Subtleties of Lisfranc Fracture-Dislocations

Tarsometatarsal (Lisfranc) fracture-dislocations can be very difficult to recognize radiographically. The evaluation of the Lisfranc joint can be simplified by meticulously studying the alignment of the metatarsal bases with their corresponding tarsal bones. The usefulness of this observation has been confirmed by: anatomic descriptions, biomechanical analysis, and clinical foot radiographs. Subtle abnormalities identified at the Lisfranc joint using this observation included: metatarsal subluxations identified only on a single projection, associated tarsal subluxations and dislocations, irreducible metatarsal subluxations after closed manipulation, and recurrent metatarsal subluxations after reduction.

The Lisfranc joint constitutes all five tarsometatarsal joints collectively and represents the articulation between the midfoot and forefoot [1]. Fractures, dislocations, and subluxations at these joints can be difficult to diagnose because of overlapping bones and unfamiliarity with normal anatomy. The mechanisms of injury have been well described [2-5], and the treatment has advanced so that a stable, functional foot can be preserved [6-10]. Adequate treatment can be instituted only after identification of the abnormalities.

Identification of the abnormalities at the Lisfranc joint is based on understanding the normal anatomy. Fortunately, the evaluation of the Lisfranc joint can be simplified by observing the alignment of the metatarsal bones with their corresponding tarsal bones. The medial and/or lateral margins of the metatarsals align with the margins of their corresponding tarsal bones (fig. 1). This alignment is a consistent finding for the ligaments anchor the metatarsal to the tarsal bones, and the bones interdigitate forming the Lisfranc joint (figs. 1 and 2) [11]. We could locate only a single reference to this important observation in the English radiologic literature [12].

Three sets of ligaments—dorsal, plantar, and interosseous—strengthen and limit the motion of the tarsometatarsal joints [4, 11]. The ligaments on the dorsum and plantar aspect of the foot secure the metatarsal bases to their corresponding tarsal bones. The interosseous ligaments bind the metatarsal and tarsal bones to the adjacent bones and help maintain the transverse arch at the Lisfranc joint (figs. 1 and 2). A strong oblique interosseous ligament, the Lisfranc ligament, tethers the base of the second metatarsal to the medial cuneiform (fig. 1) [4, 9]. In addition to ligaments, the wedged shape of the bones at the Lisfranc joint maintain the alignment of the bones by forming an exquisite Roman arch (fig. 2) [11].

The Lisfranc joint includes three synovial cavities (fig. 1) [11]. Very limited flexion and extension and slight adduction and abduction occur at the joints, particularly the fourth and fifth tarsometatarsal joints. The side to side motion is greatest at the fifth [11, 13, 14]. Slight, normal offsets can be identified because of the gliding action at the Lisfranc joint, and these offsets must be differentiated from significant subluxations and dislocations [12].
If closely analyzed, routine non-weight-bearing dorsoplantar, oblique, and lateral views of the foot will usually provide adequate visualization of the Lisfranc joint. When there is difficulty profiling the tarsometatarsal joints, slight beam angulation toward the calcaneus with the foot in the dorsoplantar position or obtaining a plantar-dorsal view the foot may suffice. Tomograms are not usually required.

Materials and Methods
During a 6 year period, 21 patients with acute Lisfranc fracture-dislocation were diagnosed. Nine of them had subtle abnormalities. This group of patients included seven men and two women 19–59 years old (mean age, 45 years). Five patients had direct trauma from crushing injuries, while four had direct trauma from falls.

To evaluate the normal radiographic anatomy of the Lisfranc joint, the routine non-weight-bearing (dorsoplantar, oblique, and lateral) films were reviewed of 100 consecutive patients seen in the emergency room for foot trauma. Clinically, these patients did not have injuries to the tarsometatarsal joints. Alignment of the metatarsal bones with their corresponding tarsal bones was evaluated and considered adequate when their medial and/or lateral margins on the dorsoplantar and oblique views and parallel joint surfaces on the lateral view were clearly identified. Inadequate visualization occurred due to overlapping bones and underpenetration. The dorsoplantar, oblique, and lateral non-weight-bearing films were further evaluated for normal offset of metatarsal bones at the tarsometatarsal joints.

Results
Nine patients had subtle abnormalities at the Lisfranc joint with three having two or more abnormalities. Four patients had subtle subluxations seen only on the dorsoplantar view, with the oblique and lateral views failing to identify the subluxations (fig. 3). Two of these patients were treated with closed reduction and two with open reduction. Three patients had associated tarsal subluxations and dislocations besides injuries to the Lisfranc joint; two of these had calcaneal-cuboid dislocations (fig. 4) and the third had a second cuneiform subluxed from the navicular bone (fig. 5). The tarsal dislocations were all treated with closed reduction. Four patients had irreducible metatarsal subluxations after closed manipulation (fig. 6). All four patients required open reduction and internal fixation. One patient had an unstable closed reduction that progressed to subluxation and degenerative changes at the first and second tarsometatarsal joints (fig. 7). Arthrodesis was recommended for this patient.

