Breast imaging protocol and how to read a breast MRI

T. Stadnik (B) ULB

Breast imaging protocol and how to read a breast MRI:

- The power injector: recommended.
- Avoid table and patient movement before the injection.
- MRI scanner:
  - 1.5 T - good compromise
  - 3 T - higher SNR but inhomogeneity problems in the B1 field
- Breast coil: a dedicated prone-positioning bilateral breast coil is mandatory

How to perform breast MRI: technical consideration and post-processing:

- Choice of sequences (key points)
- Spatial and Temporal Resolution
- Imaging plane
- Fat suppression
- T1 or T2
- Post-processing
- Diffusion weighted imaging
- Molecular imaging

Before you start the imaging

- Follow the questionnaire / efficient PACS
- Optimal time in pre-menopausal women: between the 5th and 12th day after the start of the menstrual cycle
- Position the patient comfortably in order to avoid motion artifacts
- Mild compression: the breasts should be slightly compressed and compressed equally to the breast thickness. Ideally, the patient should be positioned so that her breasts are parallel to the imaging planes.

Before you start the imaging

- The nipples should be pointing down
- Both arms at the side of the body or above the patient's head

Coil specifications

Tremendous evolution from 4 channel coils

- 16-Channel (32) coils with biopsy capabilities
- Lateral, medial, cranial access
- Grid or PostiPillar

Choice of sequences

Key points about T2 in benign lesions

- T2 hyperintensity within the enhancing portion of the lesion is highly suggestive of benign histology.
- Myxoid fibroadenomas in young women typically demonstrate increased T2 signal intensity.
- Benign fibroadenomas typically show hypointense internal septa on T2 images.

Benign Fibroadenoma

T2SE

T1SE

STIR
**Choice of sequences**

Key points about T2 in malignant lesions:
- Most of the breast cancers (87%) show iso- or low signal on T2 images.
- Occasional malignant lesions show high intensity on T2.
- Colloid (mucinous) and inflammatory cancer may show also hyperintensity.
- In case of irregular or spiculated mass, T2 hyperintensity is not a reliable predictor of malignancy.

**Choice of sequences**

Key points about T1 in malignant lesions:
- Occasional malignant lesions show high intensity on T1.
- In case of irregular or spiculated mass, T1 hyperintensity is not a reliable predictor of malignancy.

**Choice of sequences**

Conclusions about T2:
- T2-weighted MR is not used in the detection of breast cancer.
- There is no evidence of added value of T2-weighted sequences in breast MRI.
- T2-weighted MR may be used as a secondary criterion to increase the probability of malignancy (fibroadenoma, fibro-cystic disease).

**Choice of sequences**

Conclusions about T1:
- T1-weighted MR is not used in the detection of breast cancer.
- T1-weighted GE is useful in the detection of fat (e.g., cancer fat necrosis) and metallic markers (surgery or biopsy planning, neoadjuvant chemotherapy).

**Choice of sequences**

Key points about T1-weighted, dynamic contrast enhanced acquisition:
- It's a key sequence in the diagnosis of breast cancer.
- Lack of enhancement has a high NPV for malignancy (88%-96%).
- Most tumors can be detected only after intravenous contrast injection.

**Choice of sequences**

Key points about T1-weighted, dynamic contrast enhanced acquisition:
- A dose of 0.1 mmol/kg is probably sufficient.
- Peak enhancement in the case of breast cancer occurs within the first 2 min after the injection of contrast medium.
- Therefore, relatively short data acquisition times, in the order of 60-120 s per volume acquisition, are necessary.
- A dynamic sequence demands at least three time points.

**Choice of sequences**

Key points about T1-weighted, dynamic contrast enhanced acquisition:
- Fatsat T1 FS GRE.
- Spatial and Temporal Resolution.
  - Evaluation of lesion morphology.
  - Spatial Resolution.
  - Evaluation of enhancement kinetics following contrast agent administration.
  - Temporal Resolution.
**Spatial and Temporal Resolution**

- The morphologic evaluation is dependent on spatial resolution.
- Smooth (NPV of 95%) versus irregular or spiculated margins (PPV of 84%-91%)

**Parameters of dynamic contrast enhanced acquisition**

- **TRUS**
  - (TD T2 Fat Sat sequence)
  - 90°, 10
  - 2.0K, 2K
  - FOV 20x16 cm
  - Matrix 320 x 256
  - TV 4.5/1.5 mm
  - TV 2.5/1.5 mm
  - TV 1.5/1.5 mm
  - 1 channel out
  - Acquisition time: 3 min 20 sec

**High Spatial Resolution**

- **Advantages**
  - High quality morphological evaluation
  - Multiphasic Reconstructions
  - Tomographic
  - Acquisition time

- **Reliable evaluation of Enhancement Kinetics needs high Temporal Resolution**

- 75% of curves that show a washout pattern are associated with cancer
- Cancer – fast and strong enhancement
- Breast – slow enhancement, generally moderate, may be strong
- The acquisition time > 120 sec is not advocated

**Temporal > Spatial resolution**

- 20 sec
- 140 sec

- **High Resolution isotropic THRIVE**

**Temporal or spatial resolution?**

- The both are important.

**Usual compromise**

- Acquisition time: 60 sec (120 sec?)
- Matrix 512* for axial/coronal plane
- Slice thickness 1 to 3 mm
- Repeated 5 to 6 times

**Is There a Benefit of Sophisticated Evaluation of Enhancement Curves for Clinical Routine?**

- Dynamic MR imaging: is there is a benefit of sophisticated Evaluation of Enhancement Curves for Clinical Routine?
- M. Delbaere, T. Janssens, T. Verellen, L. Bogaerts, J. Deke, P. Vanhoogstraten, S. Vandertop
- CROS 2017, p. 397-398

- The morphological evaluation of the lesion has to be performed on the early post-contrast images:
  - When the optimal contrast between lesion enhancement and matrix enhancement is available.

