatarsophalangeal sesamoids with little overlap
- Occlusal film technique
- For improved detail, a similar projection may be performed using an occlusal film. The film is placed on a sandbag as illustrated in Fig. 6-42 and then is appropriately processed.

Fig. 6-43 Tangential sesamoids.
**AP OR AP AXIAL PROJECTION**

Radiographs may be obtained by directing the central ray perpendicular to the plane of the IR or by angling the central ray 10 degrees posteriorly. When a 10-degree posterior angle is used, the central ray is perpendicular to the metatarsals, therefore reducing foreshortening. The tarsometatarsal joint spaces of the midfoot are also demonstrated better (Figs. 6-44 and 6-45).

**Image receptor:** 24 × 30 cm lengthwise.

**Position of patient**
- Place the patient in the supine position.
- Flex the knee of the affected side enough to rest the sole of the foot firmly on the radiographic table.

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**Fig. 6-44** AP axial foot with posterior angulation of 10 degrees.

**Fig. 6-45** AP axial foot with posterior angulation of 10 degrees.
Position of part
- Position the IR under the patient's foot, center it to the base of the third metatarsal, and adjust it so that its long axis is parallel with the long axis of the foot.
- Hold the leg in the vertical position by having the patient flex the opposite knee and lean it against the knee of the affected side.
- In this foot position the entire plantar surface rests on the IR; thus it is necessary to take precautions against the IR slipping.
- Ensure that no rotation of the foot occurs.
- Shield gonads.

Central ray
- Directed one of two ways: (1) 10 degrees toward the heel to the base of the third metatarsal (see Fig. 6-44) or (2) perpendicular to the IR and toward the base of the third metatarsal (Fig. 6-46)

Fig. 6-46 AP foot with perpendicular central ray.
Structures shown
The resulting image shows an AP (dorso-plantar) projection of the tarsals anterior to the talus, metatarsals, and phalanges (Figs. 6-45, 6-47, and 6-48). This projection is used for localizing foreign bodies, determining the location of fragments in fractures of the metatarsals and anterior tarsals, and performing general surveys of the bones of the foot.
EVALUATION CRITERIA

The following should be clearly demonstrated:

- No rotation of the foot
- Equal amount of space between the adjacent midshafts of the second through fourth metatarsals
- Overlap of the second through fifth metatarsal bases
- Visualization of the phalanges and tarsals distal to the talus, as well as the metatarsals

Fig. 6-48  
A, AP foot of a 6-year-old patient. Note the epiphyseal lines (arrows). B, AP foot showing deformed tarsal bones and displaced medial cuneiform (arrow).
Foot

AP OBLIQUE PROJECTION
Medial rotation

Image receptor: 24 x 30 lengthwise

Position of patient
• Place the patient in the supine position.
• Flex the knee of the affected side enough to have the plantar surface of the foot rest firmly on the radiographic table.

Position of part
• Place the IR under the patient's foot, parallel with its long axis, and center it to the midline of the foot at the level of the base of the third metatarsal.
• Rotate the patient's leg medially until the plantar surface of the foot forms an angle of 30 degrees to the plane of the IR (Fig. 6-49). If the angle of the foot is increased more than 30 degrees, the lateral cuneiform tends to be thrown over the other cuneiforms.
• Shield gonads.

Central ray
• Perpendicular to the base of the third metatarsal

NOTE: A similar projection using a 45-degree medial rotation of the foot and a PA oblique projection is described on page 266. A greater rotation can be helpful in demonstrating the joint spaces of the foot.

1Doub HP: A useful position for examining the foot, Radiology 16:764, 1931.
Structures shown
The resulting image shows the interspaces between the following: the cuboid and the calcaneus; the cuboid and the fourth and fifth metatarsals; the cuboid and the lateral cuneiform; and the talus and the navicular bone. The cuboid is shown in profile. The sinus tarsi is also well demonstrated (Fig. 6-50).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Third through fifth metatarsal bases free of superimposition
- Lateral tarsals with less superimposition than in the AP projection
- Lateral tarsometatarsal and intertarsal joints
- Sinus tarsi
- Tuberosity of the fifth metatarsal
- Bases of the first and second metatarsals
- Equal amount of space between the shafts of the second through fifth metatarsals
- Sufficient density to demonstrate the phalanges, metatarsals, and tarsals

Fig. 6-50 A, AP oblique projection foot; medial rotation. B, Fracture of the distal aspect of the fifth metatarsal (arrow). Calcaneus was not included and technique adjusted to better visualize the fracture.
AP OBLIQUE PROJECTION
Lateral rotation

Image receptor: 24 × 30 cm length-wise

Position of patient
- Place the patient in the supine position.
- Flex the knee of the affected side enough for the plantar surface of the foot to rest firmly on the radiographic table.

Position of part
- Place the IR under the patient’s foot, parallel with its long axis, and center it to the midline of the foot at the level of the base of the third metatarsal.
- Rotate the leg laterally until the plantar surface of the foot forms an angle of 30 degrees to the IR.
- Support the elevated side of the foot on a 30-degree foam wedge to ensure consistent results (Fig. 6-51).
- Shield gonads.

Fig. 6-51 AP oblique foot, lateral rotation.
Central ray
• Perpendicular to the base of the third metatarsal

Structures shown
The resulting image shows the interspaces between the first and second metatarsals and between the medial and intermediate cuneiforms (Fig. 6-52).

EVALUATION CRITERIA
The following should be clearly demonstrated:
• Separate first and second metatarsal bases
• No superimposition of the medial and intermediate cuneiforms
• Navicular bone more clearly demonstrated than in the medial rotation
• Sufficient density to demonstrate the phalanges, metatarsals, and tarsals

Fig. 6-52 AP oblique foot.
Foot

PA OBLIQUE PROJECTIONS
GRASHEY METHODS
Medial or lateral rotations

Image receptor: 24 × 30 cm lengthwise

Position of patient
- Place the patient in the prone position.
- Elevate the affected foot on sandbags. If desired, place a folded towel under the knee.

Position of part
- Adjust the elevation of the patient’s foot to place its dorsal surface in contact with the IR.
- Position the IR under the foot, parallel with its long axis, and center it to the base of the third metatarsal.
- To demonstrate the interspace between the first and second metatarsals, rotate the heel medially approximately 30 degrees (Figs. 6-53 and 6-54).
- To demonstrate the interspaces between the second and third, the third and fourth, and the fourth and fifth metatarsals, adjust the foot so that the heel is rotated laterally approximately 20 degrees (see Fig. 6-54).
- Shield gonads.

Central ray
- Perpendicular to the base of the third metatarsal

Structures shown
The resulting image shows a PA oblique projection of the bones of the foot and the interspaces of the proximal ends of the metatarsals.

EVALUATION CRITERIA
The following should be clearly demonstrated:

Heel medially rotated 30 degrees (Fig. 6-55)
- First and second metatarsal bases free of superimposition
- Medial cuneiform projected without superimposition
- Navicular bone seen in profile

Heel laterally rotated 20 degrees (Fig. 6-56)
- Third through fifth metatarsal bases free of superimposition
- Tuberosity of the fifth metatarsal and cuboid

Fig. 6-53 PA oblique foot, 30 degrees lateral rotation.

Fig. 6-54 Coronal section near base of metatarsals of right foot.
Fig. 6-55 PA oblique foot, 30 degrees lateral rotation.

Fig. 6-56 PA oblique foot, 20 degrees medial rotation.
PA OBLIQUE PROJECTION

Medial rotation

NOTE: This is essentially the same projection as the AP oblique foot projection described on page 260. Placing the lateral aspect of the foot closer to the IR and using a 45-degree medial rotation can provide better visualization of the bones of the foot.

Image receptor: 24 × 30 cm lengthwise

Position of patient
• Place the patient in the lateral recumbent position on the affected side, and flex the knees.

Position of part
• Fully extend the leg of the side being examined.
• Have the patient turn toward the prone position until the plantar surface of the foot forms an angle of 45 degrees to the plane of the IR.
• Center the IR opposite the base of the fifth metatarsal, and adjust it so that its midline is parallel with the long axis of the foot.
• Rest the dorsum of the foot against a foam wedge. The general survey study is usually made with the foot at an angle of 45 degrees to obtain uniform results (Fig. 6-57).
• Shield gonads.

Central ray
• Perpendicular to the midline of the foot at the level of the base of the fifth metatarsal

Structures shown
The resulting image shows a PA oblique projection of the bones of the foot. The articulations between the cuboid and the adjacent bones (the calcaneus, lateral cuneiform, and fourth and fifth metatarsals) are clearly shown (Fig. 6-58). The articulations between the following bones are usually shown: talus and navicular bone; navicular bone and cuneiforms; and sustentaculum tali and talus. The cuboid is shown in profile.

EVALUATION CRITERIA
The following should be clearly demonstrated:
• A more oblique projection than obtained with the Grashey method
• Third through fifth metatarsal bases and the tarsals

• Tarso metatarsal and intersosalar joints
• Tuberosity of the fifth metatarsal
• Some superimposition of the first and second metatarsals
• Sufficient density to demonstrate the phalanges, metatarsals, and tarsals

Fig. 6-57 PA oblique foot, medial rotation.

Fig. 6-58 PA oblique foot.
The lateral (mediolateral) projection is routinely used in most radiology departments because it is a comfortable position for the patient to assume. The lateromedial projection, however, is the recommended alternative when the patient's condition permits.

**Image receptor:** 24 x 30 cm lengthwise

**Position of patient**
- Have the patient lie on the radiographic table and turn toward the affected side until the leg and foot are lateral.
- Place the opposite leg behind the patient.

**Position of part**
- Elevate the patient's knee enough to place the patella perpendicular to the horizontal plane, and adjust a sandbag support under the knee (Fig. 6-59).
- Center the IR to the midarea of the foot, and adjust it so that its long axis is parallel with the long axis of the foot.
- Dorsiflex the foot to form a 90-degree angle with the lower leg.
- Shield gonads.

**Central ray**
- Perpendicular to the base of the third metatarsal

**Structures shown**
- The resulting image shows the entire foot in profile, the ankle joint, and the distal ends of the tibia and fibula (Fig. 6-60).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Metatarsals nearly superimposed
- Distal leg
- Fibula overlapping the posterior portion of the tibia
- Tibiotalar joint
- Sufficient density to demonstrate the superimposed tarsals and metatarsals
LATERAL PROJECTION

Lateromedial

Whenever possible, lateral projections of the foot should be made with the medial side in contact with the IR. In the absence of an unusually prominent medial malleolus, hallux valgus, or other deformity, the foot assumes an exact or nearly exact lateral position when resting on its medial side. Although the medial position may be more difficult for some patients to achieve, true lateral projections are more easily and consistently obtained with the foot in this position.

**Image receptor:** 24 x 30 cm lengthwise

**Position of patient**
- Place the patient in the supine position.
- Turn the patient onto the unaffected side until the affected leg and foot are laterally placed. The patient's body will be in an LPO or RPO position.

**Position of part**
- Elevate the patient's knee enough to place the patella perpendicular to the horizontal plane, and support the knee on a sandbag or sponge (Fig. 6-61).
- Center the IR to the middle area of the foot, and adjust it so that its long axis is parallel with the long axis of the foot.
- Adjust the foot so that the plantar surface is perpendicular to the IR.
- Shield gonads.

**Central ray**
- Perpendicular to the base of the third metatarsal

**Structures shown**
The resulting image shows a true lateromedial projection of the foot, ankle joint, and distal ends of the tibia and fibula (Fig. 6-62).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Metatarsals usually more superimposed than in the mediolateral image, depending on the transverse arch of the foot
- Distal leg
- Fibula overlapping the posterior portion of the tibia
- Tibiotalar joint
- Sufficient density to demonstrate the superimposed tarsals and metatarsals
Fig. 6-62  Lateral foot.
Longitudinal Arch
LATERAL PROJECTION
Lateromedial
WEIGHT-BEARING METHOD
Standing

Image receptor: 24 × 30 cm length-wise

Position of patient
• Place the patient in the upright position, preferably on a low riser that has an IR groove. If such a riser is not available, use blocks to elevate the feet to the level of the x-ray tube (Figs. 6-63 and 6-64).
• If needed, use a mobile unit to allow the x-ray tube to reach the floor level.

Position of part
• Place the IR in the IR groove of the stool or between blocks.
• Have the patient stand in a natural position, one foot on each side of the IR, with the weight of the body equally distributed on the feet.
• Adjust the IR so that it is centered to the base of the third metatarsal.
• After the exposure, replace the IR and position the new one to image the opposite foot.
• Shield gonads.

Central ray
• Perpendicular to a point just above the base of the third metatarsal

Structures shown
The resulting image shows a lateromedial projection of the bones of the foot with weight-bearing. The projection is used to demonstrate the structural status of the longitudinal arch. The right and left sides are examined for comparison (Fig. 6-65).

EVALUATION CRITERIA
• Superimposed plantar surfaces of the metatarsal heads
• Entire foot and distal leg
• Fibula overlapping the posterior portion of the tibia
• Sufficient density to visualize the superimposed tarsals and metatarsals
Foot

Fig. 6-65 Weight-bearing lateral foot.
AP AXIAL PROJECTION
WEIGHT-BEARING METHOD
Standing

**Image receptor:** 24 × 30 cm crosswise for both feet on one IR

**SID:** 48 inches (122 cm). This SID is used to reduce magnification and improve recorded detail in the image.

**Position of patient**
- Place the patient in the standing-upright position.

**Position of part**
- Place the IR on the floor, and have the patient stand on the IR with the feet centered on each side.
- Pull the patient’s pants up to the knee level, if necessary.
- Ensure that right and left markers and an upright marker are placed on the IR.
- Ensure that the patient’s weight is distributed equally on each foot (Fig. 6-66).
- The patient may hold the x-ray tube crane for stability.
- Shield gonads.

**Central ray**
- Angled 10 degrees toward the heel is optimal. A minimum of 15 degrees is usually necessary to have enough room to position the tube and allow the patient to stand. The central ray is positioned between the feet and at the level of the base of the third metatarsal.

**Structures shown**
The resulting image demonstrates a weight-bearing AP axial projection of both feet permitting an accurate evaluation and comparison of the tarsals and metatarsals (Fig. 6-67).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Both feet centered on one image
- Phalanges, metatarsals, and distal tarsals.
- Correct right and left marker placement and a weight-bearing marker
- Correct exposure technique to visualize all the components

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*Fig. 6-66* Weight-bearing AP both feet, standing. **A,** Correct position of both feet on IR. **B,** Lateral perspective of the same projection shows the position of the feet on IR and the central ray.

*Fig. 6-67* Weight-bearing AP both feet, standing.
AP AXIAL PROJECTION
WEIGHT-BEARING COMPOSITE METHOD
Standing

Image receptor: 24 x 30 cm lengthwise

Position of patient
- Place the patient in the standing-upright position. The patient should stand at a comfortable height on a low stool or on the floor.

Position of part
- With the patient standing upright, adjust the IR under the foot and center its midline to the long axis of the foot.
- To prevent superimposition of the leg shadow on that of the ankle joint, have the patient place the opposite foot one step backward for the exposure of the forefoot and one step forward for the exposure of the hindfoot or calcaneus.
- Shield gonads.

Central ray
- To use the masking effect of the leg, direct the central ray along the plane of alignment of the foot in both exposures.
- With the tube in front of the patient and adjusted for a posterior angulation of 15 degrees, center the central ray to the base of the third metatarsal for the first exposure (Figs. 6-68 and 6-69).
- Caution the patient to carefully maintain the position of the affected foot and place the opposite foot one step forward in preparation for the second exposure.
- Move the tube behind the patient, adjust it for an anterior angulation of 25 degrees, and direct the central ray to the posterior surface of the ankle. The central ray emerges on the plantar surface at the level of the lateral malleolus (Figs. 6-70 and 6-71). An increase in technical factors is recommended for this exposure.
Structures shown
The resulting image shows a weight-bearing AP axial projection of all bones of the foot. The full outline of the foot is projected free of the leg (Fig. 6-72).

Evaluation Criteria
The following should be clearly demonstrated:
- All tarsals
- Shadow of leg not overlapping the tarsals
- Foot not rotated
- Tarsals, metatarsals, and toes with similar densities
Congenital Clubfoot

**AP PROJECTION**

**KITE METHODS**

The typical clubfoot, called *talipes equinovarus*, shows three deviations from the normal alignment of the foot in relation to the weight-bearing axis of the leg. These deviations are plantar flexion and inversion of the calcaneus (equinus), medial displacement of the forefoot (adduction), and elevation of the medial border of the foot (supination). The typical clubfoot has numerous variations. Furthermore, each of the typical abnormalities just described has varying degrees of deformity.

The classic Kite methods—exactly placed AP and lateral projections—for radiography of the clubfoot are used to demonstrate the anatomy of the foot and the bone or ossification centers of the tarsals and their relation to one another. A primary objective makes it essential that no attempt be made to change the abnormal alignment of the foot when placing it on the IR.

Davis and Hatt stated that even slight rotation of the foot can result in marked alteration in the radiographically projected relation of the ossification centers.

**Image receptor:** 8 × 10 inch (18 × 24 cm)

**Position of patient**

- Place the infant in the supine position, with the hips and knees flexed to permit the foot to rest flat on the IR. Elevate the body on firm pillows to knee height to simplify both gonad shielding and leg adjustment.

**Central ray**

- Perpendicular to the tarsals, midway between the tarsal areas for a bilateral projection.
- An approximately 15-degree posterior angle is generally required for the central ray to be perpendicular to the tarsals.

**Position of part**

- Rest the feet flat on the IR with the ankles extended slightly to prevent superimposition of the leg shadow.
- Hold the infant's knees together or in such a way that the legs are exactly vertical (i.e., so that they do not lean medially or laterally).
- Using a lead glove, hold the infant's toes. When the adduction deformity is too great to permit correct placement of the legs and feet for bilateral images without overlap of the feet, they must be examined separately (Figs. 6-73 and 6-74).
- Shield gonads.

**Fig. 6-73** AP foot for demonstration of clubfoot deformity.

**Fig. 6-74** AP projection showing nearly 90-degree adduction of forefoot.
### Congenital Clubfoot

**LATERAL PROJECTION**

**Mediolateral**

**KITE METHOD**

The Kite method lateral radiograph demonstrates the anterior talar subluxation and the degree of plantar flexion (equinus).

**Position of patient**

- Place the infant on his or her side in as near the lateral position as possible.
- Flex the uppermost limb, draw it forward, and hold it in place.

**Position of part**

- After adjusting the IR under the foot, place a support that has the same thickness as the IR under the infant’s knee to prevent angulation of the foot and to ensure a lateral foot position.
- Hold the infant’s toes in position with tape or a protected hand (Figs. 6-75 to 6-79).
- Shield gonads.

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**Fig. 6-75** Lateral foot.

**Fig. 6-76** Lateral foot projection showing pitch of calcaneus. Other tarsals are obscured by the adducted forefoot.

**Fig. 6-77** Nonroutine 45-degree medial rotation showing extent of talipes equinovarus.
Foot

Central ray

- Perpendicular to the midtarsal area

EVALUATION CRITERIA

The following should be clearly demonstrated:

- No medial or lateral angulation of the leg
- Fibula in lateral projection overlapping the posterior half of the tibia
- The need for a repeat examination if slight variations in rotation are seen in either image when compared with previous radiographs
- Sufficient density of the talus, calcaneus, and metatarsals to allow assessment of alignment variations.

NOTE: Freiberger, Hersh, and Harrison¹ recommended that dorsiflexion of the infant foot could be obtained by pressing a small plywood board against the sole of the foot. The older child or adult is placed in the upright position for a horizontal projection. With the upright position the patient leans the leg forward to dorsiflex the foot.

NOTE: Conway and Cowell² recommended tomography for the demonstration of coalition at the middle facet and particularly for the hidden coalition involving the anterior facet.


Fig. 6-78 AP projection after treatment (same patient as in Fig. 6-77).

Fig. 6-79 Lateral projection after treatment (same patient as in Fig. 6-76).
Foot

Congenital Clubfoot

AXIAL PROJECTION

Dorsoplantar

KANDEL METHOD

Kandel recommended the inclusion of a dorsoplantar axial projection in the examination of the patient with a clubfoot (Fig. 6-80).

For this method the infant is held in a vertical or a bending-forward position. The plantar surface of the foot should rest on the IR, although a moderate elevation of the heel is acceptable when the equinus deformity is well marked. The central ray is directed 40 degrees anteriorly through the lower leg, as for the usual dorsoplantar projection of the calcaneus (Fig. 6-81).

Freiberger, Hersh, and Harrison stated that sustentaculum talar joint fusion cannot be assumed on one projection, because the central ray may not have been parallel with the articular surfaces. They recommended that three radiographs be obtained with varying central ray angulations (35, 45, and 55 degrees).


**Calcaneus**

**AXIAL PROJECTION**

**Plantodorsal**

**Image receptor:** 8 x 10 inch (18 x 24 cm)

**Position of patient**
- Place the patient in the supine or seated position with the legs fully extended.

**Position of part**
- Place the IR under the patient’s ankle, centered to the midline of the ankle (Figs. 6-82 and 6-83).
- Place a long strip of gauze around the ball of the foot. Have the patient grasp the gauze to hold the ankle in right-angle dorsiflexion.
- If the patient’s ankles cannot be flexed enough to place the plantar surface of the foot perpendicular to the IR, elevate the leg on sandbags to obtain the correct position.
- *Shield gonads.*

**Central ray**
- Directed to the midpoint of the IR at a cephalic angle of 40 degrees to the long axis of the foot. The central ray enters the base of the third metatarsal.

**Structures shown**
The resulting image shows an axial projection of the calcaneus (Fig. 6-84).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Calcaneus and subtalar joint.
- No rotation of the calcaneus—the first or fifth metatarsals not projected to the sides of the foot.
- Anterior portion of the calcaneus without excessive density over the posterior portion. Otherwise two images may be needed for the two regions of thickness.
AXIAL PROJECTION
Dorsoplantar

Image receptor: 8 × 10 inch (18 × 24 cm)

Position of patient
• Place the patient in the prone position.

Position of part
• Elevate the patient’s ankle on sandbags.
• Adjust the height and position of the sandbags under the ankle in such a way that the patient can dorsiflex the ankle enough to place the long axis of the foot perpendicular to the tabletop.
• Place the IR against the plantar surface of the foot, and support it in position with sandbags or a portable IR holder (Figs. 6-85 and 6-86).
• Shield gonads.

Fig. 6-85 Axial (dorsoplantar) calcaneus.
Fig. 6-86 Axial (dorsoplantar) calcaneus.
Central ray
- Directed to the midpoint of the IR at a caudal angle of 40 degrees to the long axis of the foot. The central ray enters the dorsal surface of the ankle joint.

Structures shown
The resulting image shows an axial projection of the calcaneus and the subtalar joint (Fig. 6-87).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Calcaneus and the subtalar joint.
- Sustentaculum tali.
- Calcaneus not rotated—the first or fifth metatarsals not projected to the sides of the foot.

- Anterior portion of the calcaneus without excessive density over posterior portion. Otherwise, two images may be needed for the two regions of thickness.

WEIGHT-BEARING "COALITION METHOD"1
This method, described by Lilienfeld1 (cit. Holzknecht), has come into use for the demonstration of calcaneotalar coalition.2,4 For this reason it has been called the "coalition position."

Position of patient
- Place the patient in the standing-upright position.

Position of part
- Center the IR to the long axis of the calcaneus, with the posterior surface of the heel at the edge of the IR.
- To prevent superimposition of the leg shadow, have the patient place the opposite foot one step forward (Fig. 6-88).

Central ray
- Angled exactly 45 degrees anteriorly and directed through the posterior surface of the flexed ankle to a point on the plantar surface at the level of the base of the fifth metatarsal

3Coventry MB: Flatfoot with special consideration of tarsal coalition, Minn Med 33:1091, 1950.
**Calcaneus**

**LATERAL PROJECTION**

**Mediolateral**

**Image receptor:** 8 x 10 inch (18 x 24 cm)

**Position of patient**
- Have the supine patient turn toward the affected side until the leg is approximately lateral. A support may be placed under the knee.

**Position of part**
- Adjust the calcaneus to the center of the IR.
- Adjust the IR so that the long axis is parallel with the plantar surface of the heel (Fig. 6-89).
- Shield gonads.

**Central ray**
- Perpendicular to the calcaneus. Center about 1 inch (2.5 cm) distal to the medial malleolus. This will place the CR at the subtalar joint.

**Structures shown**
The resulting radiograph shows the ankle joint and the calcaneus in lateral profile (Fig. 6-90).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- No rotation of the calcaneus
- Density of the sustentaculum tali, lateral tuberosity, and soft tissue
- Sinus tarsi
- Ankle joint and adjacent tarsals

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Fig. 6-89 Lateral calcaneus.

Fig. 6-90 Lateral calcaneus.
LATEROMEDIAL OBLIQUE PROJECTION
WEIGHT-BEARING METHOD

Image receptor: 8 x 10 inch (18 x 24 cm)

Position of patient
• Have the patient stand with the affected heel centered toward the lateral border of the IR (Fig. 6-91).
• A mobile radiographic unit may assist in this examination.

Position of part
• Adjust the patient’s leg to ensure that it is exactly perpendicular.
• Center the calcaneus so that it will be projected to the center of the IR.
• Center the lateral malleolus to the midline axis of the IR.
• Shield gonads.

Central ray
• Directed medially at a caudal angle of 45 degrees to enter the lateral malleolus.

Structures shown
The resulting image shows the calcaneal tuberosity and is useful in diagnosing stress fractures of the calcaneus or tuberosity (Fig. 6-92).

EVALUATION CRITERIA
The following should be clearly demonstrated:
■ Calcaneal tuberosity
■ Sinus tarsi
■ Cuboid

Fig. 6-91 Weight-bearing lateromedial oblique calcaneus.

Fig. 6-92 Weight-bearing lateromedial oblique calcaneus.
Subtalar Joint

PA AXIAL OBLIQUE PROJECTION
Lateral rotation
The calcaneus has three articular surfaces: anterior, middle, and posterior. These surfaces are located on the superior calcaneus and articulate with the inferior talus. The articulations form the subtalar (talocalcaneal) joint (see Fig. 6-11). This projection best demonstrates the middle and posterior articulations.

Image receptor: 8 × 10 inch (18 × 24 cm)

Position of patient
• Have the patient lie on the affected side in the lateral position.
• Flex the uppermost knee to a comfortable position, and support it on sandbags to prevent too much forward rotation of the body (Fig. 6-93).

Position of part
• Ask the patient to extend the affected limb.
• Roll the limb slightly forward from the lateral position.
• Center the IR 1 to 1 1/2 inches (2.5 to 3.8 cm) distal to the ankle joint and adjust it so that its midline is parallel with the long axis of the leg.

• Adjust the obliquity of the foot so that the heel is elevated about 11/2 inches (3.8 cm) from the exact lateral position. The ball of the foot (the metatarsophalangeal area) will be angled forward approximately 25 degrees.
• Shield gonads.

Central ray
• Directed to the ankle joint at a double angle of 5 degrees anterior and 23 degrees caudal.

NOTE: Some x-ray tubes may not double angle.

Structures shown
The resulting image shows the middle and posterior articulations of the subtalar joint and gives an "end-on" image of the sinus tarsi and an unobstructed projection of the lateral malleolus (Fig. 6-94).

EVALUATION CRITERIA
The following should be clearly demonstrated:
■ Open subtalar (talocalcaneal) joint articulations
■ Sinus tarsi
■ Lateral malleolus seen in profile
Subtalar Joint

AP AXIAL OBLIQUE PROJECTION
BRODEN METHOD
Medial Rotation
Broden recommended the lateromedial and mediolateral right-angle oblique projections for demonstration of the posterior articular facet of the calcaneus to determine the presence of joint involvement in cases of comminuted fracture.

Image receptor: 8 × 10 inch (18 × 24 cm)

Position of patient
- Place the patient in the supine position.
- Adjust a small sandbag under each knee.

Position of part
- Place the IR under the patient’s lower leg and heel with its midline parallel with and centered to the leg.
- Adjust the IR so that the lower edge is about 1 inch (2.5 cm) distal to the plantar surface of the heel.

- Loop a strip of bandage around the ball of the foot. Have the patient grasp the ends of the bandage and dorsiflex the foot enough to obtain right-angle flexion at the ankle joint. Ask the patient to maintain the flexion for the exposure.
- With patient’s ankle joint maintained in right-angle flexion, rotate the leg and foot 45 degrees medially, and rest the foot against a 45-degree foam wedge (Fig. 6-95).
- Shield gonads.

Fig. 6-95 AP axial oblique subtalar joint, medial rotation.
Subtalar Joint

Central ray
- Angled cephalad at 40, 30, 20, and 10 degrees, respectively. Four separate images are obtained.
- For each image, direct the central ray to a point 2 or 3 cm caudoanteriorly to the lateral malleolus, to the midpoint of an imaginary line extending between the most prominent point of the lateral malleolus and the base of the fifth metatarsal (Figs. 6-96 to 6-99).

Structures shown
The anterior portion of the posterior facet is shown best in the 40-degree projection. The 10-degree projection shows the posterior portion. The articulation between the talus and sustentaculum tali (middle facet) is usually shown best in one of the intermediate projections.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Anterior and posterior portions of the posterior subtalar joint
Subtalar Joint

AP AXIAL OBLIQUE PROJECTION
BRODEN METHOD
Lateral rotation

Image receptor: 8 x 10 inch (18 x 24 cm)

Position of patient

- Place the patient in the supine position.
- Adjust a small sandbag under each knee.

Position of part

- With the patient's ankle joint held in right-angle flexion, rotate the leg and foot 45 degrees laterally (Fig. 6-100).
- The foot may rest against a 45-degree foam wedge.
- Shield gonads.

Central ray

- Directed to a point 2 cm distal and 2 cm anterior to the medial malleolus, at a cephalic angle of 15 degrees for the first exposure (Fig. 6-101).
- Two or three images may be made with a 3- or 4-degree difference in central ray angulation (Fig. 6-102).

Structures shown

The posterior facet of the calcaneus is shown in profile. The articulation between the talus and sustentaculum tali is usually shown.

EVALUATION CRITERIA

The following should be clearly demonstrated:
- Posterior portion of the subtalar joint

Fig. 6-100 AP axial oblique subtalar joint, lateral rotation.

Fig. 6-101 AP axial oblique subtalar joint with angulation of 15 degrees.

Fig. 6-102 AP axial oblique subtalar joint with angulation of 18 degrees.
Subtalar Joint

LATEROMEDIAL OBLIQUE PROJECTION
ISHERWOOD METHOD

Medial rotation foot

Isherwood devised a method for each of the three separate articulations of the subtalar joint: (1) a medial rotation foot position for the demonstration of the anterior talar articular surface, (2) a medial rotation ankle position for the middle talar articular surface, and (3) a lateral rotation ankle position for the posterior talar articular surface. Feist later described a similar position.

Image receptor: 8 x 10 inch (18 x 24 cm) for each position

Position of patient
• Place the patient in a semisupine or seated position, turned away from the side being examined
• Ask the patient to flex the knee enough to place the ankle joint in nearly right-angle flexion and then to lean the leg and foot medially.

Position of part
• With the medial border of the foot resting on the IR, place a 45-degree foam wedge under the elevated leg.
• Adjust the leg so that its long axis is in the same plane as the central ray.
• Adjust the foot to be at a right angle.
• Place a support under the knee (Fig. 6-103).
• Shield gonads.

Central ray
• Perpendicular to a point 1 inch (2.5 cm) distal and 1 inch (2.5 cm) anterior to the lateral malleolus

Structures shown
The resulting image shows the anterior subtalar articular surface and an oblique projection of the tarsals (Fig. 6-104). The Feist-Mankin method produces a similar image representation.

EVALUATION CRITERIA
The following should be clearly demonstrated:
• Anterior talar articular surface

Fig. 6-103 Lateromedial oblique subtalar joint, medial rotation: Isherwood method.

Fig. 6-104 Lateromedial oblique subtalar joint demonstrating anterior articular surface: Isherwood method.

Subtalar Joint

AP AXIAL OBLIQUE PROJECTION
ISHERWOOD METHOD
Medial rotation ankle

Image receptor: 8 × 10 in (18 × 24 cm)

Position of patient
- Have the patient assume a seated position on the radiographic table and turn with body weight resting on the flexed hip and thigh of the unaffected side.
- If a semilateral recumbent position is more comfortable, adjust the patient accordingly.

Position of part
- Ask the patient to rotate the leg and foot medially enough to rest the side of the foot and affected ankle on an optional 30-degree foam wedge (Fig. 6-105).
- Place a support under the knee. If the patient is recumbent, place another under the greater trochanter.
- Dorsiflex the foot, then invert it if possible, and have the patient maintain the position by pulling on a strip of 2- or 3-inch (5- to 7.6-cm) bandage looped around the ball of the foot.
- Shield gonads.

Central ray
- Directed to a point 1 inch (2.5 cm) distal and 1 inch (2.5 cm) anterior to the lateral malleolus at an angle of 10 degrees cephalad.

Structures shown
The resulting image shows the middle articulation of the subtalar joint and an "end-on" projection of the sinus tarsi (Fig. 6-106).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Middle (subtalar) articulation
- Open sinus tarsi

Fig. 6-105 AP axial oblique subtalar joint; medial rotation: Isherwood method.

Fig. 6-106 AP axial oblique subtalar joint: Isherwood method.
Subtalar Joint

AP AXIAL OBLIQUE PROJECTION
ISHERWOOD METHOD
Lateral rotation ankle

Image receptor: 8 × 10 inch (18 × 24 cm)

Position of patient
• Place the patient in the supine or seated position.

Position of part
• Ask the patient to rotate the leg and foot laterally until the side of the foot and ankle rests against an optional 30-degree foam wedge.
• Dorsiflex the foot, evert it if possible, and have the patient maintain the position by pulling on a broad bandage looped around the ball of the foot (Fig. 6-107).
• Shield gonads.

Central ray
• Directed to a point 1 inch (2.5 cm) distal to the medial malleolus at an angle of 10 degrees cephalad

Structures shown
The resulting image shows the posterior articulation of the subtalar joint in profile (Fig. 6-108).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Posterior subtalar articulation

Fig. 6-107 AP axial oblique subtalar joint, lateral rotation: Isherwood method.

Fig. 6-108 AP oblique subtalar joint: Isherwood method.
Ankle

AP PROJECTION

Image receptor: 8 × 10 inch (18 × 24 cm) lengthwise or 24 × 30 cm crosswise for two images on one IR.

Position of patient
• Place the patient in the supine position with the affected limb fully extended.

Position of part
• Adjust the ankle joint in the anatomic position to obtain a true AP projection. Flex the ankle and foot enough to place the long axis of the foot in the vertical position (Fig. 6-109).
• Ball and Egbert\(^1\) stated that the appearance of the ankle mortise is not appreciably altered by moderate plantar flexion or dorsiflexion as long as the leg is rotated neither laterally nor medially.
• Shield gonads.

Central ray
• Perpendicular through the ankle joint at a point midway between the malleoli.

Structures shown
The resulting image shows a true AP projection of the ankle joint, the distal ends of the tibia and fibula, and the proximal portion of the talus.

NOTE: The inferior tibiotalar articulation and the talotibial articulation will not be “open” nor shown in profile in the true AP projection. This is a positive sign for the radiologist because it indicates that the patient has no ruptured ligaments or other type of separations. For this reason it is important that the position of the ankle be anatomically "true" for the AP projection demonstrated (Fig. 6-110).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Tibiotalar joint space
- Ankle joint centered to exposure area
- Normal overlapping of the tibiotalar articulation with the anterior tubercle slightly superimposed over the fibula
- Talus slightly overlapping the distal fibula
- No overlapping of the medial talo-malleolar articulation
- Medial and lateral malleoli
- Talus with proper density
- Soft tissue

\(^1\)Ball RP, Egbert EW: Ruptured ligaments of the ankle, AJR 50:770, 1943.
**LATERAL PROJECTION**

Mediolateral

*Image receptor: 8 × 10 inch (18 × 24 cm)*

**Position of patient**
- Have the supine patient turn toward the affected side until the ankle is lateral (Fig. 6-111).

**Position of part**
- Place the long axis of the IR parallel with the long axis of the patient’s leg and center it to the ankle joint.
- Ensure that the lateral surface of the foot is in contact with the IR.
- Dorsiflex the foot, and adjust it in the lateral position. Dorsiflexion is required to prevent lateral rotation of the ankle.
- *Shield gonads.*

**Central ray**
- Perpendicular to the ankle joint, entering the medial malleolus

**Structures shown**
The resulting image shows a true lateral projection of the lower third of the tibia and fibula, the ankle joint, and the tarsals (Fig. 6-112).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Ankle joint centered to exposure area
- Tibiotalar joint well visualized, with the medial and lateral talar domes superimposed
- Fibula over the posterior half of the tibia
- Distal tibia and fibula, talus, and adjacent tarsals
- Density of the ankle sufficient to see the outline of distal portion of the fibula

*Fig. 6-111 Lateral ankle, mediolateral.*
Fig. 6-112 A, and B, Lateral ankle, mediolateral. C, Lateral ankle of an 8-year-old patient. Note the tibial epiphysis (arrow).
LATERAL PROJECTION
Lateromedial
It is often recommended that the lateral projection of the ankle joint be made with the medial side of the ankle in contact with the IR. Exact positioning of the ankle is more easily and more consistently obtained when the limb is rested on its comparatively flat medial surface.

Image receptor: 8 x 10 inch (18 x 24 cm)

Position of patient
- Have the supine patient turn away from the affected side until the extended leg is placed laterally.

Position of part
- Center the IR to the ankle joint, and adjust the IR so that its long axis is parallel with the long axis of the leg.
- Adjust the foot in the lateral position.
- Have the patient turn anteriorly or posteriorly as required to place the patella perpendicular to the horizontal plane (Fig. 6-113).
- If necessary, place a support under the patient's knee.
- Shield gonads.

Central ray
- Perpendicular through the ankle joint, entering ½ inch (1.3 cm) superior to the lateral malleolus

Structures shown
The resulting image shows a lateral projection of the lower third of the tibia and fibula, the ankle joint, and the tarsals (Fig. 6-114).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Ankle joint centered to exposure area
- Tibiotalar joint well visualized, with the medial and lateral talar domes superimposed
- Fibula over the posterior half of the tibia
- Distal tibia and fibula, talus, and adjacent tarsals
- Density of the ankle sufficient to see the outline of distal portion of the fibula

Fig. 6-113 Lateral ankle, lateromedial.

Fig. 6-114 Lateral ankle, lateromedial.
**AP OBLIQUE PROJECTION**

**Medial rotation**

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise or 24 × 30 cm crosswise for two images on one IR

**Position of patient**
- Place the patient in the supine position with the affected limb fully extended.

**Position of part**
- Center the IR to the ankle joint midway between the malleoli, and adjust the IR so that its long axis is parallel with the long axis of the leg.
- Dorsiflex the foot enough to place the ankle at nearly right-angle flexion (Fig. 6-115). The ankle may be immobilized with sandbags placed against the sole of the foot or by having the patient hold the ends of a strip of bandage looped around the ball of the foot.
- Rotate the patient’s *leg* primarily and the *foot* for all oblique projections of the ankle. Because the knee is a hinge joint, rotation of the leg can come only from the hip joint. Positioning the ankle for the oblique projection requires that the *leg* and *foot* be medially rotated 45 degrees.
- Grasp the lower femur area with one hand and the foot with the other. Internally rotate the entire leg and foot together until the 45-degree position is achieved.
- The foot can be placed against a foam wedge for support.
- *Shield gonads.*

**Central ray**
- Perpendicular to the ankle joint, entering midway between the malleoli

**Structures shown**
- The 45-degree medial oblique projection demonstrates the distal ends of the tibia and fibula, parts of which are often superimposed over the talus. The tibiofibular articulation also should be demonstrated (Fig. 6-116).

**EVALUATION CRITERIA**
- Distal tibia, fibula, and talus
- Distal tibia and fibula overlap some of the talus
- Talus and distal tibia and fibula adequately penetrated
- Tibiofibular articulation

---

**Fig. 6-115** AP oblique ankle, 45-degree medial rotation.

**Fig. 6-116** AP oblique ankle, 45-degree medial rotation.
Ankle

Mortise Joint

**AP OBLIQUE**

*Medial rotation*

**Image receptor:** 8 x 10 inch (18 x 24 cm) lengthwise or 24 x 30 cm crosswise for two images on one IR

**Position of patient**
- Place the patient in the supine position.


- Center the patient's ankle joint to the IR.
- Grasp the distal femur area with one hand and the foot with the other. Assist the patient by internally rotating the entire leg and foot together 15 to 20 degrees until the intermalleolar plane is parallel with the IR (Fig. 6-117).
- The plantar surface of the foot should be placed at a right angle to the leg (Fig. 6-118).
- Shield gonads.

**Central ray**
- Perpendicular, entering the ankle joint midway between the malleoli

---

**Fig. 6-117** AP oblique ankle, 15- to 20-degree medial rotation for demonstration of the ankle mortise joint.

**Fig. 6-118** Radiographer properly positioning the leg for demonstration of the ankle mortise joint. Note the action of the left hand (arrow) in turning the leg medially. Proper positioning requires turning the leg but not the foot.

**Fig. 6-119** AP oblique ankle, 15- to 20-degree medial rotation for demonstration of the ankle mortise joint. **A,** Properly positioned leg for demonstration of the mortise joint. **B,** Poorly positioned leg; radiograph had to be repeated. The foot was turned medially (white arrow) but not the leg. Note that the lateral mortise is closed (black arrow) because the "leg" was not medially rotated.
Structures shown
The entire ankle mortise joint should be demonstrated in profile. The three sides of the mortise joint should be visualized (Figs. 6-119 and 6-120).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:

- Entire ankle mortise joint
- No overlap of the anterior tubercle of the tibia and the superolateral portion of the talus with the fibula

- Talofibular joint space in profile
- Talus demonstrated with proper density

---

Fig. 6-120 Axial drawing of the inferior surface of the tibia and fibula at the ankle joint along with matching radiographs. **A**, AP ankle position with no rotation of the leg and foot. The drawing demonstrates the lateral malleolus positioned posteriorly when the leg is in true anatomic position. The radiograph shows normal overlap of the anterior tubercle and superolateral talus over the fibula (white arrows). **B**, AP oblique ankle, 15- to 20-degree medial rotation for demonstration of the ankle mortise. The drawing demonstrates both malleoli parallel with the IR. The radiograph clearly shows all three aspects of the mortise joint (arrows). **C**, AP oblique ankle, 45-degree medial rotation. The radiograph shows the tibiotalar joint (arrow) and the entire distal fibula in profile. Note the larger upper arrows that show the wider space created between the tibia and fibula as the leg is turned medially for the two AP oblique projections. This space should be observed when the ankle radiographs are checked for proper positioning.
Ankle

AP OBLIQUE PROJECTION

Lateral rotation

Image receptor: 8 x 10 inch (18 x 24 cm)

Position of patient
- Seat the patient on the radiographic table with the affected leg extended.

Position of part
- Place the plantar surface of the patient’s foot in the vertical position, and laterally rotate the leg and foot 45 degrees.
- Rest the foot against a foam wedge for support, and center the ankle joint to the IR (Fig. 6-121).
- Shield gonads.

Central ray
- Perpendicular, entering the ankle joint midway between the malleoli

Structures shown
The lateral rotation oblique projection is useful in determining fractures and demonstrating the superior aspect of the calcaneus (Fig. 6-122).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Subtalar joint
- Calcaneal sulcus (superior portion of calcaneus)

Fig. 6-121 AP oblique ankle, lateral rotation.

Fig. 6-122 AP oblique ankle, lateral rotation.
Ankle

AP PROJECTION
STRESS METHOD

Stress studies of the ankle joint usually are obtained after an inversion or eversion injury to verify the presence of a ligamentous tear. Rupture of a ligament is demonstrated by widening of the joint space on the side of the injury when, without moving or rotating the lower leg from the supine position, the foot is forcibly turned toward the opposite side.

When the injury is recent and the ankle is acutely sensitive to movement, the orthopedic surgeon may inject a local anesthetic into the sinus tarsi preceding the examination. The physician adjusts the foot when it must be turned into extreme stress and holds or straps it in position for the exposure. The patient usually can hold the foot in the stress position when the injury is not too painful or after he or she has received a local anesthetic by asymmetrically pulling on a strip of bandage looped around the ball of the foot (Figs. 6-123 to 6-125).

Fig. 6-123 AP ankle in neutral position. Use of lead glove and stress of the joint is required to obtain inversion and eversion radiographs (see Figs. 6-125 and 6-126).

Fig. 6-124 AP ankle, neutral position.

Fig. 6-125 A, Eversion stress. No damage to the medial ligament is indicated. B, Inversion stress. Change in joint and rupture of lateral ligament (arrow) are seen.
Ankles

AP PROJECTION
WEIGHT-BEARING METHOD
Standing
This projection is performed to identify ankle joint space narrowing with weight-bearing.

Image receptor: 24 × 30 cm crosswise

Position of patient
• Place the patient in the upright position, preferably on a low platform that has a cassette groove. If such a platform is not available, use blocks to elevate the feet to the level of the x-ray tube (Fig. 6-126, A).
• Ensure that the patient has proper support. Never stand the patient on the radiographic table.

Position of part
• Place the cassette in the cassette groove of the platform or between blocks.
• Have the patient stand with heels pushed back against the cassette and toes pointing straight ahead toward the x-ray tube.
• Shield gonads.
Ankles

Central ray
Perpendicular to the center of the cassette

TECHNICAL NOTE: If needed, use a mobile unit to allow the x-ray tube to reach the floor level.

Structures shown
The resulting image shows an AP projection of both ankle joints and the relationship of the distal tibia and fibula with weight-bearing. It also demonstrates side to side comparison of the joint (Fig. 6-126, B).

EVALUATION CRITERIA
- Both ankles centered on the image
- Medial mortise is open
- Distal tibia and talus partially superimpose the distal fibula
- Lateral mortise is closed

RESEARCH: Catherine E. Hearty, MS, RT(R) performed the research and provided this new projection for this edition of the atlas.

Fig. 6-126 A, AP weight-bearing ankles. B, AP weight-bearing ankles.
AP PROJECTION

For this projection, as well as the lateral and oblique projections described in the following sections, the long axis of the IR is placed parallel with the long axis of the leg and centered to the midshaft. Unless the leg is unusually long, the IR will extend beyond the knee and ankle joints enough to prevent their being projected off the IR by the divergence of the x-ray beam. The IR must extend from 1 to 1½ (2.5 to 3.8 cm) inches beyond the joints. When the leg is too long for these allowances and the site of the lesion is not known, two images should be made. Diagonal use of a 35 X 43 cm IR is also an option if the leg is too long to fit lengthwise and if such use is permitted by the facility.

Image receptor: 18 X 43 cm or 35 X 43 cm for two images on one IR

Position of patient

- Place the patient in the supine position.

Position of part

- Adjust the patient’s body so that the pelvis is not rotated.
- Adjust the leg so that the femoral condyles are parallel with the IR and the foot is vertical.
- Flex the ankle until the foot is in the vertical position.
- If necessary, place a sandbag against the plantar surface of the foot to immobilize it in the correct position (Fig. 6-127).
- Shield gonads.

Central ray

- Perpendicular to the center of the leg

COMPUTED RADIOGRAPHY

If one IR is used for two images, the unexposed side must be covered with lead. Scattered radiation reaching the IP phosphor will produce an undiagnostic image or computer artifacts on both sides.

Fig. 6-127 AP tibia and fibula.
Structures shown
The resulting image shows the tibia, fibula, and adjacent joints (Fig. 6-128).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Ankle and knee joints on one or more AP projections
- Ankle and knee joints without rotation
- Proximal and distal articulations of the tibia and fibula moderately overlapped
- Trabecular detail and soft tissue for the entire leg

---

Fig. 6-128  
A, AP tibia and fibula. Long leg length prevented demonstration of the entire leg. A separate knee projection had to be performed on this patient.  
B, Short leg length allowed the entire leg to be shown. A spiral fracture of the distal tibia with accompanying spiral fracture of the proximal fibula (arrows) is seen. This radiograph demonstrates the importance of including the entire length of a long bone in trauma cases.  
C, AP tibia and fibula on a 4 year old with neurofibromatosis.  
(C, Courtesy of Tamie Krohn.)
**LATERAL PROJECTION**

**Mediolateral**

*Image receptor:* 18 × 43 cm or 35 × 43 cm for two images on one IR.

**Position of patient**
- Place the patient in the supine position.

**Position of part**
- Turn the patient toward the affected side with the leg on the IR.
- Adjust the rotation of the body to place the patella perpendicular to the IR, and ensure that a line drawn through the femoral condyles is also perpendicular.
- Place sandbag supports where needed for the patient’s comfort and to stabilize the body position (Fig. 6-129).

**Alternate method**
- When the patient cannot be turned from the supine position, the lateral projection may be taken cross-table using a horizontal central ray.
- Lift the leg enough for an assistant to slide a rigid support under the patient’s leg.
- The IR may be placed between the legs and the central ray directed from the lateral side.
- **Shield gonads.**

**Central ray**
- Perpendicular to the midpoint of the leg.

**COMPUTED RADIOGRAPHY**

If one IR is used for two images, the unexposed side must be covered with lead. Scattered radiation reaching the IP phosphor will produce an undiagnostic image or computer artifacts on both sides.

**Structures shown**
The resulting image shows the tibia, fibula, and adjacent joints (Fig. 6-130).

![Fig. 6-129 Lateral tibia and fibula.](image-url)
EVALUATION CRITERIA

The following should be clearly demonstrated:

- Ankle and knee joints on one or more images
- Distal fibula lying over the posterior half of the tibia
- Slight overlap of the tibia on the proximal fibular head
- Ankle and knee joints not rotated
- Possibly no superimposition of femoral condyles because of divergence of the beam
- Moderate separation of the tibial and fibular bodies, or shafts except at their articular ends
- Trabecular detail and soft tissue

**Fig. 6-130** A, and B, Lateral tibia and fibula. C, Lateral postreduction tibia and fibula, showing a fixation device.
AP OBLIQUE PROJECTIONS
Medial and lateral rotations

Image receptor: 18 × 43 cm or 35 × 43 cm for two exposures on one IR

Position of patient
• Place the patient in the supine position on the radiographic table.

