How to Identify Unstable Lisfranc Injuries? Review of Diagnostic Strategies and Algorithm Proposal

German Joannas, MD[a,b,c], Jorge Filippi, MD, MBA[d,e,*]

KEYWORDS

• Lisfranc • Tarsometatarsal • Instability • Midfoot arthrodesis • Imaging • Injury • Diagnosis

KEY POINTS

- Misdiagnosed Lisfranc injuries can be as high as 50%, leading to chronic pain, functional impairment, and posttraumatic arthritis. Subtle or incomplete lesions are the most problematic group for an adequate diagnosis.
- When clinical suspicion for a midfoot injury is present, all efforts must be done to rule out Lisfranc instability. Conventional non–weight-bearing radiographs can overlook up to 30% of unstable cases.
- Abduction stress radiographs and anteroposterior monopodial comparative weight-bearing radiographic views are very useful to identify instability, and they are recommended as the initial study for a potentially unstable Lisfranc injury.
- Computed tomography gives detailed information about fracture patterns and comminution, but its role in detecting occult instability is unclear.
- MRI can predict instability but it is expensive and not readily available in the acute setting.

INTRODUCTION

The incidence of reported injuries to the Lisfranc joint is estimated at 1 per 55,000 people per year.[1] Misdiagnosed Lisfranc injuries can be as high as 50%, leading to chronic

[a] Foot and Ankle Division “CEPP”, Instituto Dupuytren, Av. Belgrano 3402, Ciudad Autónoma de Buenos Aires CP 1078, Argentina; [b] Foot and Ankle Division, Orthopaedics Department, Centro Artroscópico Jorge Batista SA, Pueyrredón 2446 1er piso, Ciudad Autónoma de Buenos Aires (CABA) CP 1119, Argentina; [c] Instituto Barrancas, Hipolito Yrigoyen 902, Quilmes, CP 1878, Buenos Aires, Argentina; [d] Department of Orthopedic Surgery, Foot and Ankle Unit, Clinica Las Condes, Estoril 450, Las Condes, Santiago 7591047, Chile; [e] Department of Orthopedic Surgery, Foot and Ankle Unit, Hospital del Trabajador, Ramon Carnicer 185, Providencia, Santiago 7501239, Chile
* Corresponding author. Estoril 450, Las Condes, Santiago 7591047, Chile.
E-mail address: jfilippi@clinicalascondes.cl

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pain, functional impairment, and posttraumatic arthritis.[2–6] Subtle or pure ligamentous lesions are the most problematic group for an adequate diagnosis because plain radiographs are not capable of addressing potential instability.

Comparative weight-bearing (WB) radiographs, abduction stress views, and MRI have been used to address tarsometatarsal (TMT) instability.[7–11]

A precise evaluation of instability is also needed during surgery to decide which joints to stabilize. Stress maneuvers under anesthesia or direct view of the joints are very helpful. Deciding on which joints to treat has important repercussions in terms of hardware usage, cartilage disruption (ie, when transarticular screws are used), and time of surgery.

This article reviews the current evidence in diagnostic tools for Lisfranc instability and presents a diagnostic algorithm for these injuries.

RELEVANT ANATOMY AND BIOMECHANICS

The TMT complex includes bony and ligamentous structures. The metatarsals display in the transverse plane as a Roman arch with the second metatarsal as the cornerstone giving inherent bone stability. It is divided into 3 functional and anatomic areas, medial column comprising the first metatarsal (M1) and medial cuneiform (C1) joint, middle column comprising the second (M2) and third metatarsal (M3) joint with intermediate (C2) and lateral cuneiform (C3), and the lateral column comprising fourth (M4) and fifth metatarsal (M5) joint with the cuboid. The lateral column has the highest degree of motion with 13 mm, and the middle column is the more stable with only 0.6 mm of dorsoplantar movement.[12]