**2 dimensional or 3 dimensional GRE?**

- In 2D acquisition the slice selection relies on selective excitation while in 3D acquisition on additional phase gradient will be applied.
ERASMUS
COURSE ON MAGNETIC RESONANCE (EMRI)
BREAST AND FEMALE IMAGING

2017
May 31st - June 2nd

Aretaieion Hospital, School of Medicine, National and Kapodistrian University of Athens

Organizers:

- 2 dimensional or 3 dimensional GRE?
  - 2D GRE
    - SNR: +
    - Slice Thickness: 3 mm
    - Gap: 0.3
    - Phase Errors: +
  - 3D GRE
    - SNR: +++
    - Slice Thickness: 1 mm or less
    - Gap: 0
    - Phase Errors: +++

- 2 dimensional or 3 dimensional GRE?
  - We advocate 3D T1 Fat Sat sequence
    - (3D T1 Fat Sat sequence)
    - S1/V 1 mm
    - FOV 34x34 cm
    - Matrix: 340x340
    - TR 5.1 msec
    - TE 2.3 msec
    - 8 or 16 channel coil
    - Acquisition time: 2 min or less

Imaging plane?
- Both breasts must be investigated to allow mirror reading
- This is important in order to differentiate the physiological glandular contrast uptake from pathological enhancement

<table>
<thead>
<tr>
<th>Imaging plane</th>
<th>advantage</th>
<th>drawback</th>
</tr>
</thead>
<tbody>
<tr>
<td>sagittal</td>
<td>Spatial resolution, Homogenous fat (no coil, no fat)</td>
<td>Lateral compression, Compression RL</td>
</tr>
<tr>
<td>coronal</td>
<td>50% BFOV, motion artifacts +, chest wall inversion</td>
<td>No compression</td>
</tr>
<tr>
<td>axial</td>
<td>Compression, compression OK, Less sensitive to motion artifacts</td>
<td></td>
</tr>
</tbody>
</table>

Tips for breast imaging
- Fat Suppression
  - "passive" with subtraction or
  - "active" with fat saturation
  (by additional radiofrequency pulses)
- Motion artefacts
  - dedicated coil with immobilisation and gently compression device

FatSat or not?
- When subtraction is performed, fat suppression in the supine position is not needed and is often discouraged, because homogenous fat suppression is difficult to obtain.
- This can be problematic since fat and water resonance frequencies are relatively close at 1.31 Hz, which implies that with less-than-ideal B1 homogeneity across the field of view, water rather than fat suppression will occur. Moreover, fat suppression increases the noise in the image and usually also compromises spatial resolution.

FatSat or not?
- "With the arrival of parallel imaging, native sequences can be acquired with fat saturation. Undertaking native sequences with fat saturation paired with subtraction improves the detection of lesions and analysis of contrast uptake when the subtractions are degraded by movement."

FatSat or not?
- Native sequences should be acquired with fat saturation and paired with subtraction.

FatSat or not?
- Native sequences should be acquired with fat saturation and paired with subtraction.

Tips for breast imaging
- To avoid inhomogeneous fat suppression
  - Patient positioning
  - Avoid the folds in the breasts and close contact with the coil

Tips for breast imaging
- To avoid inhomogeneous fat suppression
  - Shimming
    - Adjust shim or a large volume shim box covering the two breasts provide the best results (generally)
3T or 1.5T breast MRI?

On 3T: increase of signal-to-noise ratio (SNR)

Disadvantages of high field: 3T requires high frequency RF pulse:
• B1 inhomogeneity

3T or 1.5T breast MRI?

In our expertise, 3T is superior to 1.5T if:
• dedicated 7 channel coil
•care to position the breast
• gently compression
•3D acquisition with fat suppression (Vibe, THRIVE).

3T or 1.5T breast MRI?

Post-processing:
• MPR (multiplanar reconstructions)
• Dynamic evaluation:
  - subtraction
  - TIC (time intensity curve)
  - (dynamic maps)

Diffusion weighted MRI

S.C. Partridge (AJR 2010; 194:1666-1673)

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• 3D acquisition with fat suppression (Vibe, THRIVE).

Diffusion weighted MRI

S.C. Partridge (AJR 2010; 194:1666-1673)

'Diffusion-weighted MRI shows promise in differentiation of benign and malignant masses'

W Bogner (Radiology 253, Febr 3-4, 2009)

'High accuracy for differentiation of benign and malignant breast tumors'

Biopsy: normal breast parenchyma!
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National and Kapodistrian University of Athens

Organizers:

Diffusion weighted MR:
Semiology: Fibroadenoma

Diffusion weighted MR:
Semiology: Carcinoma

Take home points:
- T1+Gd+FatSat - key sequence in the diagnosis of breast cancer
- Usual compromise between temporal and spatial resolution
- Acquisition time: 60 - 120 sec
- Matrix 512x1024 for axial/coronal plane
- Slice thickness 1 (to 2 mm)
- Repeated to 5 to 6 times (3 times)

Molecular Imaging

Using Single-Shot multi-echo multi-slice (SS-MSR) or T2*WI images of the breast, MRI allows for a rapid and non-invasive assessment of spatial and temporal changes in T2* values. The study has shown a high sensitivity and specificity in detecting benign and malignant lesions.

Take home points:
- What we need?
- 1.5 or 3T MRI system with dedicated multi-channel coil.
- 16 (16) channel system capabilities including SENSE imaging
- Diffusion-weighted MRI and molecular imaging show promise in differentiation of benign and malignant masses
Pre-treatment MRI

Julia Camps-Herrero
Hospital Universitario de la Ribera, Alzira. Spain

In this lecture, we will review the current evidence on pre-treatment MRI, one of the most debated indications for breast MRI. In doing so, the pros and cons of the pre-treatment MRI debate will be laid out. It is also crucial to review what to look for in this clinical setting, because there is a certain type of information that will allow the radiologist together with the surgeon, to plan the preoperative marking of complex lesions and to enhance and maintain a high number of breast conserving procedures. Management of additional lesions is of utmost importance in order to allow overtreatment and last, but not least, the pathologist should make aware of the presence of subtle and multifocal complex lesions that have to be correlated and properly located in the surgical specimen. We will also review our experience and results at Hospital de la Ribera in Alzira (Spain), where pre-treatment MRI is the norm since 2003.