Position of part
• Perform oblique projections of the leg by alternately rotating the limb 45 degrees medially (Fig. 6-131) or laterally (Fig. 6-132). For the medial rotation, ensure that the leg is turned inward and not just the foot.
• For the medial oblique projection, elevate the affected hip enough to rest the medial side of the foot and ankle against a 45-degree foam wedge, and place a support under the greater trochanter.
• Shield gonads.

Central ray
• Perpendicular to the midpoint of the IR

Fig. 6-131 AP oblique leg, medial rotation.
Fig. 6-132 AP oblique leg, lateral rotation.
If one IR is used for two images, ensure that the unexposed side is covered with lead. Scattered radiation reaching the IP phosphor will produce an undiagnostic image or computer artifacts, on both sides.

**Structures shown**

The resulting image shows a 45-degree oblique projection of the bones and soft tissues of the leg and one or both of the adjacent joints (Figs. 6-133 and 6-134).

**EVALUATION CRITERIA**

The following should be clearly demonstrated:

**Medial rotation**

- Proximal and distal tibiotalar articulations
- Maximum interosseous space between the tibia and fibula
- Ankle and knee joints

**Lateral rotation**

- Fibula superimposed by lateral portion of tibia
- Ankle and knee joints

---

**Fig. 6-133** AP oblique leg, medial rotation, showing a fixation device.

**Fig. 6-134** AP oblique leg, lateral rotation, with a fixation device in place.
Knee

**AP PROJECTION**

Radiographs of the knee may be taken with or without use of a grid. The size of the patient's knee and the preference of the radiographer and physician are the factors considered in reaching a decision.

Attention is again called to the need for gonad shielding in examinations of the lower limbs. (Lead shielding is not shown on illustrations of the patient model because it would obstruct demonstration of the body position.)

**Image receptor:** 24 X 30 cm lengthwise

**Position of patient**

- Place the patient in the supine position, and adjust the body so that the pelvis is not rotated.

**Position of part**

- With the IR under the patient's knee, flex the joint slightly, locate the apex of the patella, and as the patient extends the knee, center the IR about 1/2 inch (1.3 cm) below the patellar apex. This will center the IR to the joint space.
- Adjust the patient's leg by placing the femoral epicondyle parallel with the IR for a true AP projection (Fig. 6-135). The patella will lie slightly off center to the medial side. If the knee cannot be fully extended, a curved IR may be used.
- *Shield gonads.*

**Central ray**

- Directed to a point 1/2 inch (1.3 cm) inferior to the patellar apex.
- Variable, depending on the measurement between the anterior superior iliac spine (ASIS) and the tabletop (Fig. 6-136), as follows:

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Central Ray Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;19 cm</td>
<td>3 to 5 degrees <em>caudad</em> (thin pelvis)</td>
</tr>
<tr>
<td>19 to 24 cm</td>
<td>0 degrees</td>
</tr>
<tr>
<td>&gt;24 cm</td>
<td>3 to 5 degrees <em>cephalad</em> (large pelvis)</td>
</tr>
</tbody>
</table>


**Structures shown**

The resulting image shows an AP projection of the knee structures (Fig. 6-137).

**EVALUATION CRITERIA**

The following should be clearly demonstrated:

- Open femorotibial joint space
- Knee fully extended if patient’s condition permits
- Interspaces of equal width on both sides if the knee is normal
- Patella completely superimposed on the femur
- No rotation of the femur and tibia
- Slight superimposition of the fibular head if the tibia is normal
- Soft tissue around the knee joint
- Bony detail surrounding the patella on the distal femur

![Fig. 6-135 AP knee.](image)

![Fig. 6-136 Pelvic thickness and central ray angles for AP knee radiographs.](image)

(Modified from Martensen KM: Alternate AP knee method assures open joint space, Radiol Technol 64:19, 1992.)
Fig. 6-137  A, AP knee with CR angled 5 degrees cephalad. Patient's ASIS to tabletop distance was greater than 25 cm. B, Same patient as A with CR perpendicular. Note joint space is not opened as well. C, AP knee on a 15 year old. Arrow pointing to a benign lesion in the tibia.
**PA PROJECTION**

**Image receptor:** 24 x 30 cm length-wise

**Position of patient**
- Place the patient in the prone position with toes resting on the radiographic table, or place sandbags under the ankle for support.

**Position of part**
- Center a point ½ inch (1.3 cm) below the patellar apex to the center of the IR, and adjust the patient’s leg so that the femoral epicondyles are parallel with the tabletop. Because the knee is balanced on the medial side of the obliquely located patella, care must be used in adjusting the knee (Fig. 6-138).
- Shield gonads.

**Central ray**
- Directed at an angle of 5 degrees caudad to exit a point ½ inch (1.3 cm) inferior to the patellar apex. Because the tibia and fibula are slightly inclined, the central ray will be parallel with the tibial plateau.

---

Fig. 6-138  PA knee.
**Structures shown**
The resulting image shows a PA projection of the knee (Fig. 6-139).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Open femorotibial joint space
- Knee fully extended if the patient's condition permits
- Interspaces of equal width on both sides if the knee is normal
- No rotation of femur if tibia is normal
- Slight superimposition of the tibial head with the tibia
- Soft tissue around the knee joint
- Bony detail surrounding the patella

![Fig. 6-139 PA knee.](image)
**LATERAL PROJECTION**

**Mediolateral**

**Image receptor:** 24 × 30 cm lengthwise

**Position of patient**
- Ask the patient to turn onto the affected side. Ensure that the pelvis is not rotated.
- For a standard lateral projection, have the patient bring the knee forward and extend the other limb behind it (Fig. 6-140). The other limb may also be placed in front of the affected knee on a support block.

**Position of part**
- A flexion of 20 to 30 degrees is usually preferred because this position relaxes the muscles and shows the maximum volume of the joint cavity.\(^1\)
- To prevent fragment separation in new or unhealed patellar fractures, the knee should not be flexed more than 10 degrees.
- Place a support under the ankle.
- Grasp the epicondyles and adjust them so that they are perpendicular to the IR (condyles superimposed). The patella will be perpendicular to the plane of the IR (Fig. 6-141).
- Shield gonads.


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Fig. 6-140 Lateral knee showing 5-degree cephalad angulation of central ray.

Fig. 6-141 A, Improperly positioned lateral knee. Note condyles not superimposed (black arrows) and patella is closed joint. B, Same patient as A after correct positioning. Condyles are superimposed and patellofemoral joint is open.
Central ray
- Directed to the knee joint 1 inch (2.5 cm) distal to the medial epicondyle at an angle of 5 to 7 degrees cephalad. This slight angulation of the central ray will prevent the joint space from being obscured by the magnified image of the medial femoral condyle. In addition, in the lateral recumbent position, the medial condyle will be slightly inferior to the lateral condyle.
- Center the IR to the central ray.

Structures shown
The resulting radiograph shows a lateral image of the distal end of the femur, patella, knee joint, proximal ends of the tibia and fibula, and adjacent soft tissue (Figs. 6-142).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Femoral condyles superimposed (Locate the adductor tubercle on the posterior surface of the medial condyle to identify the medial condyle to determine whether the knee is overrotated or underrotated.)
- Open joint space between femoral condyles and tibia
- Patella in a lateral profile
- Open patellofemoral joint space
- Fibular head and tibia slightly superimposed (Overrotation causes less superimposition, and underrotation causes more superimposition.)
- Knee flexed 20 to 30 degrees
- All soft tissue around the knee
- Femoral condyles with proper density

Fig. 6-142 A, Lateral knee. B, Lateral knee showing severe arthritis.
Knees

△ AP PROJECTION
WEIGHT-BEARING METHOD
Standing
Leach, Gregg, and Siber\(^1\) recommended that a bilateral weight-bearing AP projection be routinely included in the radiographic examination of arthritic knees. They found that a weight-bearing study often reveals narrowing of a joint space that appears normal on the non-weight-bearing study.

Image receptor: 35 × 43 cm crosswise for bilateral image


Position of patient
- Place the patient in the upright position with back toward a vertical grid device.

Position of part
- Adjust the patient’s position to center the knees to the IR.
- Place the toes straight ahead, with the feet separated enough for good balance.
- Ask the patient to stand straight with knees fully extended and weight equally distributed on the feet.
- Center the IR ½ inch (1.3 cm) below the apices of the patellae (Fig. 6-143).
- Shield gonads.

Central ray
- Horizontal and perpendicular to the center of the IR, entering at a point ½ inch (1.3 cm) below the apices of the patellae

Structures shown
The resulting image shows the joint spaces of the knees. Varus and valgus deformities can also be evaluated with this procedure (Fig. 6-144).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- No rotation of the knees
- Both knees
- Knee joint space centered to the exposure area
- Adequate IR size to demonstrate the longitudinal axis of the femoral and tibial bodies or shafts

Fig. 6-143 AP bilateral weight-bearing knees.

Fig. 6-144 AP bilateral weight-bearing knees.
Knees

PA PROJECTION
ROSENBERG METHOD\(^1\)

WEIGHT-BEARING

Standing flexion

**Image receptor:** 35 × 43 cm crosswise for bilateral knees

**Position of patient**
- Place the patient in the standing position with the anterior aspect of the knees centered to the vertical grid device.

**Position of part**
- For a direct PA projection, have the patient stand upright with knees in contact with the vertical grid device.
- Center the IR at a level \(\frac{1}{2}\) inch (1.3 cm) below the apices of the patellae.
- Have the patient grasp the edge of the grid device and flex knees to place the femurs at an angle of 45 degrees (Fig. 6-145).
- **Shield gonads.**

**Central ray**
- Horizontal and perpendicular to the center of the IR. The CR is perpendicular to the tibia and fibula. A 10-degree caudal angle is sometimes used.

**Structures shown**
PA weight-bearing method is useful for evaluating joint space narrowing and demonstrating articular cartilage disease (Fig. 6-146). The image is similar to those obtained when radiographing the intercondylar fossa.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- No rotation of the knees
- Both knees
- Knee joint centered to the exposure area

**NOTE:** For a weight-bearing study of a single knee, the patient puts full weight on the affected side. The patient may balance with slight pressure on the toes of the unaffected side.

**AP OBLIQUE PROJECTION**

**Lateral rotation**

**Image receptor:** 24 x 30 cm lengthwise

**Position of patient**
- Place the patient on the radiographic table in the supine position, and support the ankles.

**Position of part**
- If necessary, elevate the hip of the unaffected side enough to rotate the affected limb.
- Support the elevated hip and knee of the unaffected side (Fig. 6-147).
- Center the IR ½ inch (1.3 cm) below the apex of the patella.
- Externally rotate the limb 45 degrees.
- *Shield gonads.*

**Central ray**
- Directed ½ inch (1.3 cm) inferior to the patellar apex. The angle is variable, depending on measurement between the ASIS and the tabletop, as follows:
  - <19 cm: 3 to 5 degrees caudad
  - 19 to 24 cm: 0 degrees
  - >24 cm: 3 to 5 degrees cephalad

**Structures shown**
The resulting image shows an AP oblique projection of the laterally rotated femoral condyles, patella, tibial condyles, and head of the fibula (Fig. 6-148).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Medial femoral and tibial condyles
- Tibial plateaus
- Open knee joint
- Fibula superimposed over the lateral half of the tibia
- Margin of the patella projected slightly beyond the edge of the lateral femoral condyle
- Soft tissue around the knee joint
- Bony detail on the distal femur and proximal tibia
AP OBLIQUE PROJECTION

Position of part
- Medially rotate the limb, and elevate the hip of the affected side enough to rotate the limb 45 degrees.
- Place a support under the hip, if needed (Fig. 6-149).
- *Shield gonads.*

Central ray
- Directed ½ inch (1.3 cm) inferior to the patellar apex; the angle is variable, depending on the measurement between the ASIS and the tabletop, as follows:
  - $<19$ cm: 3 to 5 degrees caudal
  - 19 to 24 cm: 0 degrees
  - $>24$ cm: 3 to 5 degrees cephalad

Position of patient
- Place the patient on the table in the supine position, and support the ankles.
- Medially rotate the limb, and elevate the hip of the affected side enough to rotate the limb 45 degrees.
- Place a support under the hip, if needed (Fig. 6-149).
- *Shield gonads.*

Structures shown
The resulting image shows an AP oblique projection of the medially rotated femoral condyles, patella, tibial condyles, proximal tibiofibular joint, and head of the fibula (Fig. 6-150).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Tibia and fibula separated at their proximal articulation
- Posterior tibia
- Lateral condyles of the femur and tibia
- Both tibial plateaus
- Open knee joint
- Margin of the patella projecting slightly beyond the medial side of the femoral condyle
- Soft tissue around the knee joint
- Bony detail on the distal femur and proximal tibia
**Knee**

**PA OBLIQUE PROJECTION**

**Lateral rotation**

**Image receptor:** 24 × 30 cm lengthwise

**Position of patient**
- Place the patient on the radiographic table in the prone position.

**Position of part**
- Elevate the hip of the affected side, and laterally rotate the toes and knee to form a 45-degree angle.
- Support the hip (Fig. 6-151).
- Shield gonads.
- Holmblad\(^1\) recommended that the knee be flexed about 10 degrees


**Central ray**
- Perpendicular through the knee joint at a level ½ inch (1.3 cm) below the patellar apex

**Structures shown**
The resulting image shows a PA oblique projection of the laterally rotated femoral condyles, patella, tibial condyles, and fibular head (Fig. 6-152).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Medial femoral and tibial condyles
- Tibial plateaus
- Open knee joint
- Fibula superimposed over the lateral portion of the tibia
- Patellar margin projecting slightly beyond the side of the lateral femoral condyle
- Soft tissue around the knee joint
- Bony detail on the distal femur and proximal tibia

---

**Fig. 6-151** PA oblique knee, lateral rotation.

**Fig. 6-152** PA oblique knee.
Knee

PA OBLIQUE PROJECTION

Medial rotation

**Image receptor:** 24 × 30 cm length-wise

**Position of patient**

- Place the patient in the prone position.

**Position of part**

- Medially rotate the leg and foot, and elevate the hip of the unaffected side to rotate the limb 45 degrees medially.
- Place a support under the hip, if needed (Fig. 6-153).
- Shield gonads.

**Central ray**

- Perpendicular through the knee joint at the level ½ inch (1.3 cm) below the apex of the patella

**Structures shown**

The resulting image shows a PA oblique projection of the medially rotated femoral condyles, patella, tibial condyles, proximal tibiofibular joint, and fibular head (Fig. 6-154).

---

**EVALUATION CRITERIA**

The following should be clearly demonstrated:

- Tibia and fibula separated at their proximal articulation
- Posterior tibia
- Lateral condyles of the femur and tibia
- Both tibial plateaus
- Open knee joint
- Margin of the patella projecting slightly beyond the side of the medial femoral condyle
- Soft tissue around the knee joint
- Bony detail on the distal femur and proximal tibia

---

Fig. 6-153  PA oblique knee, medial rotation.

Fig. 6-154  PA oblique knee.
**PA AXIAL PROJECTION**

**HOLMBlAD METHOD**

The PA axial, or "tunnel," projection, first described by Holmblad in 1937, required that the patient assume a kneeling position on the radiographic table. In 1983 the Holmblad method was modified so that if the patient's condition allowed, a standing position could be used.

- **Image receptor:** $8 \times 10$ inch ($18 \times 24$ cm)

**Position of patient**

- After consideration of the patient's safety, place the patient in one of three positions: (1) standing with the knee of interest flexed and resting on a stool at the side of the radiographic table (Fig. 6-155), (2) standing at the side of the radiographic table with the affected knee flexed and placed in contact with the front of the IR (Fig. 6-156), or (3) kneeling on the radiographic table as originally described by Holmblad, with the affected knee over the IR (Fig. 6-157). In all three approaches, the patient leans on the radiographic table for support.

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Intercondylar Fossa

Position of part
• For all positions, place the IR against the anterior surface of the patient's knee, and center the IR to the apex of the patella. Flex the knee 70 degrees from full extension (20-degree difference from the central ray, as shown in Fig. 6-158).
• Shield gonads.

Central ray
• Perpendicular to the lower leg, entering the midpoint of the IR for all three positions

Structures shown
The resulting image shows the intercondylar fossa of the femur and the medial and lateral intercondylar tubercles of the intercondylar eminence in profile (Fig. 6-159). Holmblad\(^1\) stated that the degree of flexion used in this position widens the joint space between the femur and tibia and gives an improved image of the joint and the surfaces of the tibia and femur.


EVALUATION CRITERIA
The following should be clearly demonstrated:
- Open fossa
- Posteroinferior surface of the femoral condyles
- Intercondylar eminence and knee joint space
- Apex of the patella not superimposing the fossa
- No rotation, evident by slight tibiofibular overlap
- Soft tissue in the fossa and interspaces
- Bony detail on the intercondylar eminence, distal femur, and proximal tibia

NOTE: The bilateral examination is described on p. 314 (also see Figs. 6-145 and 6-146).

Fig. 6-158 Alignment relationship for any of three intercondylar fossa approaches: Holmblad method.

Fig. 6-159 PA axial ("tunnel") intercondylar fossa: Holmblad method.
Intercondylar Fossa

**PA AXIAL PROJECTION**

**CAMP-COVENTRY METHOD**

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise

**Position of patient**
- Place the patient in the prone position, and adjust the body so that it is not rotated.

**Position of part**
- Flex the patient’s knee to either a 40- or 50-degree angle, and rest the foot on a suitable support.
- Center the upper half of the IR to the knee joint; the central ray angulation projects the joint to the center of the IR (Figs. 6-160 and 6-161).
- A protractor may be used beside the leg to determine the correct leg angle.
- Adjust the leg so that the knee has no medial or lateral rotation.
- Shield gonads.

**Central ray**
- Perpendicular to the long axis of the leg and centered to the knee joint (i.e., over the popliteal depression)
- Angled 40 degrees when the knee is flexed 40 degrees and 50 degrees when the knee is flexed 50 degrees

**Structures shown**
This axial image demonstrates an unobstructed projection of the intercondylar fossa and the medial and lateral intercondylar tubercles of the intercondylar eminence (Figs. 6-162 and 6-163).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Open fossa
- Posteroinferior surface of the femoral condyles
- Intercondylar eminence and knee joint space
- Apex of the patella not superimposing the fossa
- No rotation, evident by slight tibiofibular overlap
- Soft tissue in the fossa and interspaces
- Bony detail on the intercondylar eminence, distal femur, and proximal tibia

**NOTE:** In routine examinations of the knee joint, an intercondylar fossa projection is usually included to detect loose bodies ("joint mice"). The projection is also used in evaluating split and displaced cartilage in osteochondritis dissecans and flattening, or underdevelopment, of the lateral femoral condyle in congenital slipped patella.

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Fig. 6-160 PA axial ("tunnel") intercondylar fossa: Camp-Coventry method.

Fig. 6-161 PA axial ("tunnel") intercondylar fossa: Camp-Coventry method.
Intercondylar Fossa

Fig. 6-162  Camp-Coventry method. A, Flexion of knee at 40 degrees (same patient as in Fig. 6-163). B, Flexion of knee at 40 degrees in a 13-year-old patient. Note epiphyses (arrows).

Fig. 6-163  Flexion of knee at 50 degrees (same patient as in Fig. 6-157). Camp-Coventry method.
**Intercondylar Fossa**

**AP AXIAL PROJECTION**  
**BÉCLÈRE METHOD**

**Image receptor:** 8 x 10 inch (18 x 24 cm) crosswise

**Position of patient**
- Place the patient in the supine position, and adjust the body so that it is not rotated.

**Position of part**
- Flex the affected knee enough to place the long axis of the femur at an angle of 60 degrees to the long axis of the tibia.
- Support the knee on sandbags (Fig. 6-164).
- Place the IR under the knee, and position the IR so that the center point coincides with the central ray.

**Central ray**
- Adjust the leg so that the femoral condyles are equidistant from the IR. Immobilize the foot with sandbags.
- Shield gonads.

**Central ray**
- Perpendicular to the long axis of the tibia, entering the knee joint ½ inch (1.3 cm) below the patellar apex.

**Structures shown**
The resulting image shows the intercondylar fossa, intercondylar eminence, and knee joint (Figs. 6-165 and 6-166).

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**Fig. 6-164** AP axial intercondylar fossa with transverse IR: Béclère method.

**Fig. 6-165** AP axial intercondylar fossa: Béclère method with identified anatomy.
EVALUATION CRITERIA
The following should be clearly demonstrated:
- Open intercondylar fossa
- Posteroinferior surface of the femoral condyles
- Intercondylar eminence and knee joint space
- No superimposition of the fossa by the apex of the patella
- No rotation, evident by slight tibiofibular overlap
- Soft tissue in the fossa and interspaces
- Bony detail on the intercondylar eminence, distal femur, and proximal tibia

Fig. 6-166 Same image as Fig. 6-165. Note clear visualization of the intercondylar fossa.
**Fig. 6-167** PA patella.

**Fig. 6-168** AP patella showing fracture (arrow).

---

**PA PROJECTION**

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise

**Position of patient**
- Place the patient in the prone position.
- If the knee is painful, place one sandbag under the thigh and another under the leg to relieve pressure on the patella.

**Position of part**
- Center the IR to the patella.
- Adjust the position of the leg to place the patella parallel with the plane of the IR. This usually requires that the heel be rotated 5 to 10 degrees laterally (Fig. 6-167).
- Shield gonads.

**Central ray**
- Perpendicular to the midpopliteal area exiting the patella.
- Collimate closely to the patellar area.

**Structures shown**
The PA projection of the patella provides sharper recorded detail than in the AP projection because of a closer object-to-image receptor distance (OID) (Figs. 6-168 and 6-169).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Patella completely superimposed by the femur
- Adequate penetration for visualization of the patella clearly through the superimposing femur
- No rotation

---

**Fig. 6-169** A, Conventional PA projection of the patella shows a vertical radiolucent line (arrow) passing through the junction of the lateral and middle third of the patella. B, On tomography this defect extends from the superior to the inferior margin of the patella. It is a bipartite patella and not a fracture.
LATERAL PROJECTION
Mediolateral

Image receptor: 8 × 10 inch (18 × 24 cm) lengthwise

Position of patient
• Place the patient in the lateral recumbent position.

Position of part
• Ask the patient to turn onto the affected hip. A sandbag may be placed under the ankle for support.
• Have the patient flex the unaffected knee and hip, and place the unaffected foot in front of the affected limb for stability.
• Flex the affected knee approximately 5 to 10 degrees. Increasing the flexion reduces the patellofemoral joint space.
• Adjust the knee in the lateral position so that the femoral epicondyles are superimposed and the patella is perpendicular to the IR (Fig. 6-170).
• Shield gonads.
• Center the IR to the patella.

Central ray
• Perpendicular to the IR, entering the knee at the midpatellofemoral joint.
• Collimate closely to the patellar area.

COMPUTED RADIOGRAPHY

Collimation must be close to keep unnecessary radiation from reaching the IP phosphor.

Structures shown
The resulting image shows a lateral projection of the patella and patellofemoral joint space (Fig. 6-171).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Knee flexed 5 to 10 degrees
- Open patellofemoral joint space
- Patella in lateral profile
- Close collimation
Patella

PA OBLIQUE PROJECTION
Medial rotation

| Image receptor: 8 × 10 inch (18 × 24 cm) lengthwise |

Position of patient
- Place the patient in the prone position.

Position of part
- Flex the patient’s knee approximately 5 to 10 degrees.
- Medially rotate the knee 45 to 55 degrees from the prone position.
- Center the medial portion of the patella to the IR (Fig. 6-172).
- Shield gonads.

Central ray
- Perpendicular to the IR, exiting the palpated patella.
- Collimate closely to the patellar area.

Structures shown
A PA oblique image of the medial portion of the patella is demonstrated free of the femur (Fig. 6-173).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Majority of the medial patella free of superimposition of the femur
- Lateral margin of patella superimposed over the femur
- Closely collimated image

Fig. 6-172 PA oblique patella, medial rotation.

Fig. 6-173 PA oblique patella.
Patella

PA OBLIQUE PROJECTION
Lateral rotation

Image receptor: 8 x 10 inch (18 x 24 cm) lengthwise

Position of patient
- Place the patient in the prone position.

Position of part
- Flex the patient’s knee 5 to 10 degrees, and externally (laterally) rotate the knee 45 to 55 degrees from the prone position.
- Center the lateral portion of the patella to the IR (Fig. 6-174).
- Shield gonads.

Central ray
- Perpendicular to the IR, exiting the palpated patella.
- Collimate closely to the patellar area.

Structures shown
The resulting image shows an oblique projection of the lateral aspect of the patella free of the femur (Fig. 6-175).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Majority of the patella free of superimposition of the femur
- Medial margin of patella superimposed over the femur
- Closely collimated image
PA AXIAL OBLIQUE PROJECTION
KUCHENDORF METHOD
Lateral rotation

- **Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise

- **Position of patient**
  - Place the patient in the prone position.
  - Elevate the hip of the affected side 2 or 3 inches.
  - Place a sandbag under the ankle and foot, and adjust it so that the knee is slightly flexed (approximately 10 degrees) to relax the muscles.

- **Position of part**
  - Center the IR to the patella.
  - Laterally rotate the knee approximately 35 to 40 degrees from the prone position (this position is more comfortable for the patient than the direct prone, because no pressure is placed on the injured patella. The patient rarely objects to the slight pressure required to displace the patella laterally).
  - Place the index finger against the medial border of the patella, and press it laterally.
  - Rest the knee on its anteromedial side to hold the patella in a position of lateral displacement (Figs. 6-176 and 6-177).
  - *Shield gonads.*

- **Central ray**
  - Directed to the joint space between the patella and the femoral condyles at an angle of 25 to 30 degrees caudad. It enters the posterior surface of the patella.

- **Structures shown**
The resulting image will show a slightly oblique PA projection of the patella, with most of the patella free of superimposed structures (Fig. 6-178).

- **EVALUATION CRITERIA**
The following should be clearly demonstrated:
  - Majority of the patella free of superimposition by the femur
  - Patella and its outline where it is superimposed by the femur
PATIENTAL PROJECTION
HUGHSTON METHOD

Radiography of the patella has been the topic of hundreds of articles. For a tangential radiograph, the patient may be placed in any of the following body positions: prone, supine, lying on the side, seated on the table, seated on the radiographic table with the leg hanging over the edge, or standing.

Various authors have described the degree of flexion of the knee joint as being as low as 20 degrees to as much as 120 degrees. Laurin reported that patellar subluxation is easier to demonstrate when the knee is flexed 20 degrees and noted a limitation of using this small angle. Modern radiographic equipment often will not permit such small angles because of the large size of the collimator.

Fodor, Malott, and Weinberg and Merchant et al. recommended a 45-degree flexion of the knee, and Hughston recommended an approximately 55-degree angle with the central ray angled 45 degrees.

**Image receptor:** 8 x 10 inch (18 x 24 cm) for unilateral examination; 24 x 30 cm crosswise for bilateral examination

**Position of patient**
- Place the patient in a prone position with the foot resting on the radiographic table.
- Adjust the body so that it is not rotated.

**Position of part**
- Place the IR under the patient’s knee, and slowly flex the affected knee so that the tibia and fibula form a 50- to 60-degree angle from the table.
- Rest the foot against the collimator, or support it in position (Fig. 6-179).

- Ensure that the collimator surface is not hot because this could burn the patient.
- Adjust the patient’s leg so that it is not rotated medially or laterally from the vertical plane.
- Shield gonads.

**Central ray**
- Angled 45 degrees cephalad and directed through the patellofemoral joint

**Structures shown**
The tangential image shows subluxation of the patella and patellar fractures and allows radiologic assessment of the femoral condyles. Hughston recommended that both knees be examined for comparison (Fig. 6-180).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Patella in profile
- Open patellofemoral articulation
- Surfaces of the femoral condyles
- Soft tissue of the femoropatellar articulation
- Bony recorded detail on the patella and femoral condyles

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Patella and Patellofemoral Joint

TANGENTIAL PROJECTION

MERCHANT METHOD¹

Image receptor: 24 × 30 cm crosswise for bilateral examination

SID: A 6-foot (2-m) SID is recommended to reduce magnification.

Position of patient

- Place the patient supine with both knees at the end of the radiographic table.
- Support the knees and lower legs by an adjustable IR-holding device.²
- To increase comfort and relaxation of the quadriceps femoris, place pillows or a foam wedge under the patient’s head and back.

Position of part

- Using the “axial viewer” device, elevate the patient’s knees approximately 2 inches to place the femora parallel with the tabletop (Figs. 6-181 and 6-182).
- Adjust the angle of knee flexion to 40 degrees. (Merchant reported that the degree of angulation may be varied between 30 to 90 degrees to demonstrate various patellofemoral disorders.)
- Strap both legs together at the calf level to control leg rotation and allow patient relaxation.
- Place the IR perpendicular to the central ray and resting on the patient’s shins (a thin foam pad aids comfort) approximately 1 foot distal to the patellae.

²Merchant AC: “The Axial Viewer,” Orthopedic Products, 2500 Hospital Dr., Bldg. 7, Mountain View, CA 94040.

Fig. 6-181 Tangential patella and patellofemoral joint: Merchant method.

Fig. 6-182 “The axial viewer” device.

• Ensure that the patient is able to relax. Relaxation of the quadriceps femoris is critical for an accurate diagnosis. If these muscles are not relaxed, a subluxed patella may be pulled back into the intercondylar sulcus, showing a false normal appearance.

• Record the angle of knee flexion for reproducibility during follow-up examinations, because the severity of patella subluxation commonly changes inversely with the angle of knee flexion.

• Shield gonads.
Patella and Patellofemoral Joint

Central ray
- Perpendicular to the IR
- With 40-degree knee flexion, angle the central ray 30 degrees caudad from the horizontal plane (60 degrees from vertical) to achieve a 30-degree central ray-to-femur angle. The central ray enters midway between the patellae at the level of the patellofemoral joint.

Structures shown
The bilateral tangential image demonstrates an axial projection of the patellae and patellofemoral joints (Fig. 6-183). Because of the right-angle alignment of the IR and central ray, the patellae are seen as nondistorted albeit slightly magnified images.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Patellae in profile
- Femoral condyles and intercondylar sulcus
- Open patellofemoral articulations

Fig. 6-183 A, Normal tangential radiograph of congruent patellofemoral joints, showing the patellae to be well centered with a normal trabecular pattern. B, Abnormal tangential radiograph showing abnormally shallow intercondylar sulci, misshapen and laterally subluxed patellae, and incongruent patellofemoral joints (left worse than right).

(Courtesy Alan J. Merchant.)
Patella and Patellofemoral Joint

TANGENTIAL PROJECTION
SETTEGAST METHOD

Because of the danger of fragment displacement by the acute knee flexion required for this procedure, this projection should not be attempted until a transverse fracture of the patella has been ruled out with a lateral image, or if the patient is in pain.

**Image receptor:** $8 \times 10$ inch ($18 \times 24$ cm)

**Position of patient**
- Place the patient in the supine or prone position. The latter is preferable because the knee can usually be flexed to a greater degree and immobilization is easier (Figs. 6-184 and 6-185).
- If the patient is seated on the radiographic table, hold the IR securely in place (Fig. 6-186). Alternative positions are shown in Figs. 6-187 and 6-188.

**Position of part**
- Flex the patient's knee slowly as much as possible or until the patella is perpendicular to the IR if the patient's condition permits. With slow, even flexion, the patient will be able to tolerate the position, whereas quick, uneven flexion may cause too much pain.
- If desired, loop a long strip of bandage around the patient's ankle or foot. Have the patient grasp the ends over the shoulder to hold the leg in position. Gently adjust the leg so that its long axis is vertical.

![Fig. 6-184 Tangential patella and patellofemoral joint: Settegast method.](image1)

![Fig. 6-185 Tangential patella and patellofemoral joint: Settegast method.](image2)

![Fig. 6-186 Tangential patella and patellofemoral joint: Settegast method.](image3)

![Fig. 6-187 Tangential patella and patellofemoral joint: patient seated.](image4)

![Fig. 6-188 Tangential patella and patellofemoral joint: patient lateral.](image5)
Patella and Patellofemoral Joint

- Place the IR transversely under the knee, and center it to the joint space between the patella and the femoral condyles.
- Shield gonads.
- By maintaining the same OID and SID relationships, this position can be obtained with the patient in a lateral or seated position (see Figs. 6-187 and 6-188).

**NOTE:** When the central ray is directed toward the patient's upper body (see Figs. 6-186 and 6-187), the thorax and thyroid should be shielded. Gonad shielding (not shown) should be used in all patients.

**Central ray**
- Perpendicular to the joint space between the patella and the femoral condyles when the joint is perpendicular. When the joint is not, the degree of central ray angulation depends on the degree of flexion of the knee. The angulation typically will be 15 to 20 degrees.
- Close collimation is recommended.

**COMPUTED RADIOGRAPHY**
Collimation must be close to prevent unnecessary radiation from reaching the IP phosphor.

**Structures shown**
The resulting image shows vertical fractures of bone and the articulating surfaces of the patellofemoral articulation (Figs. 6-189 and 6-190).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Patella in profile
- Open patellofemoral articulation
- Surfaces of the femoral condyles
- Soft tissue of the patellofemoral articulation
- Bony detail on the patella and femoral condyles

Fig. 6-189 A, Tangential patella and patellofemoral joint: Settgest method. B, Fracture (arrow).

Fig. 6-190 Bilateral patella examination. For this examination, the legs should be strapped together at the level of the calf, using an appropriate binding to control femoral rotation.
Femur

AP PROJECTION

If the femoral heads are separated by an unusually broad pelvis, the bodies (shafts) will be more strongly angled toward the midline.

**Image receptor:** 18 × 43 cm or 35 × 43 cm

**Position of patient**
- Place the patient in the supine position.
- Check the pelvis to ensure it is not rotated.

**Position of part**
- Center the affected thigh to the midline of the IR. When the patient is too tall to include the entire femur, include the joint closest to the area of interest on one image (Fig. 6-191).

**With the knee included**
- For projection of the distal femur, rotate the patient’s limb internally to place it in true anatomic position. The limb will naturally be turned externally when laying on the table. Ensure that the epicondyles are parallel with the IR.
- Place the bottom of the IR 2 inches (5 cm) below the knee joint.

**With the hip included**
- For projection of the proximal femur, which must include the hip joint, place the top of the IR at the level of the ASIS.
- Rotate the limb internally 10 to 15 degrees to place the femoral neck in profile.
- Shield gonads.

**Central ray**
- Perpendicular to the midfemur and the center of the IR

**Structures shown**
The resulting image shows an AP projection of the femur, including the knee joint and/or hip (Figs. 6-192 and 6-193).
**EVALUATION CRITERIA**

The following should be clearly demonstrated:

- Majority of the femur and the joint nearest to the pathologic condition or site of injury (A second projection of the other joint is recommended.)
- Femoral neck not foreshortened on the proximal femur
- Lesser trochanter not seen beyond the medial border of the femur or only a very small portion seen on the proximal femur
- No knee rotation on the distal femur
- Gonad shielding when indicated, but the shield not covering proximal femur
- Any orthopedic appliance in its entirety
- Trabecular recorded detail on the femoral shaft

---

![Fig. 6-193](image)

**Fig. 6-193** A, AP proximal femur. B, AP proximal femur showing a "total hip" arthroplasty procedure.
**Femur**

**LATERAL PROJECTION**

Mediolateral

Image receptor: 18 × 43 cm or 35 × 43 cm lengthwise

Position of patient
- Ask the patient to turn onto the affected side.
- Adjust the body position, and center the affected thigh to the midline of the grid.

Position of part

*With the knee included*
- For projection of the distal femur, draw the patient's uppermost limb forward and support it at hip level on sandbags.
- Adjust the pelvis in a true lateral position (Fig. 6-194).
- Flex the affected knee about 45 degrees, place a sandbag under the ankle, and adjust the body rotation to place the epicondyles perpendicular to the tabletop.
- Adjust the position of the Bucky tray so that the IR projects approximately 2 inches (5 cm) beyond the knee to be included.

*With the hip included*
- For projection of the proximal femur, place the top of the IR at the level of the ASIS.
- Draw the upper limb posteriorly, and support it.
- Adjust the pelvis so that it is rolled posteriorly just enough to prevent superimposition; 10 to 15 degrees from the lateral position is sufficient (Fig. 6-195).
- Shield gonads.

---

*Fig. 6-194 Lateral distal femur*

*Fig. 6-195 Lateral proximal femur.*
Central ray
- Perpendicular to the midfemur and the center of the IR

Structures shown
The resulting image shows a lateral projection of about three fourths of the femur and the adjacent joint. If needed, use two IRs for demonstration of the entire length of the adult femur (Figs. 6-196 and 6-197).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Majority of the femur and the joint nearest to the pathologic condition or site of injury (A second radiograph of the other end of the femur is recommended.)
- Any orthopedic appliance in its entirety
- Trabecular detail on the femoral body
  - With the knee included
  - Superimposed anterior surface of the femoral condyles
  - Patella in profile
  - Open patellofemoral space
  - Inferior surface of the femoral condyles not superimposed because of divergent rays
  - With the hip included
    - Opposite thigh not over area of interest
    - Greater and lesser trochanters not prominent

NOTE: Because of the danger of fragment displacement, the aforementioned position is not recommended for patients with fracture or patients who may have destructive disease. Patients with these conditions should be examined in the supine position by placing the IR vertically along the medial or lateral aspect of the thigh and knee and then directing the central ray horizontally. A wafer grid or a grid-front IR should be used to minimize secondary radiation.
Hips, Knees, and Ankles

AP PROJECTION
WEIGHT-BEARING METHOD

NOTE: A specially built, long grid holder consisting of three grids, each 17 inches (43 cm) long, is required to hold the 51-inch (130 cm) IR and its trifold film.

Image receptor: 14 x 51 inch (31 x 130 cm) lengthwise

SID: 8 feet (244 cm). This minimum-length SID is required to open the collimators wide enough to expose the entire 51-inch length of the IR.

Position of patient
- Stand the patient with the back against the upright grid unit.
- Have the patient stand on a 2-inch (5 cm) riser so that the ankle joint is visible on the image. The bottom of the grid unit is positioned behind and below the riser.
- Measure both lateral malleoli, and position the legs so that they are exactly 20 cm apart. If this distance cannot be achieved, measure the width of the malleoli and indicate this number on the request form. This image must be performed the same way for each return visit by the patient.
- Ensure that the patient’s toes are positioned straight forward in the anatomic position (Fig. 6-198).
- Ensure that the patient is distributing weight equally on both feet.
- Mark with a right or left side marker, and place a magnification marker in the area of the knee.
- Place a wedge filter (commercially available for this projection) in the appropriate position on the collimator (Fig. 6-199). This filter is necessary to compensate for the difference in thickness between the hip joint and ankle joint.
- Shield gonads.
- Respiration: Suspend.

NOTE: A graduated speed screen (3 sections/3 speeds) may be used in place of a wedge filter.

Central ray
- Perpendicular to the IR, entering midway between the knees at the level of the knee joint.
- Collimate appropriately, and ensure that the hip joints and ankle joints will be seen on the image.

Structures shown
This projection demonstrates the entire right and left limbs from the hip joint to the ankle joint (Fig. 6-200).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Appropriate density to visualize the hips to the ankles
- Both feet in anatomic position
- Hips, knees, and ankles
- Right or left marker and a magnification marker near the knee

Fig. 6-198 Patient in position for radiograph of lower limbs: hips, knees, and ankles. The patient is placed in the anatomic position. Note that the patient is standing on a raised platform so that the ankles are shown.

Fig. 6-199 Special filter for lower limb projections. The filter enables the hips, knees, and ankles to be demonstrated on one radiograph.
Fig. 6-200 A, and B, Lower limbs: hips, knees, and ankles. Arrows point to magnification marker taped to knee.
Mobile AP pelvis radiograph. This patient has a comminuted fracture of the left acetabulum with medial displacement of the medial acetabular wall (arrow). Residual barium is seen in the colon, sigmoid, and rectum.
# SUMMARY OF PROJECTIONS

## PROJECTIONS, POSITIONS & METHODS

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<td>PA oblique</td>
<td>RAO or LAO</td>
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<td></td>
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<td>Mediolateral oblique</td>
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<td>PA axial oblique</td>
<td>RAO or LAO</td>
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<tr>
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<td>Acetabulum</td>
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<td>RPO or LPO</td>
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<tr>
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<td>388</td>
<td></td>
<td>Ilium</td>
<td>AP and PA oblique</td>
<td>RPO and LPO, RAO and LAO</td>
<td></td>
</tr>
</tbody>
</table>

Icons in the Essential column indicate projections frequently performed in the United States and Canada. Students should be competent in these projections.
The pelvis serves as a base for the trunk and a girdle for the attachment of the lower limbs. The pelvis consists of four bones: two hip bones, the sacrum, and the coccyx. The pelvic girdle is composed of only the two hip bones, however.

**Hip Bone**

The *hip bone* is often referred to as the os coxae, and some textbooks continue to refer to it as the innominate bone. The most widely used term is hip bone.

The hip bone consists of the *ilium, pubis,* and *ischium* (Figs. 7-1 and 7-2). These three bones join together to form the *acetabulum,* the cup-shaped socket that receives the head of the femur. The ilium, pubis, and ischium are separated by cartilage in youth but become fused into one bone in adulthood.

**ILIUM**

The *ilium* consists of a *body* and a broad, curved portion called the *ala.* The body of the ilium forms approximately two fifths of the acetabulum superiorly (Fig. 7-3). The ala projects superiorly from the body to form the prominence of the hip. The ala has three borders: anterior, posterior, and superior. The anterior and posterior borders present four prominent projections:

- Anterior superior iliac spine
- Anterior inferior iliac spine
- Posterior superior iliac spine
- Posterior inferior iliac spine

The *anterior superior iliac spine (ASIS)* is an important and frequently used radiographic positioning reference point. The superior margin extending from the ASIS to the posterior superior iliac spine is called the *iliac crest.* The medial surface of the wing contains the *iliac fossa* and is separated from the body of the bone by a smooth, arc-shaped ridge, the *arcuate line,* which forms a part of the circumference of the pelvic brim. The arcuate line passes obliquely, inferiorly, and medially to its junction with the pubis. The inferior and posterior portions of the wing present a large, rough surface, the *auricular surface,* for articulation with the sacrum. This articular surface and the articular surface of the adjacent sacrum have irregular elevations and depressions that cause a partial interlock of the two bones. Below this surface the ilium curves inward, forming the *greater sciatic notch.*

---

Fig. 7-1 Anterior aspect of right hip bone.

Fig. 7-2 Lateral aspect of right hip bone.

Fig. 7-3 Lateral aspect of right hip bone showing its three parts.
**PUBLIS**
The pubis consists of a body, the superior ramus, and the inferior ramus. The body of the pubis forms approximately one fifth of the acetabulum anteriorly (see Fig. 7-3). The superior ramus projects inferiorly and medially from the acetabulum to the midline of the body. There the bone curves inferiorly and then posteriorly and laterally to join the ischium. The lower prong is termed the inferior ramus.

**ISCHIUM**
The ischium consists of a body and the ischial ramus. The body of the ischium forms approximately two fifths of the acetabulum posteriorly (see Fig. 7-3). It projects posteriorly and inferiorly from the acetabulum to form an expanded portion called the ischial tuberosity. When the body is in a seated-upright position, its weight rests on the two ischial tuberosities. The ischial ramus projects anteriorly and medially from the tuberosity to its junction with the inferior ramus of the pubis. By this posterior union the rami of the pubis and ischium enclose the obturator foramen. At the superoposterior border of the body is a prominent projection called the ischial spine. Just below the ischial spine is an indentation, the lesser sciatic notch.

**Fig. 7-4** Proximal right femur. **A**, Anterior aspect. **B**, Medial aspect. Note that the body is positioned 15 to 20 degrees posterior from the head. **C**, Posterior aspect. **D**, Posterior aspect of right proximal human femur. Note anatomical details, compare to C.
Proximal Femur

The femur is the longest, strongest, and heaviest bone in the body. The proximal end of the femur consists of a head, a neck, and two large processes: the greater and lesser trochanters (Fig. 7-4). The smooth, rounded head is connected to the femoral body by a pyramid-shaped neck and is received into the acetabular cavity of the hip bone. A small depression at the center of the head, the fovea capitis, attaches to the ligamentum capitis femoris (Fig. 7-5). The neck is constricted near the head but expands to a broad base at the body of the bone. The neck projects medially, superiorly, and anteriorly from the body. The trochanters are situated at the junction of the body and the base of the neck. The greater trochanter is at the superolateral part of the femoral body, and the lesser trochanter is at the posteromedial part. The prominent ridge extending between the trochanters at the base of the neck on the posterior surface of the body is called the intertrochanteric crest. The less prominent ridge connecting the trochanters anteriorly is called the intertrochanteric line. The femoral neck and the intertrochanteric crest are two common sites of fractures in the elderly. The superior portion of the greater trochanter projects above the neck and curves slightly posteriorly and medially.

Fig. 7-5 Hip joint. Coronal section of proximal femur in acetabulum.
The angulation of the neck of the femur varies considerably with age, sex, and stature. In the average adult the neck projects anteriorly from the body at an angle of approximately 15 to 20 degrees and superiorly at an angle of approximately 120 to 130 degrees to the long axis of the femoral body (Fig. 7-6). The longitudinal plane of the femur is angled about 10 degrees from vertical. In youth the latter angle is wider; that is, the neck is more vertical in position. In wide pelvises the angle is narrower, placing the neck in a more horizontal position.

Fig. 7-6 A, Anterior aspect of right femur. B, Lateral aspect of right femur. C, Superoinferior view of posterior aspect of a human femur showing the 15 to 20 degree anterior angle of the femoral neck.
Articulations of the Pelvis

A summary of the three joints of the pelvis and upper femora is contained in Table 7-1 and Fig. 7-7, and a description follows. The articulation between the acetabulum and the head of the femur (the hip joint) is a synovial ball-and-socket joint that permits free movement in all directions. The knee and ankle joints are hinge joints; thus the wide range of motion of the lower limb depends on the ball-and-socket joint of the hip. Because the knee and ankle joints are hinge joints, medial and lateral rotations of the foot cause rotation of the entire limb, which is centered at the hip joint.

TABLE 7-1

Joints of the pelvis and upper femora

<table>
<thead>
<tr>
<th>Joint</th>
<th>Structural classification</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip joint</td>
<td>Synovial</td>
<td>Freely movable</td>
</tr>
<tr>
<td>Pubic symphysis</td>
<td>Cartilaginous</td>
<td>Slightly movable</td>
</tr>
<tr>
<td>Sacroiliac</td>
<td>Synovial</td>
<td>Slightly movable</td>
</tr>
</tbody>
</table>

*Some anatomists term this a synovial fibrous joint.
The pubes of the hip bones articulate with each other at the anterior midline of the body, forming a joint called the pubic symphysis. The pubic symphysis is a cartilaginous symphysis joint.

The right and left ilia articulate with the sacrum posteriorly at the sacroiliac joints. The sacroiliac articulations are synovial irregular gliding joints. Because the bones of the sacroiliac joints interlock, movement is very limited or nonexistent.

**Pelvis**

The female pelvis (Fig. 7-8) is lighter in structure than the male pelvis (Fig. 7-9). It is wider and shallower, and the inlet is larger and more oval shaped. The sacrum is wider, it curves more sharply posteriorly, and the sacral promontory is flatter. The width and depth of the pelvis vary with stature and gender (Table 7-2). The female pelvis is shaped for childbearing and delivery.

The pelvis is divided into two portions by an oblique plane that extends from the upper anterior margin of the sacrum to the upper margin of the pubic symphysis. The boundary line of this plane is called the brim of the pelvis (see Figs. 7-8 and 7-9). The region above the brim is called the false or greater pelvis, and the region below the brim is called the true or lesser pelvis.

The brim forms the superior aperture, or inlet, of the true pelvis. The inferior aperture, or outlet, of the true pelvis is measured from the tip of the coccyx to the inferior margin of the pubic symphysis in the anteroposterior direction and between the ischial tuberosities in the horizontal direction. The region between the inlet and the outlet is called the pelvic cavity (Fig. 7-10).

When the body is in the upright or seated position, the brim of the pelvis forms an angle of approximately 60 degrees to the horizontal plane. This angle varies with other body positions; the degree and direction of the variation depend on the lumbar and sacral curves.

---

**TABLE 7-2**

Female and male pelvis characteristics

<table>
<thead>
<tr>
<th>Feature</th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape</td>
<td>Wide, shallow</td>
<td>Narrow, deep</td>
</tr>
<tr>
<td>Bony structure</td>
<td>Light</td>
<td>Heavy</td>
</tr>
<tr>
<td>Superior aperture (inlet)</td>
<td>Oval</td>
<td>Round</td>
</tr>
<tr>
<td>Inferior aperture (outlet)</td>
<td>Wide</td>
<td>Narrow</td>
</tr>
</tbody>
</table>

---

The pubic symphysis is a cartilaginous symphysis joint.
Localizing Anatomic Structures

The bony landmarks used in radiography of the pelvis and hips are as follows:
- Iliac crest
- ASIS
- Pubic symphysis
- Greater trochanter of the femur
- Ischial tuberosity
- Tip of the coccyx

Most of these points are easily palpable, even in hypersthenic patients (Fig. 7-11). However, because of the heavy muscles immediately above the iliac crest, care must be exercised in locating this structure to avoid centering errors. It is advisable to have the patient inhale deeply; while the muscles are relaxed during expiration, the radiographer should palpate for the highest point of the iliac crest.

The highest point of the greater trochanter, which can be palpated immediately below the depression in the soft tissues of the lateral surface of the hip, is in the same horizontal plane as the midpoint of the hip joint and the coccyx. The most prominent point of the greater trochanter is in the same horizontal plane as the pubic symphysis (see Fig. 7-11).

The greater trochanter is most prominent laterally and more easily palpated when the lower leg is medially rotated. When properly used, medial rotation facilitates localization of hip and pelvis centering points and avoids distortion of the proximal end of the femur during radiography. Improper rotation of the lower leg can rotate the pelvis. Consequently, the positioning of the lower leg is important in radiography of the hip and pelvis; the feet must be immobilized in the correct position to avoid distortion of the image. Traumatic injuries or pathologic conditions of the pubis or lower limb may rule out the possibility of medial rotation.