The most clinically relevant ligament is the C1-M2 (Lisfranc) ligament. It has 3 components, dorsal, interosseous, and plantar, the interosseous being the strongest.[13,14] Its importance is that it is the only structure that connects the medial and middle column since the absence of an M1-M2 interosseous ligament.[15,16]

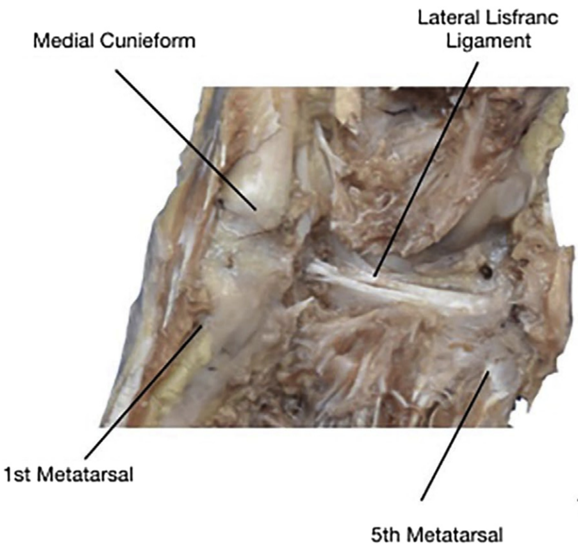

Fig. 1. Anatomic preparation of the lateral Lisfranc ligament (Liverpool ligament). (*From* Mason L, Jayatilaka MLT, Fisher A, et al. Anatomy of the lateral plantar ligaments of the transverse metatarsal arch. Foot Ankle Int. 2020;41(1):109–14; with permission).

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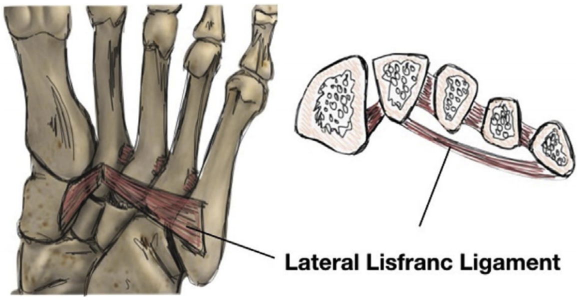

Fig. 2. The lateral Lisfranc ligament (Liverpool ligament). (*From* Mason L, Jayatilaka MLT, Fisher A, et al. Anatomy of the lateral plantar ligaments of the transverse metatarsal arch. Foot Ankle Int. 2020;41(1):109–14; with permission).

Interosseous ligaments are present between each of the metatarsals from the second to the fifth. The presence of intermetatarsal ligaments explains the conjoined behavior of the middle and the lateral columns in certain types of injuries. A study by Mayne and colleagues[17] suggested that when intermetatarsal ligaments are intact, stabilizing the medial cuneiform to the second metatarsal base combined with stabilization of the fourth and fifth TMT joints with K-wires will stabilize the first and third TMT joints.

Recently, Mason and colleagues described the lateral Lisfranc ligament ("The Liverpool ligament"). This newly described structure provides a connection through the long plantar ligament of both the transverse and the longitudinal arches. This ligament connects the plantar aspect of M2 to M5, and the investigators hypothesized that this could be the reason why the lateral column can get stabilized after fixation of the middle column. They suspected that in most of the homolateral and divergent types of TMT injuries, the lateral Lisfranc ligament remains intact and explains the physiopathology for this type of injury[18] (**Figs. 1 and 2**).