Learning objectives:
1. To review the scientific evidence concerning pre-treatment MRI
2. To learn what type and kind information the surgeon and the oncologist expect from the radiologist in order to produce a perfect pre-treatment map
3. To know why radio-pathological correlation is important and how to perform it

References:

Update on BIRADS classification of breast MRI

E. Panourgias (GR)

Dynamic contrast enhanced MRI (DCE-MRI) of the breast has altered the management of patients with breast cancer. The American Cancer Society issued, in 2007, a new guideline recommending annual MRI screening for high risk women, as an adjunct to mammography.

The Breast Imaging-Reporting and Data System (BI-RADS) MRI lexicon was developed by the American College of Radiology (ACR) to be used as a tool that would minimize ambiguity regarding breast MRI reports. An updated edition for breast MRI was published in 2013 that included several additions with regards to breast MRI reporting that included fibroglandular tissue composition and breast parenchymal enhancement.

The standardized lexicon already used by the ACR BI-RADS for mammography was incorporated, to describe corresponding MRI features. The diagnosis of breast MRI involves the description of breast composition, morphological and enhancement kinetics criteria. For findings seen on MRI only, new terms were developed for the MRI lexicon. Terms like non-mass-like enhancement, enhancement patterns and description of contrast enhancement kinetics were unique to breast MRI lexicon. The terminologies for breast composition, including fatty, scattered fibroglandular tissue, heterogeneously dense fibroglandular tissue, and extremely dense fibroglandular tissue were also adopted.

ACR BI-RADS MRI lexicon includes two major categories of descriptors: morphology and enhancement kinetics. Morphologically, lesions can be separated into focus/foci, mass, and non-mass-like enhancements. A new definition for focus has been included in this recent updated edition that describes a breast lesion smaller than 5 mm. A mass is a 3-dimensional space-occupying lesion and is characterized by shape (round, oval, lobulated, irregular), margin (smooth, irregular, spiculated), and internal mass enhancement characteristics (homogeneous, heterogeneous, rim enhancement, dark internal septations, enhancing internal septations, and central enhancement). The term non-mass-like enhancement has been substituted for non-mass enhancement and is characterized by the distribution pattern (focal, linear, ductal, segmental, regional, multiple regions, and diffuse). The distribution pattern of non-mass enhancement can be further characterized by internal characteristics (homogeneous, heterogeneous, stippled/punctate, clumped, reticular/and/or irregular), and whether the enhancement is symmetric or asymmetric between both breasts. Other associated findings such as lymphadenopathy, and invasion of pectoralis muscle are reported as well.

Evaluation of enhancement kinetic curve is based on the temporal enhancement characteristics of the lesion over time. The initial enhancement phase refers to increase in signal intensity within the first 2 minutes after contrast injection, or when the curve starts to change. It is described as fast, medium, and slow, which is more qualitative than quantitative. The delayed enhancement phase refers to the signal intensity curve after 2 minutes after contrast starts to change, and it is described as persistent (continuously increasing enhancement), plateau (signal intensity remains constant after the initial peak), or wash-out (decrease in signal intensity). Implant assessment as well as non-enhancing findings have been added to the recent edition of the lexicon.
The updated edition published in 2013 includes several additions with regards to breast MRI reporting such as fibroglandular tissue composition and breast parenchymal enhancement. An estimation of the fibroglandular tissue (FGT), ranging from A (fatty) to D (dense) breast tissue is assessed on precontrast images. The intensity of background parenchymal enhancement (BPE) which is not directly related to the amount of FGT, is assessed on the first post-contrast series and ranges from minimal to marked enhancement.

Morphological Descriptors

Mass
A mass is a space-occupying lesion ≥ 5mm.

Shape and Margin
A "Round" mass is spherical, ball shaped or circular. An "Oval" mass is elliptical or egg-shaped. An "Irregular" mass is uneven in shape and cannot be characterized as either round or oval. Margin refers to the border of the mass lesion with surrounding breast tissues. "Smooth" margin is well-defined and sharply demarcated. "Irregular" margin is uneven, ill-defined or indistinct and can have round or jagged edges but is not smooth or spiculated. "Spiculated" margin is characterized by radiating lines extending from the margin of the mass.

Internal Enhancement Characteristics

This describes the enhancement pattern within the abnormally enhancing structure. "Homogenous enhancement" shows confluent uniform enhancement within the entire mass. "Heterogeneous enhancement" is non-uniform with symmetric or asymmetric Non-mass-like enhancement. Variable signal intensity. "Rim enhancement" shows more pronounced enhancement towards the periphery than the center. "Dark Internal Septations" are non-enhancing lines within a mass; while "Enhancing Internal Septations" are edge enhancement in both breasts; while asymmetric enhancement refers to enhancement that is more pronounced in the periphery within a mass. The "Central Enhancement pattern" shows more pronounced enhancement at the center breast compared to the other. Bilateral symmetric non-mass-like enhancement in any distribution is highly suggestive of malignancy. Margin assessment is considered as one of the most important features with high positive predictive value of benign changes in characterization of a breast mass. Masses with smooth margins strongly suggest benign disease. Poorly enhancing masses with non-enhancing septations are also benign features, predominantly representing fibroadenoma. A mass with moderate to marked heterogeneous enhancement of a mass with wash-out kinetics is highly suggestive of malignancy; however, not specific to certain cancer types.