Discussion
Evaluation of the Lisfranc joint may present a problem because of the overlap of bones and articulating surfaces. We used the alignment of the metatarsal bases with their corresponding tarsal bones to simplify this evaluation. The validity of this observation has been verified by biomechanical analysis and clinical foot radiographs. Using this observation, subtle abnormalities can be identified at the Lisfranc joint.

Tarsometatarsal Alignment
Biomechanical analysis. Biomechanical analysis has shown the importance of the alignment of metatarsals with
the corresponding tarsal bones. The alignment and shape of the bones allow transmission of compression force to adjacent bones, thereby causing increased stability through mechanical braces, that is, self-locking wedges, trusses, and a complex space framework (fig. 2) [15, 16]. The compression forces can be visualized by tracing the primary trabecular patterns from the metatarsals into the tarsal bones [13, 17, 18]. When the alignment of the metatarsals and tarsal bones are abnormal, the lines of stress are transmitted improperly, causing strain on the ligaments and

Fig. 3.—A, Dorsoplantar view. Lateral subluxation of fourth and fifth metatarsals with fragment of fourth metatarsal (arrows) remaining with cuboid. Cuboid is also fractured. Oblique (B) and lateral (C) views. Fourth and fifth metatarsal subluxations not identified; however, cuboid fracture is seen.

Fig. 4.—A, Lateral view. Calcaneal (C)-cuboid (c) dislocation and talo (T)-navicular (N) subluxation. Normal alignment of dorsum of second metatarsal and cuneiform (arrows). Lisfranc injury included fractures of third, fourth, and fifth metatarsal bases, plus cuboid fracture on dorsoplantar and oblique views. B, Lateral view, different patient. Calcaneal (C)-cuboid (c) dislocation. Second metatarsal (distal arrow) is subluxed dorsally; second cuneiform (proximal arrow). Lisfranc injury included dorsal subluxation or dislocation of all metatarsals.
Fig. 6.—Two patients with metatarsal base avulsions. A, Dorsoplantar view. Avulsion fracture causes irreducible second metatarsal subluxation. B, Dorsoplantar view. Avulsion fracture causes irreducible third and fourth metatarsal subluxations.

Fig. 7.—A, Initial dorsoplantar view. Small avulsion fracture at medial corner of second metatarsal (arrow). B, Dorsoplantar view 9 months later. Lateral subluxations of first and second metatarsal have developed. C, Oblique views same time as B. Subchondral cysts and joint space narrowing have developed at first and second tarsometatarsal joints.

Fig. 8.—Dorsoplantar (A) and lateral (B) views of foot in diabetic patient with pes planus. Abnormal transmission of compression forces at tarsometatarsal joints have caused diabetic neuropathic joint with dorsal osteophytes at Lisfranc joint.

eventually causing subluxation and hypermobility at the joints (fig. 8) [13, 18, 19].

Clinical foot radiographs. After reviewing the routine non-weight-bearing feet in 100 emergency room patients, we found that, with close attention, the alignment of the individual tarsometatarsal joints can usually be visualized. The first, second, and third tarsometatarsal joints were seen 96%–100% of the time except for the third on the dorso-
plantar view, which could be identified in only 80% of instances. The fourth was seen on 90%–100% of the dorsoplantar and oblique projections. The fifth was identified 80% of the time on the oblique film. The lateral views for the fourth and fifth tarsometatarsal joints were usually not helpful.

Foster and Foster [12] were the first to point out many of the normal radiographic relationships at the Lisfranc joint. We agree with them that on dorsoplantar and oblique views the margins of the first and second metatarsals consistently align with the margins of their corresponding cuneiforms (figs. 9A and 9B). In contradistinction to their findings on the third tarsometatarsal joint, we have routinely identified the normal alignment on the dorsoplantar and oblique views. On the dorsoplantar view, the lateral margins of the third metatarsal and third cuneiform can be identified in 72% of the patients, the medial margin in 3%, and both margins in 7% (fig. 9A). On the oblique view, the wedge shapes of the third metatarsal and third cuneiform allow the alignment to be documented either at the broader dorsal surface or the narrower plantar surfaces (fig. 9B). The medial margin of the fourth metatarsal aligns with the medial margin of the cuboid on the dorsoplantar and oblique views (figs. 9A and 9B). A small notch on the articulating surface of the fifth metatarsal can be identified aligning with the lateral surface of the cuboid in 80% of the patients on the oblique view (fig. 9B).