The pubic symphysis can be palpated on the midsagittal plane and on the same horizontal plane as the greater trochanters. By placing the fingertips at this location and performing a brief downward palpation with the hand flat, palm down, and fingers together, the radiographer can locate the superior margin of the pubic symphysis. To avoid possible embarrassment or misunderstanding, the radiographer should advise the patient in advance that this and other palpations of pelvic landmarks are part of normal procedure and necessary for an accurate examination. When carried out in an efficient and professional manner with respect for the patient’s condition, such palpations are generally well tolerated.

The hip joint can be located by palpating the ASIS and the superior margin of the pubic symphysis (Fig. 7-12). The midpoint of a line drawn between these two points is directly above the center of the dome of the acetabular cavity. A line drawn at right angles to the midpoint of the first line lies parallel to the long axis of the femoral neck of an average adult in the anatomic position. The femoral head lies 1½ inches (3.8 cm) distal and the femoral neck is 2½ (6.4 cm) distal to this point.

For accurate localization of the femoral neck in atypical patients or in those in whom the limb is not in the anatomic position, a line is drawn between the ASIS and the superior margin of the pubic symphysis, and a second line is drawn from a point 1 inch (2.5 cm) inferior to the greater trochanter to the midpoint of the previously marked line. The femoral head and neck lies along this line (see Fig. 7-12).
**ALTERNATIVE POSITIONING LANDMARK**

An alternative positioning landmark for the pelvis and hip has been described by Bello.


**Projections Removed**

The following two projections have been removed from this edition of the atlas. Computed tomography (CT) is now commonly used to demonstrate the acetabulum and special projections of the hip. Please see previous editions of the atlas for reference.

**Hip**
- Axiolateral, Leonard-George Method

**Acetabulum**
- Axiolateral, Dunlap, Swanson, & Penner

**SUMMARY OF ANATOMY**

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<tr>
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<th>iliac fossa</th>
<th>arcuate line</th>
<th>auricular surface</th>
<th>greater sciatic notch</th>
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<td>pelvic girdle</td>
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<td>coccyx</td>
<td>pelvic girdle</td>
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<tr>
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<td>pubis</td>
<td>ischium</td>
<td>acetabulum</td>
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<td>pubis</td>
<td>ischium</td>
<td>acetabulum</td>
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<td>superior spine</td>
<td>inferior spine</td>
<td>anterior superior iliac spine (ASIS)</td>
<td>anterior inferior iliac spine</td>
<td>posterior superior iliac spine</td>
</tr>
<tr>
<td>wing</td>
<td>superior spine</td>
<td>inferior spine</td>
<td>anterior superior iliac spine (ASIS)</td>
<td>anterior inferior iliac spine</td>
<td>posterior superior iliac spine</td>
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<td>Articulations</td>
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<td>pubic symphysis</td>
<td>sacroiliac joints</td>
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<td>ilium</td>
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<td>ischial tuberosity</td>
<td>obturator foramen</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>inferior ramus</td>
<td>ischial ramus</td>
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<td>Ischium</td>
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<td>ischial tuberosity</td>
<td>obturator foramen</td>
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<td>Femur (proximal aspect)</td>
<td>head</td>
<td>neck</td>
<td>body</td>
<td>fovea capitis</td>
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<td>greater trochanter</td>
<td>lesser trochanter</td>
<td>intertrochanteric crest</td>
<td>intertrochanteric line</td>
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*See Addendum at the end of the volume for a summary of the changes in the anatomic terms used in this edition.
## SUMMARY OF PATHOLOGY

<table>
<thead>
<tr>
<th>Condition</th>
<th>Radiographic Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankylosing Spondylitis</td>
<td>Rheumatoid arthritis variant involving the SI joints and spine</td>
</tr>
<tr>
<td>Congenital Hip Dysplasia</td>
<td>Malformation of the acetabulum causing displacement of the Femoral head</td>
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<tr>
<td>Dislocation</td>
<td>Displacement of a bone from the joint space</td>
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<tr>
<td>Fracture</td>
<td>Disruption in the continuity of bone</td>
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<tr>
<td>Legg-Calvé-Perthes Disease</td>
<td>Flattening of the femoral head due to vascular interruption</td>
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<tr>
<td>Metastases</td>
<td>Transfer of a cancerous lesion from one area to another</td>
</tr>
<tr>
<td>Osteoarthritis or Degenerative Joint Disease</td>
<td>Form of arthritis marked by progressive cartilage deterioration in Synovial joints and vertebrae</td>
</tr>
<tr>
<td>Osteopetrosis</td>
<td>Increased density of atypically soft bone</td>
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<tr>
<td>Osteoporosis</td>
<td>Loss of bone density</td>
</tr>
<tr>
<td>Paget’s Disease</td>
<td>Thick, soft bone marked by bowing and fractures</td>
</tr>
<tr>
<td>Slipped Epiphysis</td>
<td>Proximal portion of femur dislocated from distal portion at the proximal epiphysis</td>
</tr>
<tr>
<td>Tumor</td>
<td>New tissue growth where cell proliferation is uncontrolled</td>
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<tr>
<td>Chondrosarcoma</td>
<td>Malignant tumor arising from cartilage cells</td>
</tr>
<tr>
<td>Multiple Myeloma</td>
<td>Malignant neoplasm of plasma cells involving the bone marrow and causing destruction of the bone</td>
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## EXPOSURE TECHNIQUE CHART ESSENTIAL PROJECTIONS

### PELVIS AND UPPER FEMORA

<table>
<thead>
<tr>
<th>Part</th>
<th>cm</th>
<th>kVp</th>
<th>Im</th>
<th>mA</th>
<th>mAs</th>
<th>AEC</th>
<th>SID</th>
<th>IR</th>
<th>Dose¹ (mrad)</th>
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<td>35 × 43 cm</td>
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<tr>
<td>Hip—AP¹</td>
<td>18</td>
<td>65</td>
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<td></td>
<td></td>
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<td>24 × 30 cm</td>
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<td></td>
<td></td>
<td>48°</td>
<td>24 × 30 cm</td>
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<tr>
<td>Hip—Axialateral (Danelius-Miller)⁶</td>
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<td>80</td>
<td>.80</td>
<td>200s</td>
<td>160</td>
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<td>48°</td>
<td>24 × 30 cm</td>
<td>347</td>
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</table>

¹Small focal spot.
²kVp values are for a 3-phase 12-pulse generator.
³Relative doses for comparison use. All doses are skin entrance for average adult at cm indicated.
⁴Bucky, 16:1 Grid, Screen/Film Speed 300.
⁵Tabletop, 8:1 Grid, Screen/Film Speed 300.
Radiation Protection

Protection of the patient from unnecessary radiation is a professional responsibility of the radiographer (see Chapter 1 for specific guidelines). In this chapter the Shield gonads statement at the end of the Position of part section indicates that the patient is to be protected from unnecessary radiation by restricting the radiation beam using proper collimation. In addition, placing lead shielding between the gonads and the radiation source is appropriate when the clinical objectives of the examination are not compromised (Figs. 7-13 and 7-14).

Fig. 7-13  Female AP pelvis with gonad shield.

Fig. 7-14  Male AP pelvis with gonad shield.
Pelvis and Upper Femora

AP PROJECTION

Image receptor: 35 x 43 cm crosswise

Position of patient
- Place the patient on the table in the supine position.

Position of part
- Center the midsagittal plane of the body to the midline of the grid, and adjust it in a true supine position.
- Unless contraindicated because of trauma or pathologic factors, medially rotate the feet and lower limbs about 15 to 20 degrees to place the femoral necks parallel with the plane of the image receptor (IR) (Figs. 7-15 and 7-16). Medial rotation is easier for the patient to maintain if the knees are supported. The heels should be placed about 8 to 10 inches (20 to 24 cm) apart.
- Immobilize the legs with a sandbag across the ankles, if needed.
- Check the distance from the ASIS to the tabletop on each side to be sure that the pelvis is not rotated.

Fig. 7-15  A, AP pelvis with femoral necks and trochanters poorly positioned because of lateral rotation of the limbs. B, Feet and lower limbs in their natural laterally rotated tabletop position, causing poor profile of the proximal femora in A.

Fig. 7-16  A, AP pelvis with femoral necks and trochanters in correct position. B, Feet and lower limbs medially rotated 15 to 20 degrees, correctly placed with the upper femora in correct profile in A.
• Center the IR midway between the ASIS and the pubic symphysis. The center of the IR will be about 2 inches (5 cm) inferior to the ASIS and 2 inches (5 cm) superior to the pubic symphysis in average-sized patients (Fig. 7-17).
• If the pelvis is deep, palpate for the iliac crest and adjust the position of the IR so that its upper border will project 1 to 1½ inches (2.5 to 3.8 cm) above the crest.
• Shield gonads.
• Respiration: Suspend.

Central ray
• Perpendicular to the midpoint of the IR

---

Fig. 7-17 AP pelvis.

---

Fig. 7-18 A, Male AP pelvis. B, Female AP pelvis.
Structures shown
The resulting image shows an AP projection of the pelvis and of the head, neck, trochanters, and proximal one third or one fourth of the shaft of the femora (Fig. 7-18).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Entire pelvis along with the proximal femora
- Lesser trochanters, if seen, demonstrated on the medial border of the femora
- Femoral necks in their full extent without superimposition
- Greater trochanters in profile
- Both ilia equidistant to the edge of the radiograph
- Both greater trochanters equidistant to the edge of the radiograph
- Lower vertebral column centered to the middle of the radiograph
- Symmetric obturator foramina
- Ischial spines equally demonstrated
- Symmetric ilia alae
- Sacrum and coccyx aligned with the pubic symphysis

Congenital dislocation of the hip
Martz and Taylor\(^1\) recommended two AP projections of the pelvis for demonstration of the relationship of the femoral head to the acetabulum in patients with congenital dislocation of the hip. The first projection is obtained with the central ray directed perpendicular to the pubic symphysis to detect any lateral or superior displacement of the femoral head. The second projection is obtained with the central ray directed to the pubic symphysis at a cephalic angulation of 45\(^\circ\) degrees (Fig. 7-19). This angulation casts the shadow of an anteriorly displaced femoral head above that of the acetabulum and the shadow of a posteriorly displaced head below that of the acetabulum.


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Fig. 7-19 Special projection taken for congenital dislocation of the hip.
**Pelvis and Upper Femora**

**LATERAL PROJECTION**

**Right or left position**

**Image receptor:** 35 x 43 cm lengthwise

**Position of patient**

- Place the patient in the lateral recumbent, dorsal decubitus, or upright position.

**Position of part**

**Recumbent position**

- When the patient can be placed in the lateral position, center the midcoronal plane of the body to the midline of the grid.
- Extend the thighs enough to prevent the femora from obscuring the pubic arch.
- Place a support under the lumbar spine, and adjust it to place the vertebral column parallel with the tabletop (Fig. 7-20). If the vertebral column is allowed to sag, it will tilt the pelvis in the longitudinal plane.
- Adjust the pelvis in a true lateral position, with the ASISs lying in the same vertical plane.
- Place one knee directly over the other knee. A pillow or other support between the knees promotes stabilization and patient comfort.
- Berkebile, Fischer, and Albrecht\(^1\) recommended a dorsal decubitus lateral projection of the pelvis for demonstration of the “gull-wing sign” in cases of fracture dislocation of the acetabular rim and posterior dislocation of the femoral head.

---


**Fig. 7-20 Lateral pelvis.**
Pelvis and Upper Femora

Upright position

- Place the patient in the lateral position in front of a vertical grid device, and center the midcoronal plane of the body to the midline of the grid.
- Have the patient stand straight, with the weight of the body equally distributed on the feet so that the midsagittal plane is parallel with the plane of the IR.
- If the limbs are of unequal length, place a support of suitable height under the foot of the short side.
- Have the patient grasp the side of the stand for support.
- Shield gonads.
- Respiration: Suspend.

Central ray

- Perpendicular to a point centered at the level of the soft tissue depression just above the greater trochanter (approximately 2 inches [5 cm]) and to the midpoint of the image receptor
- Center the IR to the central ray

Computed Radiography

The higher kilovolt (peak) (kVp) used for this projection requires that the collimation be very close. Scattered and primary radiation reaching the IP phosphor may cause computer artifacts.

Structures shown

The resulting image shows a lateral radiograph of the lumbosacral junction, sacrum, coccyx, and superimposed hip bones and upper femora (Fig. 7-21).

EVALUATION CRITERIA

The following should be clearly demonstrated:

- Entire pelvis and the proximal femora.
- Sacrum and coccyx.
- Superimposed posterior margins of the ischium and ilium.
- Superimposed femora.
- Superimposed acetabular shadows. The larger circle of the fossa (farther from the IR) will be equidistant from the smaller circle of the fossa nearer the IR throughout their circumference.
- Pubic arch unobscured by the femora.

![Fig. 7-21 Lateral pelvis.](image-url)
NOTE: This examination is contraindicated for patients with a suspected fracture or pathologic condition.

**Position of patient**

Seat the patient well back on the end or side of the radiographic table so that the posterior surface of the knees is in contact with the edge of the table.

**Position of part**

- If the patient is seated at the side of the table, place the longitudinal axis of the IR perpendicular to the midsagittal plane. If the patient is seated on the end of the table, center the midsagittal plane of the body to the midline of the grid. If needed, place a stool or other suitable support under the feet (Fig. 7-22).
- To prevent the thighs from limiting flexion of the body too greatly, have the patient abduct them as far as the end of the table permits.
- Instruct the patient to lean directly forward until the pubic symphysis is in close contact with the table; the vertical axis of the pelvis will be tilted forward approximately 45 degrees. The average patient can achieve this degree of flexion without strain.
- Have the patient grasp the ankles to aid in maintaining the position.
- *Shield gonads.*
- *Respiration:* Suspend.

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**AXIAL PROJECTION**

**CHASSARD-LAPINÉ METHOD**

Chassard and Lapiné devised this method for the purpose of measuring the horizontal, or biischial, diameter in pelvimetry. Some radiographers use this method to determine the relationship of the femoral head to the acetabulum, and others employ it to demonstrate the opacified rectosigmoid portion of the colon.

Central ray
- Perpendicular through the lumbosacral region at the level of the greater trochanters.
- When flexion of the body is restricted, direct the central ray anteriorly, perpendicular to the coronal plane of the pubic symphysis.

Structures shown
The resulting image shows an axial projection of the pelvis, demonstrating the relationship between the femoral heads and the acetabula, the pelvic bones, and any opacified structure within the pelvis (Fig. 7-23).

Evaluation criteria
The following should be clearly demonstrated:
- Femoral heads and acetabula
- Entire pelvis along with the proximal femora
- Symmetric hip bones
- Greater trochanters equidistant to the sacrum

Fig. 7-23 Axial pelvis.
**Femoral Necks**

**AP OBLIQUE PROJECTION**
**MODIFIED CLEAVES METHOD**

*Image receptor:* 35 x 43 cm cross-wise

This projection is often called the bilateral “frog leg” position.

**NOTE:** This examination is contraindicated for the patient suspected of having a fracture or other pathologic disease.

**Position of patient**
- Place the patient in the supine position.

**Position of part**
- Center the mid-sagittal plane of the body to the midline of the grid.
- Flex the patient’s elbows, and rest the hands on the upper chest.
- Adjust the patient so that the pelvis is not rotated. This can be achieved by placing the two ASISs equidistant from the radiographic table.
- Place a compression band across the patient well above the hip joints for stability, if needed.

**Bilateral projection**

**Step 1**
- Have the patient flex the hips and knees and draw the feet up as much as possible (i.e., enough to place the femora in a nearly vertical position if the affected side permits).
- Instruct the patient to hold this position, which is relatively comfortable, while the x-ray tube and IR are adjusted.

**Step 2**
- Center the IR 1 inch (2.5 cm) superior to the pubic symphysis.

**Step 3**
- Abduct the thighs as much as possible, and have the patient turn the feet inward to brace the soles against each other for support. According to Cleave, the angle may vary between 25 and 45 degrees, depending on how vertical the femora can be placed.
- Center the feet to the midline of the grid (Fig. 7-24).
- If possible, abduct the thighs approximately 45 degrees from the vertical plane to place the long axes of the femoral necks parallel with the plane of the IR.
- Check the position of the thighs, being careful to abduct them to the same degree.

**Unilateral projection**

- Adjust the body position to center the ASIS of the affected side to the midline of the grid.
- Have the patient flex the hip and knee of the affected side and draw the foot up to the opposite knee as much as possible.
- After adjusting the perpendicular central ray and positioning the IR tray, have the patient brace the sole of the foot against the opposite knee and abduct the thigh laterally approximately 45 degrees (Fig. 7-25). The pelvis may rotate slightly.
- **Shield gonads.**
- **Respiration:** Suspend.

**Fig. 7-24** AP oblique femoral necks with perpendicular central ray; modified Cleaves method.

**Fig. 7-25** Unilateral AP oblique femoral neck; modified Cleaves method.
Femoral Necks

Central ray
- Perpendicular to enter the patient’s midsagittal plane at the level 1 inch (2.5 cm) superior to the pubic symphysis. For the unilateral position, direct the central ray to the femoral neck (see Fig. 7-12).

Structures shown
The bilateral resulting image shows an AP oblique projection of the femoral heads, necks, and trochanteric areas projected onto one radiograph for comparison (Figs. 7-26 to 7-28).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- No rotation of the pelvis, as evidenced by a symmetric appearance.
- Acetabulum, femoral head, and femoral neck.
- Lesser trochanter on the medial side of the femur.
- Femoral neck without superimposition by the greater trochanter. Excess abduction causes the greater trochanter to obstruct the neck.
- Femoral axes extended from the hip bones at equal angles.

Fig. 7-26 AP femoral necks. Note the fixation device in the right hip, as well as the male gonad shield.

Fig. 7-27 AP oblique femoral necks: modified Cleaves method (same patient as in Fig. 7-26).

Fig. 7-28 AP oblique femoral neck: modified Cleaves method.
Femoral Necks

AXIOLATERAL PROJECTION
ORIGINAL CLEAVES METHOD

NOTE: This examination is contraindicated for patients with suspected fracture or pathologic condition.

Image receptor: 35 x 43 cm crosswise

Position of patient
• Place the patient in the supine position.

Position of part
NOTE: This is the same part position as the modified Cleaves method previously described. The projection can be performed unilaterally or bilaterally.

• Before having the patient abduct the thighs (described in step 3 on p. 362), direct the x-ray tube parallel to the long axes of the femoral shafts (Fig. 7-29).
• Adjust the IR so the midpoint coincides with the central ray.
• Shield gonads.
• Respiration: Suspend.

Central ray
Parallel with the femoral shafts. According to Cleaves,1 the angle may vary between 25 and 45 degrees, depending on how vertical the femora can be placed.


Fig. 7-29 Axiolateral femoral necks: Cleaves method.
Structures shown
The resulting image shows an axiolateral projection of the femoral heads, necks, and trochanteric areas (Fig. 7-30).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Axiolateral projections of the femoral necks
- Femoral necks without overlap from the greater trochanters
- Small parts of the lesser trochanters on the posterior surfaces of the femurs
- Small amount of the greater trochanters on both the posterior and anterior surfaces of the femurs
- Both sides equidistant from the edge of the radiograph
- Greater amount of the proximal femur on a unilateral examination
- Femoral neck angles approximately 15 to 20 degrees superior to the femoral bodies.

Congenital dislocation of the hip
The diagnosis of congenital dislocation of the hip in newborns has been discussed in numerous articles. Andren and von Rosén\(^1\) described a method based on certain theoretic considerations. Their method requires accurate and judicious application of the positioning technique to make an accurate diagnosis. The Andren-von Rosén approach involves taking a bilateral hip projection with both legs forcibly abducted to at least 45 degrees with appreciable inward rotation of the femora. Knake and Kuhns\(^2\) described the construction of a device that controlled the degree of abduction and rotation of both limbs. They reported that the device essentially eliminated and greatly simplified the positioning difficulties, thereby reducing the number of repeat examinations.


Fig. 7-30  Axiolateral femoral necks: Cleaves method. A, Bilateral examination. B and C, Unilateral hip examination of a patient who fell. No fractures were seen on the initial AP hip radiograph (B), and a second projection using the Cleaves method was performed. A chip fracture of the femoral head (arrow) was seen (C). At least two projections are required in trauma diagnoses.
Hip

AP PROJECTION

Image receptor: 24 × 30 cm lengthwise

Position of patient
• Place the patient in the supine position.

Position of part
• Adjust the patient’s pelvis so it is not rotated. This is accomplished by placing the ASISs equidistant from the table (Figs. 7-31 and 7-32).
• Place the patient’s arms in a comfortable position.
• Medially rotate the lower limb and foot approximately 15 to 20 degrees to place the femoral neck parallel with the plane of the IR, unless this maneuver is contraindicated or other instructions are given.
• Place a support under the knee and a sandbag across the ankle. This makes it easier for the patient to maintain this position.
• Shield gonads.
• Respiration: Suspend.

Central ray
• Perpendicular to the femoral neck. Using the localizing technique previously described (see Fig. 7-12), place the central ray approximately 2½ inches (6.4 cm) distal on a line drawn perpendicular to the midpoint of a line between the ASIS and the pubic symphysis.
• Center the IR to the central ray.
• Make any necessary adjustments in the IR size and central ray point when an entire orthopedic device is to be shown on one image.

Fig. 7-31 AP hip.

Fig. 7-32 AP hip.
Structures shown
The resulting image shows the head, neck, trochanters, and proximal one third of the body of the femur (Fig. 7-33).

In the initial examination of a hip lesion, whether traumatic or pathologic in origin, the AP projection is often obtained using an image receptor large enough to include the entire pelvic girdle and upper femora. Progress studies may be restricted to the affected side.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Femoral head, penetrated and seen through the acetabulum.
- Regions of the ilium and pubic bones adjoining the pubic symphysis.
- Any orthopedic appliance in its entirety.
- Hip joint.
- Greater trochanter in profile.
- Entire long axis of the femoral neck not foreshortened.
- Proximal one third of the femur.
- Lesser trochanter is usually not projected beyond the medial border of the femur, or only a very small amount of the trochanter is seen.

NOTE: Trauma patients who have sustained severe injury are not usually transferred to the radiographic table but are radiographed on the stretcher or bed. After the localization point has been established and marked, one assistant should be on each side of the stretcher to grasp the sheet and lift the pelvis just enough for placement of the IR while a third person supports the injured limb. Any necessary manipulation of the limb must be made by a physician.
**LATERAL PROJECTION**

**Mediolateral**

**LAUENSTEIN AND HICKEY METHODS**

**NOTE:** This examination is contraindicated for patients with a suspected fracture or pathologic condition.

The Lauenstein and Hickey methods are used to demonstrate the hip joint and the relationship of the femoral head to the acetabulum. This position is similar to the previously described modified Cleaves method.

**Image receptor:** 24 x 30 cm crosswise

**Position of patient**
- From the supine position, rotate the patient slightly toward the affected side to an oblique position. The degree of obliquity will depend on how much the patient can abduct the leg.

**Position of part**
- Adjust the patient’s body, and center the affected hip to the midline of the grid.
- Ask the patient to flex the affected knee and draw the thigh up to a position at nearly a right angle to the hip bone.
- Keep the body of the affected femur parallel to the table.
- Extend the opposite limb and support it at hip level and under the knee.
- Rotate the pelvis no more than necessary to accommodate flexion of the thigh and to avoid superimposition of the affected side (Fig. 7-34).
- Shield gonads.
- Respiration: Suspend.

**Central ray**
- Perpendicular through the hip joint, which is located midway between the ASIS and the pubic symphysis for the Lauenstein method (Fig. 7-35) and at a cephalic angle of 20 to 25 degrees for the Hickey method (Fig. 7-36).
- Center the IR to the central ray.

**Structures shown**

The resulting image shows a lateral projection of the hip, including the acetabulum, the proximal end of the femur, and the relationship of the femoral head to the acetabulum (see Figs. 7-35 and 7-36).

**EVALUATION CRITERIA**

The following should be clearly demonstrated:
- Hip joint centered to the radiograph
- Hip joint, acetabulum, and femoral head
- Femoral neck overlapped by the greater trochanter in the Lauenstein method
- With cephalic angulation in the Hickey method, the femoral neck free of superimposition
Fig. 7-35  A. Mediolateral hip with perpendicular central ray: Lauenstein method. B. Mediolateral hip with perpendicular central ray using male gonad (contact) shield.

Fig. 7-36 Mediolateral hip with 20-degree cephalad angulation: Hickey method.
AXIOLATERAL PROJECTION
DANELIUS-MILLER METHOD

Image receptor: 24 x 30 cm
lengthwise

Position of patient
• Place the patient in the supine position.

Position of part
• When examining a patient who is thin or who is lying on a soft bed, elevate the pelvis on a firm pillow or folded sheets sufficiently to center the most prominent point of the greater trochanter to the midline of the IR. The support must not extend beyond the lateral surface of the body; otherwise it will interfere with the placement of the IR.
• When the pelvis is elevated, support the affected limb at hip level on sandbags or firm pillows.
• Flex the knee and hip of the unaffected side to elevate the thigh in a vertical position.
• Rest the unaffected leg on a suitable support that will not interfere with the central ray. Special support devices are available.
• Adjust the pelvis so that it is not rotated (Figs. 7-37 and 7-38).
• Unless contraindicated, grasp the heel and medially rotate the foot and lower limb of the affected side about 15 or 20 degrees. A sandbag may be used to hold the leg and foot in this position, and a small support can be placed under the knee. The manipulation of patients with unhealed fractures should be performed by a physician.

Fig. 7-37 A, Axiolateral hip: Danelius-Miller method. IR supported with sandbags. B, Same projection, patient holding IR. Note that the foot is on a footrest.

Fig. 7-38 Axiolateral hip: Danelius-Miller method.
Position of IR
- Place the IR in the vertical position with its upper border in the crease above the iliac crest.
- Angle the lower border away from the body until the IR is exactly parallel with the long axis of the femoral neck.
- Support the IR in this position with sandbags or a vertical IR holder. These are the preferred methods. Alternatively, the patient may support the IR with the hand.
- Be careful to position the grid so that the lead strips are in the horizontal position.
- Shield gonads.
- Respiration: Suspend.

Central ray
- Perpendicular to the long axis of the femoral neck. The central ray enters midthigh and passes through the femoral neck about 2 ½ inches (6.4 cm) below the point of intersection of the localization lines described previously (see Fig. 7-12).

COMPUTED RADIOGRAPHY
Both dense and nondense body areas will be exposed. The kVp must be sufficient to penetrate the dense area. Collimation must be very close to keep unnecessary radiation from reaching the IP phosphor.

Structures shown
The resulting image shows the acetabulum, head, neck, and trochanters of the femur (Fig. 7-39).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Femoral neck without overlap from the greater trochanter
- Small amount of the lesser trochanter on the posterior surface of the femur
- Small amount of the greater trochanter on the anterior and posterior surfaces of the proximal femur when the femur is properly inverted
- Soft tissue shadow of the unaffected thigh not overlapping the hip joint or proximal femur
- Hip joint with the acetabulum
- Any orthopedic appliance in its entirety
- Ischial tuberosity below the femoral head

Fig. 7-39 Axiolateral hip: Danelius-Miller method.
AXIOLATERAL PROJECTION
CLEMENTS-NAKAYAMA MODIFICATION

When the patient has bilateral hip fractures, bilateral hip arthroplasty (plastic surgery of the hip joints), or limitation of movement of the unaffected leg, the Danelius-Miller method cannot be used. Clements and Nakayama described a modification using a 15-degree posterior angulation of the central ray (Fig. 7-40).

Image receptor: 24 × 30 cm

Position of patient
- Position the patient supine on the radiographic table with the affected side near the edge of the table.

Position of part
- For this position, do not rotate the lower limb internally. Instead, the limb remains in a neutral or slightly externally rotated position.
- Support a grid IR on the Bucky tray so that its lower margin is below the patient. Position the grid so the lines run parallel with the floor.
- Adjust the grid parallel to the axis of the femoral neck and tilt its top back 15 degrees.
- Shield gonads.
- Respiration: Suspend.

Central ray

- Directed 15 degrees posteriorly and aligned perpendicular to the femoral neck and grid IR

Structures shown

This leg position demonstrates a lateral hip image because the central ray is angled 15 degrees posterior instead of the toes being medially rotated. The resulting image shows the acetabulum and the proximal femur, including the head, neck, and trochanters in lateral profile. The Clements-Nakayama modification (Fig. 7-41) can be compared to the Danelius-Miller approach described previously (Fig. 7-42).

EVALUATION CRITERIA

The following should be clearly demonstrated:
- Hip joint with the acetabulum
- Femoral head, neck, and trochanters
- Any orthopedic appliance in its entirety
AXIOLATERAL PROJECTION
FRIEDMAN METHOD

NOTE: This examination is contraindicated for patients with a suspected fracture or pathologic condition.

**Image receptor:** 24 × 30 cm lengthwise

**Position of patient**
- Have the patient lie in the lateral recumbent position on the affected side.
- Center the midcoronal plane of the body to the midline of the radiographic table.

**Position of part**
- Extend the affected limb and adjust it in a lateral position.
- Roll the upper side of the patient’s limb gently posteriorly, approximately 10 degrees, and place a support under the knee to support it at hip level. The affected femur does not change position if it is properly immobilized; the pelvis rotates from the femoral head (Fig. 7-43).
- With the IR in the Bucky tray, adjust its position so that the midpoint of the IR coincides with the central ray.
- **Shield gonads.**
- **Respiration:** Suspend.
Central ray
• Directed to the femoral neck at an angle of 35 degrees cephalad (Figs. 7-44 and 7-45).
• Kisch\(^1\) recommended that the central ray be angled 15 or 20 degrees cephalad for this position (Fig. 7-46).

Structures shown
The resulting image shows an axiolateral projection of the head, neck, trochanters, and proximal body (shaft) of the femur.

\(^1\)Kisch E: Eine neue Methode für röntgenologische Darstellung des Hüftgelenks in frontaler Ebene. *Fortschr Roentgenstr* 27:309, 1920

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Moderately distorted femoral head, neck, and trochanters because of the angulation of the x-ray beam
- Hip joint

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Fig. 7-45  Axiolateral hip showing bone anatomy.

Fig. 7-46  Axiolateral hip with central ray angulation of 20 degrees: Friedman method.
**PA OBLIQUE PROJECTION**

**HSIEH METHOD**

**RAO or LAO position**

Hsieh\(^1\) recommended this projection for demonstrating posterior dislocations of the femoral head in cases other than acute fracture dislocations.

**Image receptor:** 24 × 30 cm lengthwise

**Position of patient**

- Place the patient with a suspected posterior hip dislocation in the semiprone position, and center the affected hip to the midline of the radiographic table.


**Position of part**

- Elevate the unaffected side approximately 40 to 45 degrees and have the patient support the body on the flexed knee and forearm of the elevated side.
- Adjust the position of the body to place the posterior surface of the affected iliac bone over the midline of the grid (Fig. 7-47).
- With the IR in the Bucky tray, adjust its position so that the center of the IR will lie at the level of the superior border of the greater trochanter.
- *Shield gonads.*
- *Respiration:* Suspend.

**Central ray**

- Perpendicular to the midpoint of the IR passing between the posterior surface of the iliac blade and the dislocated femoral head

**Structures shown**

The resulting image shows a PA oblique projection of the ilium, hip joint, and proximal femur (Figs. 7-48 and 7-49).


**EVALUATION CRITERIA**

The following should be clearly demonstrated:

- Hip joint near the center of the radiograph
- Acetabulum and femoral head
- Superimposed soft tissue of buttock over the area of the femoral neck

Hsieh\(^1\) recommended a right or left posterior oblique position (AP projection) for demonstration of the posterior rim of the acetabulum in acute fracture-dislocation injuries of the hip. For this projection, the patient is adjusted from the supine position. The injured hip is elevated 60 degrees to place the posterior rim of the acetabulum in profile, and the body is adjusted to center the sagittal plane passing through the ASIS to the midline of the table. The IR is centered at the level of the upper border of the greater trochanter. The central ray is directed perpendicular to the midpoint of the IR (Figs. 7-50 and 7-51).
Fig. 7-48 PA oblique hip: Hsieh method. No dislocation is seen.

Fig. 7-49 PA oblique hip showing bone anatomy.

Fig. 7-50 AP oblique hip with 60-degree rotation: Utist method.

Fig. 7-51 AP oblique hip showing bone anatomy.
**Mediolateral Oblique Projection**

**Lilienfeld Method**

**RAO or LAO position**

**NOTE:** This examination is contraindicated for patients with a suspected fracture or pathologic condition.

**Image receptor:** 24 × 30 cm lengthwise

**Position of patient**
- Have the patient lie in the lateral recumbent position on the affected side.

**Position of part**
- Center the midcoronal plane of the body to the midline of the grid.
- Fully extend the affected thigh, adjust it in a true lateral position, and immobilize it with sandbags.
- Roll the upper side gently forward approximately 15 degrees or just enough to separate the two sides of the pelvis.
- Support the limb at hip level on sandbags.
- If the affected side is well immobilized and the upper side is gently rolled forward, the affected hip will not change position; the pelvis will rotate from the femoral head (Fig. 7-52).
- With the IR in the Bucky tray, adjust its position so that the center point of the IR lies at the level of the greater trochanter.
- Shield gonads.
- Respiration: Suspend.

**Central ray**
- Perpendicular to the midpoint of the IR, traversing the affected hip joint

**Structures shown**

The resulting image shows a mediolateral oblique projection of the ilium, acetabulum, and proximal femur (Fig. 7-53).

**Evaluation Criteria**

The following should be clearly demonstrated:
- Hip joint near the center of the radiograph
- Femoral head and acetabulum
- Unaffected hip and acetabulum not overlapping the same structures of the side of interest

**NOTE:** Because the Lilienfeld projection is not used with patients who have an acute hip injury, these patients can be comfortably, safely, and satisfactorily examined in the position described by Colonna. Positioning is approximately the same as for the Lilienfeld method except that the patient is placed on the unaffected side and adjusted to center the uppermost hip to the midline of the radiographic table. Colonna recommended that the uppermost side—the affected side—be rotated about 17 degrees anteriorly from the true lateral position. He stated that this degree of rotation separates the shadows of the hip joints and gives the optimum projection of the slope of the acetabular roof and the depth of the socket (Fig. 7-54).

A similar position, the “False Profile” position, is used to demonstrate the anterior acetabular roof. See the Merrill’s website for further information.

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Fig. 7-52 Mediolateral oblique hip, LAO position: Lilienfeld method.
Fig. 7-53 Mediolateral oblique hip: Lilienfeld method demonstrating left hip.

Fig. 7-54 Colonna method of patient positioning, demonstrating elevated right hip.
Acetabulum

PA AXIAL OBLIQUE PROJECTION
TEUFEL METHOD
RAO or LAO position

Image receptor: 8 \times 10 \text{ inch} (18 \times 24 \text{ cm}) lengthwise

Position of patient
• Have the patient lie in a semiprone position on the affected side.

Position of part
• Align the body, and center the hip being examined to the midline of the grid.
• Elevate the unaffected side so that the anterior surface of the body forms a 38-degree angle from the table (Fig. 7-55).
• Have the patient support the body on the forearm and flexed knee of the elevated side.
• With the IR in the Bucky tray, adjust the position of the IR so that its midpoint coincides with the central ray.
• Shield gonads.
• Respiration: Suspend.

Fig. 7-55 PA axial oblique acetabulum: Teufel method.
Central ray
- Directed through the acetabulum at an angle of 12 degrees cephalad. The central ray enters the body at the inferior level of the coccyx and approximately 2 inches (5 cm) lateral to the midsagittal plane toward the side being examined.

Structures shown
The resulting image shows the fovea capitis and particularly the superoposterior wall of the acetabulum (Fig. 7-56).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Hip joint and acetabulum near the center of the radiograph
- Femoral head in profile to show the concave area of the fovea capitis
- Superoposterior wall of the acetabulum

Fig. 7-56  PA axial oblique acetabulum: Teufel method.
Acetabulum

AP OBLIQUE PROJECTION

Acetabulum
JUDET METHOD
RPO or LPO position

Juddet, Juddet, and Letournel described two 45-degree posterior oblique positions that are useful in diagnosing fractures of the acetabulum: the internal oblique position (affected side up) and the external oblique position (affected side down).

**Image receptor:** 24 x 30 cm lengthwise

**Internal oblique:**
For a patient with a suspected fracture of the iliopubic column (anterior) and the posterior rim of the acetabulum

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2 Iliopubic column (anterior)—composed of a short segment of the ilium and the pubis and extends up as far as the anterior spine of the ilium and extends from the symphysis pubis and obturator foramen through acetabulum to ASIS

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**Position of patient**
- Place the patient in a semisupine position with the affected hip up.

**Position of part**
- Align the body, and center the hip being examined to the middle of the IR.
- Elevate the affected side so that the anterior surface of the body forms a 45 degree angle from the table (Fig. 7-57, A).
- Shield gonads.
- Respiration: Suspend.

**Central ray**
- Perpendicular to the IR and entering 2 inches inferior to the ASIS of the affected side

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**Fig. 7-57** A, AP oblique projection. Judet method for the right hip. The LPO places the right hip in the internal oblique position. B, AP oblique projection. Judet method for the right hip. This RPO places the right hip in the external oblique position.
External oblique:
For a patient with a suspected fracture of the ilioischial column\(^1\) (posterior) and the anterior rim of the acetabulum

**Position of patient**
- Place the patient in a semisupine position with the affected hip down.

**Position of part**
- Align the body, and center the hip being examined to the middle of the IR.
- Elevate the affected side so that the anterior surface of the body forms a 45 degree angle from the table (Fig. 7-57, B).
- **Shield gonads.**
- **Respiration:** Suspend.

**Central ray**
- Perpendicular to the IR and entering at the pubic symphysis

**Structures shown**
The resulting image shows the acetabular rim (Fig. 7-58).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Acetabulum should be centered to the IR.
- The iliopubic column and the posterior rim of the affected acetabulum are seen on the internal oblique.
- The ilioischial column and the anterior rim of the acetabulum are seen on the external oblique.

\(^1\)Ilioischial column (posterior)—composed of the vertical portion of the ischium and the portion of the ilium immediately above the ischium and extends from the obturator foramen through the posterior aspect of the acetabulum

### Fig. 7-58
AP oblique projection, Judet method, right hip. A, LPO, B, RPO.

(From Long BW, Rafert JA: Orthopaedic radiography, Philadelphia, 1995, Saunders.)

**NOTE:** Rafert and Long\(^1\) describe a modification of the Judet method on trauma patients.

**RESEARCH:** Catherine E. Hearty, MS, RT(R) performed the research and provided this new projection for this edition of the atlas.

Anterior Pelvic Bones

PA PROJECTION

**Image receptor:** 8 × 10 inch (18 × 24 cm) crosswise

**Position of patient**
- Place the patient in the prone position, and center the midsagittal plane of the body to the midline of the grid.

**Position of part**
- With the IR in the Bucky tray, center the IR at the level of the greater trochanters. This positioning also centers the IR to the pubic symphysis (Fig. 7-59).
- **Shield gonads.**
- **Respiration:** Suspend.

**Central ray**
- Perpendicular to the midpoint of the IR. The central ray enters the distal coccyx and exits the pubic symphysis.

**Structures shown**
The resulting image shows a PA projection of the pubic symphysis and ischia, including the obturator foramina (Fig. 7-60).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Pubic and ischial bones not magnified or superimposing the sacrum or coccyx
- Pubic and ischial bones near the center of the radiograph
- Hip joints
- Symmetric obturator foramina
Anterior Pelvic Bones

AP AXIAL "OUTLET" PROJECTION
TAYLOR METHOD

Image receptor: 24 × 30 cm crosswise

Position of patient
• Place the patient in the supine position.

Position of part
• Center the midsagittal plane of the patient's body to the midline of the grid, and adjust the pelvis so that it is not rotated. The ASISs should be equidistant from the table (Fig. 7-61).
• With the IR in the Bucky tray, adjust the tray's position so the midpoint of the IR will coincide with the central ray.
• Shield gonads.
• Respiration: Suspend.

Central ray
Males
• Directed 20 to 35 degrees cephalad and centered to a point 2 inches (5 cm) distal to the superior border of the pubic symphysis.

Females
• Directed 30 to 45 degrees cephalad and centered to a point 2 inches (5 cm) distal to the upper border of the pubic symphysis.

Structures shown
The resulting image shows the rami without the foreshortening seen in a PA or AP projection (due to the CR more perpendicular to the rami (Figs. 7-62 and 7-63).

EVALUATION CRITERIA
The following should be clearly demonstrated:
• Pubic and ischial bones magnified with pubic bones superimposed over the sacrum and coccyx
• Symmetric obturator foramina
• Pubic and ischial rami near the center of the radiograph
• Hip joints

Anterior Pelvic Bones

SUPERINOFE|ERIOR AXIAL "INLET" PROJECTION
LILIENFELD METHOD

Image receptor: 8 x 10 inch (18 x 24 cm) crosswise

Position of patient
- Place the patient on the radiographic table in a seated-upright position.

Position of part
- Center the midsagittal plane of the patient's body to the midline of the grid.
- Flex the knees slightly and support them to relieve strain. If the travel of the IR tray is great enough to permit centering near the end of the table, have the patient sit so that the legs can hang over and the feet can rest on a suitable support.
- Adjust the pelvis so that the ASISs are equidistant from the table.

- Have the patient extend the arms for support, lean backward 45 or 50 degrees, and then arch the back, if possible, to place the pubic arch in a vertical position (Fig. 7-64).
- With the IR in the Bucky tray, center it at the level of the greater trochanters.
- Shield gonads.
- Respiration: Suspend.

Central ray
- Perpendicular to the midpoint of the image receptor and entering 1/2 inches (3.8 cm) superior to the pubic symphysis

Structures shown
The resulting image shows a superoinferior axial projection of the anterior pubic and ischial bones and the pubic symphysis (Fig. 7-65).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Medially superimposed superior and inferior rami of the pubic bones
- Nearly superimposed lateral two thirds of the pubic and ischial bones
- Symmetric pubes and ischia
- Pubic and ischial bones centered to the radiograph
- Hip joints
- Anterior pelvic bones

NOTE: The "Inlet" can also be demonstrated with the patient supine and the CR angled 40 degrees caudal.
Anterior Pelvic Bones

PA AXIAL "INLET" PROJECTION
STAUNIG METHOD

Image receptor: 8 × 10 inch (18 × 24 cm) crosswise

Position of patient
• Place the patient in the prone position.

Position of part
• Center the midsagittal plane of the body to the midline of the radiographic table.
• Adjust the body so that the pelvis is not rotated.
• With the IR in the Bucky tray, adjust its position so that the midpoint of the IR will coincide with the central ray (Fig. 7-66).
• Shield gonads.
• Respiration: Suspend.

Central ray
• Directed 35 degrees cephalad exiting the pubic symphysis on the midsagittal plane anteriorly at the level of the greater trochanters

Structures shown
The resulting image shows a PA axial projection of the pubic and ischial bones and the pubic symphysis. The appearance of this radiograph will be nearly identical to the superoinferior axial projection discussed previously.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Medially superimposed superior and inferior rami of the pubic bones
- Nearly superimposed lateral two thirds of the pubic and ischial bones
- Symmetric pubes and ischia
- Pubic and ischial bones centered to the radiograph
- Hip joints

Fig. 7-66 PA axial anterior pelvic bones: Staunig method.

1Staunig K: Die axiale Aufnahme der Regio pubica, Fortschr Roentgenstr 27:514, 1919-1921.
AP AND PA OBLIQUE PROJECTIONS

Image receptor: 24 x 30 cm length-wise

RPO and LPO positions

Position of patient
- Place the patient in the supine position.

Position of part
- Center the sagittal plane passing through the hip joint of the affected side to the midline of the grid.
- Elevate the unaffected side approximately 40 degrees to place the broad surface of the wing of the affected ilium parallel with the plane of the IR.
- Support the elevated shoulder, hip, and knee on sandbags.
- Adjust the position of the uppermost limb to place the ASISs in the same transverse plane (Fig. 7-67).
- Center the IR at the level of the ASIS.
- Shield gonads.
- Respiration: Suspend.

RAO and LAO positions

Position of patient
- Place the patient in the prone position.

Position of part
- Center the sagittal plane passing through the hip joint of the affected side to the midline of the grid.
- Elevate the unaffected side about 40 degrees to place the affected ilium perpendicular to the plane of the IR.
- Have the patient rest on the forearm and flexed knee of the elevated side.
- Adjust the position of the uppermost thigh to place the iliac crests in the same horizontal plane.
- Center the IR at the level of the ASIS (Fig. 7-68).
- Shield gonads.
- Respiration: Suspend.

Central ray
- Perpendicular to the midpoint of the IR

Structures shown
The AP oblique image shows an unobstructed projection of the ala and sciatic notches and a profile image of the acetabulum (Fig. 7-69).

The PA oblique image shows the ilium in profile and the femoral head within the acetabulum (Fig. 7-70).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Entire ilium
- Hip joint, proximal femur, and sacroiliac joint
- AP oblique projection
- Broad surface of the iliac wing without rotation
- PA oblique projection
- Ilium in profile
Fig. 7-69 AP oblique ilium, RPO.

Fig. 7-70 PA oblique ilium, LAO.
AP lumbar spine demonstrating spina bifida (arrows).
### SUMMARY OF PROJECTIONS

#### PROJECTIONS, POSITIONS & METHODS

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<td></td>
<td>Pubic symphisis</td>
<td>PA</td>
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<td>CHAMBERLAIN</td>
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<td>AP axial (sacrum)</td>
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<td></td>
<td>Sacrum and coccyx</td>
<td>AP axial (coccyx)</td>
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<tr>
<td>472</td>
<td></td>
<td>Sacrum and coccyx</td>
<td>Lateral (sacrum)</td>
<td>R or L</td>
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<td></td>
<td>Sacrum and coccyx</td>
<td>Lateral (coccyx)</td>
<td>R or L</td>
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<td></td>
<td>Sacral vertebral canal and sacroiliac joints</td>
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<td>NÖLKE</td>
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<td></td>
<td>Lumbar intervertebral disks</td>
<td>PA</td>
<td>R and L bending</td>
<td>WEIGHT-BEARING</td>
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<td>Thoracolumbar spine: scoliosis</td>
<td>PA, lateral</td>
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<td>FERGUSON</td>
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<td>PA, lateral</td>
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<td>482</td>
<td></td>
<td>Lumbar spine: spinal fusion</td>
<td>AP</td>
<td>R and L bending</td>
<td></td>
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<tr>
<td>484</td>
<td></td>
<td>Lumbar spine: spinal fusion</td>
<td>Lateral</td>
<td>R or L hyperflexion and hyperextension</td>
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</table>
**Vertebral Column**

The *vertebral column*, or *spine*, forms the central axis of the skeleton and is centered in the midsagittal plane of the posterior part of the trunk. The vertebral column has many functions: it encloses and protects the spinal cord; it acts as a support for the trunk; it supports the skull superiorly; and it provides for attachment for the deep muscles of the back and the ribs laterally. The upper limbs are supported indirectly via the ribs, which articulate with the sternum. The sternum in turn articulates with the shoulder girdle. The vertebral column articulates with each hip bone at the sacroiliac joints. This articulation supports the vertebral column and transmits the weight of the trunk through the hip joints and to the lower limbs.

The vertebral column is composed of small segments of bone called *vertebrae*. Disks of fibrocartilage are interposed between the vertebrae and act as cushions. The vertebral column is held together by ligaments, and it is jointed and curved so that it has considerable flexibility and resilience.

In early life the vertebral column usually consists of 33 small, irregularly shaped bones. These bones are divided into five groups and named according to the region they occupy (Fig. 8-1). The most superior seven vertebrae occupy the region of the neck and are termed *cervical vertebrae*. The succeeding 12 bones lie in the dorsal, or posterior, portion of the thorax and are called the *thoracic vertebrae*. The five vertebrae occupying the region of the loin are termed *lumbar vertebrae*. The next five vertebrae, located in the pelvic region, are termed *sacral vertebrae*. The terminal vertebrae, also in the pelvic region, vary from three to five in number in the adult and are called the *coccygeal vertebrae*.

The 24 vertebral segments in the upper three regions remain distinct throughout life and are termed the *true* or movable vertebrae. The pelvic segments in the two lower regions are called *false* or fixed vertebrae because of the change they undergo in adults. The sacral segments usually fuse into one bone called the *sacrum*, and the coccygeal segments, referred to as the *coccyx*, also fuse into one bone.

![Fig. 8-1](image-url) A, Anterior aspect of vertebral column. B, Lateral aspect of vertebral column, showing regions and curvatures.
Vertebral Curvature

Viewed from the side, the vertebral column has four curves that arch anteriorly and posteriorly from the midcoronal plane of the body. The cervical, thoracic, lumbar, and pelvic curves are named for the regions they occupy.

In this text the vertebral curves are discussed in reference to the anatomic position and are referred to as “convex anteriorly” or “concave anteriorly.” Because physicians and surgeons evaluate the spine from the posterior aspect of the body, convex and concave terminology can be the exact opposite. For example, when viewed posteriorly, the normal lumbar curve can correctly be referred to as “concave posteriorly.” Whether the curve is described as “convex anteriorly” or “concave posteriorly,” the curvature of the patient’s spine is the same. The cervical and lumbar curves, which are convex anteriorly, are called lordotic curves. The thoracic and pelvic curves are concave anteriorly and are called kyphotic curves (see Fig. 8-1, B). The cervical and thoracic curves merge smoothly.

The lumbar and pelvic curves join at an obtuse angle termed the lumbosacral angle. The acuity of the angle in the junction of these curves varies in different patients. The thoracic and pelvic curves are called primary curves because they are present at birth. The cervical and lumbar curves are called secondary or compensatory curves because they develop after birth. The cervical curve, which is the least pronounced of the curves, develops when the child begins to hold the head up at about 3 or 4 months of age and begins to sit alone at about 8 or 9 months of age. The lumbar curve develops when the child begins to walk at about 1 to 1½ years of age. The lumbar and pelvic curves are more pronounced in females, who therefore have a more acute angle at the lumbosacral junction.