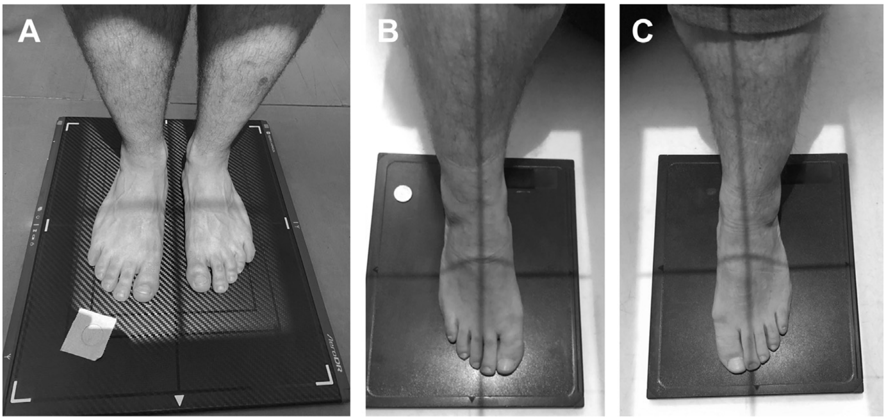

Fig. 3. Different methods to obtain WB radiographs. (*A*) Bipedal WB comparative view in the same cassette. Note that the beam is centered in the area between both feet. (*B*, *C*) Monopodial WB comparative view on both feet. In this case, the beam is centered in the second metatarsal.

Fig. 4. Patient with pain in the left foot after direct trauma. (*A*) Bipedal WB view with no evident displacement on the left foot. (*B*) Monopodial WB view of the right (noninjured) foot. (*C*) Monopodial WB view of the injured foot that reveals intercuneiform and C1-M2 instability.

The complex anatomy of the midfoot with several ligament interconnections and inherent bone stability makes it difficult to diagnose a subtle Lisfranc instability accurately. This can explain the multiple and different injury patterns of the midfoot and also gives an explanation of the fact that during surgery after stabilizing the middle column, sometimes the others get stability without fixation.

DIAGNOSTIC STUDIES

Conventional Radiographs

Conventional radiographs provide important information about Lisfranc injuries. However, undiagnosed and misdiagnosed lesions can easily occur. Rankine and

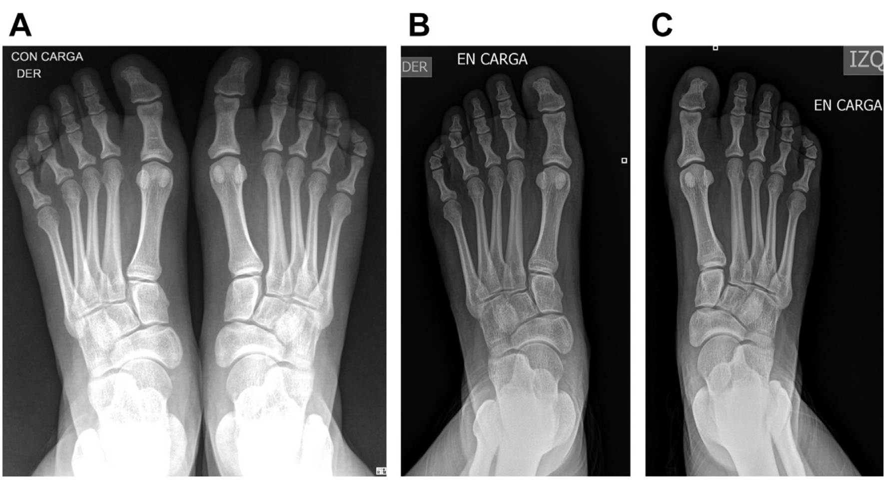

Fig. 5. Radiographs of a patient who had a hyperextension injury in his left midfoot. (*A*) Bipedal WB view with a nonconclusive asymmetry of the C1-M2 distance. (*B*) Monopodial WB view of the right (noninjured) foot. (*C*) Monopodial WB view of the left (injured) foot that shows more evidently the increase in C1-M2 distance.

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colleagues[19] reported that non-WB radiographs correctly identified only 68.9% of Lisfranc injuries.