Foci/Foci
A focus is a focal enhancement smaller than 5mm where definite morphologic descriptors cannot be applied, that stands out from background enhancement. The management of a focus lesion should depend on other findings in the same or a different feature in the enhancement kinetics curve are defined in two separate phases, and described as ‘slow’, ‘medium’, and the opposite breast (such as symmetry), corresponding findings from mammography or ultrasound, as well as the risk status of the patient

Non-Mass Enhancement
Non-mass enhancement has substituted the term non-mass like enhancement of the previous edition and defines an area of enhancement that varies in size and differs to background enhancement.
REPORTING SYSTEM
The clinical history of the patient, comparison to old studies, and findings on mammography and ultrasound if available should be included in the final report. Description of the MR method and technical parameters such as the use of a dedicated breast coil, pulse sequences, contrast dose and the type of post-processing technique used, needs to be mentioned. There should be succinct description of the morphological findings and kinetic enhancement characteristics. The lesion type, size, location, distribution, and associated findings need to be included. Finally, based on the morphological and kinetic features, overall assessment of the lesion should be given, including category 0 – need additional imaging evaluation; category 1 – negative findings; category 2 – benign findings; category 3 – probably benign finding – short-interval follow-up suggested; category 4 – suspicious abnormalities-biopsy should be performed; category 5 – highly suggestive of malignancy-appropriate action should be taken; and category 6 – known biopsy-proven malignancy-appropriate action should be taken. In cases of multiple lesions, the final assessment should be based on the most worrisome finding.

CONCLUSION
ACR BI-RADS MRI lexicon has clearly defined different morphological and kinetic features of breast lesions shown on MRI. A comprehensive analysis of both morphological and kinetic features based on the common terminology of this lexicon will result in unambiguous MRI reports and facilitate appropriate diagnostic conclusions and clinical management recommendations, and more effective communications between radiologists, clinicians, and patients.

References
### Ovarian transposition
- Ovarian protection before radiotherapy in premenopausal age
- Surgical transposition outside of radiation field
- Mostly:
  - paracolic space
  - above pelvic brim
  - anterior

### Patient preparation
- Fasting 4 hours
- Middle full bladder
- Menopausal status
- Prior surgery
- Sonographic findings
- Clinical information
  - Abnormal bleeding
  - Pain
  - Bloody results
  - Medication, past. Tamoxifen

### Basic pelvic protocol
- Fasting, antiperistaltic agents
- T2WI in 2 planes
  - 4mm
  - FOV 25-30cm
- T1 and ideally T1FS

### Applied anatomy
- Essentials in MRI imaging technique of the female pelvis
- Tailored protocols

### Complementary techniques
- Gd T1FS
- DWI
- FS T2WI
- 3D T2WI
- Double angulation
- Vaginal distension

### Diffusion weighted MRI (DWI)
- b value: 0, >800 mm²/s
- Malignant tumors: restricted diffusion
- Improved tumor depiction
- Adjusted for staging
- Ovarian mass characterization
- Recurrent disease
- Gd of Gadolinium

### Benign adnexal lesions with diffusion restriction in DWI
- Endometrioma
- Dermoids
- Tubo ovarian abscess

### Lymph nodes in DWI
- Benign and malignant lymph nodes: hypointense on DWI and low ADC
- Low lesion for BI-RADS characterization
- Combine morphological criteria (size, contrast vascular)
- PET-CT/MRI for LN evaluation
Double angulation in flexed uterus

3D T2 TSE
- Faster acquisition time
- Multiplanar reformats
- Image quality lower
- Similar acc. to 2D T2WI for endometriosis

Vaginal distension
- 40ml ultrasound gel
- Small cervical cancer before trachelectomy
- Invasion of fornix
- Vaginal pathology
- Endometriosis

Adnexal mass
- Failing, antiperistaltic spots
- Sag T2
- Axial/oblique coronal T2 and T1
- 4mm
- T1FS, DWI
- Gd T1, dynamic CE MRI

Staging of uterine cervical cancer with MRI: guidelines of the European Society of Gynaecological Radiology

- Faster, multiparametric agents
- Sequences
  - T2WI in 2 planes
  - T1 axial
  - DWI
- Slice thickness: 4mm
- Include mesorectum for lymph nodes
- Optimal:
  - Vaginal distension
  - Gadolinium

Staging of endometrial cancer with MRI: Guidelines of the European Society of Gynaecological Radiology

- 3 planes T2WI
- Ax T1 and T1FS
- Deep endometriosis
- Ax Gd
- Rectal and vaginal contrast
- Not during menstruation

Protocol endometriosis/pelvic pain
Chronic Pelvic pain
R. Forstner, (AT)

Learning objectives
- To learn about prevalence and mechanism of chronic pelvic pain (CPP)
- To become familiar with gynecological and non-gynecological causes of CPP
- To learn typical imaging findings with emphasis on gynecological causes

CHRONIC PELVIC PAIN

- At least 6 months duration
- Severe enough to impact daily function and quality of life
- Requires medical or surgical treatment
- Comprises gynecologic and non-gynecologic causes
- Primarily non-malignant

CPP: impact on health care issues
- 2-4% of women in reproductive age
- 10% of visits to gynecology
- 40% of diagnostic laparoscopies
- 20% of hysterectomies
- Estimated cost in USA: 880 million USD

Etiologies
- 33% Endometriosis
- 58% Adhesions
- 9% Other causes

Gynaecological etiologies 58%
- Endometriosis 33%
- PID/Adhesions 23%
- Adenomyosis 13%
- Fibroids 9%
- Pelvic congestion syndrome

Imaging findings and clinical characteristics

Endometriosis
- Functional endometrial tissue outside uterus
- Pain, often 6-12 hours after menstruation
- Pelvic adhesions, peritoneal implants

T2 Spot Sign
- Hemorrhagic ovarian cysts
- Deep endometriosis
- Hyperplastic fibrotic muscular tissue
- Small hemorrhagic cysts
**Endometriosis of Ovary**

- Deep endometriosis of the posterior fornix, tons illi and rectum
- If isolated, often only mild pain

**Deep Endometriosis Involving the Bowel**

- More often associated with non-cyclical pain

**Endometriosis-Related Pain Mechanisms**

- Active peritoneal inflammation and proangiogenic cytokines
- Microbleeds with induction of autonomic innervation (nerve growth factor NGF)
- Nervous involvement
- Endometriosis related adhesions