Any abnormal increase in the anterior concavity (or posterior convexity) of the thoracic curve is termed kyphosis (Fig. 8-2, B). Any abnormal increase in the anterior convexity (or posterior concavity) of the lumbar or cervical curve is termed lordosis.

In frontal view the vertebral column varies in width in several regions (see Fig. 8-1). Generally the width of the spine gradually increases from the second cervical vertebra to the superior part of the sacrum and then decreases sharply. A slight lateral curvature is sometimes present in the upper thoracic region. The curve is to the right in right-handed persons and to the left in left-handed persons. For this reason, lateral curvature of the vertebral column is believed to be the result of muscle action and to be influenced by occupation. An abnormal lateral curvature of the spine is called scoliosis. This condition also causes the vertebrae to rotate toward the concavity. The vertebral column then develops a second or compensatory curve in the opposite direction to keep the head centered over the feet (Fig. 8-2, A).

![Fig. 8-2 A, Scoliosis, lateral curvature of the spine. B, Kyphosis, increased convexity of the thoracic spine. Lordosis, increased concavity of the lumbar spine.](image-url)
Typical Vertebra

A typical vertebra is composed of two main parts: an anterior mass of bone called the body and a posterior ringlike portion called the vertebral arch (Figs. 8-3 and 8-4). The vertebral body and arch enclose a space called the vertebral foramen. In the articulated column, the vertebral foramina form the vertebral canal.

The body of the vertebra is approximately cylindric in shape and is composed largely of cancellous bony tissue covered by a layer of compact tissue. From the superior aspect, the posterior surface is flattened, and from the lateral aspect, the anterior and lateral surfaces are concave. The superior and inferior surfaces of the bodies are flattened and covered by a thin plate of articular cartilage.

In the articulated spine, the vertebral bodies are separated by intervertebral disks. These disks account for approximately one fourth of the length of the vertebral column. Each disk has a central mass of soft, pulpy, semigelatinous material called the nucleus pulposus, which is surrounded by an outer fibrocartilaginous disk called the annulus fibrosus. It is fairly common for the pulpy nucleus to rupture or protrude into the vertebral canal, thereby impinging on a spinal nerve. This condition is called herniated nucleus pulposus (HNP), or more commonly slipped disk. HNP most often occurs in the lumbar region as a result of improper body mechanics, and it can cause considerable discomfort and pain.

The vertebral arch (see Figs. 8-3 and 8-4) is formed by two pedicles and two laminae that support four articular processes, two transverse processes, and one spinous process. The pedicles are short, thick processes that project posteriorly, one from each side, from the superior and lateral parts of the posterior surface of the vertebral body. The superior and inferior surfaces of the pedicles, or roots, are concave. These concavities are called vertebral notches. By articulation with the vertebrae above and below, the notches form intervertebral foramina for the transmission of spinal nerves and blood vessels. The broad, flat laminae are directed posteriorly and medially from the pedicles.

The transverse processes project laterally and slightly posteriorly from the junction of the pedicles and laminae. The spinous process projects posteriorly and inferiorly from the junction of the laminae in the posterior midline. A congenital defect of the vertebral column in which the laminae fail to unite posteriorly at the midline is called spina bifida. In serious cases of spina bifida, the spinal cord may protrude from the affected individual’s body.

Four articular processes, two superior and two inferior, arise from the junction of the pedicles and laminae to articulate with the vertebrae above and below (see Fig. 8-4). The articulating surfaces of the four articular processes are covered with fibrocartilage and are called facets. In a typical vertebra, each superior articular process has an articular facet on its posterior surface, and each inferior articular process has an articular facet on the anterior surface. The planes of the facets vary in direction in the different regions of the vertebral column and often vary within the same vertebra. The articulations between the articular processes of the vertebral arches are referred to as zygapophysial joints. Some texts refer to these joints as interarticular facet joints.

The movable vertebrae, with the exception of the first and second cervical vertebrae, are similar in general structure. However, each group has certain distinguishing characteristics that must be considered in radiography of the vertebral column.

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Fig. 8-3 Superior aspect of a thoracic vertebra, showing structures common to all vertebral regions.

Fig. 8-4 Lateral aspect of a thoracic vertebra, showing structures common to all vertebral regions.
Cervical Vertebrae

The first two cervical vertebrae are atypical in that they are structurally modified to join the skull. The seventh vertebra is atypical also and slightly modified to join the thoracic spine. Atypical and typical vertebrae are described in the following sections.

**ATLAS**
The *atlas*, the first cervical vertebra, is a ringlike structure with no body and a very short spinous process (Fig. 8-5). The atlas consists of an *anterior arch*, a *posterior arch*, two *lateral masses*, and two transverse processes. The anterior and posterior arches extend between the lateral masses. The ring formed by the arches is divided into anterior and posterior portions by a ligament called the *transverse atlantal ligament*. The anterior portion of the ring receives the dens (odontoid process) of the axis, and the posterior portion transmits the proximal spinal cord.

The transverse processes of the atlas are longer than those of the other cervical vertebrae, and they project laterally and slightly inferiorly from the lateral masses. Each lateral mass bears a superior and an inferior articular process. The superior processes lie in a horizontal plane, are large and deeply concave, and are shaped to receive the condyles of the occipital bone of the cranium.

**AXIS**
The *axis*, the second cervical vertebra (Figs. 8-6 and 8-7), has a strong conical process arising from the upper surface of its body. This process, called the *dens* or *odontoid process*, is received into the anterior portion of the atlantal ring to act as the pivot or body for the atlas. At each side of the dens on the superior surface of the vertebral body are the superior articular processes, which are adapted to join with the inferior articular processes of the atlas. These joints, which differ in position and direction from the other cervical zygapophyseal joints, are clearly visualized in an anteroposterior (AP) projection if the patient is properly positioned. The inferior articular processes of the axis have the same direction as those of the succeeding cervical vertebrae. The laminae of the axis are broad and thick. The spinous process is horizontal in position.

**SEVENTH VERTEBRA**
The seventh cervical vertebra, termed the *vertebra prominens*, has a long, prominent spinous process that projects almost horizontally to the posterior. The spinous process of this vertebra is easily palpable at the posterior base of the neck. It is convenient to use this process as a guide in localizing other vertebrae.
**TYPICAL CERVICAL VERTEBRA**

The typical cervical vertebrae (C3-C6) have a small, transversely located, oblong body with slightly elongated anteroinferior borders (Figs. 8-8 and 8-9). The result is anteroposterior overlapping of the bodies in the articulated column. The transverse processes of the typical cervical vertebra arise partly from the sides of the body and partly from the vertebral arch. These processes are short and wide, are perforated by the transverse foramina for the transmission of the vertebral artery and vein, and present a deep concavity on their upper surfaces for the passage of the spinal nerves. All cervical vertebrae contain three foramina: the right and left transverse foramina and the vertebral foramen.

The pedicles of the typical cervical vertebra project laterally and posteriorly from the body, and their superior and inferior vertebral notches are nearly equal in depth. The laminae are narrow and thin. The spinous processes are short, have double pointed (bifid) tips, and are directed posteriorly and slightly inferiorly. Their palpable tips lie at the level of the interspace below the body of the vertebra from which they arise.

The superior and inferior articular processes are located posterior to the transverse processes at the point where the pedicles and laminae unite. Together the processes form short, thick columns of bone called articular pillars. The fibrocartilaginous articulating surfaces of the articular pillars contain facets. The zygapophyseal facet joints of the second through seventh cervical vertebrae lie at right angles to the midsagittal plane and are clearly demonstrated in a lateral projection (Fig. 8-10, A).

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**Fig. 8-8** Superior aspect of typical cervical vertebra.

**Fig. 8-9** Lateral aspect of typical cervical vertebra.

**Fig. 8-10 A, B** Direction of cervical zygapophyseal joints. B, Direction of cervical intervertebral foramina.
The intervertebral foramina of the cervical region are directed anteriorly at a 45-degree angle from the midsagittal plane of the body (Figs. 8-10, B, and 8-11). The foramina are also directed at a 15-degree inferior angle to the horizontal plane of the body. Accurate radiographic demonstration of these foramina requires a 15-degree longitudinal angulation of the central ray and a 45-degree medial rotation of the patient (or a 45-degree medial angulation of the central ray). A lateral projection is necessary to demonstrate the cervical zygapophyseal joints. The positioning rotations required for demonstrating the intervertebral foramina and zygapophyseal joints of the cervical spine are summarized in Table 8-1. A full view of the cervical spine is shown in Fig. 8-12 along with surrounding tissues.

**TABLE 8-1**

<table>
<thead>
<tr>
<th>Area of spine</th>
<th>Intervertebral foramina</th>
<th>Zygapophyseal joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical spine</td>
<td>45 degrees oblique AP-side up PA-side down</td>
<td>Lateral</td>
</tr>
<tr>
<td>Thoracic spine</td>
<td>Lateral</td>
<td>70 degrees* AP-side up PA-side down</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>Lateral</td>
<td>30 to 50 degrees* AP-side down PA-side up</td>
</tr>
</tbody>
</table>

*From the anatomic position.

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**Fig. 8-11** Anterior oblique of cervical vertebrae showing intervertebral transverse foramina and zygapophyseal joints.

**Fig. 8-12** MRI sagittal plane of the cervical spine. Note position of the spinal cord (arrow) in relation to vertebral bodies.
Thoracic Vertebrae

The bodies of the thoracic vertebrae increase in size from the first to the twelfth vertebrae. They also vary in form, with the superior thoracic bodies resembling cervical bodies and the inferior thoracic bodies resembling lumbar bodies. The bodies of the typical (third through ninth) thoracic vertebrae are approximately triangular in form (Figs. 8-13 and 8-14). These vertebral bodies are deeper posteriorly than anteriorly, and their posterior surface is concave from side to side.

The posterolateral margins of each thoracic body have costal facets for articulation with the heads of the ribs (Fig. 8-15). The body of the first thoracic vertebra presents a whole costal facet near its superior border for articulation with the head of the first rib and presents a demi-facet (half facet) on its inferior border for articulation with the head of the second rib. The bodies of the second through eighth thoracic vertebrae contain demifacets both superiorly and inferiorly. The ninth thoracic vertebra has only a superior demifacet. Finally, the tenth, eleventh, and twelfth thoracic vertebral bodies have a single whole facet at the superior margin for articulation with the eleventh and twelfth ribs (Table 8-2).
The transverse processes of the thoracic vertebrae project obliquely, laterally, and posteriorly. With the exception of the eleventh and twelfth pairs, each process has on the anterior surface of its extremity a small concave facet for articulation with the tubercle of a rib. The laminae are broad and thick, and they overlap the subjacent lamina. The spinous processes are long. From the fifth to the ninth vertebrae the spinous processes project sharply inferiorly and overlap each other, but they are less vertical above and below this region. The palpable tip of each spinous process of the fifth to ninth thoracic vertebrae corresponds in position to the interspace below the vertebra from which it projects.

The zygapophyseal joints of the thoracic region angle (except the inferior articular processes of the twelfth vertebra) anteriorly approximately 15 to 20 degrees to form an angle of 70 to 75 degrees (open anteriorly) to the midsagittal plane of the body (see Figs. 8-15 and 8-16, A). For radiographic demonstration of the zygapophyseal joints of the thoracic region, the patient’s body must be rotated 70 to 75 degrees from the anatomic position or 15 to 20 degrees from the lateral position.

The intervertebral foramina of the thoracic region are perpendicular to the midsagittal plane of the body (see Figs. 8-15 and 8-16, B). These foramina are clearly demonstrated radiographically with the patient in a true lateral position (see Table 8-1). During inspiration the ribs are elevated. The arms must also be raised enough to elevate the ribs, which otherwise cross the intervertebral foramina. A full view of the thoracic vertebrae is seen in Fig. 8-17 along with surrounding tissues.

### TABLE 8-2

<table>
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<tr>
<th>Vertebrae</th>
<th>Vertebral border</th>
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<tr>
<td>T1</td>
<td>Superior</td>
<td>Whole facet</td>
</tr>
<tr>
<td>T2-T8</td>
<td>Superior</td>
<td>Demifacet</td>
</tr>
<tr>
<td>T9</td>
<td>Superior</td>
<td>Demifacet</td>
</tr>
<tr>
<td>T10-T12</td>
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<tr>
<td></td>
<td>Inferior</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Inferior</td>
<td>Whole facet</td>
</tr>
</tbody>
</table>

*On each side of a vertebral body.

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**Fig. 8-16** A, Direction of thoracic zygapophyseal joints. B, Direction of thoracic intervertebral foramina.

**Fig. 8-17** MRI image of the thoracic vertebrae region showing vertebral bodies and relation to spinal cord.
Lumbar Vertebrae

The lumbar vertebrae have large, bean-shaped bodies that increase in size from the first to the fifth vertebra in this region. The lumbar bodies are deeper anteriorly than posteriorly, and their superior and inferior surfaces are flattened or slightly concave (Fig. 8-18). At their posterior surface these vertebrae are flattened anteriorly to posteriorly, and they are transversely concave. The anterior and lateral surfaces are concave from the top to the bottom (Fig. 8-19).

The transverse processes of lumbar vertebrae are smaller than those of the thoracic vertebrae. The superior three pairs are directed almost exactly laterally, whereas the inferior two pairs are inclined slightly superiorly. The lumbar pedicles are strong and are directed posteriorly; the laminae are thick. The spinae processes are large, thick, and blunt, and they have an almost horizontal projection posteriorly. The palpable tip of each spinous process corresponds in position with the interspace below the vertebra from which it projects. The mamillary process is a smoothly rounded projection on the back of each superior articular process. The accessory process is at the back of the root of the transverse process.

The laminae lie posterior to the pedicles and transverse processes. The part of the lamina between the superior and inferior articular processes is called the pars interarticularis.

The body of the fifth lumbar segment is considerably deeper in front than behind, which gives it a wedge shape that adapts it for articulation with the sacrum. The intervertebral disk of this joint is also more wedge shaped than the disks in the interspaces above the lumbar region. The spinae process of the fifth lumbar vertebra is smaller and shorter, and the transverse processes are much thicker than those of the upper lumbar vertebrae.
The zygapophyseal joints of the lumbar region (Figs. 8-20 and 8-21, A) are inclined posteriorly from the coronal plane, forming an angle (open posteriorly) of 30 to 50 degrees to the midsagittal plane of the body. These joints can be demonstrated radiographically by rotating the body from the anatomic position.

The intervertebral foramina of the lumbar region are situated at right angles to the midsagittal plane of the body, except the fifth, which turns slightly anteriorly (Fig. 8-21, B). The superior four pairs of foramina are demonstrated radiographically with the patient in a true lateral position; the last pair requires slight obliquity of the body (see Table 8-1).

Spondylolysis is an acquired bony defect occurring in the pars interarticularis, the area of the lamina between the two articular processes. The defect may occur on one or both sides of the vertebra, resulting in a condition termed spondylolisthesis. This condition is characterized by the anterior displacement of one vertebra over another, generally the fifth lumbar over the sacrum. Spondylolisthesis almost exclusively involves the lumbar spine.

Spondylolisthesis is of radiologic importance because oblique-position radiographs demonstrate the “neck” area of the “Scottie dog” (i.e., the pars interarticularis). (Oblique positions involving the lumbar spine, including the “Scottie dog,” are presented later in this chapter, starting with Fig. 8-104.) A full view of the lumbar vertebrae is seen in Fig. 8-22 along with surrounding tissues.
**Sacrum**

The sacrum is formed by fusion of the five sacral vertebral segments into a curved, triangular bone (Figs. 8-23, 8-24, and 8-25). The sacrum is wedged between the iliac bones of the pelvis, with its broad base directed obliquely, superiorly, and anteriorly and its apex directed posteriorly and inferiorly. Although the size and degree of curvature of the sacrum vary considerably in different patients, the bone is normally longer, narrower, more evenly curved, and more vertical in position in males than in females. The female sacrum is more acutely curved, with its greatest curvature in the lower half of the bone; it also lies in a more oblique plane, which results in a sharper angle at the junction of the lumbar and pelvic curves.

The superior portion of the first sacral segment remains distinct and resembles the vertebrae of the lumbar region (see Fig. 8-25). The superior surface of the base of the sacrum corresponds in size and shape to the inferior surface of the last lumbar segment, with which it articulates to form the lumbosacral junction. The concavities on the upper surface of the pedicles of the first sacral segment and the corresponding concavities on the lower surface of the pedicles of the last lumbar segment form the last pair of intervertebral foramina. The superior articular processes of the first sacral segment articulate with the inferior articular processes of the last lumbar vertebra to form the last pair of zygapophyseal joints.

At its superior anterior margin the base of the sacrum has a prominent ridge termed the sacral promontory. Directly behind the bodies of the sacral segments is the sacral canal, which is the continuation of the vertebral canal. The sacral canal is contained within the bone and transmits the sacral nerves. The anterior and posterior walls of the sacral canal are each perforated by four pairs of pelvic sacral foramina for the passage of the sacral nerves and blood vessels.

**Fig. 8-23** Anterior aspect of sacrum and coccyx.

**Fig. 8-24** Lateral aspect of sacrum and coccyx.
On each side of the sacral base is a large, winglike lateral mass called the *ala* (Fig. 8-26). At the superoanterior part of the lateral surface of each ala is the *auricular surface*, a large articular process for articulation with similarly shaped processes on the iliac bones of the pelvis.

The inferior surface of the *apex* of the sacrum (Fig. 8-27) has an oval facet for articulation with the coccyx and the *sacral cornua*, two processes that project inferiorly from the posterolateral aspect of the last sacral segment to join the *coccygeal cornua*.

**Coccyx**

The *coccyx* is composed of three to five (usually four) rudimentary *vertebrae* that have a tendency to fuse into one bone in the adult (see Figs. 8-23 and 8-24). The coccyx diminishes in size from its *base* inferiorly to its *apex*. From its articulation with the sacrum it curves inferiorly and anteriorly, often deviating from the midline of the body. The *coccygeal cornua* project superiorly from the posterolateral aspect of the first coccygeal segment to join the sacral cornua.
Vertebral Articulations

The joints of the vertebral column are summarized in Table 8-3. A detailed description follows.

The vertebral articulations consist of two types of joints: (1) intervertebral joints, which are between the two vertebral bodies and are cartilaginous-symphysis joints that permit only slight movement of individual vertebrae but considerable motility for the column as a whole, and (2) zygapophyseal joints, which are between the articulation processes of the vertebral arches and are synovial gliding joints that permit free movements. The movements permitted in the vertebral column by the combined action of the joints are flexion, extension, lateral flexion, and rotation.

The articulations between the atlas and the occipital bone are synovial ellipsoidal joints and are called the atlanto-occipital articulations. The anterior arch of the atlas rotates about the dens of the axis to form the atlantoaxial joint, which is both a synovial gliding articulation and a synovial pivot articulation (see Table 8-3).

In the thoracic region, the heads of the ribs articulate with the bodies of the vertebrae to form the costovertebral joints, which are synovial gliding articulations. The tubercles of the ribs and the transverse processes of the thoracic vertebrae articulate to form costotransverse joints, which are also synovial gliding articulations.

The articulations between the sacrum and the two ilia—the sacroiliac joints—were discussed in Chapter 7.

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<th>Structural classification</th>
<th>Movement</th>
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<td>cervical</td>
<td>transverse processes</td>
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<td>thoracic</td>
<td>spinous process facets</td>
<td>Lumbar vertebrae</td>
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<td>lumbar</td>
<td>superior articular processes</td>
<td>mammillary process</td>
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<td>pelvic</td>
<td>inferior articular processes</td>
<td>accessory process</td>
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<td>lordotic curve</td>
<td>zygapophyseal joints</td>
<td>pars interarticularis</td>
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<td>kyphotic curve</td>
<td>(interarticular facet joints)</td>
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<tr>
<td>primary curves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>secondary or</td>
<td></td>
<td></td>
</tr>
<tr>
<td>compensatory curves</td>
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</table>

*See Addendum at the end of the volume for a summary of the changes in the anatomic terms used in this edition.
## SUMMARY OF PATHOLOGY

<table>
<thead>
<tr>
<th>Condition</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankylosing Spondylitis</td>
<td>Rheumatoid arthritis variant involving the SI joints and spine</td>
</tr>
<tr>
<td>Fracture</td>
<td>Disruption in the continuity of bone</td>
</tr>
<tr>
<td>Clay Shoveler's</td>
<td>Avulsion fracture of the spinous process in the lower cervical and upper thoracic region</td>
</tr>
<tr>
<td>Compression</td>
<td>Fracture that causes compaction of bone and a decrease in length or width</td>
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<tr>
<td>Hangman's</td>
<td>Fracture of the anterior arch of C2 due to hyperextension</td>
</tr>
<tr>
<td>Jefferson</td>
<td>Comminuted fracture of the ring of C2</td>
</tr>
<tr>
<td>Herniated Nucleus Pulposus (HNP)</td>
<td>Rupture or prolapse of the nucleus pulposus into the spinal canal</td>
</tr>
<tr>
<td>Kyphosis</td>
<td>Abnormally increased convexity in the thoracic curvature</td>
</tr>
<tr>
<td>Lordosis</td>
<td>Abnormal forward curvature of the cervical and lumbar spine</td>
</tr>
<tr>
<td>Metastases</td>
<td>Transfer of a cancerous lesion from one area to another</td>
</tr>
<tr>
<td>Osteoarthritis or Degenerative Joint Disease</td>
<td>Form of arthritis marked by progressive cartilage deterioration in synovial joints and vertebrae</td>
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<tr>
<td>Osteopetrosis</td>
<td>Increased density of atypically soft bone</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>Loss of bone density</td>
</tr>
<tr>
<td>Paget’s Disease</td>
<td>Thick, soft bone marked by bowing and fractures</td>
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<tr>
<td>Scheuermann’s Disease or Adolescent Kyphosis</td>
<td>Kyphosis with onset in adolescence</td>
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<tr>
<td>Scoliosis</td>
<td>Lateral deviation of the spine with possible vertebral rotation</td>
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<tr>
<td>Spina Bifida</td>
<td>Failure of the posterior encasement of the spinal cord to close</td>
</tr>
<tr>
<td>Spondylolisthesis</td>
<td>Forward displacement of a vertebra over a lower vertebra, usually L5-S1</td>
</tr>
<tr>
<td>Spondylolysis</td>
<td>Breaking down of the vertebra</td>
</tr>
<tr>
<td>Subluxation</td>
<td>Incomplete or partial dislocation</td>
</tr>
<tr>
<td>Tumor</td>
<td>New tissue growth where cell proliferation is uncontrolled</td>
</tr>
<tr>
<td>Multiple Myeloma</td>
<td>Malignant neoplasm of plasma cells involving the bone marrow and causing destruction of the bone</td>
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## EXPOSURE TECHNIQUE CHART ESSENTIAL PROJECTIONS

### VERTEBRAL COLUMN

<table>
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<tr>
<th>Part</th>
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<th>kVp*</th>
<th>tm</th>
<th>mA2</th>
<th>mAs</th>
<th>AEC</th>
<th>SID</th>
<th>IR</th>
<th>Dose† (mrad)</th>
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<td>11</td>
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<td>85</td>
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<td>200s</td>
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<td>48*</td>
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<td>200s</td>
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<td>200s</td>
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<td>48*</td>
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<tr>
<td>Coccyx—Lateral‡</td>
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<td>80</td>
<td>0.5</td>
<td>200s</td>
<td>100</td>
<td></td>
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<td>10 in</td>
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<td>90</td>
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<td>200s</td>
<td>40</td>
<td></td>
<td>48*</td>
<td>35</td>
<td>43 cm</td>
</tr>
</tbody>
</table>

s. Small focal spot.
* kVp values are for a 3-phase 12-pulse generator.
† Relative doses for comparison use. All doses are skin entrance for average adult at cm indicated.
‡ Bucky, 16:1 Grid, Screen/Film Speed 300.
+++ Bucky, 16:1 Grid, Screen/Film Speed 300.
**Radiation Protection**

The radiographer has a professional responsibility to protect patients from unnecessary radiation (see Chapter 1 for specific guidelines). In this chapter the *Shield gonads* statement at the end of the *Position of part* sections indicates that the patient is to be protected from unnecessary radiation by restricting the radiation beam through proper collimation. The placement of lead shielding between the gonads and the radiation source is also appropriate when the clinical objectives of the examination are not compromised.

For any procedure discussed in this chapter, contact gonad shields can be used to protect male patients. Female gonad shields can only be used when the ovaries do not lie within the area of interest.

**AP OBLIQUE PROJECTION**

**R and L head rotations**

**Image receptor:** 8 x 10 inch (18 x 24 cm)

**Position of patient**

- Place the patient in the supine position.
- Center the midsagittal plane of the body to the midline of the grid, and adjust the shoulders to lie in the same horizontal plane.
- Place a support under the patient’s knees for comfort.

**Position of part**

- Place the IR in the Bucky tray, and adjust the patient’s head so that the midpoint of the IR is 1 inch (2.5 cm) lateral to the midsagittal plane of the head at the level of the external acoustic meatus (EAM).
- Rotate the head 45 to 60 degrees away from the side being examined (Fig. 8-28).
- Adjust the flexion of the neck to place the infraorbitomeatal line (IOML) perpendicular to the IR.
- *Shield gonads.*
- *Respiration:* Suspend.

**Central ray**

- Perpendicular to the midpoint of the IR. It enters 1 inch (2.5 cm) anterior to the EAM and emerges at the atlanto-occipital articulation.

---

*Fig. 8-28 AP oblique atlanto-occipital joint.*
**Atlanto-Occipital Articulations**

**Structures shown**
The resulting image shows an AP oblique projection of the atlanto-occipital articulation, with the joint being shown between the orbit and the ramus of the mandible. Both sides should be examined for comparison (Fig. 8-29).

The dens of the axis is also well demonstrated in this position. Therefore it can be used for this purpose when a patient cannot be adjusted in the open-mouth position.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Open atlanto-occipital articulation
- Dens

**NOTE:** Buetti recommended a position for the atlanto-occipital articulations wherein the head is turned 45 to 50 degrees to one side and, with the mouth wide open, the chin is drawn down as much as the open mouth allows. The central ray is then directed vertically through the open mouth to the dependent mastoid tip.

Atlanto-Occipital Articulations

PA PROJECTION

Image receptor: 8 × 10 inch (18 × 24 cm) crosswise

Position of patient
- Place the patient in the prone position.
- Center the midsagittal plane of the body to the midline of the grid.
- If the patient is thin, place a small, firm pillow under the chest to relieve strain in holding the position.
- Flex the patient's elbows, place the arms in a comfortable position, and adjust the shoulders to lie in the same horizontal plane.

Position of part
- Rest the patient's forehead and nose on the table, and adjust the head so that the midsagittal plane is perpendicular to the midline of the grid (Fig. 8-30).
- Adjust the flexion of the neck to place the orbitomeatal line (OML) perpendicular to the plane of the IR; center the IR at or slightly below the level of the infraorbital margins.
- Shield gonads.
- Respiration: Suspend.

Central ray
- Perpendicular to the midpoint of the IR. It enters the back of the neck on the midsagittal plane and exits at the level of the infraorbital margins.

Structures shown
The resulting image shows a PA projection of the atlanto-occipital joints projected through the maxillary sinuses (Fig. 8-31).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Open bilateral atlanto-occipital articulations
- Mandibular condyles equidistant from the midline

Fig. 8-30 PA atlanto-occipital articulations.

Fig. 8-31 PA atlanto-occipital articulations.
Fuchs' has recommended the AP projection for demonstration of the dens when its upper half is not clearly shown in the open-mouth position. This patient position must not be attempted if fracture or degenerative disease of the upper cervical region is suspected.

**Image receptor:** 8 x 10 inch (18 x 24 cm) crosswise

**Position of patient**
- Place the patient in the supine position.
- Center the midsagittal plane of the body to the midline of the grid.
- Place the arms along the sides of the body, and adjust the shoulders to lie in the same horizontal plane.
- Place a support under the patient’s knees for comfort.

**Position of part**
- Place the IR in the Bucky tray, and center the IR to the level of the tips of the mastoid processes.
- Extend the chin until the tip of the chin and the tip of the mastoid process are vertical (Fig. 8-32).
- Adjust the head so that the midsagittal plane is perpendicular to the plane of the grid.
- **Shield gonads.**
- **Respiration:** Suspend.

**Central ray**
- Perpendicular to the midpoint of the IR; it enters the neck on the midsagittal plane just distal to the tip of the chin.

**Structures shown**
The resulting image shows an AP projection of the dens lying within the circular foramen magnum (Fig. 8-33).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Entire dens within the foramen magnum
- Symmetry of the mandible, cranium, and vertebrae, indicating no rotation of the head or neck

Smith and Abel described a method for demonstrating the laminae and articular facets of the upper cervical vertebrae. They slightly extend the patient’s neck, and the mouth is opened wide. The central ray is directed 35 degrees caudad and centered to C3. The exposure is made with the head passively rotated 10 degrees to the side, thereby removing the mandible from the overlying areas of interest.

---

1Fuchs AW: Cervical vertebrae (part 1), Radiogr Clin Photogr 16:2, 1940.
**AP PROJECTION**

### Open mouth

The open-mouth technique was described by Albers-Schönberg¹ in 1910 and by George² in 1919.

**Image receptor:** 8 x 10 inch (18 x 24 cm)

### Position of patient

- Place the patient in the supine position.
- Center the midsagittal plane of the body to the midline of the grid.
- Place the patient’s arms along the sides of the body, and adjust the shoulders to lie in the same horizontal plane.
- Place a support under the patient’s knees for comfort.


--

**Position of part**

- Place the IR in the Bucky tray, and center the IR at the level of the axis.
- Adjust the patient’s head so that the midsagittal plane is perpendicular to the plane of the table (Figs. 8-34 and 8-35).
- Select the exposure factors, and move the x-ray tube into position so that any minor change can be made quickly after the final adjustment of the patient's head. Although this position is not easy to hold, the patient is usually able to cooperate fully unless he or she is kept in the final, strained position too long.
- Have the patient open the mouth as wide as possible, and then adjust the head so that a line from the lower edge of the upper incisors to the tip of the mastoid process (occlusal plane) is perpendicular to the IR. A small support under the back of the head may be needed to facilitate opening of the mouth while proper alignment of the upper incisors and mastoid tips is maintained.
- **Shield gonads.**
- **Respiration:** Instruct the patient to keep the mouth wide open and to softly phonate “ah” during the exposure. This will place the tongue in the floor of the mouth so that it is not projected on the atlas and axis and will prevent movement of the mandible.

---

Fig. 8-34 AP atlas and axis.

---

Fig. 8-35 Open-mouth spine alignment.
Atlas and Axis

Central ray
- Perpendicular to the center of the IR and entering the midpoint of the open mouth

Structures shown
The resulting image demonstrates an AP projection of the atlas and axis through the open mouth (Fig. 8-36).

If the patient has a deep head or a long mandible, the entire atlas is not demonstrated. When the exactly superimposed shadows of the occlusal surface of the upper central incisors and the base of the skull are in line with those of the tips of the mastoid processes, the position cannot be improved.

If the patient cannot open the mouth, tomography may be required (Fig. 8-37).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Dens, atlas, axis, and articulations between the first and second cervical vertebrae
- Entire articular surfaces of the atlas and axis (to check for lateral displacement)
- Superimposed occlusal plane of the upper central incisors and the base of the skull
- Wide-open mouth
- Shadow of the tongue not projected over the atlas and axis
- Mandibular rami equidistant from dens

NOTE: A 30-inch (76 cm) SID is often used for this projection to increase the field of view of the odontoid area.

Fig. 8-36 A, Open-mouth atlas and axis. 
B, Same projection, showing fracture of the left lateral mass of axis (arrow).

Fig. 8-37 AP upper cervical vertebrae tomogram of a patient who fell and landed on his head. A bursting-type Jefferson fracture caused outward displacement of both lateral masses of the atlas. A tomogram is often necessary to demonstrate the upper cervical area in trauma patients who cannot move their heads or open their mouths.
**PA PROJECTION**

**JUDD METHOD**

**NOTE:** The radiographer must not attempt this position with a patient who has an unhealed fracture or who has a degenerative disease or suspected fracture of the upper cervical region.

**Image receptor:** 8 x 10 inch (18 x 24 cm) crosswise

**Position of patient**
- Place the patient in the prone position.
- Center the midsagittal plane of the body to the midline of the grid.
- Flex the patient’s elbows, place the arms in a comfortable position, and adjust the shoulders to lie in the same horizontal plane.

**Position of part**
- Have the patient extend the neck and rest the chin on the table.
- Place the IR in the Bucky tray, and adjust the IR so that the midpoint is centered to the throat at the level of the upper margin of the thyroid cartilage (Fig. 8-38).
- Adjust the head so that the chin and mastoid tips are vertical or the OML is approximately 37 degrees to the plane of the IR (Fig. 8-39).
- Adjust the midsagittal plane to be perpendicular to the table.
- **Respiration:** Suspend.

**Central ray**
- Perpendicular to the midpoint of the IR. It enters on the midsagittal plane just distal to the level of the mastoid tips.

**Structures shown**
The resulting image demonstrates a PA projection of the dens and atlas as seen through the foramen magnum (Fig. 8-40).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Entire dens within foramen magnum
- Anterior and posterior arches of atlas
- No rotation of head or neck

---

**Fig. 8-38** PA atlas and dens: Judd method.

**Fig. 8-39** PA dens.

**Fig. 8-40** PA atlas and dens: Judd method.
AP AXIAL OBLIQUE PROJECTION

KASABACH METHOD

R or L head rotations

NOTE: The head of a patient who has a possible fracture or degenerative disease must not be rotated. Kasabach \(^1\) recommended that the entire body, rather than only the head, be rotated.

**Image receptor:** 8 × 10 inch (18 × 24 cm)

**Position of patient**
- Place the patient in the supine position.
- Center the midsagittal plane of the body to the midline of the grid.
- Place the arms along the sides of the body, and adjust the shoulders to lie in the same horizontal plane.
- Place a support under the patient’s knees for comfort.

**Position of part**
- Place the IR in the Bucky tray, and center the IR to the midsagittal plane at the level of the mastoid tip.
- Rotate the head either right or left approximately 40 to 45 degrees. Adjust the head so that the IOML is perpendicular to the plane of the table (Fig. 8-41).
- For right-angle images of the dens, make one exposure with the head turned to the right and one exposure with the head turned to the left.
- **Shield gonads.**
- **Respiration:** Suspend.

**Central ray**
- Angled 10 to 15 degrees caudad. Center to a point midway between the outer canthus and the EAM.

**Structures shown**
The resulting image shows an AP axial oblique projection of the dens and was recommended by Kasabach \(^1\) for use in conjunction with the AP and lateral projections (Fig. 8-42).

**EVALUATION CRITERIA**
- The radiograph should clearly demonstrate the dens.


---

LATERAL PROJECTION
R or L position

Image receptor: 8 × 10 inch (18 × 24 cm)

Position of patient
- Place the patient in the supine position.
- Place the arms along the sides of the body, and adjust the shoulders to lie in the same horizontal plane.
- Place a sponge or pad under the patient’s head unless traumatic injury has been sustained, in which case the neck should not be moved.

Position of part
- With the IR in the vertical position and in contact with the upper neck, center it at the level of the atlantoaxial articulation (1 inch [2.5 cm] distal to the tip of the mastoid process).
- Adjust the IR so that it is parallel with the midsagittal plane of the neck, and then support the IR in position (Fig. 8-43).
- Extend the neck slightly so that the shadow of the mandibular rami does not overlap that of the spine.
- Adjust the head so that the midsagittal plane is perpendicular to the table.
- Shield gonads.
- Respiration: Suspend.

Central ray
- Perpendicular to a point 1 inch (2.5 cm) distal to the adjacent mastoid tip. A grid and close collimation should be used to minimize secondary radiation.

Structures shown
The resulting image demonstrates a lateral projection of the atlas and axis. The atlanto-occipital articulations are also demonstrated (Fig. 8-44). Because of the short object-to-image receptor distance (OID), better definition is obtained with this technique than with the customary method of performing the lateral examination of the cervical vertebrae using a 72-inch (183-cm) source-to-image receptor distance (SID).

Fig. 8-43 Lateral atlas and axis.
EVALUATION CRITERIA
The following should be clearly demonstrated:

- Upper cervical vertebrae
- Superimposed laminae of the axis and superimposed posterior arches of the atlas
- Neck extended so the mandibular rami does not overlap the axis or atlas
- Nearly superimposed rami of the mandible

NOTE: Pancoast, Pendergrass, and Schaeffer\(^1\) recommended that the head be rotated slightly to prevent superimposition of the laminae of the atlas. They further recommended a slight horizontal tilt of the head for demonstration of the arches of the atlas.


Fig. 8-44  
Cervical Vertebrae

AP AXIAL PROJECTION

**Image receptor:** 8 x 10 inch (18 x 24 cm) lengthwise

**Position of patient**
- Place the patient in the supine or upright position with the back against the IR holder.
- Adjust the patient’s shoulders to lie in the same horizontal plane to prevent rotation.

**Position of part**
- Center the midsagittal plane of the patient’s body to the midline of the table or vertical grid device.
- Extend the chin enough so that the occlusal plane is perpendicular to the tabletop. This prevents superimposition of the mandible and midcervical vertebrae (Figs. 8-45 and 8-46).
- Center the IR at the level of C4.
- Adjust the head so that the midsagittal plane is in straight alignment and perpendicular to the IR.
- Provide support for the head of any patient who has a pronounced lordotic curvature. This support helps compensate for the curvature and reduce image distortion.
- **Shield gonads.**
- **Respiration:** Suspend.

**Central ray**
- Directed through C4 at an angle of 15 to 20 degrees cephalad. The central ray enters at or slightly inferior to the most prominent point of the thyroid cartilage.

---

**Fig. 8-45** AP axial cervical vertebrae: upright.

**Fig. 8-46** AP axial cervical vertebrae: recumbent.
Cervical Vertebrae

Structures shown
The resulting image shows the lower five cervical bodies and the upper two or three thoracic bodies, the interpediculate spaces, the superimposed transverse and articular processes, and the intervertebral disk spaces (Fig. 8-47).

This projection is also used to demonstrate the presence or absence of cervical ribs.

EVALUATION CRITERIA
The following should be clearly demonstrated:

- Area from superior portion of C3 to T2 and surrounding soft tissue
- Shadows of the mandible and occiput superimposed over the atlas and most of the axis
- Open intervertebral disk spaces
- Spinous processes equidistant to the pedicles
- Mandibular angles equidistant to the vertebrae

Fig. 8-47 AP axial cervical vertebrae.
Cervical Vertebrae

**LATERAL PROJECTION**

**GRANDY METHOD**

*R or L position*

*Image receptor: 8 x 10 inch (18 x 24 cm) lengthwise*

*SID: A 60- to 72-inch (152- to 183-cm) SID is recommended because of the increased OID. A longer distance helps demonstrate C7.*

**Position of patient**

- Place the patient in a true lateral position, either seated or standing, before a vertical grid device. The long axis of the cervical vertebrae should be parallel to the plane of the IR.
- Have the patient sit or stand straight, and adjust the height of the IR so that it is centered at the level of C4. The top of the IR will be about 1-inch (2.5 cm) above the EAM.

**Position of part**

- Center the coronal plane that passes through the mastoid tips to the midline of the IR.
- Move the patient close enough to the vertical grid device to permit the adjacent shoulder to rest against the device for support (Fig. 8-48). (This projection may be performed without the use of a grid.)
- Rotate the shoulders anteriorly or posteriorly according to the natural kyphosis of the back: if the patient is round shouldered, rotate the shoulder anteriorly; otherwise, rotate them posteriorly.
- Adjust the shoulders to lie in the same horizontal plane, depress them as much as possible, and immobilize them by attaching one small sandbag to each wrist. The sandbags should be of equal weight.
- Be careful to ensure that the patient does not elevate the shoulder.
- Elevate the chin slightly, or have the patient protrude the mandible to prevent superimposition of the mandibular rami and the spine. At the same time and with the midsagittal plane of the head vertical, ask the patient to look steadily at one spot on the wall. This helps maintain the position of the head.
- **Shield gonads.**
- **Respiration:** Suspend respiration at the end of full expiration to obtain maximum depression of the shoulders.

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Fig. 8-48 Lateral cervical vertebrae: Grandy method.
Central ray
• Horizontal and perpendicular to C4.
  With such centering, the magnified outline of the shoulder farthest from the IR is be projected below the lower cervical vertebrae.

Structures shown
The resulting image demonstrates a lateral projection of the cervical bodies and their interspaces, the articular pillars, the lower five zygapophyseal joints, and the spinous processes (Fig. 8-49). Depending on how well the shoulders can be depressed, a good lateral projection must include C7; sometimes T1 and T2 can also be seen.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- All seven cervical vertebrae and at least one third of the T1. (Otherwise a separate radiograph of the cervicothoracic region is recommended.)
- Neck extended so that mandibular rami are not overlapping the atlas or axis.
- Superimposed or nearly superimposed rami of the mandible.
- No rotation or tilt of the cervical spine indicated by superimposed open zygapophyseal joints.
- C4 in the center of the radiograph.
- Bone and soft tissue detail.

Fig. 8-49 Lateral cervical vertebrae: Grandy method.
Cervical Vertebrae

**LATERAL PROJECTION**

**R or L position**  
**Hyperflexion and hyperextension**

**NOTE:** This procedure must not be attempted until cervical spine pathology or fracture has been ruled out.

Functional studies of the cervical vertebrae in the lateral position are performed to demonstrate normal anteroposterior movement or an absence of movement resulting from trauma or disease. The spinous processes are elevated and widely separated in the hyperflexion position and are depressed in close approximation in the hyperextension position.

**Image receptor:** 24 × 30 cm lengthwise

**SID:** A 60- to 72-inch (152- to 183-cm) SID is recommended because of the increased OID. A longer distance helps demonstrate C7.

**Position of patient**
- Place the patient in a true lateral position, either seated or standing, before a vertical grid device.
- Have the patient sit or stand straight, and adjust the height of the IR so that it is centered at the level of C4. The top of the IR will be about 2-inches (5 cm) above the EAM.

**Position of part**
- Move the patient close enough to the vertical grid device to permit the adjacent shoulder to rest against the grid for support.
- Keep the mid sagittal plane of the patient’s head and neck parallel with the plane of the IR.
- Alternately, perform the projection without using a grid.

**Hyperflexion**
- Ask the patient to drop the head forward and then draw the chin as close as possible to the chest so that the cervical vertebrae are placed in a position of hyperflexion (forced flexion) for the first exposure (Fig. 8-50).
- Shield gonads.
- Respiration: Suspend.

**Hyperextension**
- Ask the patient to elevate the chin as much as possible so that the cervical vertebrae are placed in a position of hyperextension (forced extension) for the second exposure (Fig. 8-51).

Fig. 8-50 Lateral cervical vertebrae: hyperflexion.  
Fig. 8-51 Lateral cervical vertebrae: hyperextension.
Cervical Vertebrae

Central ray
- Horizontal and perpendicular to C4

Structures shown
The resulting images show the motility of the cervical spine when hyperflexed (Fig. 8-52) and hyperextended (Fig. 8-53). The intervertebral disks and the zygapophyseal joints are also shown.

EVALUATION CRITERIA
The following should be clearly demonstrated:

- **Hyperflexion**
  - Body of the mandible almost vertical for hyperflexion in the normal patient
  - All seven spinous processes

- **Hyperextension**
  - Body of the mandible almost horizontal in the normal patient
  - All seven cervical vertebrae in true lateral position

Fig. 8-52 Hyperflexion lateral cervical spine.

Fig. 8-53 Hyperextension lateral cervical spine.
Cervical Intervertebral Foramina

**AP AXIAL OBLIQUE PROJECTION**

**RPO and LPO positions**

Oblique projections for demonstrating the cervical intervertebral foramina were first described by Barsőny and Koppenstein.1,2 Both sides are examined for comparison.


**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise

**SID:** A 60- to 72-inch (152 to 183-cm) SID is recommended because of the increased OID.

**Position of patient**

- Place the patient in a supine or upright position facing the x-ray tube. The upright position (standing or seated) is preferable for the patient’s comfort and makes it easier to position the patient.

**Upright position**

- Ask the patient to sit or stand straight without strain and to rest the adjacent shoulder firmly against the vertical grid device for support.
- Ensure that the degree of body rotation is 45 degrees.
- While the patient looks straight ahead, elevate and, if needed, protrude the chin so that the mandible does not overlap the spine (Fig. 8-54). Turning the chin to the side causes slight rotation of the superior vertebrae and should be avoided.

**Semisupine position**

- Rotate the patient’s head and body approximately 45 degrees.
- Center the cervical spine to the midline of the grid.
- Place suitable supports under the lower thorax and the elevated hip.
- Place a support under the patient’s head, and adjust it so that the cervical column is horizontal.
- Check and adjust the 45-degree body rotation.
- Elevate the patient’s chin and protrude the jaw as for the upright study (Fig. 8-55). Turning the chin to the side causes slight rotation of the superior vertebrae and should be avoided.

**Shield gonads.**

**Respiration:** Suspend.
Central ray

- Directed to C4 at a cephalad angle of 15 to 20 degrees so that the central ray coincides with the angle of the foramina.

Structures shown

The resulting image shows the intervertebral foramina and pedicles farthest from the IR and an oblique projection of the bodies and other parts of the cervical vertebrae (Fig. 8-56). (See Summary of Oblique Projections page 486.)

EVALUATION CRITERIA

The following should be clearly demonstrated:

- Open intervertebral foramina farthest from the IR, from C2-C3 to C7-T1
- Open intervertebral disk spaces
- Uniform size and contour of the foramina
- Elevated chin that does not overlap the atlas and axis
- Occipital bone not overlapping the axis
- C1-C7 and T1

AP OBLIQUE PROJECTION

Hyperflexion and hyperextension

Boylston suggested using functional studies of the cervical vertebrae in the oblique to demonstrate fractures of the articular processes as well as obscure dislocations and subluxations. When acute injury has been sustained, manipulation of the patient's head must be performed by a physician.

The patient is placed in a direct frontal body position facing the x-ray tube, with the shoulders held firmly against the grid device. The head is carefully rotated maximally to one side and kept in that position while the neck is flexed for the first exposure and extended for the second exposure. Both sides are examined for comparison.


Fig. 8-56  AP axial oblique intervertebral foramina. A, LPO position demonstrating right side. B, RPO position demonstrating left side.
**PA AXIAL OBLIQUE PROJECTION**

**RAO and LAO positions**

**Image receptor:** 8 x 10 inch (18 x 24 cm) lengthwise

**SID:** A 60- to 72-inch (152- to 183-cm) SID is recommended because of the increased OID.

**Position of patient**
- Place the patient prone or upright with the back toward the x-ray tube. For the patient's comfort and accurate adjustment of the part, the standing or seated-upright position is preferred.

**Position of part**
- **Upright position,** ask the patient to sit or stand straight with arms by side and rest shoulder against the grid device. Rotate the patient's entire body to a 45-degree angle to place the foramina openings parallel with the IR. Center the cervical spine to the midline of the grid device (Fig. 8-57).
- **Semiprone position,** place the patient's body at an angle of 45-degrees and the cervical spine centered to the midline of the grid. Have the patient use the forearm and flexed knee of the elevated side to support the body and maintain the position (Figs. 8-58 and 8-59). Place a suitable support under the patient's head to place the long axis of the cervical column parallel with the IR.
- To allow for the caudal angulation of the central ray, center the IR at the level of C5 (1-inch [2.5 cm] caudal to the most prominent point of the thyroid cartilage).
- Adjust the position of the patient's head so that the midsagittal plane is aligned with the plane of the spine.
- Elevate and protrude the patient's chin just enough to prevent superimposition of the mandible with the upper cervical vertebrae. Turning the chin to the side causes rotation of the superior vertebrae and should be avoided. (The chin will have to be turned slightly for the semiprone position.)
- **Shield gonads.**
- **Respiration:** Suspend.

**Central ray**
- Directed to C4 at an angle of 15 to 20 degrees caudad so that it coincides with the angle of the foramina.

**Structures shown**
The resulting image shows the intervertebral foramina and pedicles closest to the IR and an oblique projection of the bodies and other parts of the cervical column (Fig. 8-60). (See Summary of Oblique Positions, page 486.)

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Open intervertebral foramina closest to the IR, from the first and second cervical vertebrae to the seventh cervical and first thoracic vertebrae.
- Open intervertebral disk spaces.
- Elevated chin and protruded jaw so the angle of the mandible does not overlap the first and second cervical vertebrae.
- Occipital bone not overlapping the axis.
- All seven cervical and the first thoracic vertebrae.

**RESEARCH:** This projection was researched and standardized by Laura Carwile, MS, RT(R)(M)(QM).
Cervical Intervertebral Foramina

Fig. 8-58 PA axial oblique right intervertebral foramina: RAO position.

Fig. 8-59 PA axial oblique left intervertebral foramina: LAO position.

Fig. 8-60 PA axial oblique intervertebral foramina. A, RAO position demonstrating right side. B, LAO position demonstrating left side.
Cervical Vertebrae

AP PROJECTION
OTTONELLO METHOD

With the Ottonello method the mandibular shadow is blurred or even obliterated by having the patient perform an even chewing motion of the mandible during the exposure. The patient's head must be rigidly immobilized to prevent movement of the vertebrae. The exposure time must be long enough to cover several complete excursions of the mandible.

Image receptor: 8 × 10 in (18 × 24 cm) lengthwise

Position of patient
• Place the patient in the supine position.
• Center the midsagittal plane of the body to the midline of the grid.
• Place the patient's arms along the sides of the body, and adjust the shoulders to lie in the same horizontal plane.
• Place a support under the knees for the patient's comfort.

Position of part
• Adjust the patient's head so that the midsagittal plane is aligned with the lower body and is perpendicular to the table.
• Elevate the patient's chin enough to place the occlusal surface of the upper incisors and the mastoid tips in the same vertical plane.
• Immobilize the head, and have the patient practice opening and closing the mouth until the mandible can be moved smoothly without striking the teeth together (Fig. 8-61).
• Place the IR in a Bucky tray, and center the IR at the level of C4.
• To blur the mandible, use an exposure technique with a low milliamperage (mA) and long exposure time (minimum of 1 second).
  • Shield gonads.
  • Respiration: Suspend.