On the anteroposterior (AP) view, the central beam is centered on M2, with 15° of caudal angulation, and in the oblique (OB) view, the foot has an internal rotation of 30°.[4]

Anatomic alignment on the AP and OB views is as follows: the lateral border of M1 aligns with the lateral border of C1, the medial border of the base of the M2 aligns with the medial border of the C2, the medial and lateral border of the M3 should align with the medial and lateral border of C3, and the medial border of the base of the M4 should be in line with the medial side of the cuboid.[5,20]

The presence of the "fleck sign" has been identified as pathognomonic for C1-M2 instability. It represents an avulsion fracture of the Lisfranc ligament from M2. Although it is commonly seen in unstable injuries, its absence does not rule out instability.[2,21]

Malalignment at the second TMT joint, with lateral displacement of the base of M2 with respect to C2, and a diastasis of more than 2 mm between the bases of M1 and M2 are indicators of instability.[5,22]

Rankine and colleagues[23] showed that 29° of craniocaudal angulation in the AP view optimizes the view of the second TMT joint and suggests its routine use when studying midfoot injuries.

A study by Seo and colleagues identified signs of instability in comparative non-WB radiographs. They compared the radiographic findings with intraoperative instability. Avulsion of the base of M2 (fleck sign) and C1-M2 and C1-C2 diastasis were found to have 100% of specificity for intraoperative instability. The sensitivity was 48%, 92%, and 60% respectively. The fleck sign was only present in 47% of this series. For M1-C1 instability, abnormal preoperative findings were present in only 43% of the cases with intraoperative first ray instability.[24]

Weight-bearing Radiographs

WB views are used to improve the diagnostic capabilities of conventional radiographs by adding physiologic stress to the TMT joints.[4] Examination of the contralateral uninjured foot is very helpful to detect asymmetries. Classically, more than 2 mm of difference in C1-M2 or M1-M2 distance with the contralateral foot may be an indicator of instability. Thomas and colleagues determined the value of the Lisfranc joint width in a standardized adult population in 100 healthy volunteers with WB views. The mean C1-M2 distance was 5.6 mm (95% confidence interval [CI] 5.39–5.81), and the mean difference between both feet was 0.7 mm (95% CI 0.63–0.77).[20]

Even though its extended use has been referenced in many studies, a detailed description of how to take WB views is hard to find. There are several options to take WB AP views: bipedal WB in the same cassette, bipedal WB in a different cassette, or monopodial WB. Each of them will provide a different view angle, and the degree of stress to the TMT joint could change.

To our knowledge, no study has compared these methods.

Our preferred method to obtain standing feet radiographs is with monopodial WB. This technique allows the standardizing of WB, and the central beam is oriented to the foot instead of the area between both feet (**Fig. 3**). **Figs. 4 and 5** show 2 cases in which the Lisfranc instability is more evident on the monopodial WB view than the bipedal comparative view.

When a patient with high clinical suspicion of a Lisfranc injury is not able to put weight on the injured foot, and the conventional non-WB radiographs do not show findings, WB images can be ordered 7 to 10 days after the injury during follow-up.

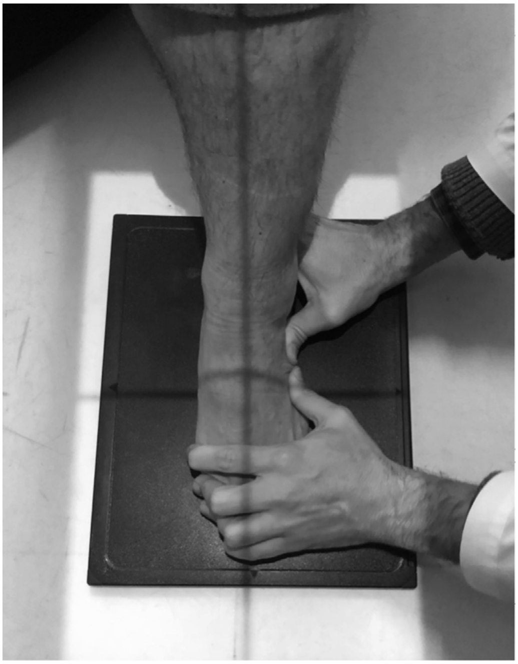

Fig. 6. Abduction stress views (*left*).