**Character and Site of Chronic Pelvic Pain**

- Dysmenorrhea
  - Ectopic pouch of Douglas, adhesions, uterosacral ligaments
- Dyspareunia
  - Vagina, cul-de-sac, uterosacral ligaments
- Pelvic defacement
  - Reduced rectovaginal septum
- Cyclical independent pain
  - Intestines, adhesions

**Vagina and Posterior Fornix**

**Endometriosis of Uterosacral Ligaments**

**Surgical Strategy in Bowel Endometriosis**

**Adhesions**

- 25% of patients with CPP
- Associated with
  - Endometriosis
  - Chronic pelvic pain
  - Infertility
  - Bowel and bladder disease
  - Multifocal
  - Tuberculosis
Chronic pelvic inflammatory disease and related adhesions
- 35% develop chronic pelvic pain
- Untreated pelvic infections
- Sexually transmitted infections, pelvic adhesions
- Recurrence, pseudocysts

Ovarian pseudocyst
- Premenopausal age
- Fluid accumulation around ovary
- Ovary within the cyst wall
- Not round, but irregular contour, predized by anatomy

DD leiomyomas, adenomyosis
- Painful period lesion
- Clinical—pelvic along adenomyosis
- Little tumor effect relative to size
- Frequently loss of T. 9th
- Breast adenomyosis: 20-

Gynaecological etiologies 58%
- Endometriosis 33%
- PID/Adhesions 23%
- Adenomyosis
- Pelvic pain

Pain in leiomyomas
- Common gyn in tumor in 20-40% of females in reproductive age
- Pain: 4th decade

Symptoms
- Dysmenorrhea
- AUS
- Pelvic pain

Pain in leiomyomas and adenomyosis
- Uterine enlargement
- Similar symptoms
- Dysmenorrhea
- Abdominal bleeding
- Chronic pelvic pain similar to adenomyosis
- MRI superior to US*
- Adenomyosis, US-MRI: Adenomyosis,
- Adenomyosis, TVS-US: Adenomyosis

Deep infiltrating endometriosis
- Under debate if adenomyosis alone
- Retroposition, if fixed, e.g. in endometritis

Malposition of the uterus
- Multifocal
- Pain, hypomenorrhea during standing
- Other findings: dyspareuna, cosmetically apparent
- Incompetent & dilated (> 7mm)
- Morbid myomas
- 4% of symptomatic patients

Pelvic congestion syndrome
- Pain & heavy bleeding
- Sinusoidal syndrome
Irritable bladder syndrome/interstitial cystitis
- Chronic inflammatory condition in young/perimenopausal age
- Chronic pelvic pain
- Urinary bladder symptoms
- Associated with several painful conditions, part. endometriosis
- More severe chronic pelvic pain

Etiologies
- 33% no pathology
- 58% Endometriosis
- 9% Adhesions
- 6% Chronic PID
- Other gyn.
- Urinary tract
- Gastrointestinal
- Neurovascular
- Mental health/psychosocial

Diagnostic approach for ovarian lesions
L.A. Moulopoulos (GR)

Non gynaecologic causes of CPP
- Urkologie/gastroenterische
- Neurovascular
- Endometriosis
- Pelvic floor paresthesia
- Pudendal neuropathy
- Fibromyalgia
- Vulvodynia
- Urinary incontinence
- Celiac disease
- Rule out structural abnormalities (tumors, inflammation)

Take home messages
- Chronic pelvic pain is a common and significant disorder
- Role of imaging: rule out structural abnormalities
- Most common are gynaecologic related pain disorders
- Endometriosis and adhesions as leading etiologies
- Cross talk sensitization and association of irritable bladder syndrome and pelvic muscular abnormalities contribute to chronic pain syndromes

Diagnostic Approach for Adnexal Masses
Lisa A. Moulopoulos, M.D.
Professor of Radiology
National and Kapodistrian University of Athens

Simple US Rules for Characterizing an Adnexal Mass

<table>
<thead>
<tr>
<th>M-features</th>
<th>B-features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Irregular edge of mass</td>
<td>1. Solid mass</td>
</tr>
<tr>
<td>2. Mixed echotexture</td>
<td>2. Less solid component</td>
</tr>
<tr>
<td>3. Cystic lesion</td>
<td>3. Fluid-debris level</td>
</tr>
<tr>
<td>4. Increased vascular flow</td>
<td>4. Smooth and locular tumor</td>
</tr>
</tbody>
</table>
| 5. 
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What Is an Adnexal Mass?
- Any mass involving the ovaries, fallopian tubes or surrounding connective tissue
- Use US to characterize

When is MRI Needed?
- Perform MRI for 5-25% of masses which are indeterminate on US
- Most of these will be fat-poor teratomas, hemorrhagic cysts, leiomyomas, fibrothecomas and very large cystic lesions

First Step: Identify the Ovary
- Look for follicles
- Follow the gonadal vein to locate the ovary
An ovarian mass displaces fascial vessels, ureter, uterus and sigmoid laterally or posteriorly.

An extraperitoneal mass displaces fascial vessels, medially.

If the mass is inseparable from the ovary, look for:

- The embedded organ sign: when part of the ovary is encased by a lesion, it is likely that the lesion originates from the ovary.
- The break sign: when normal ovarian tissue is partly wrapped around a lesion forming a break, the lesion arises from the ovary.

Non-Gynecologic Mimics of Ovarian Pathology

- GIST
- Appendiceal neoplasms
- Perineural cysts (Tadpole cysts)
- Neurogenic tumors

Ovarian Tumor Classification

1. Surface epithelial stromal tumors (10%)
2. Germ cell tumors (15%)
3. Sex cord-stromal tumors (10%)
4. Metastatic tumors (5%)

Ovarian Tumor Classification

- Granulosa cell
- Thecoma Fibroma
- Sertoli-Leydig
- Stromal
- GIST
- Adenocarcinoma
- Chloroma
- Embryonal cell carcinoma

Remember: an intact ovary virtually excludes ovarian origin for a pelvic mass.
MRI Protocol for Adnexal Masses

- T2-weighted images (at least two planes)
- T1-weighted images
- T2-weighted FLAIR images with chemical suppression
- Diffusion-weighted images (DWI)
- Dynamic contrast-enhanced images (DCE)
- Patent preparation with smooth muscle relaxant

DCE-MRI

- Select plane to include both adnexal and ovaries.
- Compare TIC of solid adnexal component to myometrium.