Fig. 8-61 AP cervical vertebrae: Ottonello method.
Cervical Vertebrae

Central ray
- Perpendicular to C4. The central ray enters at the most prominent point of the thyroid cartilage.

Structures shown
The resulting image shows an AP projection of the entire cervical column, with the mandible blurred if not obliterated (Figs. 8-62 and 8-63).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- All seven cervical vertebrae
- Blurred mandible with resultant visualization of the underlying atlas and axis
Cervical and Upper Thoracic Vertebrae

Vertebral Arch (Pillars)
AP AXIAL PROJECTION

NOTE: The procedure must not be attempted until cervical spine pathology or fracture has been ruled out.

The vertebral arch projections, sometimes referred to as pillar or lateral mass projections, are used to demonstrate the posterior elements of the cervical vertebrae, the upper three or four thoracic vertebrae, the articular processes and their facets, the laminae, and the spinous processes. The central ray angulations that are employed project the vertebral arch elements free of the anteriorly situated vertebral bodies and transverse processes. When the central ray angulation is correct, the resultant image resembles a hemisection of the vertebrae. In addition to frontal plane delineation of the articular pillars and facets, vertebral arch projections are especially useful for demonstrating the cervicothoracic spinous processes in patients with whiplash injury.

Image receptor: 8 x 10 inch (18 x 24 cm) or 24 x 30 cm

1Dorland P. Frémont J: Aspect radiologique normal du rachis postérieur cervicodorsal (vue postérieure ascendant), Semaine Hop 1457, 1957.

Position of patient
- Adjust the patient in the supine position with the midsagittal plane of the body centered to the midline of the grid.
- Depress the patient's shoulders, and adjust them to lie in the same horizontal plane.

Position of part
- With the midsagittal plane of the head perpendicular to the table, hyperextend the patient's neck. The success of this projection depends on this hyperextension (Figs. 8-64 and 8-65).
- If the patient cannot tolerate hyperextension without undue discomfort, the oblique projection described in the next section is recommended.
- Shield gonads.
- Respiration: Suspend.
Cervical and Upper Thoracic Vertebrae

Central ray
- Directed to C7 at an average angle of 25 degrees caudad (range: 20 to 30 degrees). The central ray enters the neck in the region of the thyroid cartilage.
- The degree of the central ray angulation is determined by the cervical lordosis. The goal is to have the central ray coincide with the plane of the articular facets so that a greater angle is required when the cervical curve is accentuated and a lesser angle is required when the curve is diminished.
- To reduce an accentuated cervical curve and thus place C3-C7 in the same plane as the T1-T4, the originators of this technique have suggested that a radiolucent wedge be placed under the patient's neck and shoulders, with the head extended somewhat over the edge of the wedge.

Structures shown
The resulting image demonstrates the posterior portion of the cervical and upper thoracic vertebrae, including the articular and spinous processes (Fig. 8-66).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Vertebral arch structures, especially the superior and inferior articulating processes (pillars), without overlapping of the vertebral bodies and transverse processes
- Articular processes
- Open zygapophyseal joints between the articular processes

NOTE: For a PA axial projection showing both sides on one IR, rest the patient's head on the table with the neck fully extended and the midsagittal plane of the head perpendicular to the table. Direct the central ray at an average angle of 40 degrees cephalad (range: 35 to 45 degrees).

Fig. 8-66 AP axial. A, Central ray parallel with plateau of articular processes. B, Head fully extended but inadequate central ray angulation; central ray not parallel with zygapophyseal joints.
Vertebral Arch (Pillars)
AP AXIAL OBLIQUE PROJECTION
R and L head rotations

These radiographic projections are used to demonstrate the vertebral arches or pillars when the patient cannot hyperextend the head for the AP or PA axial projection. Both sides are examined for comparison.

Image receptor: 8 × 10 inch (18 × 24 cm)

Position of patient
• Place the patient in the supine position.

Central ray
• Directed to exit the spinous process of C7 at an average angle of 35 degrees caudad (range: 30 to 40 degrees)

Position of part
• Rotate the patient's head 45 to 50 degrees, turning the jaw away from the side of interest. A 45- to 50-degree rotation of the head usually demonstrates the articular processes of C2-C7 and T1. A rotation of as much as 60 to 70 degrees is sometimes required to demonstrate the processes of C6 and T1-T4 (Figs. 8-67 and 8-68).
• Position the IR so that the top edge is at the level of the mastoid tip.
• Shield gonads.
• Respiration: Suspend.

Fig. 8-67 AP axial oblique demonstrating right vertebral arches.

Fig. 8-68 AP axial oblique demonstrating right vertebral arches.

Cervical and Upper Thoracic Vertebrae

Vertebral Arch (Pillars)

PA AXIAL OBLIQUE PROJECTIONS
R and L head rotations

Image receptor: 8 × 10 inch (18 × 24 cm)

Position of patient
• Unless contraindicated, place the patient in the prone position. For injured patients, the prone position seems to be more comfortable than the supine position.
• Center the midsagittal plane of the patient’s body to the midline of the grid.
• When the patient is thin, place a pillow under the chest to obviate accentuation of the cervical curve.
• Depress the patient’s shoulders and adjust them to lie in the same horizontal plane.

Position of part
• Rest the patient’s head on one cheek, turning the jaw away from the side of interest. Adjust the head so that the midsagittal plane is at an angle of 45 degrees.
• To demonstrate the C2-C5, flex the patient’s neck somewhat to reduce the cervical curve.
• To demonstrate C5-C7 and T1-T4, adjust the patient’s head in moderate extension.
• Position the IR so that its bottom edge is at the level of the tip of the C7 spinous process (Fig. 8-69).
• Shield gonads.
• Respiration: Suspend.

Central ray
• Directed to C7 at an average angle of 35 degrees cephalad (range: 30 to 40 degrees) and exiting at the level of the mandibular symphysis

Structures shown
The resulting AP and PA projections show the posterior arch and pillars of the cervical and upper thoracic vertebrae with open zygapophyseal articulations (see Figs. 8-68 and 8-70).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Vertebral arch structures, especially the superior and inferior articular processes, free of overlap of the vertebral bodies and transverse processes
- Articular processes and facets on the side of interest
- Open joints between the articular facets on the side of interest

Fig. 8-69 PA axial oblique demonstrating left vertebral arches.

Fig. 8-70 PA axial oblique demonstrating left vertebral arches.
LATERAL PROJECTION
TWINING METHOD
R or L position
Upright
This projection is often called the "swimmer's lateral" projection.

Image receptor: 24 × 30 cm length-wise

Position of patient
- Place the patient in a lateral position, either seated or standing, against a vertical grid device.

Position of part
- Center the midsagittal plane of the body to the midline of the grid.
- Move the patient close enough to the grid device so that the shoulder can rest firmly against the grid for support.
- Elevate the arm that is adjacent to the vertical grid device to a vertical position, flex the elbow, and rest the fore-arm on the patient's head.
- Adjust the height of the IR so that it is centered at the level of C7-T1, which will be at the level of the vertebral prominence posteriorly.
- Adjust the patient's head and body into a true lateral position, with the midsagittal plane parallel to the plane of the IR (Fig. 8-71).
- Depress the patient's shoulder that is farthest from the IR as much as possible, and move this shoulder anteriorly. Then move the shoulder closest to the IR posteriorly.
- The goal is to have one shoulder placed slightly anterior and the other slightly posterior, with simultaneous elevation of one shoulder and depression of the opposite one. This shoulder placement is sufficient to prevent the humeral heads from being superimposed over the vertebrae.
- Shield gonads.
- Respiration: Suspend.
- If the patient can cooperate and can be immobilized, a long exposure time (low mA) should be used while the patient takes shallow breaths. Shallow breathing blurs the lung anatomy.

Fig. 8-71 Upright lateral cervicothoracic region: Twining method.
Central ray
- Directed to the inter-disk space of C7 and T1: (1) perpendicular if the shoulder is well depressed or (2) at a caudal angle of 5 degrees if the shoulder cannot be well depressed. Collimation should be very close to reduce scattered radiation and improve contrast.

COMPUTED RADIOGRAPHY
Both dense and nondense body areas will be exposed. The kilovolts (peak) (kVp) must be sufficient to penetrate the dense area. Collimation must be very close to keep unnecessary radiation from reaching the IP phosphor.

Structures shown
The resulting image demonstrates a lateral projection of the lower cervical and upper thoracic vertebrae between the two shoulders (Figs. 8-72 and 8-73).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Lateral vertebrae, not appreciably rotated
- Shoulders separated from each other
- Area from approximately C5 to T4
- X-ray penetration of the shoulder region

Fig. 8-72 Lateral cervicothoracic region: Twining method.

Fig. 8-73 Lateral cervicothoracic region: Twining method, showing bony structures.
Cervicothoracic Region

**LATERAL PROJECTION**

**PAWLOW METHOD AND MODIFIED PAWLOW METHOD**

**R or L position**

**Recumbent**

This projection is also called the "swim­mer's lateral" projection. It is most often performed with either a lateral cervical or lateral thoracic projection when the shoul­ders superimpose the vertebrae in the area of interest.

**Image receptor:** 24 × 30 cm

**Position of patient**

- Place the patient in a lateral recumbent position, with the head elevated on the patient’s arm, sandbags, or a small, firm pillow.

**Position of part**

- Center the midcoronal plane of the pa­tient’s body to the midline of the grid.
- Adjust the support under the patient’s head, and place another support under the lower thorax so that the long axis of the cervicothoracic vertebrae is hor­i­zontal.
- Grasp the arm on which the patient is lying, and extend it above the head. Move the humeral head posteriorly.
- Place the top arm at the patient’s side, and immobilize it by having the patient grab the posterior thigh. Move the humeral head posteriorly.
- Adjust the body into a true lateral posi­tion (Fig. 8-74).
- Center the IR at the level of the inter­disk space of C7-T1 which is located 2 inches (5 cm) above the jugular notch.
- **Shield gonads.**
- **Respiration:** Suspend.

**Central ray**

- Directed to the inter-disk of C7 and T1 at an angle of 3 to 5 degrees caudad.
- Monda modified the central ray by angling it 5 to 15 degrees cephalad due to the slope of the spine and a non-elevated lower spine. Collimation should be very close to reduce scattered radiation and improve contrast.

**COMPUTED RADIOGRAPHY**

Both dense and non-dense body areas will be exposed. The kVp must be sufficient to penetrate the dense area. Collimation must be very close to keep unnecessary radiation from reaching the IP phosphor.

**Structures shown**

The resulting image shows a lateral pro­jection of the cervicothoracic vertebrae be­tween the shoulders (Figs. 8-75 and 8-76).

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![Fig. 8-74 Recumbent lateral cervicothoracic region: Pawlow method.](image-url)
Cervicothoracic Region

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Lateral vertebrae not appreciably rotated
- Shoulders separated from each other
- Area from approximately C5 to T4
- X-ray penetration of the shoulder region

Fig. 8-75 Lateral cervicothoracic region: Pawlow method.

Fig. 8-76 Lateral cervicothoracic region: Pawlow method showing bony structures.
Thoracic Vertebrae

AP PROJECTION

Image receptor: 35 × 43 cm or 18 × 43 cm lengthwise

Position of patient
- Place the patient in the supine or upright position.
- Place the patient’s arms along the sides of the body, and adjust the shoulders to lie in the same horizontal plane.
- If the patient is supine, let the head rest directly on the table or on a thin pillow to avoid accentuating the thoracic kyphosis.
- If the upright position is used, ask the patient to sit or stand up as straight as possible.

Position of part
- Center the midsagittal plane of the body to the midline of the grid.
- For the supine position, to reduce kyphosis, flex the patient’s hips and knees to place thighs in vertical position. Immobilize the feet with sandbags (Fig. 8-77).
- If the patient’s limbs cannot be flexed, support the knees to relieve strain.
- For the upright position, have the patient stand so the patient’s weight is equally distributed on the feet to prevent rotation of the vertebral column.
- If the patient’s lower limbs are of unequal length, place support of correct height under the foot of the shorter side.
- Place the superior edge of the IR ½ to 2 inches (3.8 to 5 cm) above the shoulders on an average patient. This will position the IR so T7 will appear near the center of the image and all the thoracic vertebrae will be shown.
- Shield gonads.
- Respiration: The patient may be allowed to take shallow breaths during the exposure or respiration is suspended at the end of full expiration.

Central ray
- Perpendicular to the IR. The center of the CR should be approximately halfway between the jugular notch and the xiphoid process (Fig. 8-77).
- Collimate closely to the spine.
- As suggested by Fuchs,1 a more uniform density of the thoracic vertebrae can be obtained if the “heel effect” of the tube is used (Fig. 8-78 and 8-79). With the tube positioned so that the cathode end is toward the feet, the greatest percentage of radiation goes through the thickest part of the thorax. A variety of wedge filters are available to assist in providing an even density of the entire thoracic spine.

Structures shown
The resulting image shows an AP projection of the thoracic bodies, intervertebral disk spaces, transverse processes, costovertebral articulations, and surrounding structures (see Figs. 8-78 and 8-79).

In many radiology departments a full 35 × 43 cm projection of the thoracic spine and chest is routinely performed, in particular for trauma patients. These larger-field projections are typically done using a thoracic filter. The larger field gives the radiologist a better look at the ribs, shoulder, diaphragm, and lungs (see Fig. 8-80).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- All 12 vertebrae
- Wide latitude of exposure (or two radiographs can be taken for the upper and lower vertebrae).
- X-ray beam collimated to the thoracic spine as shown in Fig. 8-82
- Spinous processes at the midline of the patient
- Vertebral column aligned to the middle of the radiograph
- Ribs, shoulders, lungs, and diaphragm if a 35 × 43 cm image receptor is used

RESEARCH: This projection was researched and standardized by Laura Carwile, MS, RT(R)(M)(QM).

Fig. 8-78 Cathode end of x-ray tube over lower thorax (more uniform density).

Fig. 8-79 Cathode end of x-ray tube over upper thorax (nonuniform density).

Fig. 8-80 Entire thorax projection.
Thoracic Vertebrae

**LATERAL PROJECTION**

**R or L position**

**Image receptor:** 35 x 43 cm or 18 x 43 cm lengthwise

**Position of patient**

- Place the patient in the lateral recumbent position. (Note: Oppenheimer [1] also suggests the use of the upright position.)
- If possible, use the left lateral position to place the heart closer to the IR which minimizes overlapping of the vertebrae by the heart.
- Have the patient dressed in an open backed gown so that the vertebral column can be exposed for adjustment of the position.


**Position of part**

- Place a firm pillow under the patient’s head to keep the long axis of the vertebral column horizontal.
- Flex the patient’s hips and knees to a comfortable position.
- Place the superior edge of the IR 1½ to 2 inches (3.8 to 5 cm) above the relaxed shoulders. Center the *posterior half* of the thorax to the midline of the grid and at the level of T7 (Fig. 8-81). T7 will be at the inferior angle of the scapulae.
- With the patient’s knees exactly superimposed to prevent rotation of the pelvis, a small sandbag may be placed between the knees.
- Adjust the patient’s arms at right angles to the long axis of the body to elevate the ribs enough to clear the intervertebral foramina.
- If the long axis of the vertebral column is not horizontal, elevate the lower or upper thoracic region with a radiolucent support (Fig. 8-82). This is the preferred method.
- Shield gonads.

**Respiration:** The exposure can be made with the patient breathing normally to obliterate or diffuse the vascular markings and ribs or at the end of expiration.

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[Fig. 8-81 Lateral view of the body, demonstrating the midcoronal plane. Note that the plane divides the thorax in half and thoracic vertebrae lie in the posterior half. Centering for lateral thoracic vertebrae is on the posterior half of the thorax.]
Thoracic Vertebrae

Central ray
- Perpendicular to the center of the IR at the level of T7 (inferior angles of the scapulae). The central ray enters the posterior half of the thorax.
- If the vertebral column is not elevated to a horizontal plane when the patient is in a recumbent position, angle the tube to direct the central ray perpendicular to the long axis of the thoracic column and then center it at the level of T7. An average angle of 10 degrees cephalad is sufficient in most female patients; an average angle of 15 degrees is satisfactory in most male patients because of their greater shoulder width (Fig. 8-82 and 8-83). Figure 8-84 shows positioning of the CR for an upright lateral thoracic spine.

COMPUTED RADIOGRAPHY

The higher kVp used for this projection requires that the collimation used be very close. Scattered and primary radiation reaching the IP phosphor may cause computer artifacts. A lead sheet should be placed on the tabletop.

Fig. 8-82 Recumbent lateral thoracic spine. Support placed under lower thoracic region; perpendicular central ray.

Fig. 8-83 No support under lower thoracic spine; central ray angled 10 to 15 degrees cephalad.

Fig. 8-84 Upright lateral thoracic spine.
Thoracic Vertebrae

Improving radiographic quality

The quality of the radiographic image can be improved if a sheet of leaded rubber is placed on the table behind the patient (see Figs. 8-82 and 8-83). The lead absorbs the scatter radiation coming from the patient and prevents table scatter from affecting the image. Scatter radiation serves only to decrease the quality of the radiograph and blacken the spinous processes. More important with automatic exposure control (AEC), the scatter radiation coming from the patient is often sufficient to terminate the exposure prematurely. The resulting image may be underexposed because of the effect of the scatter radiation on the AEC device. For the same reason, close collimation is necessary for lateral spine radiographs. This is critically important when using computed tomography.

Structures shown

The resulting image is a lateral projection of the thoracic bodies that demonstrates their interspaces, the intervertebral foramina, and the lower spinous processes. Because of the overlapping shoulders the upper vertebrae may not be demonstrated in this position (Figs. 8-85 and 8-86). If the upper thoracic area is the area of interest, a “swimmer’s lateral” may be included with the examination. The younger the patient, the easier it is to show the upper thoracic bodies.

EVALUATION CRITERIA

The following should be clearly demonstrated:
- Vertebrae clearly seen through rib and lung shadows.
- Twelve thoracic vertebrae centered on the image receptor. Superimposition of the shoulders on the upper vertebrae may cause underexposure in this area. The number of vertebrae visualized depends on the size and shape of the patient. T1 to T3 will not be well visualized.
- Ribs superimposed posteriorly to indicate that the patient was not rotated.
- Open intervertebral disk spaces.
- Wide latitude of exposure.
- X-ray beam tightly collimated to reduce scatter radiation.

RESEARCH: This projection was researched and standardized by Laura Carwile, MS, RT(R)(M)(QM).

Fig. 8-85 Lateral thoracic spine. A, Suspended respiration for an exposure of 0.75 second. B, Normal breathing for an exposure of 7.5 seconds.

Fig. 8-86 Lateral thoracic spine with breathing technique.
Zygapophyseal Joints

AP OR PA OBLIQUE PROJECTION
RAO and LAO or RPO and LPO
Upright and recumbent positions

The thoracic zygapophyseal joints are examined using PA oblique projections as recommended by Oppenheimer\(^1\) or using AP oblique projections as recommended by Fuchs.\(^2\) The joints are well demonstrated with either projection. The AP obliques demonstrate the joints farthest from the IR, and the PA obliques demonstrate the joints closest to the IR. Although the difference in OID between the two projections is not great, the same rotation technique is used bilaterally.

**Image receptor:** 35 x 43 cm


**Upright position**

**Position of patient**
- Place the patient, standing or sitting upright, in a lateral position before a vertical grid.

**Position of part**
- Rotate the body 20 degrees anterior (PA oblique) or posterior (AP oblique) so that the coronal plane forms an angle of 70 degrees from the plane of the IR.
- Center the patient's vertebral column to the midline of the grid, and have the patient rest the adjacent shoulder firmly against it for support.
- Adjust the height of the IR \(1\frac{1}{2}\) to 2 inches (3.8-5 cm) above the shoulders to center the IR to T7.
- For the PA oblique, flex the elbow of the arm adjacent to the grid and rest the hand on the hip. For the AP oblique, the arm adjacent to the grid is brought forward to avoid superimposing the humerus on the upper thoracic vertebrae.
- For the PA oblique, have the patient grasp the side of the grid device with the outer hand (Fig. 8-87). For the AP oblique, have the patient place the outer hand on the hip.
- Adjust the patient's shoulders to lie in the same horizontal plane.
- Have the patient stand straight to place the long axis of the vertebral column parallel with the IR.
- The weight of the patient's body must be equally distributed on the feet, and the head must not be turned laterally.
- **Shield gonads.**
- **Respiration:** Suspend the end of expiration.

![Fig. 8-87 PA oblique zygapophyseal joints. RAO for joints closest to film.](image-url)
Zygapophyseal Joints

Recumbent position

Image receptor: 35 × 43 cm or 18 × 43 cm

Position of patient

- Place the patient in a lateral recumbent position.
- Elevate the head on a firm pillow so that its midsagittal plane is continuous with that of the vertebral column.
- Flex the patient’s hips and knees to a comfortable position.

Position of part

- For anterior (PA oblique) rotation, place the lower arm behind the back and the upper arm forward with the hand on the table for support (Fig. 8-88).
- For posterior (AP oblique) rotation, adjust the lower arm at right angles to the long axis of the body, flex the elbow, and place the hand under or beside the head. Place the upper arm posteriorly and support it (Fig. 8-89).
- Rotate the body slightly, either anteriorly or posteriorly 20 degrees, so that the coronal plane forms an angle of 70 degrees with the horizontal.
- Center the vertebral column to the midline of the grid.
- Center the IR 1½ to 2 inches (3.8-5 cm) above the shoulders to center it at the level of T7.

Central ray

- Perpendicular to the IR exiting or entering the level of T7

Fig. 8-88 PA oblique zygapophyseal joints: LAO for joints closest to film.

Fig. 8-89 AP oblique zygapophyseal joints: RPO for joints farthest from film.

- If needed, apply a compression band across the hips, but be careful not to change the position.
- Shield gonads.
- Respiration: Suspend at the end of expiration.
Zygapophyseal Joints

Structures shown
The resulting images show oblique projections of the zygapophyseal joints (arrows on Figs. 8-90 and 8-91). The number of joints shown depends on the thoracic curve. A greater degree of rotation from the lateral position is required to show the joints at the proximal and distal ends of the region in patients with an accentuated dorsal kyphosis. The inferior articular processes of T12, having an inclination of about 45 degrees, are not shown in this projection. (See Summary of Oblique Positions on page 486.)

EVALUATION CRITERIA
The following should be clearly demonstrated:
- All twelve thoracic vertebrae
- Zygapophyseal joints closest to the IR on PA obliques and the joints farthest from the film on AP obliques
- Wide exposure latitude

NOTE: The AP oblique projection gives an excellent demonstration of the cervicothoracic spinous processes and is used for this purpose when the patient cannot be satisfactorily positioned for a direct lateral projection.

Fig. 8-90 Upright PA oblique zygapophyseal joints: LAO position. The arrow indicates the articulation that is closest to the IR.

Fig. 8-91 Recumbent AP oblique zygapophyseal joints: RPO position. The arrow indicates the articulation that is farthest from the IR.
Lumbar-Lumbosacral Vertebrae

**AP PROJECTION**

**PA PROJECTION (OPTIONAL)**

If possible, gas and fecal material should be cleared from the intestinal tract for the examination of bones lying within the abdominal and pelvic regions. The urinary bladder should be emptied just before the examination to eliminate superimposition caused by the secondary radiation generated within the filled bladder.

An AP or PA projection may be used, but the AP projection is more commonly employed. The AP projection is generally used for recumbent examinations. The extended limb position accentuates the lordotic curve resulting in distortion of the bodies and poor delineation of the intervertebral disk spaces (Figs. 8-92 and 8-93). This curve can be reduced by flexing the patient’s hips and knees enough to place the back in firm contact with the radiographic table (Figs. 8-94 and 8-95).

The PA projection places the intervertebral disk spaces at an angle closely paralleling the divergence of the beam of radiation (see Figs. 8-96 and 8-93, C). This projection also reduces the dose to the patient. For this reason the PA projection is sometimes used for upright studies of the lumbar and lumbosacral spine.

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Fig. 8-92 Lumbar spine demonstrating intervertebral disk spaces are not parallel; diverging central ray.

Fig. 8-93 Lumbar spine: AP and PA comparison on same patient. A, AP with limbs extended. B, AP with limbs flexed. C, PA.

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**Special Positioning**

- If a patient is having severe back pain, place a footboard on the radiographic table and stand the table upright before beginning the examination.
- Have the patient stand on the footboard, and position the part for the projection.
- Turn the table to the horizontal position for the exposure and return it to the upright position for the next projection.
- Although this procedure takes a few minutes, the patient will appreciate its ability to minimize the pain.

**Image receptor:** 35 x 43 cm or 30 x 35 cm.

**SID:** 48 inches (122 cm) is recommended to reduce distortion, more completely open the intervertebral joint spaces, and improve the overall quality of the examination.

**Position of patient**

- Examine the lumbar or lumbosacral spine with the patient recumbent.

**NOTE:** Upright may be used when the patient has excruciating pain to reduce the physical discomfort associated with the examination.

**Position of part**

- Center the midsagittal plane of the patient’s body to the midline of the grid.
- Adjust the patient’s shoulders and hips to lie in the same horizontal plane.
- Flex the patient’s elbows, and place the hands on the upper chest so that the forearms do not lie within the exposure field.
- A radiolucent support under the lower pelvic side can be used to reduce rotation when necessary.
- Reduce lumbar lordosis by flexing the patient’s hips and knees enough to place the back in firm contact with table (see Fig. 8-95).
- For demonstration of the lumbar spine and sacrum, center the 35 x 43 cm IR at the level of the iliac crests (L4). Carefully palpate the crest of the ilium. It is possible to be misled by the contour of the heavy muscles and fatty tissue lying above the bone.
- For demonstration of the lumbar spine only, center the 30 x 35 cm IR 1½ inches (3.8 cm) above the iliac crest (L3).
- Shield gonads.
- Respiration: Suspend at the end of expiration.

**Central ray**

- Perpendicular to the IR at the level of the iliac crests (L4) for a lumbosacral examination or 1½ inches (3.8 cm) above the iliac crests (L3) for a lumbar examination.

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**Fig. 8-94** AP lumbar spine with limbs extended, creating increased lordotic curve.

**Fig. 8-95** AP lumbar spine with limbs flexed, decreasing lordotic curve.

**Fig. 8-96** Lumbar spine showing intervertebral disk spaces nearly parallel with divergent PA x-ray beam.
Lumbar-Lumbosacral Vertebrae

Structures shown, AP and PA

The resulting image shows the lumbar bodies, intervertebral disk spaces, interpediculate spaces, laminae, and spinous and transverse processes (Figs. 8-97 and 8-98). When the larger IR is used, the images include one or two of the lower thoracic vertebrae, the sacrum coccyx, and the pelvic bones. Because of the angle at which the last lumbar segment joins the sacrum, this lumbosacral disk space is not shown well in the AP projection. The positions used for this purpose are described in the next several sections.

Many radiologists request or prefer that the AP projection be performed with the collimator open to the IR size. This provides additional information about the abdomen, in particular when the projection is done for trauma purposes. The larger field enables visualization of the liver, kidney, spleen, and psoas muscle margins along with air or gas patterns (Fig. 8-97, B).

EVALUATION CRITERIA

The following should be clearly demonstrated:

- Area from the lower thoracic vertebrae to the sacrum
- X-ray beam collimated to the lateral margin of the psoas muscles
- No artifact across the midabdomen from any elastic in the patient’s underclothing
- X-ray penetration of all vertebral structures
- Open intervertebral joints
- Sacroiliac joints equidistant from the vertebral column
- Symmetric vertebrae, with spinous processes centered to the bodies

RESEARCH: This projection was researched and standardized by Laura Carwile, MS, RT(R)(M)(QM).
Fig. 8-97 AP lumbosacral spine. A, Close collimation technique. B, Collimation opened to IR size 35 x 43 cm (14 x 17 inch) to show the abdomen along with the lumbar spine.

Fig. 8-98 AP lumbar spine demonstrating spina bifida (arrows).
**LATERAL PROJECTION**

**R or L position**

**Image receptor:** 35 × 43 cm or 30 × 35 cm

**Position of patient**
- For the lateral position, use the same body position (recumbent or upright) as for the AP or PA projection.
- Have the patient dressed in an open-backed gown so that the spine can be exposed for final adjustment of the position.

**Position of part**

**Recumbent position**
- Ask the patient to turn onto the affected side and flex hips and knees to a comfortable position.
- When examining a thin patient, adjust a suitable pad under the dependent hip to relieve pressure.
- Align the midcoronal plane of the body to the midline of the grid and ensure that it is vertical. Remember that no matter how large the patient, the long axis of the body of the lumbar spine is situated in the midcoronal plane (Fig. 8-99).
- With the patient's elbow flexed, adjust the dependent arm at right angles to the body.
- To prevent rotation, exactly superimpose the knees and place a small sandbag between them.
- Place a suitable radiolucent support under the lower thorax, and adjust it so that the long axis of the spine is horizontal (Fig. 8-100, A). This is the preferred method of positioning the spine.
- When using a 35 × 43 cm IR, center it at the level of the crest of the ilium (L4). With a 30 × 35 cm IR, center it 1½ inches (3.8 cm) above the crest.
- Shield gonads.
- Respiration: Suspend at the end of expiration.

**Central ray**
- Perpendicular to the level of the crest of the ilium (L4) when using a 35 × 43 cm IR for the lumbosacral spine, or 1½ inches (3.8 cm) above the crest (L3) if a 30 × 35 cm IR is used for the lumbar spine only. The central ray enters the midcoronal plane (Fig. 8-100, A).
- When the spine cannot be adjusted so that it is horizontal, angle the central ray caudad so that it is perpendicular to the long axis (Fig. 8-100, B). The degree of central ray angulation depends on the angulation of the lumbar column and the breadth of the pelvis. In most instances an average caudal angle of 5 degrees for men and 8 degrees for women with a wide pelvis is used.

**COMPUTED RADIOGRAPHY**

Because of the higher kVp used for this projection, the collimation must be very close. Scattered and primary radiation reaching the IR IP may cause computer artifacts. The tabletop should be covered with a lead sheet.

**Structures shown**

The resulting image shows the lumbar bodies and their interspaces, the spinous processes, and the lumbosacral junction (Fig. 8-101). This projection gives a profile image of the intervertebral foramina of L1-4. The L5 intervertebral foramina (right and left) are not usually well visualized in this projection because of their oblique direction. Consequently, oblique projections are used for these foramina.

**EVALUATION CRITERIA**

The following should be clearly demonstrated:
- Area from the lower thoracic vertebrae to the coccyx using a 35 × 43 cm image receptor
- Area from the lower thoracic vertebrae to the sacrum using a 30 × 35 cm image receptor
- Open intervertebral disk spaces
- Superimposed posterior margins of each vertebral body
- Vertebrae aligned down the middle of the radiograph
- Nearly superimposed crests of the ilia when the x-ray beam is not angled
- Spinous processes

**RESEARCH:** This projection was rewritten and standardized by Laura Carwile, MS, RT(R) (M)(QM).
Lumbar-Lumbosacral Vertebrae

Improving radiographic quality

The quality of the radiographic image can be improved if a sheet of leaded rubber is placed on the table behind the patient (see Fig. 8-100). The lead absorbs scatter radiation coming from the patient and also prevents table scatter. Scatter radiation serves only to decrease the quality of the radiograph and to blacken the spinous processes. More important is that with AEC, scatter radiation coming from the patient is often sufficient to prematurely terminate the exposure. As a result, the image may be underexposed. For the same reason, close collimation is necessary for lateral spine radiographs. Scattered radiation control is critically important when using computed tomography.

Fig. 8-100 Lateral lumbar spine. A, Horizontal spine and perpendicular central ray. B, Spine is angled and central ray directed caudal to be perpendicular to the long axis of the spine.

Fig. 8-101 A, Lateral lumbar spine, 30 x 35 cm IR. B, Lateral lumbosacral spine, 35 x 43 cm IR.
L5-S1 Lumbosacral Junction

**LATERAL PROJECTION**

**R or L position**

- **Image receptor:** 8 × 10 inch (18 × 24 cm)

**Position of patient**

- Examine the L5-S1 lumbosacral region with the patient in the lateral recumbent position.

**Position of part**

- With the patient in the recumbent position, adjust the pillow to place the mid-sagittal plane of the head in the same plane with the spine.

- Adjust the midcoronal plane of the body (passing through the hips and shoulders) so it is perpendicular to the IR.
- Flex the patient's elbow, and adjust the dependent arm in a position at right angles to the body (Fig. 8-102, A).
- If possible, fully extend the patient's hips for this study.
- As described for the lateral projection, place a radiolucent support under the lower thorax and adjust it so that the long axis of the spine is horizontal (see Fig. 8-102, A). This is the preferred method.
- Superimpose the knees exactly, and place a support between them.
- Shield gonads.
- **Respiration:** Suspend.

**COMPUTED RADIOGRAPHY**

The higher kVp used for this projection requires the use of very close collimation. Computer artifacts may be caused by scattered and primary radiation that could reach the IP phosphor. Therefore the top of the radiography table should be covered by a lead sheet. If collimation is done correctly, no primary radiation should reach the IR.

**Central ray**

- The elevated anterior superior iliac spine (ASIS) is easily palpated and found in all patients when lying on their side. The ASIS provides a standardized and accurate reference point from which to center the L5-S1 junction.
- Center on a coronal plane 2 inches (5 cm) posterior to the ASIS and 1¼ inches (3.8 cm) inferior to the iliac crest.

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![Diagram](image_url)

Fig. 8-102  **A**, Lateral L5-S1. **B**, Optimal L5-S1 joint position. The lower abdomen is blocked to place the spine parallel with the IR. The interiliac (IL) line is perpendicular, and the central ray (CR) is perpendicular. **C**, Typical lumbar spine curvature. If blocking cannot be used, angle the CR caudad and parallel to the IL. **D**, Typical lumbar spine position in a patient with a large waist. The IL demonstrates that the CR must be angled cephalad to open the joint space.

(Modified from Francis C: Method improves consistency in L5-S1 joint-space films, Radiol Technol 63:302, 1992.)
L5-S1 Lumbosacral Junction

- Center the IR to the central ray.
- Use close collimation.
- When the spine is not in the true horizontal position, the central ray is angled 5 degrees caudally for male patients and 8 degrees caudally for female patients.
- Francis identified an alternate technique to demonstrate the open L5-S1 interspace when the spine is not horizontal:
  1. With the patient in the lateral position, locate both iliac crests.
  2. Draw an imaginary line between the two points (the interiliac plane).
  3. Adjust central ray angulation to be parallel with the interiliac line (see Fig. 8-102, B, C, and D).

Structures shown
The resulting image shows a lateral projection of the lumbosacral junction, the lower one or two lumbar vertebrae, and the upper sacrum (Fig. 8-103).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Open lumbosacral joint
- Collimated x-ray beam that includes all of L5 and the upper sacrum
- Lumbosacral joint in the center of the exposure area
- Crests of the ilia closely superimposing each other when the x-ray beam is not angled

**Zygapophyseal Joints**

### AP OBLIQUE PROJECTION

**RPO and LPO positions**

The articular processes of the lumbar vertebrae form an angle of 30 to 50 degrees, and those between the last lumbar vertebra and the sacrum form an angle of 30 degrees to the midsagittal plane in the majority of patients. However, the angulation varies from patient to patient and from side to side in the same patient. For comparison, radiographs are generally obtained from both sides.

**Image receptor:** 35 × 43 cm or 30 × 35 cm lengthwise; 8 × 10 inch (18 × 24 cm) for the last zygapophyseal joint

**Position of patient**

- When oblique projections are indicated, they are generally performed immediately after the AP projection and in the same body position (recumbent or upright).

**Position of part**

- Have the patient turn from the supine position toward the affected side approximately 45 degrees to demonstrate the joints closest to the IR (opposite the thoracic zygapophyseal joints).
- Adjust the patient's body so that the long axis of the patient is parallel with the long axis of the radiographic table.
- Center the patient's spine to the midline of the grid. In the oblique position the lumbar spine lies in the longitudinal plane that passes 2 inches (5 cm) medial to the elevated ASIS.
- Ask the patient to place the arms in a comfortable position. A support may be placed under the elevated shoulder, hip, and knee (Figs. 8-104 and 8-105).
- Check the degree of body rotation, and make any necessary adjustments. Adjust at an angle of 45 degrees for demonstration of the articular processes in the lumbar region and at an angle of 30 degrees for demonstration of the lumbosacral processes.

**Shield gonads.**

**Respiration:** Suspend at the end of expiration.

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**Fig. 8-104** AP oblique lumbar spine: RPO for right zygapophyseal joints.

**Fig. 8-105** AP oblique lumbar spine: LPO for left zygapophyseal joints.

**Fig. 8-106** Parts of "Scottie dog."
Zygapophyseal Joints

Central ray

Lumbar region
- Enter 2 inches (5 cm) medial to the elevated ASIS and 1½ inches (3.8 cm) above the iliac crest (L3).

Fifth zygapophyseal joint
- Enter 2 inches (5 cm) medial to the elevated ASIS and then up to a point midway between the iliac crest and the ASIS.
- Center the IR to the central ray.

Structures shown
The resulting image shows an oblique projection of the lumbar and/or lumbosacral spine, demonstrating the articular processes of the side closest to the IR. Both sides are examined for comparison (Figs. 8-106 to 8-108).

When the body is placed in a 30- to 50-degree oblique position and the lumbar spine is radiographed, the articular processes and the zygapophyseal joints are demonstrated. When the patient has been properly positioned, images of the lumbar vertebrae have the appearance of “Scottie dogs.” Fig. 8-106 identifies the different structures that comprise the “Scottie dog” (See Summary of Obliques, p. 486.)

EVALUATION CRITERIA

The following should be clearly demonstrated:
- Area from the lower thoracic vertebrae to the sacrum.
- Zygapophyseal joints closest to the IR-open and uniformly visible through the vertebral bodies.
  - When the joint is not well demonstrated and the pedicle is anterior on the vertebral body, the patient is not rotated enough.
  - When the joint is not well demonstrated and the pedicle is posterior on the vertebral body, the patient is rotated too much.
- Vertebral column parallel with the tabletop so that the T12-L1 and L1-L2 joint spaces remain open.

Fig. 8-107 AP oblique lumbar spine: RPO for right zygapophyseal joints. (Note “Scottie dogs.”)

Fig. 8-108 AP oblique lumbar spine: RPO demonstrating L5 zygapophyseal joint (arrows) using a 30-degree position.
Zygapophyseal Joints

PA OBLIQUE PROJECTION
RAO and LAO positions

Image receptor: 35 × 43 cm or 30 × 35 cm lengthwise; 8 × 10 inch (18 × 24 cm) for the last zygapophyseal joint

Position of patient
- Examine the patient in the upright or recumbent prone position. The recumbent position is generally used because it facilitates immobilization.
- Greater ease in positioning the patient and a resultant higher percentage of success in duplicating results make the semiprone position preferable to the semisupine position. However, the OID is increased, which can affect resolution.

Position of part
- The joints farthest from the IR are demonstrated with the PA oblique projection (opposite the thoracic zygapophyseal joints).
- From the prone position, have the patient turn to a semiprone position and support the body on the forearm and flexed knee.
- Align the body to center L3 to the midline of the grid (Fig. 8-109).
- Adjust the degree of body rotation to an angle of 45 degrees for the lumbar region and 30 degrees from the horizontal for the lumbosacral zygapophyseal joint.
- Center the IR at the level of L3.
- To demonstrate the lumbosacral joint, position the patient as described above but center L5.
- Shield gonads.
- Respiration: Suspend at the end of expiration.

Central ray
- Perpendicular to enter the L3 (1 to 1½ inches [2.5 to 3.8 cm] above the crest of the ilium). The central ray enters the elevated side approximately 2 inches (5 cm) lateral to the palpable spinous process.

Structures shown
The resulting image shows an oblique projection of the lumbar or lumbosacral vertebrae, demonstrating the articular processes of the side farther from the IR (Figs. 8-110, 8-111, and 8-112). The T12-L1 articulation between the twelfth thoracic and first lumbar vertebrae, having the same direction as those in the lumbar region, is shown on the larger IR.

The fifth lumbosacral joint is usually well demonstrated in oblique positions (see Fig. 8-112).

When the body is placed in a 30- to 50-degree oblique position and the lumbar spine is radiographed, the articular processes and zygapophyseal joints are demonstrated. When the patient has been properly positioned, images of the lumbar vertebrae have the appearance of “Scottie dogs.” Fig. 8-110 identifies the different structures that comprise the “Scottie dog.” (See Summary of Obliques page 486.)
EVALUATION CRITERIA

The following should be clearly demonstrated:

- Area from the lower thoracic vertebrae to the sacrum.
- Zygapophyseal joints farthest from the IR.
- When the joint is not well demonstrated and the pedicle is quite anterior on the vertebral body, the patient is not rotated enough.
- When the joint is not well demonstrated and the pedicle is quite posterior on the vertebral body, the patient is rotated too much.
- Vertebral column parallel with the tabletop so that the T12-L1 and L1-L2 joint spaces remain open.
Intervertebral Foramen

Fifth Lumbar
PA AXIAL OBLIQUE PROJECTION
KOVÁCS METHOD
RAO and LAO positions

Image receptor: 8 × 10 inch (18 × 24 cm) lengthwise.

Position of patient
- Place the patient in the lateral recumbent position lying on the side being examined.


Position of part
- With the patient in the lateral position, align the body so that a plane passing 1½ inches (3.8 cm) posterior to the midcoronal plane is centered to the midline.
- Have the patient extend the upper arm and grasp the end of the radiographic table to maintain the thorax in the lateral position when the pelvis is rotated.
- Keeping the patient’s thorax exactly lateral, rotate the pelvis 30 degrees anteriorly from the lateral position.
- Place a sandbag support under the flexed uppermost knee to prevent too much rotation of the hips (Fig. 8-113).
- Adjust the position of the IR so that its midpoint coincides with the central ray.
- Shield gonads.
- Respiration: Suspend.

Central ray
- Directed along a straight line extending from the superior edge of the crest of the uppermost ilium through L5 to the inguinal region of the dependent side. Depending on the alignment of the spine, the central ray angulation may vary from 15 to 30 degrees caudad.

Fig. 8-113 PA axial oblique intervertebral foramen, L5, RAO: Kovács method.
Intervertebral Foramen

Structures shown
The resulting image shows the L5 intervertebral foramen. Both sides are examined for comparison.

The Kovács method (Figs. 8-114 and 8-115, A) is shown beside the lateral L5-S1 (Fig. 8-115, B) for comparison purposes.

EVALUATION CRITERIA
The following should be clearly demonstrated:

- Open L5 intervertebral foramen on the side closer to the IR
- L5 intervertebral foramen in the center of the radiograph

Fig. 8-114 PA axial oblique, intervertebral foramen, L5.

Fig. 8-115 A, PA axial oblique intervertebral foramen, L5, RAO: Kovács method. Intervertebral foramen (arrow). B, Lateral L5-S1 in the same patient.
Lumbosacral Junction and Sacroiliac Joints

**AP OR PA AXIAL PROJECTION**

**Image receptor:** 8 x 10 inch (18 x 24 cm) or 24 x 30 cm lengthwise

**Position of patient**
- For the AP axial projection of the lumbosacral and sacroiliac joints, position the patient in the supine position.

**Position of part**
- With the patient supine and the mid-sagittal plane centered to the grid, extend patient's lower limbs or abduct the thighs and adjust in the vertical position (Fig. 8-116).
- Ensure that the pelvis is not rotated.
- *Shield gonads.*
- *Respiration:* Suspend.

**Central ray**
- Directed through the lumbosacral joint at an average angle of 30 to 35 degrees cephalad. The central ray enters about 1 1/2 inches (3.8 cm) superior to the pubic symphysis on the midsagittal plane (Fig. 8-117).
- An angulation of 30 degrees in male patients and 35 degrees in female patients is usually satisfactory. By noting the contour of the lower back, unusual accentuation or diminution of the lumbosacral angle can be estimated and the central ray angulation can be varied accordingly.
- Center the IR to the CR.

**Structures shown**
The resulting image shows the lumbosacral joint and a symmetric image of both sacroiliac joints free of superimposition (Fig. 8-118).
Lumbosacral Junction and Sacroiliac Joints

EVALUATION CRITERIA

The following should be clearly demonstrated:

- Lumbosacral junction and sacrum
- Open intervertebral space between L5 and S1
- Both sacroiliac joints adequately penetrated

NOTE: The PA axial projection for the lumbosacral junction can be modified in accordance with the AP axial projection just described. With the patient in the prone position, the central ray is directed through the lumbosacral joint to the midpoint of the IR at an average angle of 35 degrees caudad. The central ray enters the spinous process of L4 (Figs. 8-119 and 8-120).

Meese' recommended the prone position for examinations of the sacroiliac joints because their obliquity places them in a position more nearly parallel with the divergence of the beam of radiation. The central ray is directed perpendicularly and is centered at the level of the ASIS. It enters the midline of the patient about 2 inches (5 cm) distal to the spinous process of L5 (Fig. 8-121).


Fig. 8-119 PA axial lumbosacral junction and sacroiliac joints.

Fig. 8-120 PA axial lumbosacral junction and sacroiliac joints.

Fig. 8-121 PA bilateral sacroiliac joints.
**Sacroiliac Joints**

### AP OBLIQUE PROJECTION

**RPO and LPO positions**

**Image receptor:** 8 × 10 inch (18 × 24 cm) or 24 × 30 cm lengthwise. Both obliques are usually obtained for comparison.

**Position of patient**

- Place the patient in the supine position, and elevate the head on a firm pillow.

**Position of part**

- Use the LPO position to demonstrate the right joint and the RPO position to show the left joint. The side being examined is farther from the IR.
- Elevate the side under examination approximately 25 to 30 degrees, and support the shoulder, lower thorax, and upper thigh (Figs. 8-122 and 8-123).
- Adjust the patient’s body so that its long axis is parallel with the long axis of the radiographic table.
- Align the body so that a sagittal plane passing 1 inch (2.5 cm) medial to the ASIS of the elevated side is centered to the midline of the grid.
- Check the rotation at several points along the back.
- Center the IR at the level of the ASIS.
- **Shield gonads.** Collimating close to the joint may shield the gonads in male patients. It may be difficult to use contact shielding in female patients.
- **Respiration:** Suspend.

---

**Fig. 8-122** AP oblique sacroiliac joint. RPO demonstrates left joint.

**Fig. 8-123** Degree of obliquity required to demonstrate sacroiliac joint for an AP projection.
Central ray

- Perpendicular to the center of the IR, entering 1 inch (2.5 cm) medial to the elevated ASIS

Structures shown

The resulting image shows the sacroiliac joint farthest from the IR and an oblique projection of the adjacent structures. Both sides are examined for comparison (Fig. 8-124). (See Summary of Oblique Positions, page 486.)

EVALUATION CRITERIA

The following should be clearly demonstrated:

- Open sacroiliac joint space with minimal overlapping of the ilium and sacrum
- Joint centered on the radiograph

NOTE: An AP axial oblique can be obtained by positioning the patient as described above. For the AP axial oblique, the central ray is directed at an angle of 20 to 25 degrees cephalad, entering 1 inch (2.5 cm) medial and 1½ inches (3.8 cm) distal to the elevated ASIS (Fig. 8-125).

NOTE: Brower and Kransdorf summarized difficulties in imaging the sacroiliac joints because of patient positioning and variability.

Sacroiliac Joints

PA OBLIQUE PROJECTION
RAO and LAO positions

**Image receptor:** 8 × 10 inch (18 × 24 cm) or 24 × 30 cm lengthwise. Both obliques are usually obtained for comparison.

**Position of patient**
- Place the patient in a semiprone position.
- Use the RAO position to demonstrate the right joint and the LAO position to show the left joint. The side being examined is closer to the IR.
- Have the patient rest on the forearm and flexed knee of the elevated side.
- Place a small, firm pillow under the head.

**Position of part**
- Adjust the patient by rotating the side of interest toward the radiographic table until a body rotation of 25 to 30 degrees is achieved. The forearm and flexed knee usually furnish sufficient support for this position.
- Check the degree of rotation at several points along the anterior surface of the patient’s body.
- Adjust the patient’s body so that its long axis is parallel with the long axis of the table.

- Center the body so that a point 1 inch (2.5 cm) medial to the ASIS closest to the IR is centered to the grid (Figs. 8-126 and 8-127).
- Center the IR at the level of the ASIS.
- Shield gonads. Collimating close to the joint may shield the gonads in male patients. It may be difficult to use contact shielding in female patients.
- Respiration: Suspend.

![Fig. 8-126](image) PA oblique sacroiliac joint; LAO demonstrates left joint.

![Fig. 8-127](image) Degree of obliquity required to demonstrate sacroiliac joint for a PA projection.
Sacroiliac Joints

Central ray
• Perpendicular to the IR and centered 1 inch (2.5 cm) medial to the ASIS closest to the IR

Structures shown
The resulting image shows the sacroiliac joint closest to the IR (Fig. 8-128). (See Summary of Oblique Positions, page 486.)

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Open sacroiliac joint space closest to the IR or minimal overlapping of the ilium and sacrum
- Joint centered on the radiograph

NOTE: A PA axial oblique can be obtained by positioning the patient as described previously. For the PA axial oblique, the central ray is directed 20 to 25 degrees caudad to enter the patient at the level of the transverse plane, pass 1 1/4 inches (3.8 cm) distal to the L5 spinous process, and exit at the level of the ASIS (Fig. 8-129).

Fig. 8-128  PA oblique sacroiliac joint. LAO demonstrates left joint.

Fig. 8-129  PA axial oblique sacroiliac joint. LAO with 20-degree caudal central ray demonstrates left joint (arrows).
PA PROJECTION
CHAMBERLAIN METHOD FOR ABNORMAL SACROILIAC MOTION
Chamberlain recommended the following projections in cases of sacroiliac slippage or relaxation:

1. A conventional lateral projection centered to the lumbosacral junction. Chamberlain suggested having this image made with the patient upright.
2. Two PA projections of the pubic bones, with the patient in the upright position and with weight-bearing on the alternate limbs to demonstrate pubic symphysis reaction by a change in the normal relation of the pubic bones in cases of sacroiliac slippage or relaxation.