A routine lateral view of the foot demonstrates the normal relationships of the first three tarsometatarsal joints (fig. 9C). Because the second metatarsal is recessed between the first and third cuneiforms (fig. 9A), the second tarsometatarsal joint is projected more proximally than the first joint (fig. 9C). However, because the Lisfranc joint has a gentle anterior convex curve, the third tarsometatarsal joint can be projected over the plantar aspect of the second tarsometatarsal joint (fig. 9C). The lateral projection allows identification of dorsal or plantar displacement by aligning the dorsal surfaces of the tarsal and metatarsal bones (fig. 4B) [12].

In anatomic descriptions, 2–3 mm medial and lateral offsets can normally occur at the fourth and fifth tarsometatarsal joints on non-weight-bearing films [11, 12]. This represents normal range of motion at these joints. Abnormal offsets at the fourth and fifth tarsometatarsal joints should be considered when there are associated avulsion fractures of these metatarsal bases or when the offsets are greater than 3 mm. Offsets never occur normally at the first, second, or third tarsometatarsal joints [12].

Tarsometatarsal Abnormalities

Metatarsal subluxations limited to the dorsoplantar view. In four patients, large metatarsal subluxations (3–5 mm) were seen only on the dorsoplantar view and not on the oblique and lateral views (fig. 3). Abnormalities may be hidden on the oblique and lateral views; however, these views are invaluable to identify other findings such as tarsal dislocations, beak fractures of the calcaneous, and fractures of the cuboid. Therefore, all the views should be scrutinized to avoid missing significant fractures and dislocations, which if untreated will affect foot stability.

Associated tarsal dislocations. Three patients had associated tarsal dislocations, subluxations with injuries to the Lisfranc joint. The injuries included calcaneal-cuboid dislocations (fig. 4) and navicular-cuneiform subluxations (fig. 5). Two patients had direct trauma (fig. 4A and 5) while the third patient had indirect trauma (fig. 4B). All the tarsal dislocations were identified on the lateral view and all the tarsal injuries were treated with closed reduction.

Irreducible metatarsal subluxations. Irreducible metatarsal subluxations after closed manipulation are usually caused by avulsion fractures from the bases of the metatarsals which prevent anatomic reduction [6, 8, 9]. The avulsions from the metatarsals occur because the ligaments attached are stronger than the cortical bone of the metatarsal and tarsal bones. An avulsion that can commonly prevent closed reduction arises at the medial corner of the second metatarsal base, and occurs because of the strong Lisfranc ligament that connects the second metatarsal to the first cuneiform (fig. 6A) [9]. Irreducible metatarsal subluxations from avulsions can occur at the other metatarsal bones and

Fig. 9.—A, Normal dorsoplantar view. Lateral margin of third metatarsal aligns with third cuneiform (arrows). B, Normal oblique view. Wedge shapes of third metatarsal and third cuneiform allow alignment to be judged either at wider dorsal surface (large arrowheads), or narrower plantar surface (small arrowheads). Lateral border of cuboid lines up with corresponding edge of base of fifth metatarsal bone (arrow). C, Normal lateral view. Tarsometatarsal joints can be recognized by identifying two parallel cortices. Second tarsometatarsal joint is recessed (most proximal) (arrows) compared with first (large arrowheads). Third tarsometatarsal projected over inferior aspect of second tarsometatarsal joint (small arrowheads).
can require open reduction (fig. 6B). However, the mere presence of a chip fracture does not mean that a tarsometatarsal fracture-dislocation cannot undergo closed reduction. Avulsion fractures usually arise from indirect trauma [4]. Other causes of metatarsal subluxations that are irreducible by closed manipulation include transverse fractures of the metatarsal bases from direct trauma and interposition of the tibialis anterior tendon between the first metatarsal and first cuneiform [9, 20].

Unstable metatarsal reductions. Unstable reductions can occur after closed reductions or spontaneously reduced dislocations. Follow-up films are necessary to confirm that the anatomic reduction is maintained. The consequence of an unstable reduction is an unstable joint with development of degenerative changes (fig. 7) [9]. Unstable metatarsal reductions should be diagnosed at closed reduction, and then treated with internal fixation. Because the instability was not appreciated in one of our patients (fig. 7), painful first and second tarsometatarsal joints have developed and arthrodesis of these joints is now required.

REFERENCES
14. Hicks JH. The mechanics of the foot. J Anat 1953;87:335-357