DCE-MRI TICs

- Normal: smooth, symmetric.
- Pathological: irregular, asymmetric.

How to Approach an Adnexal Lesion?

- Is it cystic?
- Is it T1 bright?
- Is it solid?
- Is it complex cystic or cystic-solid?

Physiologic Ovarian Cysts

- Cystic lesions up to 5cm are considered physiologic cysts in premenopausal women and may not be reported.

Postmenopausal Ovaries

- In postmenopausal women, cysts >5cm should be reported.
- Even in postmenopausal women, the incidence of cancer in a unilocular cyst is very low.

Corpus Luteum Cyst

- Thick, enhancing wall — may have hemorrhagic content.

Physiologic Ovarian Cyst

- Should repeat at follow-up after 3 months.

Postmenopausal Cysts

- Takes shape of space — surrounds every tube.

Hydrosalpinx

- Tubular structure with incomplete aspiration.

Organizers:
Areteaien Hospital, School of Medicine, National and Kapodistrian University of Athens

2017 May 31st - June 2nd
Breast and Female Imaging
Serous Ovarian Cystadenoma
- Clear fluid
- Thin wall, few or no septa (< 3 mm)
- Papillary projections rare (small, low T2, non-enhancing)
- Enhancing papillary projections should raise suspicion of a borderline tumor.

Serous Ovarian Cystadenoma
- Permits at 3-month follow-up

Mucinous Ovarian Cystadenoma

Mucinous Ovarian Cystadenoma
- Stained glass appearance, thin septa, minimal enhancement

Serous Ovarian Cystadenoma

Mucinous Ovarian Cystadenoma
- Less common
- Multilocular, with content of varying signal intensity
- Larger size

Mature Cystic Teratoma
- Derived from at least two germ-cell layers
- Sebum-filled cyst
- Risk of ovarian torsion
- 2% cancer risk

Benign Adnexal Masses with Restricted Diffusion
- Teratoma
- Endometriomas
- Tuboovarian abscess

Mature Cystic Teratoma

2. T1 'Bright' Adnexal Mass
- Mature cystic teratoma
- Hemorrhagic cyst
- Endometrioma
- Perform T1FS sequence to identify macroscopic fat

There should be no enhancing solid tissue invading the wall of a mature cystic teratoma.
Hemorrhagic Cyst versus Endometrioma

- Hemorrhagic Cyst: Less bright on T1, Thinner wall, No T2 shading, No enhancement, Single, Regresses within 2m.
- Endometrioma: Very bright on T1, Thicker wall, T2 shading, Ring sign, C+, No enhancement, Multiple, Persistent > 2m.

Hemorrhagic Cyst

- Hypo-intense to skeletal muscle on T1.
- Remains bright on T1FS images.
- Subacute hemorrhage: methemoglobin (3 days to 3 months).
- Intracellular: high T1, low T2.
- Extracellular: high T1, high T2.
- Pseudocyst: follow yearly if ≤ 5cm.
- Late postcontrast: remove any cyst with hemorrhage.

Hemorrhagic Cyst with Clots

- Hemorrhagic cysts have both coagulated and hematomas, highly specific for endometriosis.
- T2 shading: loss of signal on T2 images due to high viscosity of repeated cystic bleeding.
- 2.5% risk of cancer (endometrioid, clear cell) – look for solid tumor with enhancement.

Endometrioma - T2 Shading

- MRI Approach for a T1 "Bright" Mass
  - Use fat suppression to distinguish blood from fat.
  - If there is suggestion of a solid component, get contrast-enhanced images – otherwise, STOP.
  - If there is substantial enhancement, consider malignancy.

Endometrioma - Dark Spot Sign

3. T2 Solid Mass

- Fibrothecoma, Brenner tumor, leiomyoma, ovarian metastases.
- Low signal on T2 and high A value (SNB), indicates a benign mass.
Fibrothecomas
- Sex cord - stromal tumors
- 3-6% of ovarian tumors
- Theomas may produce estrogen
- Low to very low T2 (cystic degeneration)
- Ectomes do not metastasize, theomas may restrict
- Type 1 TIC on DCE-MRI

Bilateral Theomas
- Low signal on T2 and \( T_{1000} \) DWI

Metastases to the Ovaries
- Stomach, breast, colon, appendix
- More often bilateral
- Variable signal intensity on T2
- Enhancement

Gastric Cancer Metastases to the Ovary
- Bilateral lesions, T2 heterogeneity, and enhancement

Thecoma
- Low signal on T2 and \( T_{1000} \) DWI

Thecoma
- Metastasis resembles mucinous colonic primary

Colon Cancer Metastasis to the Ovary
- Low T2
  - Perform DWI
    - Low signal on \( T_{1000} \) - probably benign
    - High signal on \( T_{1000} \) - DCE-MRI - II TIC Type 1: probably benign
  - High / Intermediate T2
    - Perform DCE-MRI + TIC Type 1: probably benign

T2 Solid Mass
- Borderline ovarian tumor
- Cystadenofibroma
- POD
- Epithelial cancer
- Epithelial tumors without stromal invasion
- Serous or mucinous, most common
- Affect younger women
- May treat with fertility-sparing laparoscopic surgery