This examination requires two blocks or supports approximately 6 inches (15 cm) high. The blocks are alternately removed to allow one leg to hang free.

Image receptor: 8 × 10 in (18 × 24 cm) lengthwise for each exposure

Position of patient
• Place the patient upright, facing the vertical grid device and standing on the two blocks.

Position of part
• Center the midsagittal plane of the body to the midline of the grid, and adjust the ASIS equidistant from the IR.
• Have the patient grasp the sides of the device for steadiness. However, the device must not be used to support the patient’s weight.
• If necessary, place a compression band across the pelvis to immobilize the patient but not to aid in supporting the weight of the body.
• Adjust the height of the grid, and center the IR to the pubic symphysis.
• For the first exposure, remove one of the blocks so that one leg hangs free. The patient should be given good instructions about letting the leg hang with no muscular resistance.
• For the second exposure, replace the support under the foot that was hanging, and remove the opposite one, permitting the second leg to hang free. Chamberlain suggested that the identification marker be placed on the weight-bearing side (Fig. 8-130).
• Shield gonads.
• Respiration: Suspend.

Fig. 8-130 PA symphysis pubis for demonstration of sacroiliac slippage.
Pubic Symphysis

Central ray
- Perpendicular and centered to the pubic symphysis.
- Use close collimation.

Structures shown
The two images show PA projections of the pubic symphysis. Abnormal motion of the sacroiliac joints is demonstrated by a change in the normal relation of the pubic bones to each other when the body weight is borne on one leg (Figs. 8-131 and 8-132).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Pubic symphysis in the center of the radiograph
- No rotation of the patient, indicated by symmetry of the pubic bones and obturator foramina
- Identification marker placed on the weight-bearing side

Fig. 8-131 PA pubic symphysis in a normal female patient.

Fig. 8-132 PA pubic symphysis in a normal male patient.
AP AND PA AXIAL PROJECTIONS

Because bowel content may interfere with the image, the colon should be free of gas and fecal material for examination of the sacrum and coccyx. A physician’s order for a bowel preparation may be needed. The urinary bladder should be emptied before the examination.

**Image receptor:** 24 × 30 cm for sacrum; 8 × 10 in (18 × 24 cm) for coccyx

**Position of patient**
- Place the patient in the supine position for the AP axial projection of the sacrum and coccyx so that the bones are as close as possible to the IR. The supine position is most often used. The prone position can be used without appreciable loss of detail and is particularly appropriate for patients with a painful injury or destructive disease.

**Position of part**
- With the patient either supine or prone, center the midsagittal plane of the body to the midline of the table grid.
- Adjust the patient so that both ASISs are equidistant from the grid.
- Have the patient flex the elbows and place the arms in a comfortable, bilaterally symmetric position.
- When the supine position is used, place a support under the patient’s knees.
- Shield gonads on men. Women cannot be shielded for this projection.
- Respiration: Suspend.

**Central ray**

**Sacrum**
- With the patient supine, direct the central ray 15 degrees cephalad and center it to a point 2 inches (5 cm) superior to the pubic symphysis (Figs. 8-133 and 8-134).
- With the patient prone, angle the central ray 15 degrees caudad and center it to the clearly visible sacral curve (Fig. 8-135).

![Fig. 8-133 AP axial sacrum.](image1)

![Fig. 8-134 AP axial sacrum.](image2)
Sacrum and Coccyx

Coccyx

- With the patient supine, direct the central ray 10 degrees caudad and center it to a point about 2 inches (5 cm) superior to the pubic symphysis (Figs. 8-136 and 8-137).
- With the patient prone, angle the central ray 10 degrees cephalad and center it to the easily palpable coccyx.
- Center the IR to the central ray.

Structures shown

The resulting image demonstrates the sacrum or coccyx free of superimposition (see Figs. 8-134, 8-135, and 8-137).

EVALUATION CRITERIA

The following should be clearly demonstrated:

Sacrum
- Sacrum free of foreshortening, with the sacral curvature straightened
- Pubic bones not overlapping the sacrum
- Short-scale contrast
- No rotation of the sacrum, as indicated by symmetric alae
- Sacrum centered and seen in its entirety
- Tight collimation evident to improve the radiographic contrast
- Fecal material not overlapping the sacrum

Coccyx
- Coccygeal segments not superimposed
- Short-scale contrast on the radiograph
- No rotation
- Coccyx centered and seen in its entirety
- Tight collimation evident to improve the visibility

Radiation protection

- Because the ovaries lie within the exposure area, use close collimation for the female patient to limit the irradiated area and the amount of scatter radiation.
- For male patients, use gonad shielding in addition to close collimation.
LATERAL PROJECTIONS

R or L position

Image receptor: 24 × 30 cm for sacrum; 8 × 10 inch (18 × 24 cm) for coccyx, lengthwise

Position of patient

- Ask the patient to turn onto the indicated side and flex the hips and knees to a comfortable position.

Position of part

- Adjust the arms in a position at right angles to the body.
- Superimpose the knees, and if needed, place positioning sponges under and between the ankles and between the knees.
- Adjust a support under the body to place the long axis of the spine horizontal. The interiliac plane is perpendicular to the IR.
- Adjust the pelvis and shoulders so that the true lateral position is maintained (i.e., no rotation) (Figs. 8-138 and 8-139).
- To prepare for accurate positioning of the central ray, center the sacrum or coccyx to the midline of the grid.
- Shield gonads.
- Respiration: Suspend.

Fig. 8-138 Lateral sacrum.

Fig. 8-139 Lateral coccyx.
Sacrum and Coccyx

Central ray
- The elevated ASIS is easily palpated and found on all patients when they are lying on their side. This provides a standardized reference point from which to center the sacrum and coccyx (Fig. 8-140).

Sacrum
- Perpendicular and directed to the level of the ASIS and to a point 3½ inches (9 cm) posterior. This centering should work for most patients. The exact position of the sacrum depends on the pelvic curve.

Coccyx
- Perpendicular and directed toward a point 3½ inches (9 cm) posterior to the ASIS and 2 inches (5 cm) inferior. This centering should work for most patients. The exact position of the coccyx depends on the pelvic curve.
- Center the IR to the central ray.
- Use close collimation.

Structures shown
The resulting image shows a lateral projection of the sacrum or coccyx (Fig. 8-141).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Sacrum and coccyx seen clearly with short-scale contrast
- Use of tight collimation and a lead rubber absorber behind the sacrum
- Closely superimposed posterior margins of the ischia and ilia

Improving radiographic quality
The quality of the radiograph can be improved if a sheet of leaded rubber is placed on the table behind the patient (see Figs. 8-138 and 8-139). The lead absorbs the scatter radiation coming from the patient. Scatter radiation serves only to decrease the quality of the radiograph. More importantly, with AEC the scatter radiation coming from the patient is often sufficient to prematurely terminate the exposure, resulting in an underexposed radiograph. For the same reason, close collimation is necessary for lateral sacrum and coccyx images. This is critically important when using computed tomography.
Position of patient
- For examination of the sacral vertebral canal, seat the patient on the end of the radiographic table. The patient should sit far enough back to center the midsagittal plane of the body to the horizontal axis of the Bucky tray.
- If the patient is too short to be comfortably seated far back on the end of the table, shift the IR off center in the Bucky tray so that its midpoint coincides with the region of the canal to be examined (unless this is contraindicated by the use of AEC).
- Support the patient's feet on a chair or a stool.

Position of part
- Adjust the position of the patient's body so that the midsagittal plane is perpendicular to the midline of the grid.
- Have the patient lean forward enough that the upper, middle, or lower portion of the sacral vertebral canal is vertical.
- Be certain that the patient is not leaning laterally.
- Have the patient grasp the legs or ankles (depending on the degree of leaning) to maintain the position.
- Center the IR to the vertically placed portion of the sacrum (Figs. 8-142 to 8-145).
- Respiration: Suspend.
Sacral Vertebral Canal and Sacroiliac Joints

Central ray
- Perpendicular to the IR and the long axis of the sacrum.
- Use close collimation.

Structures shown
The resulting image with the spine slightly flexed shows the lower sacral vertebral canal, the junction of the sacrum and coccyx, and the last lumbar vertebra (Fig. 8-146).

When the patient is leaning forward in a position of moderate flexion (see Fig. 8-144), the resultant image shows a cross section of the upper and lower sacral vertebral canal. The sacroiliac joints are also demonstrated (Fig. 8-147).

When the patient is leaning forward in a position of acute flexion (see Fig. 8-145), the resultant image shows the upper sacral vertebral canal projected into the angle formed by the ascending rami of the ischial bones just posterior to the pubic symphysis (Fig. 8-148). The spinous process of the last lumbar segment is projected across the shadow of the canal.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Sacral vertebral canal in the center of the exposure area
- No lateral rotation of the patient (sacral and pelvic structures are symmetric)
Lumbar Intervertebral Disks

PA PROJECTION

WEIGHT-BEARING METHOD

R and L bending

Image receptor: $35 \times 43$ cm lengthwise

Position of part
- With the patient facing the vertical grid device, adjust the height of the to be at the level of L3.
- Adjust the patient’s pelvis for rotation by ensuring that the ASISs are equidistant from the IR.
- Center the midsagittal plane of the patient’s body to the midline of the vertical grid device (Fig. 8-149).
- Let the patient’s arms hang unsupported by the sides.
- Make one radiograph with the patient bending to the right and one with the patient bending to the left (see Fig. 8-149).
- Have the patient lean directly lateral as far as possible without rotation and without lifting the foot. The degree of bending must not be forced, and the patient must not be supported in position.
- Be certain that the midsagittal plane of the lower lumbar column and sacrum remains centered to the grid device as the upper portion moves laterally.
- Shield gonads.
- Respiration: Suspend.

Central ray
- Directed perpendicular to L3 at an angle of 15 to 20 degrees caudad or projected through the L4-L5 or L5-S1 interspaces, if these are the areas of interest.
- Use close collimation.

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Fig. 8-149 PA lumbar intervertebral disks with right bending.
Lumbar Intervertebral Disks

Structures shown
The resulting images show bending PA projections of the lower thoracic region and the lumbar region for demonstration of the mobility of the intervertebral joints. In patients with disk protrusion, this type of examination is used to localize the involved joint as shown by limitation of motion at the site of the lesion (see Fig. 8-149).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Area from the lower thoracic interspaces to all of the sacrum
- No rotation of the patient in the bending position
- Bending direction correctly identified on the image with appropriate lead markers

**Radiation protection**
The PA projection is recommended over the AP projection whenever the clinical information provided by the examination is not compromised. With the PA projection the patient’s gonad area and breast tissue receive significantly less radiation than when the AP projection is used. In addition, proper collimation reduces the radiation dose to the patient. Lead shielding material should be placed between the x-ray tube and the male patient’s gonads to further protect this area from unnecessary radiation.
Scoliosis is an abnormal lateral curvature of the vertebral column with some associated rotation of the vertebral bodies at the curve. This condition may be caused by disease, surgery, or trauma, but it is frequently idiopathic. Scoliosis is commonly detected in the adolescent years. If not detected and treated, it may progress to the point of debilitation.

Diagnosis and monitoring of scoliosis requires a series of radiographs that may include upright, supine, and bending studies. A typical scoliosis study might include the following projections:

- PA (or AP) upright
- PA (or AP) upright with lateral bending
- Lateral upright (with or without bending)
- PA (or AP) prone or supine

The PA (or AP) and lateral upright projections demonstrate the amount/degree of curvature that occurs with the force of gravity acting on the body (Fig. 8-150). Spinal fixation devices, such as Harrington rods, may also be evaluated. Bending studies are often used to differentiate primary from compensatory curves. Primary curves will not change when the patient bends; secondary curves will.

Because scoliosis is generally diagnosed and evaluated during the teenage years, proper radiographic techniques are important. Ideally, large film-screen systems and grids, such as 14 x 36 inches (35 x 90 cm), are used to demonstrate the entire spine with one exposure. The wide range of body-part thicknesses and specific gravities in the thoracic and abdominal areas necessitates the use of compensating filters.

To expose the length of the 36-inch (90 cm) IR, a minimum 60-inch (152 cm) SID is used.

Fig. 8-150 Standing full spine radiography, using a 14 x 36 inch (35 x 90 cm) IR. A, PA projection. B, Lateral projection.
RADIATION PROTECTION

In 1983 Frank et al. described the use of the PA projection for scoliosis radiography. Also in 1983, Frank and Kuntz described a simple method of protecting the breasts during scoliosis radiography. By 1986 the federal government had endorsed the use of these techniques in an article by Butler et al.¹

Radiation protection is crucial. Collimation must be closely limited to irradiate only the thoracic and lumbar spine. The gonads should be shielded by placing a lead apron at the level of the ASIS between the patient and the x-ray tube. The breasts should be shielded with leaded rubber or leaded acrylic (Figs. 8-151 and 8-152), or the breast radiation exposure should be decreased by performing PA projections. Rare earth screens and high kVp techniques can also decrease the radiation dose.


Fig. 8-151  Standing full spine radiography. A, PA projection. Note the cloverleaf gonad shield and the bilateral breast shielding. B, Lateral projection. Note the breast shielding.

Fig. 8-152  Collimator face showing magnetically held breast shields and gonad shield.

(Courtesy Nuclear Associates, Carlyle, Pa.)
Thoracolumbar Spine: Scoliosis

PA

FERGUSON METHOD

The patient should be positioned to obtain a PA projection (in lieu of the AP projection) to reduce radiation exposure to selected radiosensitive organs. The decision on whether to use a PA or AP projection is often determined by the physician or the institutional policy.

Image receptor: 14 x 36 inch (35 x 90 cm) or 35 x 43 cm lengthwise

Position of patient
- For a PA projection, place the patient in a seated or standing position in front of a vertical grid device.
- Have the patient sit or stand straight, and then adjust the height of the IR to include about 1 inch (2.5 cm) of the iliac crests (Fig. 8-153).

Position of part
- For the first radiograph, adjust the patient in a normally seated or standing position to check the spinal curvature.
- Center the midsagittal plane of the patient’s body to the midline of the grid.
- Allow the patient’s arms to hang relaxed at the sides. If the patient is seated, flex the elbows and rest the hands on the lap (Fig. 8-154).
- Do not support the patient or use a compression band.
- Shield gonads.
- For the second radiograph, elevate the patient’s hip or foot on the convex side of the primary curve approximately 3 or 4 inches (7.6 to 10.2 cm) by placing a block, a book, or sandbags under the buttock or foot (Fig. 8-155). Ferguson specified that the elevation must be sufficient to make the patient expend some effort in maintaining the position.
- Do not support the patient in these positions.
- Do not employ a compression band.
- Shield gonads.
- Respiration: Suspend.

Obtain additional radiographs (if needed) with elevation of the hip on the side opposite the major or primary curve (Fig. 8-156) or with the patient in a recumbent position (Fig. 8-157).

Central ray
- Perpendicular to the midpoint of the IR

Structures shown
The resulting images show PA projections of the thoracic and lumbar vertebrae, which are used for comparison to distinguish the deforming or primary curve from the compensatory curve in patients with scoliosis (see Figs. 8-154 to 8-157).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Thoracic and lumbar vertebrae to include about 1 inch (2.5 cm) of the iliac crests
- Vertebral column aligned down the center of the radiograph
- Correct identification marker

Fig. 8-153  PA thoracic and lumbar spine for scoliosis, upright.

Fig. 8-154  PA thoracic and lumbar spine for scoliosis, upright, demonstrating structural (major or primary) curve (arrow).
NOTE: Another widely used scoliosis series consists of four images of the thoracic and lumbar spine: a direct PA projection with the patient standing, a direct PA projection with the patient prone, and PA projections with alternate right and left lateral flexion in the prone position. The right and left bending positions are described in the next section. For the scoliosis series, however, 35 x 43 cm (14 x 17 inch) IRs are used and are placed to include about 1 inch (2.5 cm) of the crests of ilia.

NOTE: Young, Oestreich, and Goldstein\(^1\) described their application of this scoliosis procedure in detail. They recommended the addition of a lateral position, made with the patient standing upright, to show spondylolisthesis or demonstrate exaggerated degrees of kyphosis or lordosis. Kittleson and Lim\(^2\) described both the Ferguson and Cobb methods of measurement of scoliosis.


Fig. 8-155 PA thoracic and lumbar spine with left hip elevated.

Fig. 8-156 PA thoracic and lumbar spine with right hip elevated.

Fig. 8-157 PA thoracic and lumbar spine for scoliosis, prone.
Lumbar Spine: Spinal Fusion

**AP PROJECTION**

*R and L bending*

- **Image receptor:** 24 × 30 cm or 35 × 43 cm lengthwise for each exposure

**Position of patient**
- Place the patient in the supine position, and center the midsagittal plane of the body to the midline of the grid.

**Position of part**
- Make the first radiograph with maximum right bending, and make the second radiograph with maximum left bending.
- To obtain equal bending force throughout the spine, cross the patient’s leg on the opposite side to be flexed over the other leg. For example, a right bending requires the left leg to be crossed over the right.
- Move both of the patient’s heels toward the side that is flexed. Immobilize the heels with sandbags.
- Move the shoulders directly lateral as far as possible without rotating the pelvis (Fig. 8-158).
- After the patient is in position, apply a compression band to prevent movement.
- **Shield gonads.**
- **Respiration:** Suspend.

Fig. 8-158 AP lumbar spine, right bending.
Central ray

- Perpendicular to the level of the third lumbar vertebra, 1 to 1½ inches (2.5 to 3.8 cm) above the iliac crest on the midsagittal plane
- Center the IR to the central ray

Structures shown

The resulting images show AP projections of the lumbar vertebrae, made in maximum right and left lateral flexion (Figs. 8-159 and 8-160). These studies are employed in patients with early scoliosis to determine the presence of structural change when bending to the right and left. The studies are also used to localize a herniated disk as shown by limitation of motion at the site of the lesion and to demonstrate whether there is motion in the area of a spinal fusion. The latter examination is usually performed 6 months after the fusion operation.

EVALUATION CRITERIA

The following should be clearly demonstrated:

- Site of the spinal fusion centered and including the superior and inferior vertebrae
- No rotation of the pelvis (symmetric ilia)
- Bending directions correctly identified with appropriate lead markers
- Sufficient radiographic density to demonstrate the degree of movement when vertebrae are superimposed

Fig. 8-159 AP lumbar spine, right bending spinal fusion series.

Fig. 8-160 AP lumbar spine, left bending spinal fusion series.
LUMBAR SPINE: SPINAL FUSION

LATERAL PROJECTION

R or L position

Hyperflexion and hyperextension

Image receptor: 35 × 43 cm lengthwise for each exposure

Position of patient
• Adjust the patient in a lateral recumbent position.
• Center the midsagittal plane to the midsagittal plane of the grid.

Position of part
• For the first radiograph, have the patient lean forward and draw the thighs up to forcibly flex the spine as much as possible (Fig. 8-161).
• For the second radiograph, have the patient lean the thorax backward and posteriorly extend the thighs and limbs as much as possible (Fig. 8-162).
• After the patient is in position, apply a compression band across the pelvis to prevent movement.
• Center the IR at the level of the spinal fusion.
• Shield gonads.
• Respiration: Suspend.

Fig. 8-161 Hyperflexion position.

Fig. 8-162 Hyperextension position.
Central ray
- Perpendicular to the spinal fusion area or L3

Structures shown
The resulting images show two lateral projections of the spine made in hyperflexion (Fig. 8-163) and hyperextension (Fig. 8-164) to determine whether motion is present in the area of a spinal fusion or to localize a herniated disk as shown by limitation of motion at the site of the lesion.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Site of the spinal fusion in the center of the radiograph
- No rotation of the vertebral column (posterior margins of the vertebral bodies are superimposed)
- Hyperflexion and hyperextension identification markers correctly used for each respective projection

Fig. 8-163 Lateral with hyperflexion.
Fig. 8-164 Lateral with hyperextension.
### Cervical Obliques

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<th>Position-Degrees</th>
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### Thoracic Obliques

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### Lumbar Obliques

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<td></td>
<td>RPO-45°</td>
<td>R - Z joints (joints down)</td>
<td>0°</td>
</tr>
<tr>
<td>PA Obliques</td>
<td>LAO-45°</td>
<td>R - Z joints (joints up)</td>
<td>0°</td>
</tr>
<tr>
<td></td>
<td>RAO-45°</td>
<td>L - Z joints (joints up)</td>
<td>0°</td>
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</tbody>
</table>

### Sacroiliac Obliques

<table>
<thead>
<tr>
<th>Projection</th>
<th>Position-Degrees</th>
<th>Structures Shown</th>
<th>CR</th>
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</thead>
<tbody>
<tr>
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<td>LPO-25°-30°</td>
<td>R - SI joint (joint up)</td>
<td>0°</td>
</tr>
<tr>
<td></td>
<td>RPO-25°-30°</td>
<td>L - SI joint (joint up)</td>
<td>0°</td>
</tr>
<tr>
<td>PA Obliques</td>
<td>LAO-25°-30°</td>
<td>L - SI joint (joint down)</td>
<td>0°</td>
</tr>
<tr>
<td></td>
<td>RAO-25°-30°</td>
<td>R - SI joint (joint down)</td>
<td>0°</td>
</tr>
</tbody>
</table>

IF: Intervertebral foramens; Z: zygapophyseal; SI: sacroiliac.
9
BONY THORAX

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PA ribs, with 10 to 15 degree caudal angulation.
## SUMMARY OF PROJECTIONS

### PROJECTIONS, POSITIONS & METHODS

<table>
<thead>
<tr>
<th>Page</th>
<th>Essential</th>
<th>Anatomy</th>
<th>Projection</th>
<th>Position</th>
<th>Method</th>
</tr>
</thead>
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<tr>
<td>500</td>
<td>●</td>
<td>Sternum</td>
<td>PA oblique</td>
<td>RAO</td>
<td>MOORE</td>
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<tr>
<td>502</td>
<td>●</td>
<td>Sternum</td>
<td>PA oblique</td>
<td>Modified prone</td>
<td>MOORE</td>
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<tr>
<td>504</td>
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<td>Sternum</td>
<td>Lateral</td>
<td>R or L upright</td>
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<td>●</td>
<td>Sternoclavicular articulations</td>
<td>PA</td>
<td></td>
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</tr>
<tr>
<td>509</td>
<td>●</td>
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<td>PA oblique</td>
<td>RAO or LAO</td>
<td>BODY ROTATION</td>
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<td>510</td>
<td>●</td>
<td>Sternoclavicular articulations</td>
<td>PA oblique</td>
<td>RAO or LAO</td>
<td>CENTRAL RAY ANGULATION</td>
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<td>512</td>
<td>●</td>
<td>Sternoclavicular articulations</td>
<td>Axiolateral</td>
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<td>KURZBAUER</td>
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<tr>
<td>518</td>
<td>●</td>
<td>Upper anterior ribs</td>
<td>PA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>520</td>
<td>●</td>
<td>Posterior ribs</td>
<td>AP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>522</td>
<td>●</td>
<td>Ribs: axillary</td>
<td>AP oblique</td>
<td>RPO or LPO</td>
<td></td>
</tr>
<tr>
<td>524</td>
<td>●</td>
<td>Ribs: axillary</td>
<td>PA oblique</td>
<td>RAO or LAO</td>
<td></td>
</tr>
<tr>
<td>526</td>
<td>●</td>
<td>Costal joints</td>
<td>AP axial</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The icons in the Essential column indicate projections that are frequently performed in the United States and Canada. Students should be competent in these projections.
Bony Thorax
The bony thorax supports the walls of the pleural cavity and diaphragm used in respiration. The thorax is constructed so that the volume of the thoracic cavity can be varied during respiration. The thorax also serves to protect the heart and lungs. The bony thorax is formed by the sternum, the 12 pairs of ribs, and the 12 thoracic vertebrae. The bony thorax protects the heart and lungs. Conical in shape, the bony thorax is narrower above than below, more wide than deep, and longer posteriorly than anteriorly.

Sternum
The sternum, or breastbone, is directed anteriorly and inferiorly and is centered over the midline of the anterior thorax (Figs. 9-1 to 9-3). A narrow, flat bone about 6 inches (15 cm) in length, the sternum consists of three parts: manubrium, body, and xiphoid process. The sternum supports the clavicles at the superior manubrial angles and provides attachment to the costal cartilages of the first seven pairs of ribs at the lateral borders.

Fig. 9-1 Anterior aspect of bony thorax.

Fig. 9-2 Anterolateral oblique aspect of bony thorax.

Fig. 9-3 A, Anterior aspect of sternum and sternoclavicular joints. B, Lateral sternum.
the *clavicular notch* articulates with the sternal extremity of the clavicle. On the lateral borders of the manubrium, immediately below the articular notches for the clavicles, are shallow depressions for the attachment of the cartilages of the first pair of ribs.

The **body** is the longest part of the sternum (4 inches [10.2 cm]) and is joined to the manubrium at the **sternal angle**, an obtuse angle that lies at the level of the junction of the second costal cartilage. Both the manubrium and the body contribute to the attachment of the second costal cartilage. The succeeding five pairs of costal cartilages are attached to the lateral borders of the body. The sternal angle is palpable; in the normally formed thorax, it lies anterior to the interspace between the fourth and fifth thoracic vertebrae when the body is upright.

The **xiphoid process**, the distal and smallest part of the sternum, is cartilaginous in early life and partially or completely ossifies, particularly the superior portion, in later life. The xiphoid process is variable in shape and often deviates from the midline of the body. In the normal thorax, the xiphoid process lies over the tenth thoracic vertebra and serves as a useful bony landmark for locating the superior portion of the liver and the inferior border of the heart.

**Ribs**

The 12 pairs of ribs are numbered consecutively superiorly to inferiorly (see Figs. 9-1, 9-2, and 9-4). The rib number corresponds to the thoracic vertebra to which it attaches. Each rib is a long, narrow, curved bone with an anteriorly attached piece of hyaline cartilage, the **costal cartilage**. The costal cartilages of the first through seventh ribs attach directly to the sternum. The costal cartilages of the eighth through tenth ribs attach to the costal cartilage of the seventh rib. The ribs are situated in an oblique plane slanting anteriorly and inferiorly so that their anterior ends lie 3 to 5 inches (7.6 to 12.5 cm) below the level of their vertebral ends. The degree of obliquity gradually increases from the first to the ninth rib and then decreases to the twelfth rib. The first seven ribs are called **true ribs** because they attach directly to the sternum. Ribs 8 to 12 are called **false ribs** because they do not attach directly to the sternum. The last two ribs (eleventh and twelfth ribs) are often called **floating ribs** because they are attached only to the vertebrae. The spaces between the ribs are referred to as the **intercostal spaces**.

The number of ribs may be increased by the presence of cervical and/or lumbar ribs. **Cervical ribs** articulate with the C7 vertebra but rarely attach to the sternum. Cervical ribs may be free, articulate, or fuse with the first rib. Lumbar ribs are less common than cervical ribs. **Lumbar ribs** can lend confusion to images. They can confirm the identification of the vertebral level, or they can be erroneously interpreted as a fractured transverse process of the L1 vertebra.

The ribs vary in breadth and length. The first rib is the shortest and broadest; the breadth gradually decreases to the twelfth rib, the narrowest rib. The length increases from the first to the seventh rib and then gradually decreases to the twelfth rib.

A typical rib consists of a **head**, a flattened **neck**, a **tubercle**, and a **body** (Figs. 9-5 and 9-6). The ribs have **facets** on their heads for articulation with the vertebrae. On some ribs, the facet is divided into a superior and inferior portion for articulation with demifacets on the vertebral bodies. The tubercle also contains a facet for articulation with the transverse process of the vertebra. The eleventh and twelfth ribs do not have a neck or tubercular facets. The two ends of a rib are termed the **vertebral end** and the **sternal end**.

From the point of articulation with the vertebral body, the rib projects posteriorly at an oblique angle to the point of articulation with the transverse process. The rib turns laterally to the **angle** of the body, where the bone arches anteriorly, medially, and inferiorly in an oblique plane. Located along the inferior and internal border of each rib is the **costal groove**, which contains costal arteries, veins, and nerves. Trauma to the ribs can damage these neurovascular structures, causing pain and hemorrhage.
Bony Thorax Articulations

The eight joints of the bony thorax are summarized in Table 9-1. A detailed description follows.

The sternoclavicular joints are the only points of articulation between the upper limbs and the trunk (see Fig. 9-3). Formed by the articulation between the sternal extremity of the clavicles and the clavicular notches of the manubrium, these synovial gliding joints permit free movement (the gliding of one surface on the other). A circular disk of fibrocartilage is interposed between the articular ends of the bones in each joint, and the joints are enclosed in articular capsules.

**TABLE 9-1**

<table>
<thead>
<tr>
<th>Joint</th>
<th>Structural classification</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tissue</td>
<td>Type</td>
</tr>
<tr>
<td>Sternoclavicular</td>
<td>Synovial</td>
<td>Gliding</td>
</tr>
<tr>
<td>Costovertebral:</td>
<td>Synovial</td>
<td>Gliding</td>
</tr>
<tr>
<td>First through twelfth ribs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costotransverse:</td>
<td>Synovial</td>
<td>Gliding</td>
</tr>
<tr>
<td>First through tenth ribs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costochondral:</td>
<td>Cartilaginous</td>
<td>Synchondroses</td>
</tr>
<tr>
<td>First through tenth ribs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sternocostal:</td>
<td>Cartilaginous</td>
<td>Synchondroses</td>
</tr>
<tr>
<td>First rib</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second through seventh ribs</td>
<td>Cartilaginous</td>
<td>Gliding</td>
</tr>
<tr>
<td>Interchondral:</td>
<td>Synovial</td>
<td>Gliding</td>
</tr>
<tr>
<td>Sixth through ninth ribs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ninth through tenth ribs</td>
<td>Fibrous</td>
<td>Syndesmoses</td>
</tr>
<tr>
<td>Manubriosternal</td>
<td>Cartilaginous</td>
<td>Symphysis</td>
</tr>
<tr>
<td>Xiphisternal</td>
<td>Cartilaginous</td>
<td>Synchondroses</td>
</tr>
</tbody>
</table>

**Fig. 9-6** A, Superior aspect of rib articulating with thoracic vertebra and sternum. B, Enlarged image of costovertebral and costotransverse articulations. C, MRI transverse image showing costovertebral and costotransverse articulations.

(C, From Kelley L: Sectional anatomy. St Louis, 1997, Mosby.)
Posteriorly, the head of a rib is closely bound to the demifacets of two adjacent vertebral bodies to form a synovial gliding articulation called the costovertebral joint (see Figs. 9-6 and 9-7, A). The first, tenth, eleventh, and twelfth ribs each articulate with only one vertebral body.

The tubercle of a rib articulates with the anterior surface of the transverse process of the lower vertebra at the costotransverse joint, and the head of the rib articulates at the costovertebral joint. The head of the rib also articulates with the body of the same vertebra and articulates with the vertebra directly above. The costotransverse articulation is also a synovial gliding articulation. The articulations between the tubercles of the ribs and the transverse processes of the vertebrae permit only superior and inferior movements of the first six pairs. Greater freedom of movement is permitted in the succeeding four pairs.

Costochondral articulations are found between the anterior extremities of the ribs and the costal cartilages (Fig. 9-7, B). These articulations are cartilaginous synchondrosis and allow no movement. The articulations between the costal cartilages of the true ribs and the sternum are called sternocostal joints. The first pair of ribs, rigidly attached to the sternum, form the first sternocostal joint. This is a cartilaginous synchondrosis type of joint, which allows no movement. The second through seventh sternocostal joints are considered synovial gliding joints and are freely movable. Interchondral joints are found between the costal cartilages of the sixth and seventh, seventh and eighth, and eighth and ninth ribs (Fig. 9-7, C). These interchondral joints are synovial gliding articulations. The interchondral articulation between the ninth and tenth ribs is fibrous syndesmosis and only slightly movable.

The manubriosternal joint is cartilaginous symphysis, and the xiphisternal joints are cartilaginous synchondrosis joints that allow very little or no movement (see Figs. 9-3, B and 9-7, B and C).

**Fig. 9-7** Rib articulations. A, Anterior aspect of thoracic spine, showing costovertebral articulations. B, Anterior aspect of manubrium, sternum, and first two ribs, showing articulations. C, Lower sternum and ribs, showing intercostal, chondrocostal, and sternocostal joints. D, CT cross-section image of the upper thorax showing the manubrium and exact position of the SC joints (arrows).
RESPIRATORY MOVEMENT

The normal oblique orientation of the ribs changes very little during quiet respiratory movements; however, the degree of obliquity decreases with deep inspiration and increases with deep expiration. The first pair of ribs, which are rigidly attached to the manubrium, rotate at their vertebral ends and move with the sternum as one structure during respiratory movements.

On deep inspiration the anterior ends of the ribs are carried anteriorly, superiorly, and laterally, while their necks are rotated inferiorly (Fig. 9-8, A). On deep expiration the anterior ends are carried inferiorly, posteriorly, and medially, while the necks are rotated superiorly (Fig. 9-8, B). The last two pairs of ribs are depressed and held in position by the action of the diaphragm when the anterior ends of the upper ribs are elevated during respiration.

![Image](image_url)

Fig. 9-8 Respiratory lung movement. A, Full inspiration with the posterior ribs numbered. B, Full expiration with the ribs numbered. The anterior ribs are labeled with a suffix.
The ribs located above the diaphragm are best examined radiographically through the air-filled lungs, whereas the ribs situated below the diaphragm must be examined through the upper abdomen. Because of the difference in penetration required for the two regions, the position and respiratory excursion of the diaphragm play a large role in radiography of the ribs.

The position of the diaphragm varies with body habitus: it is at a higher level in hypersthenic patients and at a lower level in hyposthenic patients (Fig. 9-9). In sthenic patients of average size and shape, the right side of the diaphragm arches posteriorly from the level of about the sixth or seventh costal cartilage to the level of the ninth or tenth thoracic vertebra when the body is in the upright position. The left side of the diaphragm lies at a slightly lower level. Because of the oblique location of both the ribs and the diaphragm, several pairs of ribs appear, on radiographs, to lie partly above and partly below the diaphragm.

The position of the diaphragm changes considerably with the body position, reaching its lowest level when the body is upright and its highest level when the body is supine. For this reason it is desirable to place the patient in the upright position for examination of the ribs above the diaphragm and in a recumbent position for examination of the ribs below the diaphragm.

The respiratory movement of the diaphragm averages about 1½ inches (3.8 cm) between deep inspiration and deep expiration. The movement is less in hypersthenic patients and more in hyposthenic patients. Deeper inspiration or expiration, and therefore greater depression or elevation of the diaphragm, is achieved on the second respiratory movement than on the first. This greater movement should be taken into consideration when the ribs that lie at the diaphragmatic level are examined.

When the body is placed in the supine position, the anterior ends of the ribs are displaced superiorly, laterally, and posteriorly. For this reason the anterior ends of the ribs are less sharply visualized when the patient is radiographed in the supine position.

Fig. 9-9 Diaphragm position and body habitus. A, A hypersthenic patient has a higher positioned diaphragm. B, An asthenic patient has a lower positioned diaphragm.
BODY POSITION

Although in rib examinations it is desirable to take advantage of the effect that body position has on the position of the diaphragm, the effect is not of sufficient importance to justify subjecting a patient to a painful change from the upright position to the recumbent position or vice versa. Even minor rib injuries are painful, and slight movement frequently causes the patient considerable distress. Therefore, unless the change in position can be effected with a tilting radiographic table, patients with recent rib injury should be examined in the position in which they arrive in the radiology department. The ambulatory patient can be positioned for recumbent images with a minimum of discomfort by bringing the tilt table to the vertical position for each positioning change. The patient stands on the footboard, is comfortably adjusted, and is then lowered to the horizontal position.

TRAUMA PATIENTS

The first and usually the only requirement in the initial radiographic examination of a patient who has sustained severe trauma to the rib cage is to take AP and lateral projections of the chest. These projections are obtained not only to demonstrate the site and extent of rib injury but also to investigate the possibility of injury to the underlying structures by depressed rib fractures. Patients are examined in the position in which they arrive, usually recumbent on a stretcher. The recumbent position is necessary to demonstrate the presence of air or fluid levels using the decubitus technique.

**SUMMARY OF ANATOMY***

<table>
<thead>
<tr>
<th>Bony thorax</th>
<th>Ribs</th>
<th>Bony thorax articulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>sternum</td>
<td>costal cartilage</td>
<td>sternoclavicular</td>
</tr>
<tr>
<td>ribs (12)</td>
<td>true ribs</td>
<td>costovertebral</td>
</tr>
<tr>
<td>thoracic spine (12)</td>
<td>false ribs</td>
<td>costotransverse</td>
</tr>
<tr>
<td>Sternum</td>
<td>floating ribs</td>
<td>costochondral</td>
</tr>
<tr>
<td>manubrium</td>
<td>cervical ribs</td>
<td>sternocostal</td>
</tr>
<tr>
<td>jugular notch</td>
<td>lumbar ribs</td>
<td>interchondral</td>
</tr>
<tr>
<td>clavicular notch</td>
<td>intercostal spaces</td>
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</tr>
<tr>
<td>body</td>
<td>head</td>
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</tr>
<tr>
<td>sternal angle</td>
<td>neck</td>
<td>xiphisternal</td>
</tr>
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</tr>
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<td>sternal end</td>
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</tr>
<tr>
<td></td>
<td>angle</td>
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</tr>
<tr>
<td></td>
<td>costal groove</td>
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*See Addendum at the end of the volume for a summary of the changes in the anatomic terms used in this edition.*
## SUMMARY OF PATHOLOGY

<table>
<thead>
<tr>
<th>Condition</th>
<th>Radiographic Findings</th>
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<tbody>
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<td>Disruption of the continuity of bone</td>
</tr>
<tr>
<td>Metastases</td>
<td>Transfer of a cancerous lesion from one area to another</td>
</tr>
<tr>
<td>Osteomyelitis</td>
<td>Inflammation of bone due to a pyogenic infection</td>
</tr>
<tr>
<td>Osteopetrosis</td>
<td>Increased density of atypically soft bone</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>Loss of bone density</td>
</tr>
<tr>
<td>Paget's Disease</td>
<td>Thick, soft bone marked by bowing and fractures</td>
</tr>
<tr>
<td>Tumor</td>
<td>New tissue growth where cell proliferation is uncontrolled</td>
</tr>
<tr>
<td>Chondrosarcoma</td>
<td>Malignant tumor arising from cartilage cells</td>
</tr>
<tr>
<td>Multiple Myeloma</td>
<td>Malignant neoplasm of plasma cells involving the bone marrow and causing destruction of the bone</td>
</tr>
</tbody>
</table>
### BONY THORAX

<table>
<thead>
<tr>
<th>Part</th>
<th>cm</th>
<th>kVp*</th>
<th>tm</th>
<th>mA</th>
<th>mAs</th>
<th>AEC</th>
<th>SID</th>
<th>IR</th>
<th>Dose(^t) (mrad)</th>
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<td>24 × 30 cm</td>
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</tr>
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<td>710</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>48°</td>
<td>8 × 10 in</td>
<td>195</td>
</tr>
<tr>
<td>S-C Articulations—PA Oblique(^t)</td>
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<td>65</td>
<td>0.15</td>
<td>200s</td>
<td>30</td>
<td></td>
<td>48°</td>
<td>8 × 10 in</td>
<td>208</td>
</tr>
<tr>
<td>Upper Anterior Ribs—PA(^t)</td>
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<td>70</td>
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<td>200s</td>
<td>32</td>
<td>48°</td>
<td>35 × 43 cm</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Posterior Ribs—AP Upper(^t)</td>
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<td>70</td>
<td>0.16</td>
<td>200s</td>
<td>32</td>
<td>48°</td>
<td>35 × 43 cm</td>
<td>60</td>
<td></td>
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<td>70</td>
<td>200s</td>
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<td></td>
<td></td>
<td>48°</td>
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<td>70</td>
<td>0.16</td>
<td>200s</td>
<td>32</td>
<td>48°</td>
<td>35 × 43 cm</td>
<td>82</td>
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<tr>
<td>Ribs—Axillary—PA Oblique(^t)</td>
<td>23</td>
<td>70</td>
<td>0.16</td>
<td>200s</td>
<td>32</td>
<td>48°</td>
<td>35 × 43 cm</td>
<td>82</td>
<td></td>
</tr>
</tbody>
</table>

\(^t\) Small focal spot.

\(^*\) kVp values are for a 3-phase 12-pulse generator.

\(^t\) Relative doses for comparison use. All doses are skin entrance for average adult at cm indicated.

\(^t\) Bucky, 16:1 Grid Screen/Film Speed 300.
Sternum

The position of the sternum with respect to the denser thoracic structures, both bony and soft, makes it one of the more difficult structures to radiograph satisfactorily. Few problems are involved in obtaining a lateral projection, but because of the location of the sternum directly anterior to the thoracic spine, an AP or PA projection provides little useful diagnostic information. To separate the vertebrae and sternum, it is necessary to rotate the body from the prone position or to angle the central ray medially. The exact degree of required angulation depends on the depth of the chest, with deep chests requiring less angulation than shallow chests (Fig. 9-10 and Table 9-2).

Angulation of the body or the central ray to project the sternum to the right of the thoracic vertebrae clears the sternum of the vertebrae but superimposes it over the posterior ribs and the lung markings (Fig. 9-11). If the sternum is projected to the left of the thoracic vertebrae, it is also projected over the heart and other mediastinal structures (Fig. 9-12). The superimposition of the homogeneous density of the heart can be used to advantage (compare Figs. 9-11 and 9-12).

The pulmonary structures, particularly in elderly persons and heavy smokers, can cast confusing markings over the sternum unless the motion of shallow breathing is used to eliminate them. If motion is desired, the exposure time should be long enough to cover several phases of shallow respiration (Figs. 9-13 and 9-14). The milliamperes (mA) must be relatively low to achieve the desired milliampere-second (mAs).

If the female patient has large, pendulous breasts, they should be drawn to the side and held in position with a wide bandage to prevent them from overlapping the sternum and to position the sternum closer to the IR. This is particularly important in the lateral projection, in which the breast can obscure the inferior portion of the sternum.

Radiation Protection

Protection of the patient from unnecessary radiation is a professional responsibility of the radiographer (see Chapters 1 and 2 for specific guidelines). In this chapter the Shield gonads statement indicates that the patient is to be protected from unnecessary radiation by restricting the radiation beam using proper collimation. In addition, the placement of lead shielding between the gonads and the radiation source is appropriate when the clinical objectives of the examination are not compromised.

Table 9-2

Sternum: thickness and central ray angulation

<table>
<thead>
<tr>
<th>Depth of thorax (cm)</th>
<th>Depth of tube angulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>22</td>
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<tr>
<td>16.5</td>
<td>21</td>
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<td>20</td>
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<tr>
<td>28.5</td>
<td>13</td>
</tr>
<tr>
<td>30</td>
<td>12</td>
</tr>
</tbody>
</table>

Fig. 9-10 A, Drawing of 24-cm chest. B, Drawing of 18-cm chest.
Sternum

Fig. 9-11 PA oblique sternum, LAO position.

Fig. 9-12 PA oblique sternum, RAO position.

Fig. 9-13 Suspended respiration.

Fig. 9-14 Shallow breathing during exposure.
**PA OBLIQUE PROJECTION**

**RAO position**

Image receptor: 24 × 30 cm lengthwise

**NOTE:** This position may be difficult to perform on trauma patients. Use an upright position if necessary or possible.

SID: A 30-inch source-to-image receptor distance (SID) is recommended to blur the posterior ribs.

**Position of patient**

- With the patient prone, adjust the body into a right anterior oblique (RAO) position to use the heart for contrast as previously described.
- Have the patient support the body on the forearm and flexed knee.

**Position of part**

- Adjust the elevation of the left shoulder and hip so that the thorax is rotated just enough to prevent superimposition of the vertebrae and sternum.
- Estimate the amount of rotation with sufficient accuracy by placing one hand on the patient’s sternum and the other hand on the thoracic vertebrae to act as guides while adjusting the degree of obliquity. The average rotation will be about 15 to 20 degrees (Fig. 9-15).
- Align the patient’s body so that the long axis of the sternum is centered to the midline of the grid.
- Place the top of the IR about 1 1/2 inches (3.8 cm) above the jugular notch.
- Shield gonads.
- Respiration: When breathing motion is to be used, instruct the patient to take slow, shallow breaths during the exposure. When a short exposure time is to be used, instruct the patient to suspend breathing at the end of expiration to obtain a more uniform density.

**NOTE:** On trauma patients, obtain this projection with the patient supine, and use the LPO position and an AP oblique projection.

---

*Fig. 9-15* PA oblique sternum, RAO position. Art is axial view (from the feet upward).
Central ray
- Perpendicular to the IR. The CR will enter the *elevated side* of the posterior thorax at the level of T7 and approximately 1 inch (2.5 cm) lateral to the midsagittal plane.

**Structures shown**
This image shows a slightly oblique projection of the sternum (Fig. 9-16). The detail demonstrated depends largely on the technical procedure employed. If breathing motion is used, the pulmonary markings will be obliterated.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Entire sternum from jugular notch to tip of the xiphoid process
- Reasonably good visibility of the sternum through the thorax, including blurred pulmonary markings if a breathing technique was used
- Minimally rotated sternum and thorax, as demonstrated by the following:
  - Sternum projected just free of superimposition from vertebral column
  - Minimally oblique vertebrae to prevent excessive rotation of the sternum
  - Lateral portion of the manubrium and sternoclavicular joint free of superimposition by the vertebrae
- Sternum projected over the heart

---

*Fig. 9-16 PA oblique sternum, RAO position.*
PA OBLIQUE PROJECTION
MOORE METHOD

Modifying prone position

Image receptor: 24 × 30 cm lengthwise

SID: A 30-inch (76-cm) SID is recommended. This short distance assists in blurring the posterior ribs.

Radiography of the sternum can be difficult to perform on an ambulatory patient who is having acute pain. The alternative positioning method described by Moore uses a modified prone position that makes it possible to produce a high-quality sternum image in a more comfortable manner for the patient.


Position of patient

- Before positioning the patient, place the IR crosswise in the Bucky tray. Place the x-ray tube at a 30-inch (76-cm) SID, angle it 25 degrees, and direct the central ray to the center of the IR. The x-ray tube is positioned over the patient’s right side.
- Place a marker on the tabletop near the patient’s head to indicate the exact center of the IR.
- Have the patient stand at the side of the radiographic table directly in front of the Bucky tray.
- Ask the patient to bend at the waist, and place the sternum in the center of the table directly over the prepositioned IR.

Position of part

- Place the patient’s arms above the shoulders and the palms down on the table. The arms then act as a support for the side of the head (Fig. 9-17, left).
- Ensure that the patient is in a true prone position and that the midsternal area is at the center of the radiographic table.
- Shield gonads.
- Respiration: A shallow breathing technique produces the best results. Instruct the patient to take slow, shallow breaths during the exposure. A low mA setting and an exposure time of 1 to 3 seconds is recommended. When a low mA setting and long exposure time technique cannot be used, instruct the patient to suspend respiration at the end of expiration to obtain a more uniform density.

Fig. 9-17 PA oblique projection: Moore method.
Central ray
- The central ray will already have been angled 25 degrees and centered to the IR. If patient positioning is accurate, the central ray enters at the level of T7 and approximately 2 inches (5 cm) to the right of the spine. This angulation places the sternum over the lung to maintain maximum contrast of the sternum.
- The x-ray tube angulation can be adjusted for extremely large or small patients. Large patients require less angulation, and thin patients require more than the standard 25-degree angle.

Structures shown
This image shows a slightly oblique projection of the sternum (Fig. 9-17, right). The degree of detail demonstrated depends largely on the technique used. If a breathing technique is used, the pulmonary markings will be obliterated.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Entire sternum from the jugular notch to the tip of the xiphoid process
- Reasonably good visibility of the sternum through the thorax
- Blurred pulmonary markings if a breathing technique was used
- Blurred posterior ribs if a reduced SID was used
- Sternum projected free of superimposition from the vertebral column
LATERAL PROJECTION

R or L position
Upright

Image receptor: 24 × 30 cm lengthwise

SID: Use a 72-inch (183-cm) SID to reduce magnification and distortion of the sternum.

Position of patient

- Place the patient in a lateral position, either seated or standing, before a vertical grid device.

Position of part

- Have the patient sit or stand straight.
- Rotate the shoulders posteriorly, and have the patient lock the hands behind the back.
- Center the sternum to the midline of the grid.
- Being careful to keep the midsagittal plane of the body vertical, place the patient close enough to the grid so that the shoulder can be rested firmly against it.
- Adjust the patient in a true lateral position so that the broad surface of the sternum is perpendicular to the plane of the IR (Fig. 9-18).
- Large breasts on female patients should be drawn to the sides and held in position with a wide bandage so that their shadows do not obscure the lower portion of the sternum.
- Adjust the height of the IR so that its upper border is 1½ inches (3.8 cm) above the jugular notch.
- For a direct lateral projection of just the sternoclavicular region, center a vertically placed 8 × 10 inch (18 × 24 cm) IR at the level of the jugular notch.
- Shield gonads.
- Respiration: Suspended deep inspiration. This provides sharper contrast between the posterior surface of the sternum and the adjacent structures.

Central ray

- Perpendicular to the center of the IR and entering the lateral border of the midsternum

COMPUTED RADIOGRAPHY

Collimation must be very close to keep unnecessary radiation from reaching the IR phosphor.

Structures shown

A lateral image of the entire length of the sternum shows the superimposed sternoclavicular joints and medial ends of the clavicles (Fig. 9-19, A). A lateral projection of only the sternoclavicular region is shown in Fig. 9-19, B.

EVALUATION CRITERIA

The following should be clearly demonstrated:
- Sternum in its entirety
- Manubrium free of superimposition by the soft tissue of the shoulders
- Sternum free of superimposition by the ribs
- Lower portion of the sternum unobscured by the breasts of a female patient (A second radiograph with increased penetration may be needed.)

Fig. 9-18 Lateral sternum.
Fig. 9-19  A, Lateral sternum. B, Lateral sternoclavicular joint (arrow).
LATERAL PROJECTION

R or L position
Recumbent

Image receptor: 24 × 30 cm lengthwise

SID: An SID of 72 inches (180 cm) is preferred. If this distance cannot be obtained with the overhead tube, the maximum allowed distance should be obtained.