Fig. 7. Abduction stress views (*right*).

Abduction Stress Views

As noted previously, non-WB radiographs can overlook up to 40% of Lisfranc instability. Regarding this problem, stress views have been described to improve these mediocre results. Abduction maneuvers were suggested by some investigators in the early 90s.[25,26] In 1998, Coss and colleagues described the parameters of

Fig. 8. Clinical case of a patient with suspected instability. Standard radiographs did not show any abnormalities. Abduction stress views revealed instability of M1-C1, M2-C1, and M3-C3. (*A*) Preoperative AP view. (*B*) Preoperative OB view. (*C*) Negative Abduction stress view. (*D*) Positive abduction stress view (instability of M1-C1, M2-C1, and M3-C3). (*E*) Postoperative surgery AP view: position screw M2C1 and plating for M1C1 and M3C3. (*F*) Postoperative surgery OB view.

abnormal abduction stress views. They compared findings in 9 cadaveric feet who had sequential sectioning of midfoot ligaments with 20 healthy volunteers. In 39 of 40 healthy feet, a line tangential to the medial aspect of the navicular and C1 (medial column line [MCL]) intersected the base of M1 on abduction stress radiographs. Three of 4 cadavers with isolated sectioning of the Lisfranc ligament had disruption of MCL. In all 9 cadavers, sectioning of the Lisfranc ligament in combination with the dorsal TMT ligaments produced a disruption of the MCL on abduction stress, whether or not, the plantar ligaments had yet been sectioned. On simulated AP WB views, M1-M2 distances did not widen more than 1.5 mm, even with completely sectioned ligaments.[9]

Fig. 9. Clinical case of a patient with hidden injury. Standard radiographs did not show any abnormalities. Abduction stress views revealed instability of M1-C1 and M2-C1. (*A*) Preoperative AP view. (*B*) Preoperative OB view. (*C*) Negative abduction stress view. (*D*) Positive abduction stress view (instability of M1-C1 and M2-C1). (*E*) Postoperative surgery AP view: position screw M2C1 and M1C1. (*F*). Postoperative surgery OB view.

Another cadaveric study compared WB radiographs with manual abduction stress views in feet with sequential ligament sectioning. They concluded that stress views showed qualitatively greater displacement when used to evaluate instability compared with WB views.[27]

The use of the abduction stress view is not widespread, possibly for the pain elicited during the examination and the need for trained personnel. In the authors' experience, this can be done without anesthesia and is very reliable to demonstrate instability. The inconvenience of needing a qualified operator is real, and this method can be done only when an orthopedic physician is available to perform and evaluate the stress

Fig 10. Clinical case of a patient with suspected instability. Standard radiographs did not show any abnormalities. Abduction stress views revealed instability of M2-C1 and "fleck sign." (*A*) Preoperative AP view. (*B*) Preoperative OB view. (*C*) Negative abduction stress view. (*D*) Positive abduction stress view (instability of M2-C1 and fleck sign). (*E*) Postoperative surgery AP view: *ONLY one* position screw M2C1. (*F*) Postoperative surgery OB view.

maneuvers. Figs. 6 and 7 show our preferred method for acquiring the abduction stress view.

Taking into consideration all these aspects, it is still believed that this is a powerful tool to diagnose an occult instability preoperatively, it helps in the decision for surgery and surgical planning, and that it should be used when possible. Figs. 8–10 show 3 cases with apparently normal conventional radiographs and the instability of medial and middle column after stress views.