Leiomyoma
- Low T2, low signal on \( T_{1000} \) DWI

Leiomyoma
- Image similar to myxoma
Borderline Mucinous Cystadenoma

- Thick, enhancing wall and septa, large tumor

Borderline Serous Cystadenoma

- Cyst with multiple enhancing papillary projections and wall thickening

Borderline Serous Cystadenoma

- Hyperintense mass with branching low signal intensity stroma

Borderline Serous Cystadenoma

- Cyst with mural nodule and solid component

Cystadenofibroma

- Uncommon epithelial tumor
- Cystic tumor with low T2 fibrous component

Cystadenofibroma

- Cystic mass with solid component

Epithelial Ovarian Cancer

- High grade serous epithelial cancer, most common ovarian malignancy
- Cystic and solid mass
- Restricted diffusion of solid component
- DCE-MRI: TIC Type 3

Epithelial Ovarian Cancer

- Cystic and solid mass

Epithelial Ovarian Cancer

- Cystic mass

Epithelial Ovarian Cancer

- Solid mass

Adnexal MR Scoring System

<table>
<thead>
<tr>
<th>Score 1</th>
<th>Score 2</th>
<th>Score 3</th>
<th>Score 4</th>
<th>Score 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/1/2</td>
<td>3/4/5</td>
<td>5/6/7</td>
<td>7/8/9</td>
<td>9/10/11</td>
</tr>
</tbody>
</table>

Take Home Message

- Uterine versus Ovarian Origin
- Obtain ovarian vs MR- (if needed get images perpendicular to the area of contact)
- Look for ovarian vascular pedicle or bridging vessels with uterus
- Look for blood signs, embedded organ sign
**Take Home Message**

**Ovarian Mass Characterization**

- Identify the presence of fat or blood
- Look for solid component
- If present, study signal on T2 and DWI b=1500 and TIC type

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**Take Home Message**

- Do not proceed without use of smooth muscle relaxant or with a full bladder
- Is very important to obtain high quality T2-weighted images in several planes - so start with those!
**ERASMUS**

**COURSE ON MAGNETIC RESONANCE (EMRI)**

**BREAST AND FEMALE IMAGING**

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**Staging of ovarian cancer**

**Revised FIGO staging system**

- Subtypes of ovarian cancer
- Guidelines for imaging
- Role of imaging in treatment planning

---

**Table 2. Stage at Diagnosis and 5-Year Survival**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Patients Diagnosed (%)</th>
<th>5-Year Survival (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local disease</td>
<td>15.0</td>
<td>91.3</td>
</tr>
<tr>
<td>Regional spread</td>
<td>17.0</td>
<td>71.9</td>
</tr>
<tr>
<td>Metastatic disease</td>
<td>61.0</td>
<td>26.9</td>
</tr>
<tr>
<td>Unknown stage</td>
<td>7.0</td>
<td>22.0</td>
</tr>
</tbody>
</table>

---

**Ovarian cancer: nodal metastases neue Folie**

- Revised FIGO staging system
- Subtypes of ovarian cancer
- Guidelines for imaging
- Role of imaging in treatment planning

---

**Stage III new:**

- Exclusive retroperitoneal lymph node metastasis stage IIIC and no longer stage IIC

- Prognosis with stage III due to lymph node only is more favorable than other types of IIIIC significantly longer DFS and OS

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**Clinicopathological characteristics of diff. subtypes of ovarian cancer**

<table>
<thead>
<tr>
<th>%</th>
<th>Serous</th>
<th>Mucinous</th>
<th>Endometroid</th>
<th>Typical/Borderline</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-70</td>
<td>S-10</td>
<td>5</td>
<td>10-30</td>
<td>5-10</td>
</tr>
</tbody>
</table>

**Preoperative Elevation**

- STIC theory: high grade serous tubal intraepithelial cancer is precurser
- High grade serous cancer of ovary
- Primary peritoneal cancer
- Fallopian tube cancer
- Staging criteria for these cancers have been unified

---

**Stage IVb**

- Ovarian cancer: nodal metastases neue Folie

---

**Stage IVc**

- Ovarian cancer

- No single entity disease, but diverse group of malignancies
- Different cancer subtypes at microscopic and molecular level identified
- Immunohistochemistry
- Genetic analysis
- 5 subtypes with different biological behaviour
- Different response to therapy and prognosis

---

**Pathological subtypes: high grade serous ov. cancer**

- 80%
- **Tumor:**
  - Pseudocyst solid (pseudomucinous cystadenocarcinoma)
  - May also be only solid
  - Bilateral (60%)
- **Spread:**
  - Diffuse peritoneal
  - Large amount of ascites
  - Bowel and mesentry

---

**Typically bilateral**
**Pathological subtypes:**
- 5-10%: Endometrioid, clear cell, mucinous
- 3%: Mucinous, high-grade serous, Brenner, endometrioid, clear cell
- Spread: Low-stage abdominal, high-grade serous, clear cell, endometrioid
- Venous involvement

**Ovarian cancer:**
- New insights
- Revised staging system
- Guidelines for imaging
- Role of imaging in treatment planning

**Preoperative staging of ovarian cancer:**
- CT is modality of choice
- MRI and PET-CT: second line modalities
  - MRI research tool for assessment of prognosis and response

**Magnetic Resonance Imaging (MRI) Technique:**
- Pelvis: high resolution imaging
- Abdomen: T2 FS and T1W FS iv contrast ( axial, coronal)
- Exudative ascites: Gd T1 5 min
- DWI, b value 0, 500, 800 or higher

**Indications for staging ovarian cancer with PET/CT:**
- Contraindications to contrast-enhanced CT
- Advanced stage and suspected extra-abdominal metastases
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New insights
- Revised staging system
- Guidelines for imaging
- Role of imaging in treatment planning

Treatment of ovarian cancer
- Two options
  - Uterine resection
  - Neoadjuvant chemotherapy (III-IV)
- Patient comorbidities
- Wide range of practice
- 14-45% of surgeries suboptimal

Changing Concepts
- Role of imaging is adjunct for treatment selection and treatment planning rather than just staging
- Guidance of surgery for mapping distribution and load of disease
- Identification of difficult to resect disease
- Exclusion of metastatic disease mimicking ovarian cancer spread - image guided biopsy

Ovarian cancer spread
- Local extension
- Intraperitoneal implantation
- Lymphatic invasion
- Transdiaphragmatic passage
- Hematogenous dissemination