Position of patient
- Place the patient in the lateral recumbent position.
- Flex the patient’s hips and knees to a comfortable position.

Position of part
- Extend the patient’s arms over the head to prevent them from overlapping the sternum.
- Rest the patient’s head on the arms or on a pillow (Fig. 9-20).
- Place a support under the lower thoracic region to position the long axis of the sternum horizontally.
- Adjust the rotation of the patient’s body so that the broad surface of the sternum is perpendicular to the plane of the IR.
- Center the sternum to the midline of the grid.
- Apply a compression band across the hips for immobilization, if necessary.
- Adjust the height of the IR so that its upper border is 1 1/2 inches (3.8 cm) above the jugular notch.
- Shield gonads.
- Respiration: Suspend at the end of deep inspiration to obtain high contrast between the posterior surface of the sternum and the adjacent structures.

NOTE: Use the dorsal decubitus position for examination of a patient with severe injury. In this situation a grid-front IR or a stationary grid should be used (Fig. 9-21). An SID of 72 inches (180 cm) can be used for this position.

Fig. 9-20 Lateral sternum.

Fig. 9-21 Dorsal decubitus position for lateral sternum.
Central ray
• Perpendicular to the center of the IR and entering the lateral border of the midsternum

**COMPUTED RADIOGRAPHY**
Collimation must be very close to keep unnecessary radiation from reaching the IR phosphor.

Structures shown
The lateral aspect of the entire length of the sternum is shown (Fig. 9-22).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Lateral image of the sternum in its entirety
- Sternum free of superimposition by the soft tissues of the shoulders or arms
- Sternum free of superimposition by the ribs
- Inferior portion of the sternum unobscured by the breasts of a female patient (A second radiograph with increased penetration may be needed.)

---

**Fig. 9-22** Lateral sternum.
PA PROJECTION

NOTE: This position may be difficult to perform on trauma patients. Use the upright position if the patient is able.

Image receptor: 8 x 10 inch (18 x 24 cm) crosswise

Position of patient
- Place the patient in the prone position.
- Center the midsagittal plane of the patient’s body to the midline of the grid.
- Adapt the same procedure for use with the patient who is standing or seated upright.

Position of part
- Center the IR at the level of the spinous process of the third thoracic vertebra, which lies posterior to the jugular notch.
- Place the patient’s arms along the sides of the body with the palms facing upward.
- Adjust the shoulders to lie in the same transverse plane.
- For a bilateral examination, rest the patient’s head on the chin and adjust it so that the midsagittal plane is vertical.
- For a unilateral projection, ask the patient to turn the head to face the affected side and rest the cheek on the table (Fig. 9-23). Turning the head rotates the spine slightly away from the side being examined and thus provides better visualization of the lateral portion of the manubrium.
- Shield gonads.
- Respiration: Suspend at the end of expiration to obtain a more uniform density.

Central ray
- Perpendicular to the center of the IR and entering T3

Structures shown
A PA projection demonstrates the sternoclavicular joints and the medial portions of the clavicles (Figs. 9-24 and 9-25).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Both sternoclavicular joints and the medial ends of the clavicles
- Sternoclavicular joints through the superimposing vertebral and rib shadows
- No rotation present on a bilateral examination; slight rotation present on a unilateral examination

Fig. 9-23 Unilateral examination to demonstrate left sternoclavicular articulation.

Fig. 9-24 Bilateral sternoclavicular joints (arrows).

Fig. 9-25 Unilateral sternoclavicular joint (arrow).
Sternoclavicular Articulations

PA OBLIQUE PROJECTION

BODY ROTATION METHOD

RAO or LAO position

NOTE: This position may be difficult to perform on trauma patients. Use the upright position if the patient is able.

Image receptor: 8 x 10 inch (18 x 24 cm) crosswise

Position of patient

- Place the patient in a prone or seated-upright position.

Position of part

- Keeping the affected side adjacent to the IR, position the patient at enough of an oblique angle to project the vertebral well behind the sternoclavicular joint closest to the IR. The angle is usually about 10 to 15 degrees.
- Adjust the patient’s position to center the joint to the midline of the grid.
- Adjust the shoulders to lie in the same transverse plane (Fig. 9-26).
- Shield gonads.
- Respiration: Suspend at the end of expiration to obtain a more uniform density.

Central ray

- Perpendicular to the sternoclavicular joint closest to the IR. The central ray enters at the level of T2-T3 (about 3 inches [7.6 cm] distal to the vertebral prominens) and 1 to 2 inches (2.5 to 5 cm) lateral (toward the joint) from the midsagittal plane.
- Center the IR to the central ray.

Structures shown

A slightly oblique image of the sternoclavicular joint is demonstrated

EVALUATION CRITERIA

The following should be clearly demonstrated:

- Sternoclavicular joint of interest in the center of the radiograph, with the manubrium and the medial end of the clavicle included.
- Open sternoclavicular joint space.
- Sternoclavicular joint of interest directly in front of the vertebral column with minimal obliquity.
- Reasonably good visibility of the sternoclavicular joint through the superimposing rib and lung fields.

Fig. 9-26 A, PA oblique sternoclavicular joint. LAO position: body rotation method. B, Axial view (from feet upward) of central ray position in relation to spine and SC joint.
PA OBLIQUE PROJECTION
CENTRAL RAY ANGULATION METHOD
Non-Bucky

Image receptor: 8 x 10 inch (18 x 24 cm) lengthwise

NOTE: For this projection, the joint is closer to the IR and less distortion is obtained than when the previously described body rotation method is used. A grid IR placed on the tabletop also enables the joint to be projected with minimal distortion. Note also, this position may be difficult to perform on trauma patients. Use the upright position if the patient is able.

Position of patient
• Place the patient in the prone position on a grid IR positioned directly under the upper chest.
• Center the grid to the level of the sternoclavicular joints.
• To avoid grid cutoff, place the grid on the radiographic table with its long axis running perpendicular to the long axis of the table.

Position of part
• Extend the patient’s arms along the sides of the body with the palms of the hands facing upward.
• Adjust the shoulders to lie in the same transverse plane.
• Ask the patient to rest the head on the chin or to rotate the chin toward the side of the joint being radiographed (Fig. 9-27).

Central ray
• From the side opposite that is being examined, direct to the midpoint of the IR at an angle of 15 degrees toward the midsagittal plane. A small angle is satisfactory in examinations of sternoclavicular articulations because only a slight anteroposterior overlapping of the vertebrae and these joints occurs.
• The central ray should enter at the level of T2-T3 (about 3 inches [7.6 cm] distal to the vertebral prominens) and 1 to 2 inches (2.5 to 5 cm) lateral to the midsagittal plane.

Structures shown
A slightly oblique image of the sternoclavicular joint is demonstrated (Figs. 9-28 and 9-29).

EVALUATION CRITERIA
The following should be clearly demonstrated:
• Sternoclavicular joint of interest in the center of the radiograph, with the manubrium and the medial end of the clavicle included
• Open sternoclavicular joint space
• Sternoclavicular joint of interest directly in front of the vertebral column with minimal obliquity
• Reasonably good visibility of the sternoclavicular joint through the superimposing rib and lung fields

Fig. 9-27 A, PA oblique sternoclavicular joint: central ray angulation method. B, Axial view (from the feet upward) of central ray position in relation to spine and SC joint.
Sternoclavicular Articulations

Fig. 9-28  PA oblique sternoclavicular joint, LAO position. The joint closest to IR is shown (arrow).

Fig. 9-29  Central ray angulation for sternoclavicular joint farthest from x-ray tube (arrow).
AXIOLATERAL PROJECTION
KURZBAUER METHOD

**Image receptor:** 8 × 10 inch (18 × 24 cm) lengthwise

**Position of patient**
- Have the patient lie in the lateral recumbent position on the affected side, with the sternoclavicular region centered to the midline of the grid.
- Flex the patient’s hips and knees in a comfortable position.

1Kurzbauer R: The lateral projection in the roentgenography of the sternoclavicular articulation, AJR 56:104, 1946.

**Position of part**
- Have the patient fully extend the arm of the affected side and grasp the end of the radiographic table for support.
- Place the patient’s other arm along the side of the body.
- Have the patient grasp the dorsal surface of the hip to hold the shoulder in a depressed position. The extension of the affected shoulder, along with the depression of the uppermost shoulder, prevents superimposition of the two articulations.
- Adjust the thorax to place the anterior surface of the manubrium perpendicular to the plane of the IR (Figs. 9-30 and 9-31).
- Although the best result is obtained with the patient in the recumbent position, a comparable image can be made in the upright position if the patient cannot lie on the affected shoulder.
- Shield gonads.
- **Respiration:** Suspend at the end of full inspiration.

---

**Fig. 9-30** Axiolateral sternoclavicular joint.

**Fig. 9-31** Axiolateral sternoclavicular joint.
Sternoclavicular Articulations

Central ray
- Directed through the sternoclavicular articulation closest to the IR at an angle of 15 degrees caudad.
- Center the IR to the central ray.

Structures shown
This image shows an unobstructed axiolateral projection of the sternoclavicular articulation closest to the IR (Fig. 9-32).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Sternoclavicular joint on affected side
- Sternoclavicular articulations, free of superimposition by the shoulders

Fig. 9-32 Axiolateral sternoclavicular joint.
Ribs

In radiography of the ribs, a 35 × 43 cm IR should be used to identify the ribs involved and to determine the extent of trauma or pathologic condition. A 28 × 36 cm IR is often used with smaller patients. Projections can be made in recumbent and upright positions. If the area in question involves the first and last ribs, additional images may be required to better demonstrate the affected area (Fig. 9-33).

After the lesion is localized, the next step is to determine (1) the position required to place the affected rib region parallel with the plane of the IR and (2) whether the radiograph should be made to include the ribs above or below the diaphragm.

The anterior portions of the ribs, usually referred to simply as the anterior ribs, are often examined with the patient facing the IR for a PA projection (Fig. 9-34). The posterior portion of the ribs, or the posterior ribs, are more commonly radiographed with the patient facing the x-ray tube in the same manner as for an AP projection (Fig. 9-35).

The axillary portion of the ribs is best shown using an oblique projection. Because the lateral projection results in superimposition of the two sides, it is generally used only when fluid or air levels are evaluated after rib fractures.

When the ribs superimposed over the heart are involved, the body must be rotated to obtain a projection of the ribs free of the heart, or the radiographic exposure must be increased to compensate for the density of the heart. Although the anterior and posterior ends are superimposed, the left ribs are cleared of the heart when the LAO position (Fig. 9-36) or RPO position (Fig. 9-37) is used. These two body positions place the right-sided ribs parallel with the plane of the IR and are reversed to obtain comparable projections of the left-sided ribs. Selection of technical factors that result in a short-scale radiograph are often used (about 70 kVp).
Ribs

Fig. 9-34 PA ribs.

Fig. 9-35 AP upper ribs.

Fig. 9-36 PA oblique ribs, LAO position.

Fig. 9-37 AP oblique ribs, RPO position.
RESPIRATION

In radiography of the ribs the patient is usually examined with respiration suspended in either full inspiration or expiration. Occasionally, shallow breathing may be used to obliterate lung markings. If this technique is used, breathing must be shallow enough to ensure that the ribs are not elevated or depressed as described in the anatomy portion of this chapter. Examples of shallow breathing and suspended respiration are compared in Figs. 9-38 and 9-39.

Rib fractures can cause a great deal of pain and hemorrhage because of the closely related neurovascular structures. This situation commonly makes it difficult for the patient to breathe deeply for the required radiograph. Deeper inspiration will be attained if the patient fully understands the importance of expanding the lungs and if the exposure is made after the patient takes the second deep breath.
Fig. 9-38 Shallow breathing technique.

Fig. 9-39 Suspended respiration technique.
Upper Anterior Ribs

PA PROJECTION

Image receptor: 35 × 43 cm lengthwise

Position of patient
- Position the patient for a PA projection, either upright or recumbent.
- Because the diaphragm descends to its lowest level in the upright position, use the standing or seated-upright position for projections of the upper ribs when the patient's condition permits (Fig. 9-40). The upright position is also valuable for demonstrating fluid levels in the chest.

Position of part
- Center the midsagittal plane of the patient's body to the midline of the grid.
- To include the upper ribs, adjust the IR position to project approximately 1 1/2 inches (3.8 cm) above the upper border of the shoulders.
- Rest the patient's hands against the hips with the palms turned outward to rotate the scapulas away from the rib cage.
- Adjust the shoulders to lie in the same transverse plane.
- If the patient is prone, rest the head on the chin and adjust the midsagittal plane to be vertical (Fig. 9-41).
- To image affected ribs unilaterally, use a 30 × 35 cm IR for contrast improvement.
- For hypersthenic patients with wide rib cages, include the entire lateral surface of the affected rib area on the radiograph. This may require moving the patient laterally to include all of the affected ribs.
- Shield gonads.
- Respiration: Suspend at full inspiration to depress the diaphragm as much as possible.

Fig. 9-40 PA ribs, upright position.

Fig. 9-41 PA ribs, recumbent position.
Upper Anterior Ribs

Central ray
- Perpendicular to the center of the IR. If the IR is positioned correctly, the central ray will be at the level of T7.
- A useful option for demonstrating the seventh, eighth, and ninth ribs is to angle the x-ray tube about 10 to 15 degrees caudad. This angulation aids in projecting the diaphragm below that of the affected ribs.

Structures shown
The PA projection best demonstrates the anterior ribs above the diaphragm (Figs. 9-42 and 9-43). The posterior ribs will be seen. However, the anterior ribs will be demonstrated with greater detail since they lie closer to the IR.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- First through ninth ribs in their entirety, with the posterior portions lying above the diaphragm
- First through seventh anterior ribs from both sides, in their entirety and above the diaphragm
- In a unilateral examination, ribs from the opposite side may not be entirely included
- Ribs visible through the lungs with sufficient contrast

Fig. 9-42 PA ribs, normal centering.
Fig. 9-43 PA ribs, with 10 to 15 degree caudal angulation.
**Posterior Ribs**

**AP PROJECTION**

**Image receptor:** 35 × 43 cm or 30 × 35 cm lengthwise

**Position of patient**
- Have the patient face the x-ray tube in either an upright or recumbent position.
- When the patient’s condition permits, use the upright position to image ribs above the diaphragm and the supine position to image ribs below the diaphragm to permit gravity to assist in moving the patient’s diaphragm.

**Position of part**
- Center the midsagittal plane of the patient’s body to the midline of the grid.

**Ribs above diaphragm**
- Place the IR lengthwise 1 1/2 inches (3.8 cm) above the upper border of the relaxed shoulders.
- Rest the patient’s hands, palms outward, against the hips. This position moves the scapula off the ribs. Alternatively, extend the arms to the vertical position with the hands under the head (Fig. 9-44).
- Adjust the patient’s shoulders to lie in the same transverse plane, and rotate them forward to draw the scapulas away from the rib cage.
- Shield gonads.
- Respiration: Suspend at full inspiration to depress the diaphragm.

**Ribs below diaphragm**
- Place the IR crosswise in the Bucky tray with the lower edge positioned at the level of the iliac crests. This positioning ensures inclusion of the lower ribs because of the divergent x-rays.
- Adjust the patient’s shoulders to lie in the same transverse plane.
- Place the patient’s arms in a comfortable position (Fig. 9-45).
- Shield gonads.
- Respiration: Suspend at full expiration to elevate the diaphragm.

---

**Fig. 9-44** AP ribs above diaphragm.

**Fig. 9-45** AP ribs below diaphragm.
Posterior Ribs

Central ray
- Perpendicular to the center of the IR.

**NOTE:** Refer to the Exposure Technique Chart on page 497 to note different exposure settings for the upper and lower rib projections.

**Structures shown**
The AP projection best demonstrates the posterior ribs above or below the diaphragm, according to the region examined (Figs. 9-46 and 9-47). The anterior ribs will be seen. However, the posterior ribs will be demonstrated with greater detail since they lie closer to the IR.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- For ribs above the diaphragm, first through tenth posterior ribs from both sides in their entirety
- For ribs below the diaphragm, eighth through twelfth posterior ribs on both sides in their entirety
- Ribs visible through the lungs or abdomen
- In a unilateral examination, ribs from the opposite side possibly not entirely included

![Fig. 9-46 AP ribs above diaphragm.](image)

![Fig. 9-47 AP lower ribs.](image)
Ribs

Axillary

AP OBLIQUE PROJECTION
RPO or LPO position

Image receptor: 35 × 43 cm or 30 × 35 cm lengthwise

Position of patient
- Examine the patient in the upright or recumbent position.
- Unless contraindicated by the patient’s condition, use the upright position to image ribs above the diaphragm and the recumbent position to image ribs below the diaphragm. Gravity assists in moving the diaphragm.

Position of part
- Position the patient’s body for a 45-degree AP oblique projection using the RPO or LPO position. Place the affected side closest to the IR.
- Center the affected side on a longitudinal plane drawn midway between the midsagittal plane and the lateral surface of the body.
- Position this plane to the midline of the grid.
- If the patient is in the recumbent position, support the elevated hip.
- Abduct the arm of the affected side, and elevate it to carry the scapula away from the rib cage.
- Rest the patient’s hand on the head if the upright position is used (Fig. 9-48), or place the hand under or above the head if in the recumbent position is used (Fig. 9-49).
- Abduct the opposite limb with the hand on the hip.
- Center the IR with the top 1½ inches (3.8 cm) above the upper border of the relaxed shoulder to image ribs above the diaphragm or with the lower edge of the IR at the level of the iliac crest to image ribs below the diaphragm.
- Shield gonads.
- Respiration: Suspend at the end of deep expiration for ribs below the diaphragm and at the end of full inspiration for ribs above the diaphragm.

Fig. 9-48 Upright AP oblique ribs, LPO position.
Fig. 9-49 Recumbent AP oblique ribs, RPO position.
Central ray
• Perpendicular to the center of the IR.

Structures shown
In these images the axillary portion of the ribs are projected free of superimposition (Fig. 9-50)

EVALUATION CRITERIA
The following should be clearly demonstrated:
• Approximately twice as much distance between the vertebral column and the lateral border of the ribs on the affected side as is present on the unaffected side
• Axillary portion of the ribs free of superimposition
• First through tenth ribs visible above the diaphragm for upper ribs
• Eighth through twelfth ribs visible below the diaphragm for lower ribs
• Ribs visible through the lungs or abdomen according to the region examined

Fig. 9-50  A, AP oblique ribs. The LPO position demonstrates left-side ribs.  B, Axial view (from feet upward) of the ribs and central ray, LPO position.
**Axillary**

**PA OBLIQUE PROJECTION**

**RAO or LAO position**

- **Image receptor:** 35 × 43 cm or 28 × 35 cm lengthwise

**Position of patient**

- Examine the patient in the upright or recumbent position.
- Unless contraindicated by the patient’s condition, use the upright position to image ribs above the diaphragm and the recumbent position to image ribs below the diaphragm. Gravity assists by moving the diaphragm.

**Position of part**

- Position the body for a 45-degree PA oblique projection using the RAO or LAO position. Place the affected side away from the IR (Fig. 9-51).
- If the recumbent position is used, have the patient rest on the forearm and flexed knee of the elevated side (Fig. 9-52).
- Align the body so that a longitudinal plane drawn midway between the midline and the lateral surface of the body side up is centered to the midline of the grid.

- Center the IR with the top 1½ inches (3.8 cm) above the upper border of the shoulder to image ribs above the diaphragm or with the lower edge of the IR at the level of the iliac crest to image ribs below the diaphragm.
- **Shield gonads.**
- **Respiration:** Suspend at the end of full expiration for ribs below the diaphragm and at the end of full inspiration for ribs above the diaphragm.

---

**Fig. 9-51** Upright PA oblique ribs, RAO position.

**Fig. 9-52** Recumbent PA oblique ribs, LAO position.
Central ray
• Perpendicular to the center of the IR.

Structures shown
• In these images the axillary portion of the ribs are projected free of bony superimposition (Fig. 9-53).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Approximately twice as much distance between the vertebral column and the lateral border of the ribs on the affected side as is present on the unaffected side
- Axillary portion of the ribs free of superimposition
- First through tenth ribs visible above the diaphragm for upper ribs
- Eighth through twelfth ribs visible below the diaphragm for lower ribs
- Rib visible through the lungs or abdomen according to the region examined.

---

**Fig. 9-53** A, PA oblique ribs. The LAO position demonstrates right side ribs. Note, PA projection radiograph is placed in the anatomical position for display. B, Axial view (from feet upward) of ribs and central ray with the patient in LAO position.
**AP AXIAL PROJECTION**

This projection is recommended for demonstration of the costal joints in patients with rheumatoid spondylitis.

**Image receptor:** 30 × 35 cm (11 × 14 inch) lengthwise

**Position of patient**
- Place the patient in the supine position.
- Have the patient's head rest directly on the radiographic table to avoid accentuating the dorsal kyphosis.

**Position of part**
- Center the midsagittal plane to the midline of the grid.
- If the patient has pronounced dorsal kyphosis, extend the arms over the head; otherwise, place the arms along the sides of the body.
- Adjust the patient's shoulders to lie in the same transverse plane (Fig. 9-54).
- With the IR in the Bucky tray, adjust its position so that the midpoint of the IR coincides with the central ray.
- Apply compression across the thorax, if necessary.
- Shield gonads.
- Respiration: Suspend at the end of full inspiration because the lung markings are less prominent at this phase of breathing.

---

Fig. 9-54 AP axial costal joints.
Central ray
- Directed 20 degrees cephalad and entering the midline about 2 inches (5 cm) above the xiphoid process.
- Increase the angulation of the central ray slightly (5 to 10 degrees) when examining patients who have pronounced dorsal kyphosis.

Structures shown
The costovertebral and costotransverse joints are demonstrated (Fig. 9-55).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Open costovertebral and costotransverse joints

NOTE: In large-boned patients the two sides may need to be examined separately to demonstrate the costovertebral joints. These projections are obtained by alternately rotating the body approximately 10 degrees medially; the elevated side is best demonstrated.

In their studies of the costal joints (costovertebral and costotransverse), Hohmann and Gasteiger¹ found that the central ray generally must be angled 30 degrees cephalad in the average patient. The central ray angulation is increased to 35 to 40 degrees when accentuated kyphosis is present. In patients with severe curvature of the spine, the pelvis is also elevated on a suitable support. For localized studies the central ray may be centered to T4 for the upper area and to T8 for the lower area.


Fig. 9-55 AP axial costal joints.
10
THORACIC VISCERA

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PA chest demonstrating pneumoconiosis in both lungs (multiple irregular shaped white areas are built up coal dust).
### SUMMARY OF PROJECTIONS

### PROJECTIONS, POSITIONS & METHODS

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<th>Position</th>
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<td></td>
<td>Trachea</td>
<td>AP</td>
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<tr>
<td>546</td>
<td></td>
<td>Trachea and superior mediastinum</td>
<td>Lateral</td>
<td>R or L</td>
<td></td>
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<tr>
<td>548</td>
<td></td>
<td>Trachea and pulmonary apex</td>
<td>Axiolateral</td>
<td></td>
<td>TWINING</td>
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<tr>
<td>550</td>
<td>🌟</td>
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<td>PA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>554</td>
<td>🌟</td>
<td>Chest: lungs and heart</td>
<td>Lateral</td>
<td>R or L</td>
<td></td>
</tr>
<tr>
<td>558</td>
<td>🌟</td>
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<td>PA oblique</td>
<td>RAO and LAO</td>
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<tr>
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<td>AP oblique</td>
<td>RPO and LPO</td>
<td></td>
</tr>
<tr>
<td>564</td>
<td>🌟</td>
<td>Chest</td>
<td>AP</td>
<td></td>
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<td>566</td>
<td>🌟</td>
<td>Pulmonary apices</td>
<td>AP axial</td>
<td>Lordotic</td>
<td>LINDBLOM</td>
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<tr>
<td>568</td>
<td></td>
<td>Pulmonary apices</td>
<td>PA axial</td>
<td></td>
<td></td>
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<tr>
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<td>Pulmonary apices</td>
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<td>Lungs and pleurae</td>
<td>AP or PA</td>
<td>R or L lateral decubitus</td>
<td></td>
</tr>
<tr>
<td>574</td>
<td>🌟</td>
<td>Lungs and pleurae</td>
<td>Lateral</td>
<td>Ventral or dorsal decubitus</td>
<td></td>
</tr>
</tbody>
</table>

Icons in the Essential column indicate projections frequently performed in the United States and Canada. Students should be competent in these projections.


**Body Habitus**

The general shape of the human body, or the *body habitus*, determines the size, shape, position, and movement of the internal organs. Fig. 10-1 outlines the general shape of the thorax in the four types of body habitus and how each appears on radiographs of the thoracic area.

**Thoracic Cavity**

The *thoracic cavity* is bounded by the walls of the thorax and extends from the superior thoracic aperture, where structures enter the thorax, to the inferior thoracic aperture. The diaphragm separates the thoracic cavity from the abdominal cavity. The anatomic structures that pass from the thorax to the abdomen go through openings in the diaphragm (Fig. 10-2).

---

**Fig. 10-1** Four types of body habitus. Note the general shape of the thorax, the size and shape of the lungs, and the position of the heart. A knowledge of this anatomy is helpful to accurately position for projections of the thorax.

**Fig. 10-2** A, Thoracic cavity. B, Thoracic cavity with anterior ribs removed.
Respiratory System

The respiratory system consists of the pharynx (described in Chapter 15), trachea, bronchi, and two lungs. The air passages of these organs communicate with the exterior through the pharynx, mouth, and nose, each of which, in addition to other described functions, is considered a part of the respiratory system.

TRACHEA

The trachea is a fibrous, muscular tube with 16 to 20 C-shaped cartilaginous rings embedded in its walls for greater rigidity (Fig. 10-3, A). It measures approximately ½ inch (1.3 cm) in diameter and 4½ inches (11 cm) in length, and its posterior aspect is flat. The cartilaginous rings are incomplete posteriorly and extend around the anterior two thirds of the tube. The trachea lies in the midline of the body, anterior to the esophagus in the neck. However, in the thorax the trachea is shifted slightly to the right of the midline as a result of the arching of the aorta. The trachea follows the curve of the vertebral column and extends from its junction with the larynx at the level of the sixth cervical vertebra inferiorly through the mediastinum to about the level of the space between the fourth and fifth thoracic vertebrae. The last tracheal cartilage is elongated and has a hooklike process, the carina, which extends posteriorly on its inferior surface. At the carina the trachea divides, or bifurcates, into two lesser tubes, the primary bronchi. One of these bronchi enters the right lung, and the other enters the left lung.

The primary bronchi slant obliquely inferiorly to their entrance into the lungs, where they branch out to form the right and left bronchial branches (Fig. 10-3, B). The right primary bronchus is shorter, wider, and more vertical than the left primary bronchus. Because of the more vertical position and greater diameter of the right main bronchus, foreign bodies entering the trachea are more likely to pass into the right bronchus than the left bronchus. After entering the lung, each primary bronchus divides, sending branches to each lobe of the lung: three to the right lung and two to the left lung. These secondary bronchi further divide and decrease in caliber. The bronchi continue dividing into tertiary bronchi, then to smaller bronchioles, and end in minute tubes called the terminal bronchioles (see Fig. 10-3). The extensive branching of the trachea is commonly referred to as the bronchial tree because it resembles a tree trunk (see box).
**ALVEOLI**

The terminal bronchioles communicate with alveolar ducts. Each duct ends in several alveolar sacs. The walls of the alveolar sacs are lined with alveoli (see Fig. 10-3, A). Each lung contains millions of alveoli. Oxygen and carbon dioxide are exchanged by diffusion within the walls of the alveoli.

**LUNGS**

The lungs are the organs of respiration (Fig. 10-4). They make up the mechanism for introducing oxygen into the blood and removing carbon dioxide from the blood. The lungs are composed of a light, spongy, highly elastic substance, the parenchyma, and they are covered by a layer of serous membrane. Each lung presents a rounded apex that reaches above the level of the clavicles into the root of the neck and a broad base that, resting on the obliquely placed diaphragm, reaches lower in back

and at the sides than in front. The right lung is about 1 inch (2.5 cm) shorter than the left lung because of the large space occupied by the liver, and it is broader than the left lung because of the position of the heart. The lateral surface of each lung conforms with the shape of the chest wall. The inferior surface of the lung is concave, fitting over the diaphragm, and the lateral margins are thin. During respiration the lungs move inferiorly for inspiration and superiorly for expiration (Fig. 10-5). During inspiration the lateral margins

---

Fig. 10-4. A, Three views of the lung. B, CT axial image through the thorax. R and L lungs are shown in actual position within thorax and in relation to the heart.

(B, Courtesy Siemens Medical Systems, Iselin, N.J.)
descend into the deep recesses of the parietal pleura. In radiology this recess is called the **costophrenic angle**. The mediastinal surface is concave with a depression, called the **hilum**, that accommodates the bronchi, pulmonary blood vessels, lymph vessels, and nerves. The inferior mediastinal surface of the left lung contains a concavity called the **cardiac notch**. This notch conforms to the shape of the heart.

Each lung is enclosed in a double-walled, serous membrane sac called the pleura (see Fig. 10-3, A). The inner layer of the pleural sac, called the visceral pleura, closely adheres to the surface of the lung, extends into the interlobar fissures, and is contiguous with the outer layer at the hilum. The outer layer, called the parietal pleura, lines the wall of the thoracic cavity occupied by the lung and closely adheres to the upper surface of the diaphragm. The two layers are moistened by serous fluid so that they move easily on each other. Thus the serous fluid prevents friction between the lungs and chest walls during respiration. The space between the two pleural walls is called the pleural cavity. Although the space is termed a cavity, the layers are actually in close contact.

Each lung is divided into **lobes** by deep fissures. The fissures lie in an oblique plane inferiorly and anteriorly from above, so that the lobes overlap each other in the AP direction. The **oblique fissures** divide the lungs into **superior** and **inferior lobes**. The superior lobes lie above and are anterior to the inferior lobes. The right superior lobe is further divided by a **horizontal fissure**, creating a **right middle lobe** (see Fig. 10-4). The left lung has no horizontal fissure and thus no middle lobe. The portion of the left lobe that corresponds in position to the right middle lobe is called the **lingula**. The lingula is a tongue-shaped process on the anteromedial border of the left lung. It fills the space between the chest wall and the heart.

Each of the five lobes divides into **bronchopulmonary segments** and subdivides into smaller units called **primary lobules**. The primary lobule is the anatomic unit of lung structure and consists of a terminal bronchiole with its expanded alveolar duct and alveolar sac.

---

**Fig. 10-5** Movement of the lungs during inspiration and expiration.
Mediastinum

The **mediastinum** is the area of the thorax bounded by the sternum anteriorly, the spine posteriorly, and the lungs laterally (Fig. 10-6). The structures associated with the mediastinum are as follows:

- Heart
- Great vessels
- Trachea
- Esophagus
- Thymus
- Lymphatics
- Nerves
- Fibrous tissue
- Fat

The **esophagus** is the part of the digestive canal that connects the pharynx with the stomach. It is a narrow, muscular-membranous tube about 9 inches (23 cm) in length. Following the curves of the vertebral column, the esophagus descends through the posterior part of the mediastinum and then runs anteriorly to pass through the esophageal hiatus of the diaphragm.

The esophagus lies just in front of the vertebral column, with its anterior surface in close relation to the trachea, aortic arch, and heart. This makes the esophagus valuable in certain heart examinations. When the esophagus is filled with barium sulfate, the posterior border of the heart and aorta are outlined well in lateral and oblique projections (Fig. 10-7). Frontal, oblique, and lateral images are often used in examinations of the esophagus. Radiography of the esophagus is discussed later in this chapter.

Fig. 10-6 Lateral view of the mediastinum, identifying the main structures.

Fig. 10-7 A, PA projection of the esophagus with barium sulfate coating its walls. B, PA oblique projection with a barium-filled esophagus (RAO position).
The thymus gland is the primary control organ of the lymphatic system. It is responsible for producing the hormone thymosin, which plays a critical role in the development and maturation of the immune system. The thymus consists of two pyramid-shaped lobes that lie in the lower neck and superior mediastinum, anterior to the trachea and great vessels of the heart and posterior to the manubrium. The thymus reaches its maximum size at puberty and then gradually undergoes atrophy until it almost disappears (Figs. 10-8 and 10-9).

In older individuals, lymphatic tissue is replaced by fat. At its maximum development the thymus rests on the pericardium and reaches as high as the thyroid gland. When the thymus is enlarged in infants and young children, it can press on the retrothymic organs, displacing them posteriorly and causing respiratory disturbances. A radiographic examination may be made in both the AP and lateral projections. For optimal image contrast, exposures should be made at the end of full inspiration.

Fig. 10-8 PA chest radiograph showing mediastinal enlargement caused by hypertrophy of the thymus (arrows).

Fig. 10-9 Lateral chest radiograph demonstrating an enlarged thymus (arrow).
# SUMMARY OF ANATOMY

<table>
<thead>
<tr>
<th>Body habitus</th>
<th>Respiratory system</th>
<th>Other structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>sthenic</td>
<td>pharynx</td>
<td>pleura</td>
</tr>
<tr>
<td>asthenic</td>
<td>trachea</td>
<td>visceral pleura</td>
</tr>
<tr>
<td>hyposthenic</td>
<td>carina</td>
<td>parietal pleura</td>
</tr>
<tr>
<td>hypersthenic</td>
<td>primary bronchi</td>
<td>serous fluid</td>
</tr>
<tr>
<td><strong>Thoracic cavity</strong></td>
<td>right primary bronchus</td>
<td>pleural cavity</td>
</tr>
<tr>
<td>superior thoracic</td>
<td>left primary bronchus</td>
<td>lobes</td>
</tr>
<tr>
<td>aperture</td>
<td>secondary bronchi</td>
<td>superior lobes</td>
</tr>
<tr>
<td>inferior thoracic</td>
<td>tertiary bronchi</td>
<td>inferior lobes</td>
</tr>
<tr>
<td>aperture</td>
<td>bronchioles</td>
<td>right middle lobe</td>
</tr>
<tr>
<td>diaphragm</td>
<td>terminal bronchioles</td>
<td>interlobar fissures</td>
</tr>
<tr>
<td>thoracic viscera</td>
<td>bronchial tree</td>
<td>oblique fissures (2)</td>
</tr>
<tr>
<td>lungs</td>
<td></td>
<td>horizontal fissure</td>
</tr>
<tr>
<td>heart</td>
<td></td>
<td>lingula</td>
</tr>
<tr>
<td>respiratory system</td>
<td></td>
<td>bronchopulmonary segments</td>
</tr>
<tr>
<td>cardiac system</td>
<td></td>
<td>primary lobules</td>
</tr>
<tr>
<td>lymphatic system</td>
<td></td>
<td><strong>Mediastinum</strong></td>
</tr>
<tr>
<td>inferior esophagus</td>
<td></td>
<td>heart</td>
</tr>
<tr>
<td>thymus gland</td>
<td></td>
<td>great vessels</td>
</tr>
<tr>
<td><strong>Lungs</strong></td>
<td></td>
<td>trachea</td>
</tr>
<tr>
<td>parenchyma</td>
<td></td>
<td>esophagus</td>
</tr>
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<td>thymus</td>
</tr>
<tr>
<td>base</td>
<td></td>
<td>lymphatics</td>
</tr>
<tr>
<td>costophrenic angles</td>
<td></td>
<td>nerves</td>
</tr>
<tr>
<td>hilum</td>
<td></td>
<td>fibrous tissue</td>
</tr>
<tr>
<td>cardiac notch</td>
<td></td>
<td>fat</td>
</tr>
</tbody>
</table>

*See Addendum at the end of the volume for a summary of the changes in the anatomic terms used in this edition.*
### SUMMARY OF PATHOLOGY

<table>
<thead>
<tr>
<th>Condition</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspiration / Foreign Body</td>
<td>Inspiration of a foreign material into the airway</td>
</tr>
<tr>
<td>Atelectasis</td>
<td>A collapse of all or part of the lung</td>
</tr>
<tr>
<td>Bronchiectasis</td>
<td>Chronic dilatation of the bronchi and bronchioles associated with secondary infection</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>Inflammation of the bronchi</td>
</tr>
<tr>
<td>Chronic Obstructive Pulmonary Disease (COPD)</td>
<td>Chronic condition of persistent obstruction of bronchial airflow</td>
</tr>
<tr>
<td>Cystic Fibrosis</td>
<td>Disorder associated with widespread dysfunction of the exocrine glands, abnormal secretion of sweat and saliva, and accumulation of thick mucus in the lungs</td>
</tr>
<tr>
<td>Emphysema</td>
<td>Destructive and obstructive airway changes leading to an increased volume of air in the lungs</td>
</tr>
<tr>
<td>Epiglottitis</td>
<td>Inflammation of the epiglottis</td>
</tr>
<tr>
<td>Fungal Disease</td>
<td>Inflammation of the lung caused by a fungal organism</td>
</tr>
<tr>
<td>Histoplasmosis</td>
<td>Infection caused by the yeast-like organism <em>H. capsulatum</em></td>
</tr>
<tr>
<td>Granulomatous Disease</td>
<td>Condition of the lung marked by formation of granulomas</td>
</tr>
<tr>
<td>Sarcoidosis</td>
<td>Condition of unknown origin often associated with pulmonary fibrosis</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>Chronic infection of the lung due to the tubercle bacillus</td>
</tr>
<tr>
<td>Hyaline Membrane Disease or Respiratory Distress Syndrome</td>
<td>Underaeration of the lungs due to a lack of surfactant</td>
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<tr>
<td>Metastases</td>
<td>Transfer of a cancerous lesion from one area to another</td>
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<tr>
<td>Pleural Effusion</td>
<td>Collection of fluid in the pleural cavity</td>
</tr>
<tr>
<td>Pneumoconiosis</td>
<td>Lung diseases resulting from inhalation of industrial substances</td>
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<tr>
<td>Anthracosis or Coal Miner’s Lung or Black Lung</td>
<td>Inflammation caused by inhalation of coal dust (anthracite)</td>
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<td>Asbestosis</td>
<td>Inflammation caused by inhalation of asbestos</td>
</tr>
<tr>
<td>Silicosis</td>
<td>Inflammation caused by inhalation of silicon dioxide</td>
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<tr>
<td>Pneumonia</td>
<td>Acute infection in the lung parenchyma</td>
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<tr>
<td>Aspiration</td>
<td>Pneumonia caused by aspiration of foreign particles</td>
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<tr>
<td>Interstitial or Viral or Pneumonitis</td>
<td>Pneumonia caused by a virus and involving the alveolar walls and interstitial structures</td>
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<tr>
<td>Lobar or Bacterial</td>
<td>Pneumonia involving the alveoli of an entire lobe without involving the bronchi</td>
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<tr>
<td>Lobular or Bronchopneumonia</td>
<td>Pneumonia involving the bronchi and scattered throughout the lung</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>Accumulation of air in the pleural cavity resulting in collapse of the lung</td>
</tr>
<tr>
<td>Pulmonary Edema</td>
<td>Replacement of air with fluid in the lung interstitium and alveoli</td>
</tr>
<tr>
<td>Tumor</td>
<td>New tissue growth where cell proliferation is uncontrolled</td>
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## Exposure Technique Chart: Essential Projections

### Thoracic Viscera

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<thead>
<tr>
<th>Part</th>
<th>cm</th>
<th>kVP*</th>
<th>tm</th>
<th>mA</th>
<th>mAs</th>
<th>AEC</th>
<th>SID</th>
<th>IR</th>
<th>Dose (mrad)</th>
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<td>300s</td>
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<td></td>
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<td>72°</td>
<td>35 x 43 cm</td>
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<td>Lateral</td>
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<td>300s</td>
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<td></td>
<td></td>
<td>72°</td>
<td>35 x 43 cm</td>
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<td>Obliques</td>
<td>25</td>
<td>125</td>
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<td></td>
<td></td>
<td>72°</td>
<td>35 x 43 cm</td>
<td>33</td>
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<tr>
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<td>0.08</td>
<td>300s</td>
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<td>3</td>
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<td>35 x 43 cm</td>
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<td>Lungs &amp; Plurae: Dorsal/Ventral Decub.§</td>
<td>33</td>
<td>125</td>
<td>0.02</td>
<td>300s</td>
<td>6</td>
<td></td>
<td>72°</td>
<td>35 x 43 cm</td>
<td>41</td>
</tr>
</tbody>
</table>

*Small focal spot.
*KVP values are for a 3-phase 12-pulse generator.
*Relative doses for comparison use. All doses are skin entrance for average adult at cm indicated.
*Tabletop, Standard IR. Screen/Film Speed 300.
*Bucky, 1:1 Grid. Screen/Film Speed 300.
Projections Removed
The bronchography section of this chapter has been removed in this edition. Advances in computed tomography (CT) has eliminated this procedure. The Fleischner Method has also been eliminated. See previous editions of the atlas for descriptions of these projections and procedures.

General Positioning Considerations
For radiography of the heart and lungs, the patient is placed in an upright position whenever possible to prevent engorgement of the pulmonary vessels and to allow gravity to depress the diaphragm. Of equal importance, the upright position demonstrates air and fluid levels. In the recumbent position, gravitational force causes the abdominal viscera and diaphragm to move superiorly; it compresses the thoracic viscera, which prevents full expansion of the lungs. Although the difference in diaphragm movement is not great in hyposthenic persons, it is marked in hypersthenic individuals. Figs. 10-10 and 10-11 illustrate the effect of body position in the same patient. The left lateral chest position (Fig. 10-12) is most commonly employed because it places the heart closer to the IR, resulting in a less magnified heart image. Right and left lateral chest images are compared in Figs. 10-12 and 10-13.

A slight amount of rotation from the PA or lateral projections causes considerable distortion of the heart shadow. To prevent this distortion, the body must be carefully positioned and immobilized.

PA CRITERIA
For PA projections, procedures are as follows:
• Instruct the patient to sit or stand upright. If the standing position is used, the weight of the body must be equally distributed on the feet.
• Position the patient's head upright, facing directly forward.
• Have the patient depress the shoulders and hold them in contact with the grid device to carry the clavicles below the lung apices. Except in the presence of an upper thoracic scoliosis, a faulty body position can be detected by the asymmetric appearance of the sterno-clavicular joints. Compare the clavicular margins in Figs. 10-14 and 10-15.

LATERAL CRITERIA
For lateral projections, procedures are as follows:
• Place the side of interest against the IR holder.
• Have the patient stand so that the weight is equally distributed on the feet. The patient should not lean toward or away from the IR holder.
• Raise the patient's arms to prevent the soft tissue of the arms from superimposing the lung fields.
• Instruct the patient to face straight ahead and raise the chin.
• To determine rotation, examine the posterior aspects of the ribs. Radiographs without rotation show superimposed posterior ribs (see Figs. 10-12 and 10-13).

OBLIQUE CRITERIA
In oblique projections, the patient rotates the hips with the thorax and points the feet directly forward. The shoulders should lie in the same transverse plane on all radiographs.

Fig. 10-10 Upright chest radiograph.
Fig. 10-11 Prone chest radiograph.
Fig. 10-12 Left lateral chest.

Fig. 10-13 Right lateral chest.

Fig. 10-14 PA chest without rotation.

Fig. 10-15 PA chest with rotation (arrow).
Breathing Instructions

During normal inspiration, the costal muscles pull the anterior ribs superiorly and laterally, the shoulders rise, and the thorax expands from front to back and from side to side. These changes in the height and AP dimension of the thorax must be considered when positioning the patient.

Deep inspiration causes the diaphragm to move inferiorly, resulting in elongation of the heart. Radiographs of the heart should therefore be obtained at the end of normal inspiration to prevent distortion. More air is inhaled during the second breath (and without strain) than during the first breath.

When a pneumothorax (gas or air in the pleural cavity) is suspected, one exposure is often made at the end of full inspiration and another at the end of full expiration to demonstrate small amounts of free air in the pleural cavity that might be obscured on the inspiration exposure (Figs. 10-16 and 10-17). Inspiration and expiration radiographs are also used to demonstrate the movement of the diaphragm, the occasional presence of a foreign body, and atelectasis (absence of air).

Technical Procedure

The projections required for an adequate demonstration of the thoracic viscera are usually requested by the attending physician and are determined by the clinical history of the patient. The PA projection of the chest is the most common projection and is used in all lung and heart examinations. Right and left oblique and lateral projections are also employed as required to supplement the PA projection. It is often necessary to improvise variations of the basic positions to project a localized area free of superimposed structures.

The exposure factors and accessories employed in examining the thoracic viscera depend on the radiographic characteristics of the individual patient’s pathologic condition. Normally, chest radiography uses a high kilovolt (peak) (kVp) to penetrate and demonstrate all thoracic anatomy on the radiograph. The kVp can be lowered if exposures are made without a grid.

However, if the selected kVp is too low, the radiographic contrast may be too high, resulting in few shades of gray. On such a radiograph the lung fields may appear properly penetrated, but the mediastinum appears underexposed. If the selected kVp is too high, the contrast may be too low, which does not allow for demonstration of the finer lung markings. Adequate kVp penetrates the mediastinum and demonstrates a faint shadow of the spine. Whenever possible, a minimum source-to-image receptor distance (SID) of 72 inches (183 cm) should be used to minimize magnification of the heart and to obtain greater recorded detail of the delicate lung structures (Fig. 10-18). A 120-inch (305-cm) SID is commonly used in radiography of the chest.

A grid technique is recommended for opaque areas within the lung fields and to demonstrate the lung structure through thickened pleural membranes (Figs. 10-19 and 10-20).
Fig. 10-18  A, Lateral chest radiograph performed at a 44-inch (112-cm) SID. B, Same patient's radiograph performed at a 72-inch (183-cm) SID. Note decreased magnification and greater recorded detail of lung structures.

Fig. 10-19  Nongrid radiograph demonstrating a fluid-type pathologic condition in the same patient as in Fig. 10-20.

Fig. 10-20  Grid radiograph of the same patient as in Fig. 10-19.
Radiation Protection
Protection of the patient from unnecessary radiation is the professional responsibility of the radiographer (see Chapter 1 for specific guidelines). In this chapter the Shield gonads statement indicates that the patient is to be protected from unnecessary radiation by restricting the radiation beam using proper collimation. In addition, the placement of lead shielding between the gonads and the radiation source is appropriate when the clinical objectives of the examination are not compromised. An example of a properly placed lead shield is shown in Fig. 10-27.

AP PROJECTION
When preparing to radiograph the trachea for the AP projection, use a grid technique to minimize secondary radiation because the kVp must be high enough to penetrate both the sternum and the cervical vertebrae.

**Image receptor:** 24 x 30 cm lengthwise

**Position of patient**
- Examine the patient in either the supine or upright position.
- Center the midsagittal plane of the body to the midline of the grid.
- Adjust the patient's shoulders to lie in the same transverse plane.
- Extend the patient's neck slightly, and adjust it so that the midsagittal plane is perpendicular to the plane of the IR (Fig. 10-21).
- Center the IR at the level of the manubrium.
- Collimate closely to the neck.
- Shield gonads.
- Respiration: Instruct the patient to inhale slowly during the exposure to ensure that the trachea is filled with air.

![Fig. 10-21 AP trachea.](image-url)
Trachea

Central ray
- Perpendicular through the manubrium to the center of the IR

Structures shown
An AP projection shows the outline of the air-filled trachea. Under normal conditions the trachea is superimposed on the shadow of the cervical vertebrae (Fig. 10-22).

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Area from the midcervical to the midthoracic region
- Air-filled trachea
- No rotation

Fig. 10-22 AP trachea during inspiration demonstrating an air-filled trachea (arrows).
Trachea and Superior Mediastinum

LATERAL PROJECTION
R or L position

Image receptor: 24 × 30 cm or 30 × 35 cm lengthwise

Position of patient

- Place the patient in a lateral position, either seated or standing, before a vertical grid device. If the standing position is used, the weight of the patient’s body must be equally distributed on the feet.

Position of part

- Instruct the patient to clasp the hands behind the body and then rotate the shoulders posteriorly as far as possible (Fig. 10-23). This will keep the superimposed shadows of the arms from obscuring the structures of the superior mediastinum. If necessary, immobilize the arms in this position with a wide bandage.
- Adjust the patient’s position to center the trachea to the midline of the IR. The trachea lies in the coronal plane that passes approximately midway between the jugular notch and the midcoronal plane.
- Adjust the height of the IR so that the upper border is at or above the level of the laryngeal prominence.
- Readjust the position of the body, being careful to have the midsagittal plane vertical and parallel with the plane of the IR.
- Extend the neck slightly.
- Shield gonads.
- Respiration: Make the exposure during slow inspiration to ensure that the trachea is filled with air.

Fig. 10-23 Lateral trachea and superior mediastinum.
Trachea and Superior Mediastinum

Central ray
- Horizontal through a point midway between the jugular notch and the mid-coronal plane (Fig. 10-24, A) and through a point 4 to 5 inches (10.2 to 12.7 cm) lower for demonstration of the superior mediastinum (Fig. 10-24, B)

Structures shown
A lateral projection demonstrates the air-filled trachea and the regions of the thyroid and thymus glands. This projection, first described by Eiselberg and Sgalitzer, is used extensively to demonstrate retrosternal extensions of the thyroid gland, thymic enlargement in infants (in the recumbent position), and the opacified pharynx and upper esophagus, as well as an outline of the trachea and bronchi. It is also used for foreign body localization.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Area from the midcervical to the midthoracic region
- Trachea and superior mediastinum free of superimposition by the shoulders
- Air-filled trachea
- No rotation

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Fig. 10-24 A, Lateral superior mediastinum. B, Thoracic mediastinum with air-filled trachea (arrows) and esophagus (arrowheads).
AXIOLATERAL PROJECTION
TWINING METHOD
R or L position
This projection is used to obtain an axi­lateral image of the apex of the lung nearest the IR and the trachea and superior mediastinum in patients who cannot rotate their shoulders posteriorly enough for a true lateral projection.