Computed Tomography

CT provides excellent visualization of bone details and helps to detect occult fractures or subtle articular subluxation and determine the degree of comminution and articular extension of the fracture. In a study, CT detected twice tarsal fractures and TMT joint malalignment and 60% more metatarsal fractures than conventional radiographs.[28]

However, conventional CT is not a dynamic study; therefore, it has the same limitations as non-WB radiographs in terms of identifying occult instability. Also, no consensus exists in the literature as to how the distance of the C1 and M2 articulation should be defined and measured[5] nor what the normal range of this value should be when evaluated by CT.[10]

An interesting study showed, in 117 patients with clinical signs compatible with midfoot injury, that in patients with positive findings in WB radiographs 54% had a negative or equivocal CT report. On the other hand, 12% of equivocal or negative WB radiographs had a positive CT. They concluded that relying on the CT report alone, a significant proportion of subtle injuries would have been misdiagnosed, and CT did not provide any additional information for patients with a positive WB film and detected only a small percentage of additional injuries.[29]

WB-CT has had great attention lately, especially in foot and ankle surgery.[30] To our knowledge, no clinical studies have been published regarding WB-CT and Lisfranc injuries. The authors only found one article that analyzed CT findings of simulated WB in 16 cadavers. After sequential ligament sectioning, they found an increase of MC-M2 and M1-M2 distance, and this value was higher when more ligaments were sectioned.[7]

CT gives excellent information about fracture details and is very helpful to determine the degree of comminution, especially in high-energy or complex midfoot injuries.[10] The authors recommend to take a CT as a complement for WB or stress views and not as the first line of study. In the future, the use of WB-CT in this type of injury is promising because it could combine high detail imaging with stress to the TMT joint.

MRI

MRI offers a detailed view of the ligaments and bony anatomy in the midfoot. Several investigators have demonstrated that injuries to Lisfranc ligaments are highly correlated with MRI findings.[5,10,11,16,28] Although it is not a dynamic study, a high degree of predictability for instability has been described. Raikin and colleagues,[31] in a clinical study with 20 patients, showed that when the plantar C1-M2-M3 ligament is torn or has a grade 2 sprain it highly suggests an unstable midfoot, also when this ligament is intact on MRI it suggests a stable TMT joint (Fig. 11). Only one case report has been published on WB MRI in Lisfranc injuries[8]; therefore, more studies are needed to have a better understanding of this alternative.

Unfortunately, MRI has some drawbacks. It is costly and not always available in the acute setting, interpretation errors could over- or underestimate the level of injury, and it is not a dynamic study.[10] Because most of the unstable Lisfranc lesions can be ruled out with WB or stress radiographs, the authors consider that MRI must be

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Fig. 11. MR axial view with absence of Lisfranc ligament.

recommended when WB or stress radiographs are normal in patients with a high clinical index of suspicion.

THE AUTHORS' RECOMMENDATION AND ALGORITHM

Based on the available evidence and the authors' hospitals' experience, they suggest the following diagnostic algorithm (**Fig. 12**).

Conventional radiographs are the first line for the study in any patient with clinical suspicion of Lisfranc instability such as plantar ecchymosis, swollen midfoot, WB pain, and history with a compatible mechanism of injury. According to the radiographic findings and the classification described by Arrondo and colleagues,[32] the injuries can be divided into hidden or evident. When evident or high-energy injury is present, CT evaluation is indicated for surgery planning to decide whether osteosynthesis or arthrodesis will be the final treatment.