Dissemination by peritoneal spread
- 70% at diagnosis
- Typical implants in HIV: serious of cancer
- Diffusion of malignant cells from tumor surface
- Peritoneal fluid circulation (to be fluid present in subphrenic space and bowel mesentery in immunocompromised patients)
- Distribution modulated by anatomic attachments

Common areas of implants: gravity/stasis
- Rectovaginal pouch
- Left lower quadrant
- Sigmoid colon
- Right paracolic gutter
- Redundant pouch
- Cecal fossa

MDC

Most common areas of implants: peritoneal fluid resorption
- Greater omentum
- Subdiaphragmatic space

Subtle findings of peritoneal carcinomatosis
- Linear thickening of peritoneum
- Thickening of ligaments
- Micromasses
- Alopecias
  - Upper abdominal
  - Omental bursa

Pleural effusion
- Histological/histological proof (e.g. IA)
- Pleural meta effusion, thickening, nodes
- Should be quantified (small, moderate, large)
- Moderate to large pleural effusion in preoperative CT: independent adverse prognostic factor
- VATS, intrapleural chemo

CT findings of non-optimal resectability - ESUR: Difficult to resect
- Polyp almost always resectable
- Large bulky disease in upper abdomen
- Lesions >2cm interm. fissure, sparcocytic ligament, porta hepatitis
- Invasive peritoneal/peritoneal metastases
- Lymph nodes above renal junction
- Mesentery, extensive small bowel involvement
- Discussed in multidisciplinary setting
- Criteria might differ from center to center

Liver metastases in ovarian cancer
- Peritoneal
- Peritoneal with liver invasion
- Liver parenchymal (<1%)

Location influences resectability

Discussed in multidisciplinary setting
- Criteria might differ from center to center

Liver resection
- Resected
- Non-resected

MDC
Reyes MA et al. Radiology. 2007
Zierhut M et al. J Gastrointest Surg. 2004


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Predicting optimal debulking
(Susan R et al. Gynecol Oncol 2014)

- Age <65 yrs
- CA125 elevated
- AUS/AT
- Biphasic/epithelial/gyneco
- Less s/p
- Small bowel resection >=20 cm
- Resect OA
- Diffuse small bowel adhesions
- Splenic hilar metastatic

Summary
- Multidisciplinary approach allows individualized treatment regimen
- CT is imaging modality of choice for staging
- MRI or PET/CT is recommended for CI for CT
- Imaging as roadmap for targeted surgery and tool for predicting "difficult to resect" disease

Pathological subtypes: low grade serious ovarian cancer
- <5%
  - Tumor
  - BL tumor and cystic and solid tumors
  - Baker
  - Slow growth
  - Spread
  - Diffuse abdominal
  - Nodular deposits, may have calcifications

Pathological subtypes: endometrioid ovarian cancer
- 15-20%
  - Adenoc. w. endometriosis
  - Tumor
  - A and C and cystic
  - Arising in endometriotic cyst
  - Spread
  - Other early stage
  - Concomitant endometrial cancer/hyperplasia

Endometrial and cervical cancer
Charis Bourgiotis, MD
School of Medicine, National and Kapodistrian University of Athens, Aretaeion Hospital, Athens, Greece

Endometrial cancer is the most common malignancy of the female pelvis and largely affects postmenopausal population. Overall 5-year survival is high, as most of the patients are diagnosed at an early stage. Important prognostic factors include tumor histology, the stage of the disease at the time of presentation and nodal status. The standard care for patients with endometrial cancer is surgery; however, classification of the endometrial cancer patients into risk categories is important in order to better select those patients at high risk who would benefit from extensive surgery (including lymphadenectomy) and avoid overtreatment of low risk patients. Endometrial cancer staging is based on International Federation of Gynecology and Obstetrics guidelines (FIGO) and it is surgicopathological (revised FIGO classification, 2009). Although not officially addressed to the FIGO staging system, MRI is recommended as the most suitable imaging modality for treatment planning, when available. Indications of MRI for the preoperative assessment of patients with endometrial cancer may differ among the different centers and include the evaluation of patients with apparent stage I (when deep myometrial involvement is suspected and lymphadenectomy is considered as an option), suspected cervical involvement, grade III endometrioid / non-endometrioid tumors and patients in whom conservative treatment is considered (fertility sparing/high perioperative risk). Dedicated MRI protocols including double angulation technique and the use of functional MRI images such as Diffusion Weighted Imaging should be applied to optimize imaging results. MRI may reliably evaluate tumor predictors such as depth of myometrial invasion, cervical involvement, extruterine tumor spread, metastatic disease and lymph node status; also, additional prognostic factors such as tumor size may be accurately estimated, while MRI seems to be helpful for the prediction of more aggressive tumor histologies like carcinosarcoma.

Uterine cervical cancer still remains an important socioeconomic issue because it largely affects women of reproductive age. Prognosis is highly associated to the extent of the disease at diagnosis and, therefore, accurate staging is crucial for optimal management. Cervical cancer is currently staged according to International Federation of Gynecology and Obstetrics guidelines (FIGO); cross sectional imaging modalities are not officially incorporated to the revised FIGO classification system (2009), however, its use is recommended, when available. Dedicated MRI is the preferred imaging method for local cervical cancer evaluation due to its excellent soft tissue resolution; MRI may reliably assess important tumor prognostic factors like size, parametral invasion, endocervical extension, pelvic side wall or adjacent/distal organs involvement, and lymph node status and therefore may provide important information for the discrimination between operable and advanced cervical cancer. Also, MRI may be useful in clinical challenging cases like the selection of suitable candidates for less radical surgical options like radical trachelectomy for fertility sparing and may accurately predict tumor origin (endometrioid vs. endocervical), in case of large uterine tumors of indeterminate histology. The aim of the present lecture is to familiarize radiologists with the available MR imaging protocols as well as with the corresponding MRI features of endometrial and cervical carcinoma and to discuss MRI indications during the course of both pathological processes.