Image receptor: 24 × 30 cm length­wise

Position of part
• Elevate the arm adjacent to the IR in extreme abduction, flex the elbow, and place the forearm across or behind the head.
• Center the IR to the region of the trachea at the level of the axilla.
• Have the patient rest the shoulder firmly against the grid device for support.
• Depress the opposite shoulder as much as possible.
• Adjust the body in a true lateral position, with the midsagittal plane parallel with the plane of the IR (Fig. 10-25).

Position of patient
• Seat or stand the patient before a vertical grid device, with the affected side toward the IR.
• Shield gonads.
• Respiration: For the trachea, instruct the patient to inspire slowly during the exposure. For the lung apex, make the exposure at the end of full inspiration.

Central ray
• Directed to the center of the IR through the adjacent supraclavicular impression at an angle of 15 degrees caudad

Structures shown
The axiolateral projection demonstrates the air-filled trachea and the apex of the lung closer to the IR (Fig. 10-26).

Fig. 10-25 Axiolateral trachea and pulmonary apex.
EVALUATION CRITERIA
The following should be clearly demonstrated:
- Shoulders well separated from each other
- Area from the midcervical to the midthoracic region
- Air-filled trachea
- No rotation

Fig. 10-26 Axiolateral trachea and pulmonary apex.
Lungs and Heart

**PA PROJECTION**

**Image receptor:** 35 × 43 cm lengthwise, or crosswise for the hypersthenic patient

**SID:** A minimum SID of 72 inches (183 cm) is recommended to decrease magnification of the heart and increase recorded detail of the thoracic structures.

**Position of patient**

- If possible, always examine patients in the upright position, either standing or seated, so that the diaphragm is at its lowest position and air or fluid levels are seen. Engorgement of the pulmonary vessels is also avoided.

**Position of part**

- Place the patient, with arms hanging at sides, before a vertical grid device.
- Adjust the height of the IR so that its upper border is about 1½ to 2 inches (3.8 to 5 cm) above the relaxed shoulders.
- Center the midsagittal plane of the patient’s body to the midline of the IR.
- Have the patient stand straight, with the weight of the body equally distributed on the feet.
- Extend the patient’s chin upward or over the top of the grid device, and adjust the head so that the midsagittal plane is vertical.
- Ask the patient to flex the arms and to rest the backs of the hands low on the hips, below the level of the costophrenic angles. This maneuver rotates the scapulae laterally so that they are not superimposed over the lungs.
- Depress the shoulders and adjust to lie in the same transverse plane. Rotate them forward to position them below the lung apices (Figs. 10-27 and 10-28).
• If an immobilization band is used, be careful not to rotate the body when applying the band. The least amount of rotation will result in considerable distortion of the heart shadow.

• If a female patient’s breasts are large enough to be superimposed over the lower part of the lung fields, ask the patient to pull the breasts upward and laterally. Have the patient hold the breasts in place by leaning against the IR holder (Figs. 10-29 and 10-30).

• Shield gonads: Place a lead shield between the x-ray tube and the patient’s pelvis (see Fig. 10-27).

Fig. 10-29 Breasts superimposed over lower lungs.

Fig. 10-30 Correct placement of breasts.
**Respiration:** Full inspiration. The exposure is made after the second full inspiration to ensure maximum expansion of the lungs. The lungs will expand transversely, anteroposteriorly, and vertically, with vertical being the greatest dimension.

- For certain conditions, such as pneumothorax and the presence of a foreign body, radiographs are sometimes made at the end of full inspiration and expiration (Figs. 10-31 to 10-33).

**Central ray**
- Perpendicular to the center of the IR. The CR should enter at the level of T7.

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**Fig. 10-31** Inspiration (posterior rib numbers).

**Fig. 10-32** Expiration in the same patient (posterior rib numbers).

**Fig. 10-33** PA chest during expiration. The patient had blunt trauma to the right chest. The left side is normal. Pneumothorax is seen on the entire right side, and a totally collapsed lung is seen near the hilum (arrows).
Structures shown
A PA projection of the thoracic viscera shows the air-filled trachea, the lungs, the diaphragmatic domes, the heart and aortic knob, and, if enlarged laterally, the thyroid or thymus gland (Fig. 10-34). The vascular markings are much more prominent on the projection made at the end of expiration. The bronchial tree is shown from an oblique angle. The esophagus is well demonstrated when it is filled with a barium sulfate suspension.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Entire lung fields from the apices to the costophrenic angles
- No rotation; sternal ends of the clavicles equidistant from the vertebral column
- Trachea visible in the midline
- Scapulae projected outside the lung fields
- Ten posterior ribs visible above the diaphragm
- Sharp outlines of heart and diaphragm
- Faint shadow of the ribs and superior thoracic vertebrae visible through the heart shadow
- Lung markings visible from the hilum to the periphery of the lung
- With inspiration and expiration chest images, diaphragm demonstrated on expiration at a higher level so that at least one fewer rib is seen within the lung field

NOTE: Inferior lobes of both lungs should be carefully checked for adequate penetration on women with large, pendulous breasts.

Cardiac studies with barium
PA chest radiographs are often obtained with the patient swallowing a bolus of barium sulfate to outline the posterior heart and aorta. The barium used in cardiac examinations should be thicker than that used for the stomach so that the contrast medium descends more slowly and adheres to the esophageal walls. The patient should hold the barium in the mouth until just before the exposure is made. Then the patient takes a deep breath and swallows the bolus of barium; at this time the exposure is made (see Fig. 10-6).
Lungs and Heart

**LATERAL PROJECTION**
* R or L position

**Image receptor:** 35 × 43 cm lengthwise

**SID:** A minimum SID of 72 inches (183 cm) is recommended to decrease magnification of the heart and increase recorded detail of the thoracic structures.

**Position of patient**
- If possible, always examine the patient in the upright position, either standing or seated, so that the diaphragm is at its lowest position and air and fluid levels can be seen. Engorgement of the pulmonary vessels is also avoided.
- Turn the patient to a true lateral position, arms by the sides.
- To show the heart and left lung, use the left lateral position with the patient’s left side against the IR.
- Use the right lateral position to best demonstrate the right lung.

**Position of part**
- Adjust the position of the patient so that the mid sagittal plane of the body is parallel with the IR and the adjacent shoulder is touching the grid device.
- Center the thorax to the grid; the mid coronal plane should be perpendicular and centered to the midline of the grid.
- Have the patient extend the arms directly upward, flex the elbows, and with the forearms resting on the elbows, hold the arms in position (Figs. 10-35 and 10-36).
- Place an IV stand in front of an unsteady patient. Have the patient extend the arms and grasp the stand as high as possible for support.
- Adjust the height of the IR so that the upper border is about 1½ to 2 inches (3.8 to 5 cm) above the shoulders.

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Fig. 10-35 Lateral chest.

Fig. 10-36 Lateral chest.
• Recheck the position of the body; the midsagittal plane must be vertical. Depending on the width of the shoulders, the lower part of the thorax and hips may be a greater distance from the IR, but this body position is necessary for a true lateral projection. Having the patient lean against the grid device (foreshortening) results in distortion of all thoracic structures (Fig. 10-37). Forward bending also results in distorted structural outlines (Fig. 10-38).
• Shield gonads.

• Respiration: Full inspiration. The exposure is made after the second full inspiration to ensure maximum expansion of the lungs.

Central ray
• Perpendicular to the center of the IR. The CR will enter the patient on the midcoronal plane at the level of T7 or the inferior aspect of the scapula.

Fig. 10-37 Foreshortening.

Fig. 10-38 Forward bending.
Structures shown
The preliminary left lateral chest position is used to demonstrate the heart, the aorta, and left-sided pulmonary lesions (Figs. 10-39 and 10-40). The right lateral chest position is used to demonstrate right-sided pulmonary lesions (Fig. 10-41). These lateral projections are employed extensively to demonstrate the interlobar fissures, to differentiate the lobes, and to localize pulmonary lesions.

EVALUATION CRITERIA
The following should be clearly demonstrated:
- Superimposition of the ribs posterior to the vertebral column
- Arm or its soft tissues not overlapping the superior lung field
- Long axis of the lung fields demonstrated in vertical position, without forward or backward leaning
- Lateral sternum with no rotation
- Costophrenic angles and the lower apices of the lungs
- Penetration of the lung fields and heart
- Open thoracic intervertebral spaces and intervertebral foramina, except in patients with scoliosis
- Sharp outlines of heart and diaphragm
- Hilum in the approximate center of the radiograph

Fig. 10-39 Left lateral chest.
Cardiac studies with barium
The left lateral position is traditionally used during cardiac studies with barium. The procedure is the same as that described for the PA chest projection (see p. 553).

Fig. 10-40 A, Left lateral chest. B, Right lateral chest on same patient as A. Note size of the heart shadows.

Fig. 10-41 A, PA Chest. B, Lateral chest, same patient as A. The importance of two projections is seen on this patient with multiple chest pathology including fluid, air-fluid level, pneumothorax and enlarged heart.
Lungs and Heart

**PA OBLIQUE PROJECTION**

**RAO and LAO positions**

**Image receptor:** 35 × 43 cm lengthwise

**SID:** A minimum SID of 72 inches (183 cm) is recommended to decrease magnification of the heart and to increase recorded detail of the thoracic structures.

**Position of patient**
- Maintain the patient in the position (standing or seated upright) used for the PA projection.
- Instruct the patient to let the arms hang free.
- Have the patient turn approximately 45 degrees toward the left side for an LAO position and approximately 45 degrees toward the right side for an RAO position.
- Ask the patient to stand or sit straight. If the standing position is used, the weight of the patient's body must be equally distributed on the feet to prevent unwanted rotation.
- For PA oblique projections, the side of interest is generally the side *farther* from the IR; however, the lung closest to the IR is also imaged.
- The top of the IR should be placed about 1½ to 2 inches (3.8 to 5 cm) above the vertebral prominens because the top of the shoulders may not be on the same plane.

![Fig. 10-42 PA oblique chest, LAO position.](image-url)
Position of part

LAO position
- Rotate the patient 45 degrees to place the left shoulder in contact with the grid device, and center the thorax to the IR. Ensure that both the right and left sides of the body are positioned to the IR.
- Instruct the patient to place the left hand on the hip with the palm outward.
- Have the patient raise the right arm to shoulder level and grasp the top of the vertical grid device for support.
- Adjust the patient’s shoulders to lie in the same horizontal plane, and instruct the patient to not rotate the head (Fig. 10-42).
- Use a 55- to 60-degree oblique position when the examination is performed for a cardiac series. This projection is usually performed with barium contrast medium. The patient swallows the barium just before the exposure.
- Shield gonads.
- Respiration: Full inspiration. The exposure is made after the second full inspiration to ensure maximum expansion of the lungs.

RAO position
- Reverse the previously described position, placing the patient’s right shoulder in contact with the grid device, the right hand on the hip and the left hand on the top of the vertical grid device (Figs. 10-43 and 10-44).
- Shield gonads.
- Respiration: Full inspiration. The exposure is made after the second full inspiration to ensure maximum expansion of the lungs.

Central ray
- Perpendicular to the center of the IR. The CR should be at the level of T7.
Chest

Fig. 10-45 PA oblique chest, LAO position.

Structures shown

**LAO position**
The maximum area of the right lung field (side farther from the IR) is demonstrated along with the thoracic viscera. The anterior portion of the left lung is superimposed by the spine (Figs. 10-45 and 10-46). Also shown are the trachea and its bifurcation (the carina) and the entire right branch of the bronchial tree. The heart, the descending aorta (lying just in front of the spinae), and the arch of the aorta are also presented.

**RAO position**
The maximum area of the left lung field (side farther from the IR) is demonstrated along with the thoracic viscera. The anterior portion of the right lung is superimposed by the spine (Figs. 10-47 and 10-48). Also shown are the trachea and the entire left branch of the bronchial tree. This position gives the best image of the left atrium, the anterior portion of the apex of the left ventricle, and the right retrocardiac space. When filled with barium, the esophagus is shown clearly in the RAO and LAO positions (see Fig. 10-48).

**NOTE:** The radiographs in this section, like the radiographs throughout this text, are printed as if the reader is looking at the patient's anterior body surface (see Chapter 1).

Fig. 10-46 PA oblique chest. The LAO position is 60 degrees with a barium-filled esophagus.
**EVALUATION CRITERIA**

The following should be clearly demonstrated:

- Both lungs in their entirety
- Trachea filled with air
- Visible identification markers
- Heart and mediastinal structures within the lung field of the elevated side in oblique images of 45 degrees
- Maximum area of the right lung on the LAO.
- Maximum area of the left lung on the RAO.

**Barium studies**

The RAO and LAO positions are routinely used during cardiac studies with barium. Follow the same procedure described in the PA chest section (see p. 553).

**NOTE:** A lesser-degree oblique position has been found to be of particular value in the study of pulmonary diseases. The patient is turned only slightly (10 to 20 degrees) from the RAO or LAO body position. This slight degree of obliquity rotates the superior segment of the respective lower lobe from behind the hilum and displays the medial part of the right middle lobe or the lingula of the left upper lobe free from the hilum. These areas are not clearly shown in the standard “cardiac oblique” of 45- to 60-degree rotation, largely because of superimposition of the spine.
Chest

Lungs and Heart

**AP OBLIQUE PROJECTION**

RPO and LPO positions

RPO and LPO positions are used when the patient is too ill to be turned to the prone position and sometimes as supplementary positions in the investigation of specific lesions. They are also used with the recumbent patient in contrast studies of the heart and great vessels.

One point the radiographer must bear in mind is that the **RPO corresponds to the LAO position** and the **LPO corresponds to the RAO position**. For AP oblique projections, the side of interest is generally the side closest to the IR. The resulting image demonstrates the greatest area of the lung closest to the IR. However, the lung farthest from the IR is also imaged, and diagnostic information is often obtained for that side.

**Image receptor:** 35 x 43 cm lengthwise

**SID:** A minimum SID of 72 inches (183 cm) is recommended to decrease magnification of the heart and increase recorded detail of the thoracic structures.

**Position of patient**

- With the patient supine or facing the x-ray tube, either upright or recumbent, adjust the IR so that the upper border of the IR is about 1½ to 2 inches (3.8 to 5 cm) above the vertebral prominens or about 5 inches (12.7 cm) above the jugular notch.
- Rotate the patient toward the correct side, adjust the body at a 45-degree angle, and center the thorax to the grid.
- If the patient is recumbent, support the elevated hip and arm. Ensure that both sides of the chest are positioned to the IR.
- Flex the patient's elbows and place the hands on the hips with the palms facing outward, or pronate the hands beside the hips. The arm closer to the IR may be raised as long as the shoulder is rotated anteriorly.
- Adjust the shoulders to lie in the same transverse plane in a position of forward rotation (Figs. 10-49 and 10-50).
- Shield gonads.
- **Respiration:** Full inspiration. The exposure is made after the second full inspiration to ensure maximum expansion of the lungs.

Fig. 10-49 Upright AP oblique chest, LPO position.

Fig. 10-50 Recumbent AP oblique chest, RPO position.
Central ray
- Perpendicular to the center of the IR at a level 3 inches (7.6 cm) below the jugular notch (The central ray will exit at T7.)

**Structures shown**
This radiograph presents an AP oblique projection of the thoracic visera similar to the corresponding PA oblique projection (Fig. 10-51). An RPO position is comparable to an LAO position. However, the lung field of the elevated side usually appears shorter because of magnification of the diaphragm. The heart and great vessels also cast magnified shadows as a result of being farther from the IR.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Both lungs in their entirety
- Trachea filled with air
- Visible identification markers
- The lung fields and mediastinal structures
- Maximum area of the left lung on the LPO
- Maximum area of the right lung on the RPO

![Fig. 10-51 AP oblique chest, LPO position.](image)
AP PROJECTION

The supine position is used when the patient is too ill to be turned to the prone position. It is sometimes used as a supplementary projection in the investigation of certain pulmonary lesions.

**Image receptor:** 35 × 43 cm lengthwise

**SID:** A SID of 72-inches (183 cm) or 60-inches (150 cm) SID is recommended if it can be attained using the equipment available.

**Position of patient**
- Place the patient in the supine or upright position with the back against the grid.

**Position of part**
- Center the midsagittal plane of the chest to the IR.
- Adjust the IR so the upper border is approximately 1½ to 2 inches (3.8 to 5 cm) above the relaxed shoulders.
- If possible, flex the patient’s elbows, pronate the hands, and place the hands on the hips to draw the scapula laterally. (Note, however, that this maneuver is often impossible because of the condition of the patient.)
- Adjust the shoulders to lie in the same transverse plane (Fig. 10-52).
- Shield gonads.
- Respiration: Full inspiration. The exposure is made after the second full inspiration to ensure maximum expansion of the lungs.

**Central ray**
- Perpendicular to the long axis of the sternum and the center of the IR. The CR should enter about 3-inches (7.6 cm) below the jugular notch.

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1See Chapter 30 for full description of Mobile AP.
Structures shown

- An AP projection of the thoracic viscera (Fig. 10-53) demonstrates an image somewhat similar to that of the PA projection (Fig. 10-54). Being farther from the IR, the heart and great vessels are magnified, as well as engorged, and the lung fields appear shorter because abdominal compression moves the diaphragm to a higher level. The clavicles are projected higher, and the ribs assume a more horizontal appearance.

EVALUATION CRITERIA

The following should be clearly demonstrated:

- Medial portion of the clavicles equidistant from the vertebral column
- Trachea visible in the midline
- Clavicles lying more horizontal and obscuring more of the apices than in the PA projection
- Equal distance from the vertebral column to the lateral border of the ribs on each side
- Faint image of the ribs and thoracic vertebrae visible through the heart shadow
- Entire lung fields, from the apices to the costophrenic angles
- Pleural markings visible from the hilar regions to the periphery of the lungs

NOTE: Resnick recommended an angled AP projection to free the basal portions of the lung fields from superimposition by the anterior diaphragmatic, abdominal, and cardiac structures. He reported that this projection also differentiates middle lobe and lingular processes from lower lobe disease. For this projection the patient may be either upright or supine, and the central ray is directed to the midsternal region at an angle of 30 degrees caudad. Resnick stated that a more suitable angulation may be chosen based on the preliminary film.

Pulmonary Apices

AP AXIAL PROJECTION
LINDBLOM METHOD
Lordotic position

Image receptor: $35 \times 43$ cm lengthwise

SID: A minimum SID of 72 inches (183 cm) is recommended to decrease magnification of the heart and to increase recorded detail of the thoracic structures.

Position of patient
- Place the patient in the upright position, facing the x-ray tube and standing approximately 1 foot (30.5 cm) in front of the vertical grid device.

Position of part
- Adjust the height of the IR so that the upper margin is about 3 inches (7.6 cm) above the upper border of the shoulders when the patient is adjusted in the lordotic position.

Lordotic position
- Adjust the patient for the AP axial projection, with the mid-sagittal plane centered to the midline of the grid (Fig. 10-55).

Oblique lordotic positions—LPO or RPO
- Rotate the patient’s body approximately 30 degrees away from the position used for the AP projection, with the affected side toward and centered to the grid (Fig. 10-56).
- With either of the preceding positions, have the patient flex the elbows and place the hands, palms out, on the hips.
- Have the patient lean backward in a position of extreme lordosis and rest the shoulders against the vertical grid device.
- Shield gonads.
- Respiration: Full inspiration. The exposure is made after the second full inspiration to ensure maximum expansion of the lungs.

Fig. 10-55 AP axial pulmonary apices, lordotic position.

Fig. 10-56 AP axial oblique pulmonary apices, LPO lordotic position.
Central ray
- Perpendicular to the center of the IR at the level of the midsternum

**COMPUTED RADIOGRAPHY**
Collimation must be very close to keep unnecessary radiation from reaching the IR phosphor.

**Structures shown**
The AP axial (Fig. 10-57) and AP axial oblique (Fig. 10-58) images of the lungs demonstrate the apices and conditions such as interlobar effusions.

**EVALUATION CRITERIA**
The following should be clearly demonstrated:

- **Lordotic position**
  - Clavicles lying superior to the apices
  - Sternal ends of the clavicles equidistant from the vertebral column
  - Apices and lungs in their entirety
  - Clavicles lying horizontally with their medial ends overlapping only the first or second ribs
  - Ribs distorted with their anterior and posterior portions somewhat superimposed

- **Oblique lordotic position**
  - Dependent apex and lung of the affected side in its entirety

Fig. 10-57 AP axial pulmonary apices, lordotic position.

Fig. 10-58 AP axial oblique pulmonary apices, LPO lordotic position.
Pulmonary Apices

**PA AXIAL PROJECTION**

*Image receptor:* 24 × 30 cm or 30 × 35 cm crosswise

*SID:* A minimum SID of 72 inches (183 cm) is recommended to decrease magnification of the heart and to increase recorded detail of the thoracic structures.

**Position of patient**
- Position the patient, either seated or standing, before a vertical grid device. If the patient is standing, the weight of the body must be equally distributed on the feet.

**Position of part**
- Adjust the height of the IR so that it is centered at the level of the jugular notch.
- Center the midsagittal plane of the patient's body to the midline of the IR, and rest the chin against the grid device.
- Adjust the patient's head so that the midsagittal plane is vertical, then flex the elbows and place the hands, palms out, on the hips.
- Depress the patient's shoulders, rotate them forward, and adjust them to lie in the same transverse plane.
- Instruct the patient to keep the shoulders in contact with the grid device to move the scapulae from the lung fields (Fig. 10-59).
- Shield gonads.
- **Respiration:** Make the exposure at the end of full inspiration or optionally at full expiration. The clavicles are elevated by inspiration and depressed by expiration; the apices move little, if at all, during either phase of respiration.

**Central ray**

*Inspiration*
- Directed 10 to 15 degrees cephalad through T3 to the center of the IR

*Expiration (optional)*
- Directed perpendicular to the plane of the IR and centered at the level of T3

Fig. 10-59 PA axial pulmonary apices (inspiration).
**Pulmonary Apices**

**Structures shown**
- The apices are projected above the shadows of the clavicles in the PA axial and PA projections (Figs. 10-60 and 10-61).

**EVALUATION CRITERIA**
The following should be clearly demonstrated:
- Apices in their entirety
- Only the superior lung region adjacent to the apices
- Clavicles lying below the apices
- Medial portion of the clavicles equidistant from the vertebral column

Fig. 10-60 PA axial pulmonary apices, inspiration with central ray angled.

Fig. 10-61 PA pulmonary apices, expiration with perpendicular central ray.
Pulmonary Apices

AP AXIAL PROJECTION

**Image receptor:** 24 × 30 cm or 30 × 35 cm crosswise

**SID:** A minimum SID of 72 inches (183 cm) is recommended to decrease magnification of the heart and to increase recorded detail of the thoracic structures.

**Position of patient**
- Examine the patient in the upright or supine position.

**Position of part**
- Center the IR to the midsagittal plane at the level of T1, and adjust the patient’s body so that it is not rotated.
- Flex the patient’s elbows and place the hands on the hips with the palms out, or pronate the hands beside the hips.
- Place the shoulders back against the grid and adjust them to lie in the same transverse plane (Fig. 10-62).
- **Shield gonads.**
- **Respiration:** Expose at the end of full inspiration.

**Central ray**
- Directed at an angle of 15 or 20 degrees cephalad to the center of the IR and entering the manubrium

**Structures shown**
An AP axial projection demonstrates the apices lying below the clavicles (Fig. 10-63).
Pulmonary Apices

EVALUATION CRITERIA

The following should be clearly demonstrated:

- Clavicles lying superior to the apices
- Sternal ends of the clavicles equidistant from the vertebral column
- Apices in their entirety
- Superior lung region adjacent to the apices
- Clavicles lying horizontally with their medial ends overlapping only the first or second ribs
- Ribs distorted, with their anterior and posterior portions somewhat superimposed

NOTE: The AP axial projection is used in preference to the PA axial projection in hypersthenic patients and patients whose clavicles occupy a high position. The AP axial projection makes it possible to separate the apical and clavicular shadows without undue distortion of the apices.

Fig. 10-63 AP axial pulmonary apices.
AP or PA Projection

R or L lateral decubitus positions

Image receptor: 35 x 43 cm lengthwise

Position of Patient

- Place the patient in a lateral decubitus position, lying on either the affected or the unaffected side, as indicated by the existing condition. A small amount of fluid in the pleural cavity is usually best shown with the patient lying on the affected side. With this positioning, the mediastinal shadows and the fluid will not overlap. A small amount of free air in the pleural cavity is generally best demonstrated with the patient lying on the unaffected side.
- Exercise care to ensure that the patient does not fall off the cart. If a cart is used, lock all wheels securely in position.
- Achieve the best visualization by allowing the patient to remain in the position for 5 minutes before the exposure. This allows fluid to settle and air to rise.

Position of part

- If the patient is lying on the affected side, elevate the body 5 to 8 cm (2 to 3 inches) on a suitable platform or a firm pad.
- Extend the arms well above the head, and adjust the thorax in a true lateral position (Fig. 10-64).
- Place the anterior or posterior surface of the chest against a vertical grid device.
- Adjust the IR so that it extends approximately 1 1/2 to 2 inches (3.8 to 5 cm) beyond the shoulders.
- Shield gonads.
- Respiration: Full inspiration. The exposure is made after the second full inspiration to ensure maximum expansion of the lungs.

Central ray

- Horizontal and perpendicular to the center of the IR at a level 3 inches (7.6 cm) below the jugular notch for the AP, and T7 for the PA

Structures shown

An AP or PA projection obtained using the lateral decubitus position demonstrates the change in fluid position and reveals any previously obscured pulmonary areas or, in the case of suspected pneumothorax, the presence of any free air (Figs. 10-65 to 10-67).

Position of Part

- If the patient is lying on the affected side, elevate the body 5 to 8 cm (2 to 3 inches) on a suitable platform or a firm pad.
- Extend the arms well above the head, and adjust the thorax in a true lateral position (Fig. 10-64).
- Place the anterior or posterior surface of the chest against a vertical grid device.
- Adjust the IR so that it extends approximately 1 1/2 to 2 inches (3.8 to 5 cm) beyond the shoulders.
- Shield gonads.
- Respiration: Full inspiration. The exposure is made after the second full inspiration to ensure maximum expansion of the lungs.

Central ray

- Horizontal and perpendicular to the center of the IR at a level 3 inches (7.6 cm) below the jugular notch for the AP, and T7 for the PA

Structures shown

An AP or PA projection obtained using the lateral decubitus position demonstrates the change in fluid position and reveals any previously obscured pulmonary areas or, in the case of suspected pneumothorax, the presence of any free air (Figs. 10-65 to 10-67).
**EVALUATION CRITERIA**

The following should be clearly demonstrated:

- No rotation of the patient from a true frontal position, as evidenced by the clavicles being equidistant from the spine
- Affected side in its entirety
- Apices
- Proper identification visible to indicate that decubitus was performed
- Patient’s arms not visible in the field of interest

**NOTE:** An exposure made with the patient leaning directly laterally from the upright PA position is sometimes useful for demonstrating fluid levels in pulmonary cavities. Ekimsky recommended this position, with the patient leaning laterally 45 degrees, for the demonstration of small pleural effusions. He reported that the inclined position is simpler to perform than the decubitus position and is equally satisfactory.


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**Fig. 10-66** AP projection, left lateral decubitus position, in same patient as in Fig. 10-67. The arrows indicate the air-fluid level (air on the side up). Note correct marker placement with the upper side of the patient indicated.

**Fig. 10-67** Upright PA chest. The arrow indicates the air-fluid level.
Lungs and Pleurae

**LATERAL PROJECTION**

- **R or L position**
- **Ventral or dorsal decubitus position**

**Image receptor:** 35 × 43 cm lengthwise

**Position of patient**
- With the patient in a prone or supine position, elevate the thorax 2 to 3 inches (5 to 7.6 cm) on folded sheets or a firm pad, centering the thorax to the grid.
- Achieve the best visualization by allowing the patient to remain in the position for 5 minutes before the exposure. This allows fluid to settle and air to rise.

**Position of part**
- Adjust the body in a true prone or supine body position, and extend the arms well above the head.
- Place the affected side against a vertical grid device, and adjust it so that the top of the IR extends to the level of the thyroid cartilage (Fig. 10-68).
- **Shield gonads.**
- **Respiration:** Full inspiration. The exposure is made after the second full inspiration to ensure maximum expansion of the lungs.

**Central ray**
- **Horizontal** and centered to the IR. The central ray enters at the level of the midcoronal plane and 3 to 4 inches (7.6 to 10.2 cm) below the jugular notch for the dorsal decubitus, and at T7 for the ventral decubitus.

**COMPUTED RADIOGRAPHY**

The kVp used for this projection requires that the collimation be very close. Scattered and primary radiation reaching the IR phosphor may cause computer artifacts.

**Structures shown**

A lateral projection in the decubitus position shows a change in the position of fluid and reveals pulmonary areas that are obscured by the fluid in standard projections (Figs. 10-69 and 10-70).
EVALUATION CRITERIA

The following should be clearly demonstrated:

- Entire lung fields, including the anterior and posterior surfaces
- No rotation of the thorax from a true lateral position
- Upper lung field not obscured by the arms
- Proper marker identification visible to indicate the decubitus was performed
- T7 in the center of the IR

Fig. 10-70 Upright PA chest in same patient as in Fig. 10-69. Note right lung fluid level (arrow).
11

LONG BONE MEASUREMENT

OUTLINE

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Leg measurement showing that the right leg is shorter than the left leg.
Radiography provides the most reliable means of obtaining accurate measurements of the length of long bones, specifically length differences between the two sides. Although studies are occasionally made of the upper limbs, radiography is most frequently applied to the lower limbs. This chapter considers only a few of the many radiographic methods that have been devised for long bone measurement.

**Radiation Protection**

Differences in limb length are not uncommon in children and may occur in association with a variety of disorders. Patients with unequal limb growth may require yearly radiographic evaluations. More frequent examinations may be necessary in patients who have undergone surgical procedures to equalize limb length. One treatment method controls bone growth on the normal side. This is usually accomplished by means of metaphysial-epiphyseal fusion at the distal femoral or proximal tibial level. Another treatment technique is to increase the growth of the shorter limb. This is achieved by surgically cutting the femur and/or tibia-fibula. A frame is then placed around the cut ends and extended to the outside of the body. Gradual pressure on the frame separates the bone, extends the leg, and promotes healing at the same time.

Because patients with limb length differences require checkups at regular intervals over a period of years, gonad shielding is necessary to guard their well-being. In addition, careful patient positioning, secure immobilization, and accurate centering of a closely collimated beam of radiation are important to prevent unnecessary repeat exposures.

**Position of Patient**

Three exposures are made of each limb, with the accuracy of the examination depending on the patient not moving the limb or limbs even slightly. Small children must be carefully immobilized to prevent motion. If movement of the limb occurs before the examination is completed, all radiographs may need to be repeated.

- Place the patient in the supine position for all techniques, and examine both sides for comparison.
- When a soft tissue abnormality (swelling or atrophy) is causing rotation of the pelvis, elevate the low side on a radiolucent support to overcome the rotation, if necessary.

**Position of Part**

The limb to be examined should be positioned as follows:

- Adjust and immobilize the limb for an AP projection.
- If the two lower limbs are examined simultaneously, separate the ankles 5 to 6 inches (13 to 15 cm) and place the specialized ruler under the pelvis and extended down between the legs.
- If the limbs are examined separately, position the patient with a special ruler beneath each limb.
- When the knee of the patient’s abnormal side cannot be fully extended, flex the normal knee to the same degree and support each knee on one of a pair of supports of identical size to ensure that the joints are flexed to the same degree and are equidistant from the IR.

**Localization of Joints**

For the methods that require centering of the ray above the joints, the following steps should be taken:

- Localize each joint accurately, and use a skin-marking pencil to indicate the central ray centering point.
- Because both sides are examined for comparison and a discrepancy in bone length usually exists, mark the joints of each side after the patient is in the supine position.
- With the upper limb, place the marks as follows: for the shoulder joint—over the superior margin of the head of the humerus; for the elbow joint—½ to ¾ inch (1.3 to 1.9 cm) below the plane of the epicondyles of the humerus (depending on the size of the patient); and for the wrist—midway between the styloid processes of the radius and ulna.
- With the lower limb, locate the hip joint by placing a mark 1 to 1¼ inches (2.5 to 3.2 cm) (depending on the size of the patient) laterodistally and at a right angle to the midpoint of an imaginary line extending from the anterior superior iliac spine to the pubic symphysis.
- Locate the knee joint just below the apex of the patella at the level of the depression between the femoral and tibial condyles.
- Locate the ankle joint directly below the depression midway between the malleoli.

In all radiographs made by a single x-ray exposure, the image is larger than the actual body part because the x-ray photons start at a very small area on the target of the x-ray tube and diverge as they travel in straight lines through the body to the IR (Fig. 11-1). This magnification can be decreased by putting the body part as close to the IR as possible and making the distance between the x-ray tube and the image receptor as long as possible (a procedure sometimes referred to as tele-oroentgenography). However, a radiographic technique called orthoroentgenology can be used to determine the exact length of a child’s limb bones.
For this radiographic technique, a metal measurement ruler is placed between the patient's lower limbs and three exposures are made on the same x-ray IR. The following steps are observed:

- Using narrow collimation and careful centering of the limb parts to the upper, middle, and lower thirds of the IR, make three exposures on one IR.
- For all three exposures, place the central ray perpendicular to and passing directly through the specified joint (hence the term orthoroentgenology, from the Greek word orthos, meaning straight).
- Do not move the limb between exposures. Because the IR is in the Bucky tray for all exposures, including that of the ankle, exposure factors must be modified accordingly.
- Position the x-ray tube directly over the patient’s hip, and make the first exposure (Fig. 11-2, A).
- Move the x-ray tube to directly over the patient’s knee joint, and make a second exposure (Fig. 11-2, B).
- Move the x-ray tube to directly over the patient’s tibiotalar joint, and make a third exposure (Fig. 11-2, C).

If the child holds the leg perfectly still while the three exposures are made, the true distance from the proximal end of the femur to the distal end of the tibia can be directly measured on the image.

Fig. 11-1 Conventional radiographs are magnified (elongated) images. Proximal elongation in above example is equal to the distance (E). Similar elongation occurs distally.

Fig. 11-2 Patient positioned for orthoroentgenographic measurement of lower limb. The central ray is centered over the hip joint (A), knee joint (B), and ankle joint (C). A metal ruler was placed near the lateral aspect of leg for photographic purposes. The ruler is normally placed between the limbs (see Fig. 11-4).
Place a special metal ruler (engraved with radiopaque centimeter or \( \frac{1}{2} \)-inch (1.3-cm) marks that show when a radiograph is made) under the leg and on top of the table (see Fig. 11-2).

If the IR is placed in the Bucky tray and then moved between the exposures (see Fig. 11-2), calculate the length of the femur and tibia by subtracting the numerical values projected over the two joints obtained by simultaneously exposing the patient and the metal ruler. Another method of measuring the lengths of the femurs and tibias is to examine both limbs simultaneously (Figs. 11-3 and 11-4):

- Center the mid sagittal plane of the patient's body to the midline of the grid.
- Adjust the patient's lower limbs in the anatomic position (i.e., slight medial rotation).
- Tape the special metal ruler to the top of the table so that part of it is included in each of the exposure fields. This records the position of each joint.
- Place an IR in the Bucky tray, and shift it for centering at the three joint levels without moving the patient.

---

**Fig. 11-3** Bilateral leg length measurement, with metal ruler placed beside leg for photographic purposes. (Proper placement of the ruler is shown in Fig. 11-4.)

**Fig. 11-4** Orthoroentgenogram for the measurement of leg length.

**Fig. 11-5** Leg measurement showing that the right leg is shorter than the left leg.
Center the IR and the tube successively at the previously marked level of the hip joints, the knee joints, and the ankle joints for simultaneous bilateral projections.

When a difference in level exists between the contralateral joints, center the tube midway between the two levels.

Make the three exposures on one 35 × 43 cm (14 × 17 inch) or 30 × 35 cm (11 × 14 inch) IR. Limb length can then be quickly determined.

The orthoroentgenographic method is reasonably accurate if the limbs are of almost the same length. When more than a slight discrepancy in limb length exists (Fig. 11-5), it is not possible to place the center of the x-ray tube exactly over both knee joints and make a single exposure or exactly over both ankle joints and make a single exposure. In such cases, the tube is centered midway between the two joints. However, this results in bilateral distortion because of the diverging x-ray beam. In Fig. 11-5 the measurement obtained for the right femur is somewhat less than the actual length of the bone, whereas the measurement of the left femur is somewhat greater than the true length. The following measure can be taken to correct this problem:

Examine each limb separately (Fig. 11-6).

Center the limb being examined on the grid, and place the special ruler beneath the limb.

Make a closely collimated exposure over each joint. This restriction of the exposure field not only increases the accuracy of the procedure but also considerably reduces radiation exposure (most importantly, to the gonads).

After making joint localization marks, position the patient and apply local gonad shielding.

Adjust the collimator to limit the exposure field as much as possible.

With successive centering to the localization marks, make exposures of the hip, knee, and ankle.

Repeat the procedure for the opposite limb.

Use the same approach to measure lengths of the long bones in the upper limbs (Fig. 11-7).
Computed Tomography Technique

Helms and McCarthy\(^1\) reported a method for using computed tomography (CT) to measure discrepancies in leg length. Temme, Chu, and Anderson\(^2\) compared conventional orthoroentgenograms with CT scans for long bone measurements. Both sets of investigators concluded that the CT scanogram is more consistently reproduced and that it causes less radiation exposure to the patient than the conventional radiographic approach. The CT approach is as follows:

- Take CT localizer or “scout” images of the femurs and tibias.
- Place cursors over the respective hip, knee, and ankle joints as described earlier in this chapter. To similarly study the upper limb, obtain scout images of the humerus, radius, and ulna.
- Place CT cursors over the shoulder, elbow, and wrist joints, and obtain the measurements. The measurements are displayed on the cathode ray tube (Figs. 11-8 to 11-10).

The accuracy of the CT examination depends on proper placement of the cursor. Helms and McCarthy\(^1\) found that accuracy improved when the cursors were placed three times and the values obtained were averaged. These authors also reported that CT examinations used radiation doses that were 50 to 200 times less than those used with conventional radiography. CT examination requires about the same amount of time as conventional radiography.


Fig. 11-8 Measurement of the arms using computed tomography (CT). Note the arm labels and measurements in the right lower corner.

Fig. 11-9 Computed tomography measurements of femurs. The right femur is 1 cm shorter than the left femur in the same patient as in Fig. 11-8.

Fig. 11-10 Computed tomography measurement of the legs in same patient as in Figs. 11-8 and 11-9.
Knee pneumoarthrogram showing normal lateral meniscus (arrows) surrounded with air above and below it.
Overview
The introduction and development of magnetic resonance imaging (MRI) have significantly reduced the number of arthrograms performed in radiology departments. Because MRI is a noninvasive imaging technique, the knee, wrist, hip, shoulder, temporomandibular joint (TMJ), and other joints previously evaluated by contrast arthrography are now studied using MRI (Fig. 12-1). As a result, radiographic contrast arthrography has increasingly specialized functions.

Arthrography (Greek arthron, meaning "joint") is radiography of a joint or joints. Pneumoarthrography, opaque arthrography, and double-contrast arthrography are terms used to denote radiologic examinations of the soft tissue structures of joints (menisci, ligaments, articular cartilage, bursae) after the injection of one or two contrast agents into the capsular space.

Fig. 12-1 Noninvasive MRI of knee, showing torn medial meniscus (arrow).
A gaseous medium is employed in pneumoarthrography, a water-soluble iodinated medium is used in opaque arthrography (Fig. 12-2), and a combination of gaseous and water-soluble iodinated media is used in double-contrast arthrography. Although contrast studies may be made on any encapsulated joint, the knee has been the most frequent site of investigation. Other joints examined by contrast arthrography include the shoulder, hip, wrist, and temporomandibular joints.

Arthrogram examinations are usually performed with a local anesthetic. The injection is made under careful aseptic conditions, usually in a combination fluoroscopic-radiographic examining room that has been carefully prepared in advance. The sterile items required, particularly the length and gauge of the needles, vary according to the part being examined. The sterile tray and the nonsterile items should be set up on a conveniently placed instrument cart or a small two-shelf table.

After aspirating any effusion, the radiologist injects the contrast agent or agents and manipulates the joint to ensure proper distribution of the contrast material. The examination is usually performed by fluoroscopy and spot images. Conventional radiographs may be taken when special images, such as an axial projection of the shoulder or an intercondylar fossa position of the knee, are desired.
Contrast Arthrography of the Knee

VERTICAL RAY METHOD

Contrast arthrography of the knee by the vertical ray method requires the use of a stress device. The following steps are observed:

• Place the limb in the frame to widen or "open up" the side of the joint space under investigation. This widening, or spreading, of the intrastructural spaces permits better distribution of the contrast material around the meniscus.

• After the contrast material is injected, place the limb in the stress device (Fig. 12-3). To delineate the medial side of the joint, for example, place the stress device just above the knee; then laterally stress the lower leg.

• When contrast arthrograms are to be made by conventional radiography, turn the patient to the prone position, and fluoroscopically localize the centering point for each side of the joint. The mark ensures accurate centering for closely collimated studies of each side of the joint and permits multiple exposures to be made on one IR. The images obtained of each side of the joint usually consist of an AP projection and a 20-degree right and left AP oblique projection.

• Obtain the oblique position by leg rotation or central ray angulation (Figs. 12-4 to 12-6).

• On completion of these studies, remove the frame and then perform a lateral and an intercondylar fossa projection.

NOTE: Anderson and Maslin\(^1\) recommended that tomography be used in knee arthrography. In addition, the technique can frequently be used for other contrast-filled joint capsules.


Fig. 12-3 Patient lying on lead rubber for gonad shielding and positioned in stress device on fluoroscopic table.
Fig. 12-4 Vertical ray double-contrast knee arthrogram.

Fig. 12-5 Enlarged image of frame with star seen in Fig. 12-4.

Fig. 12-6 Knee pneumoarthrogram showing normal lateral meniscus (arrows) surrounded with air above and below it.
Double-Contrast Arthrography of the Knee

HORIZONTAL RAY METHOD

The horizontal central ray method of performing double-contrast arthrography of the knee was described first by Andreén and Wehlin and later by Freiberger, Killoran, and Cardona. These investigators found that using a horizontal x-ray beam position and a comparatively small amount of each of the two contrast agents (gaseous medium and water-soluble iodinated medium) improved double-contrast delineation of the knee joint structures. With this technique, the excess of the heavy iodinated solutions drains into the dependent part of the joint, leaving only the desired thin opaque coating on the gas-enveloped uppermost part, the part then under investigation.


Medial meniscus

- Adjust the patient in a semiprone position that places the posterior aspect of the medial meniscus uppermost (Figs. 12-7 and 12-8).
- To widen the joint space, manually stress the knee.
- Draw a line on the medial side of the knee, and then direct the central ray along the line and centered to the meniscus.
- With rotation toward the supine position, turn the leg 30 degrees for each of the succeeding five exposures.
- Direct the central ray along the localization line for each exposure, ensuring that it is centered to the meniscus.

Fig. 12-7 Medial meniscus with a tear in posterior half. Note irregular streaks of positive contrast material within meniscal wedge (arrows).
Lateral meniscus

- Adjust the patient in a semiprone position that places the posterior aspect of the lateral meniscus uppermost (Fig. 12-9).
- To widen the joint space, manually stress the knee.
- As with the medial meniscus, make six images on one IR.
- With movement toward the supine position, rotate the leg 30 degrees for each of the consecutive exposures, from the initial prone oblique position to the supine oblique position.
- Adjust the central ray angulation as required to direct it along the localization line and center it to the meniscus.

NOTE: For demonstration of the cruciate ligaments after filming of the menisci is completed, the patient sits with the knee flexed 90 degrees over the side of the radiographic table. A firm cotton pillow is placed under the knee and adjusted so that some forward pressure can be applied to the leg. With the patient holding a grid in position, a closely collimated and slightly overexposed lateral projection is made.


Fig. 12-8 Enlarged image showing tear in medial meniscus of the same patient as in Fig. 12-7.

Fig. 12-9 Normal lateral meniscus (arrows) in the same patient as in Figs. 12-7 and 12-8.
**Wrist Arthrography**

The primary indications for wrist arthrography are trauma, persistent pain, and limitation of motion. After contrast material (approximately 1.5 to 4 ml) is injected through the dorsal wrist at the articulation of the radius, scaphoid, and lunate, the wrist is gently manipulated to disperse the medium. The projections most commonly used are the PA, lateral, and both obliques (Figs. 12-10 and 12-11). Fluoroscopy or tape recording of the wrist during rotation is recommended for the exact detection of contrast medium leaks.

**Hip Arthrography**

Hip arthrography is performed most often in children to evaluate congenital hip dislocation before treatment (see Fig. 12-2) and after treatment (Figs. 12-12 and 12-13). In adults, the primary use of hip arthrography is to detect a loose hip prosthesis or confirm the presence of infection. The cement used to fasten hip prosthesis components has barium sulfate added to make the cement and the cement-bone interface radiographically visible (Fig. 12-14). Although the addition of barium sulfate to cement is helpful in confirming proper seating of the prosthesis, it makes evaluation of the same joint by arthrography difficult.

Because both the cement and contrast material produce the same approximate radiographic density, a subtraction technique is recommended—either photographic subtraction, as shown in Figs. 12-15 and 12-16 (see Chapter 26), or digital subtraction as shown in Figs. 12-17 and 12-18 (see Chapter 35). A common puncture site for hip arthrography is ½ inch (1.9 cm) distal to the inguinal crease and ½ inch (1.9 cm) lateral to the palpated femoral pulse. A spinal needle is useful for reaching the joint capsule.
Fig. 12-14 AP hip radiograph showing radiopaque cement (arrows) used to secure hip prosthesis.

Fig. 12-15 AP hip arthrogram showing hip prosthesis in proper position. Cement with radiopaque additive is difficult to distinguish from contrast medium used to perform arthrography (arrows).

Fig. 12-16 Normal photographic subtraction AP hip arthrogram in same patient as in Fig. 12-14. Contrast medium (black image) is readily distinguished from the hip prosthesis by the subtraction technique. Contrast medium does not extend inferiorty below the level of the injection needle (arrow). (See Chapter 26 for description of subtraction technique.)

Fig. 12-17 AP hip radiograph after injection of contrast medium.

Fig. 12-18 Digital subtraction hip arthrogram in the same patient as in Fig. 12-17. Contrast medium around the prosthesis in the proximal lateral femoral shaft (arrows) indicates a loose prosthesis. Lines on the medial and lateral aspect of the femur (arrowheads) are a subtraction registration artifact caused by slight patient movement during the injection of contrast medium. (See Chapter 35 for description of subtraction technique.)
Shoulder Arthrography

Arthrography of the shoulder is performed primarily for the evaluation of partial or complete tears in the rotator cuff or glenoid labrum, persistent pain or weakness, and frozen shoulder. A single-contrast technique (Fig. 12-19) or a double-contrast technique (Fig. 12-20) may be used.

The usual injection site is approximately ½ inch (1.3 cm) inferior and lateral to the coracoid process. Because the joint capsule is usually deep, use of a spinal needle is recommended.

For a single-contrast arthrogram (Fig. 12-21), approximately 10 to 12 ml of positive contrast medium is injected into the shoulder.

Fig. 12-19 Normal AP single-contrast shoulder arthrogram with contrast medium surrounding the biceps tendon sleeve and lying in the intertubercular (bicipital) groove (arrows). The axillary recess is filled but has a normal medial filling defect (arrowheads) created by the glenoid labrum.

Fig. 12-20 Normal AP double-contrast shoulder arthrogram.

Fig. 12-21 Single-contrast arthrogram showing rotator cuff tear (arrow).
For double-contrast examinations, approximately 3 to 4 ml of positive contrast medium and 10 to 12 ml of air are injected into the shoulder.

The projections most often used are the AP (both internal and external rotation), 30-degree AP oblique, axillary (Figs. 12-22 and 12-23), and tangential. (See Volume I, Chapter 5, a description of patient and part positioning.)

After double-contrast shoulder arthrography is performed, computed tomography (CT) may be used to examine some patients. CT images may be obtained at each approximate 5 mm through the shoulder joint. In shoulder arthrography, CT has been found to be very sensitive and reliable in diagnosis. Radiographs and CT scans of the same patient are presented in Figs. 12-20 and 12-24.
Temporomandibular Joint Arthrography

CT of the temporomandibular joint (TMJ) is often used instead of arthrography because CT is a noninvasive method of investigation. In many institutions, MRI has replaced CT, because MRI is also a noninvasive procedure with well-established diagnostic value (Fig. 12-25).

Contrast arthrography of the TMJ is useful in diagnosing abnormalities of the articular disk, the small, oval, fibrocartilaginous or fibrous tissue plate located between the condyle of the mandible and mandibular fossa. Abnormalities of this disk can be the result of trauma or a stretched or loose posterior ligament that allows the disk to be anteriorly displaced, causing pain.

Single-contrast opaque arthrography of the TMJ, although relatively uncomfortable for the patient, is easy to perform and requires 0.5 to 1 ml of contrast medium. The puncture site is approximately ½ inch (1.3 cm) anterior to the tragus of the ear. The following steps are observed:

• Before the arthrogram is performed, take preliminary tomographic images with the patient’s mouth in both the closed and open positions.
• After injection of the contrast medium, fluoroscopically observe the joint and take spot images to evaluate mandibular motion.

Fig. 12-25 Open-mouth lateral MRI of the TMJ, showing mandibular condyle (arrow), mandibular fossa of temporal bone (arrowheads), and articular disk (dots).
In general, obtain tomograms and/or radiographs (Figs. 12-26 and 12-27) with the patient's mouth in the closed, partially open, and fully open positions.

**Other Joints**

Essentially any joint can be evaluated by arthrography. However, the joints discussed in this chapter—the knee, shoulder, hip, wrist, and TMJ—are the ones most often investigated.

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**Fig. 12-26** Postinjection tomographic arthrogram of the TMJ taken with patient's mouth closed (**A**) and fully open (**B**). Positive contrast medium anterior to condyle (arrow) demonstrates anterior dislocation of the meniscus.

**Fig. 12-27** Postinjection radiographs on same patient as in Fig. 12-26. Dislocated meniscus is shown with the mouth half open (**A**) and completely open (**B**). Mandibular fossa (arrow) and condyle (arrowhead) are shown.