When the information of the radiographs is not clear or negative (hidden injuries), it is recommended to use comparative abduction stress radiographs. It is believed that it is the most effective method to evaluate the potential instability in the 3 columns of the midfoot. This maneuver provides essential information about C1-M2 (Lisfranc ligament), C1-M1, and M3-C3 stability. When the abduction stress view is positive for instability, it is not necessary to do any other study, and surgery is indicated. If the stress view is negative and a high clinical suspicion is present, the authors consider

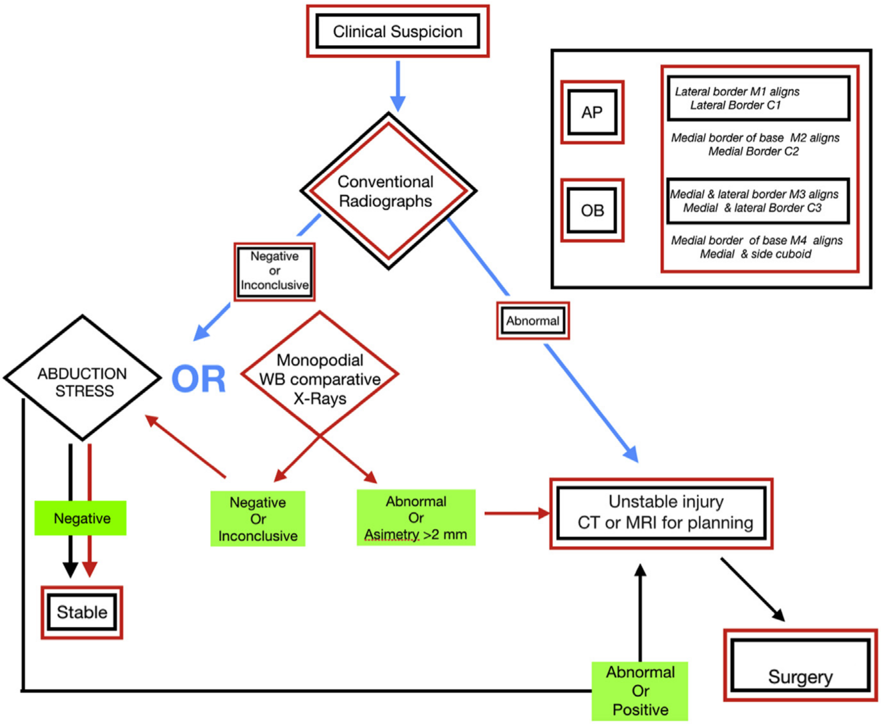

Fig. 12. Diagnostic algorithm: the authors' preference is given in black boxes.

the use of MRI. If MRI shows an intact Lisfranc ligament, conservative treatment is indicated, and when the plantar C1-M2-M3 is torn, surgery is indicated.

If the abduction stress view cannot be performed, the authors suggest the use of comparative monopodial WB radiographs instead. Even though it does not produce as much stress as the abduction test, it is very helpful and can reveal occult instability as well.

SUMMARY

Undetected or misdiagnosed Lisfranc injuries are frequent and lead to bad results, chronic pain, functional impairment, and arthritis. The complex anatomy of the midfoot explains the multiple and different injury patterns. Subtle injuries are the most challenging in terms of diagnosis. When clinical suspicion is present, all efforts must be done to rule out Lisfranc instability. CT gives detailed information about fracture patterns and comminution, but its role in detecting occult instability is unclear. Because conventional radiographs can overlook up to one-third of occult injuries, the use of dynamic or stress methods is mandatory. The authors recommend to start with the abduction stress radiographs because they provide a thorough understanding of the midfoot instability and they believe is the best method to differentiate a stable injury from an unstable one. If the abduction stress radiographs cannot be performed, the authors recommend the use of monopodial WB comparative radiographs. If the aforementioned studies are negative and there is a high clinical suspicion, MRI findings could help to decide if surgical treatment is necessary.

CLINICS CARE POINTS

- Up to 30% of unstable Lisfranc injuries look normal in non-weightbearing x-rays.
- Abduction stress radiographs by trained personnel are very useful to address instability. In the authors' experience, there is no need for anesthesia.
- Comparative monopodial weightbearing x-rays is an excellent alternative to get stress views.
- CT and MRI are useful for preoperative planning, but the surgical decision must be based on dynamic studies.

DISCLOSURE

The authors have nothing to disclose.

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