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Technical Tips

Subtle tarsometatarsal ligament injury in a professional ballerina: weight-bearing computed tomography technical tip

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Abstract

Early detection of Lisfranc instability is critical for improving clinical outcomes, but diagnosing subtle injury can be challenging. Magnetic Resonance imaging associated with weight-bearing computed tomography (WBCT) allows evaluation of such injuries in 3 dimensions (3D) under physiologic load. This WBCT technical tip aimed to assess the utility of the 3D measurements between medial cuneiform and the base of the second metatarsal (C1-M2), between the medial and intermediate cuneiforms (C1-C2), and between the first and second metatarsals (M1-M2) to diagnose subtle injury in isolated ligamentous Lisfranc injuries.

Level of evidence V, Therapeutic studies, Expert opinion.

Keywords: Wounds and injuries; Metatarsal bones; Weight-bearing; Computed tomography.

Introduction

The Lisfranc ligament stabilizes the foot's medial arch. The rupture of this structure can lead to the instability of the forefoot and midfoot[1]. Low-energy traumas usually cause ligament injuries and can be called subtle Lisfranc injuries[2-4].

While the weight-bearing radiograph is the traditional exam for diagnosing fractures and joint displacement, they have a higher chance of misdiagnosing ligament injuries. Among professional athletes, the rate of misdiagnosis is up to 41%, directly affecting the return to practice and the athlete's performance [5,6].

For this reason, computed tomographgy (CT) and magnetic resonance imaging (MRI) became standard care to evaluate the subtle Lisfranc injuries[6]. However, these exams are performed with the foot in a non-weight-bearing position when the joint is not in its most stressful position[6]. The cone beam CT allows it to do weight-bearing CT (WBCT) and to stress the foot joint in different positions[7-10].

This is a technical image tip for the decision-making of a professional ballerina for whom using the WBCT allowed us to define tarsometatarsal joint stability and decide between surgical and non-surgical treatment.

Case presentation

A 17-year-old female with 14 years of ballet experience was rehearsing. While in a jump, she felt and twisted her right foot in eversion. After this, she started to feel pain and difficulty walking. She went for an evaluation in the emergency room (ER).

In the first evaluation, the patient had swollen feet, midfoot pain, and pain in the foot mobilization. The initial radiograph

Study performed at the Hospital das Clínicas, Faculdade de Medicina, Universidade de São Paulo, São Paulo, SP, Brazil.

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was performed without weight-bearing and didn't reveal alteration. To complete the ER analysis, a CT scan indicated a possible Lisfranc ligament injury but without fracture or dislocation (Figure 1).

The patient was immobilized with a cam boot. She was released from the ER with a request for an MRI and to follow up with a foot and ankle specialist. The MRI showed a Lisfranc ligament injury without bone fracture, but it could not demonstrate if there were instabilities in the Lisfranc area (Figure 2).

The patient arrived for our evaluation with decreased pain and swelling. In our assessment, the patient presented without weight-bearing in the right lower limb and had a subtle positive piano key test. For these reasons, we used weight-bearing dynamic digital radiography and WBCT images to define the final treatment.

The weight-bearing radiograph, compared to the contralateral, did not show an increase in the Lisfranc space (Figure 3).

Technical image tip

The patient underwent a unique protocol with the WBCT.

Pre-treatment protocol

The first was a sitting-position bilateral WBCT scan, the second was a normal weight-bearing bilateral WBCT scan

Figure 1. Initial non-weight bearing radiograph and computer tomography did not show fracture and did not show significant increase of the Lisfranc area.

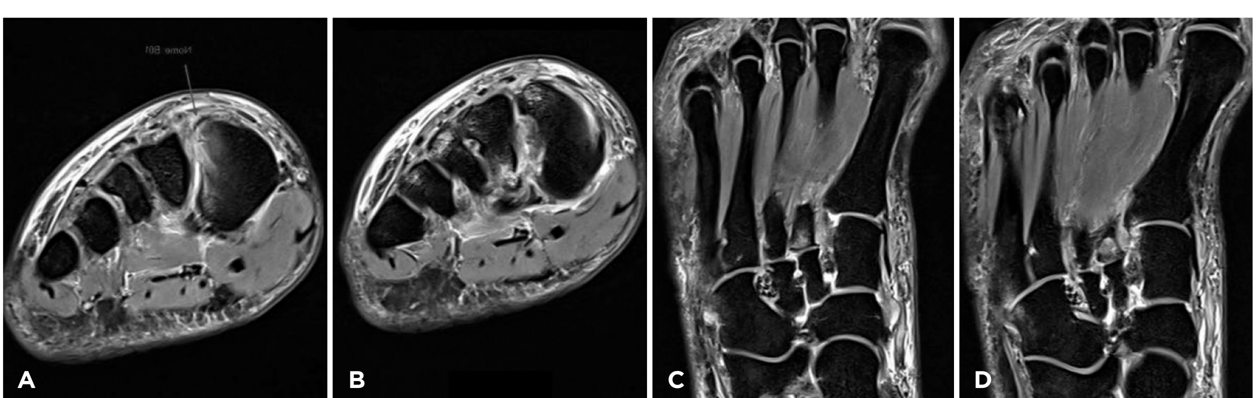

Figure 2. Initial magnetic resonance imaging of the edema and the Lisfranc ligament injury.

(Figure 4), the third was a demi-pointe weight-bearing bilateral WBCT scan to understand how the Lisfranc injury would affect the Lisfranc area since this is a position that the patient typically does in her ballet practice.

Figure 3. Weight-bearing dynamic digital radiography -without significant increase of Lisfranc the area comparing the right side to the left side.

Post-treatment protocol

The first was a sitting-position bilateral WBCT scan, the second was a normal weight-bearing bilateral WBCT scan (Figure 4), the third was a demi-pointe weight-bearing bilateral WBCT scan to understand how the Lisfranc injury would affect the Lisfranc area since this is a position that the patient typically does in her ballet practice, the forth was a pointe weight-bearing bilateral WBCT scan to understand how the Lisfranc healed injury affected midfoot bone relation and joint areas, since this is a final position that the ballerina typically does in her ballet performance.

The Lisfranc interosseous distance measurements were performed in the axial plane at the junction of the upper and middle third of the medial cuneiform, defined as 10 mm below its dorsal surface, as described by Bhimani et al[10]. These distances were between the medial cuneiform and the base of the second metatarsal (C1-M2), between the medial and intermediate cuneiforms (C1-C2), and between the first and second metatarsals (M1-M2) (Figures 5 and 6).

All measurements were performed using CubeVue software (Curvebeam, Pennsylvania, USA). Bhimani et al.[10] describes that C1-C2 and M1-M2 injury had normally a difference of 1.3 mm between foot, and 3.2 mm in the C1-M2. The differences C1-C2, C1-M2, and M1-M2 are described in Table 1.

Since the injury did not significantly increase the affected area, a non-surgical treatment was opted for the patient.

A protected weight-bearing with foam walker boot was allowed associated with insole midfoot arch support for eight weeks when the patient had no more symptoms, and after that, a full weight-bearing was allowed.

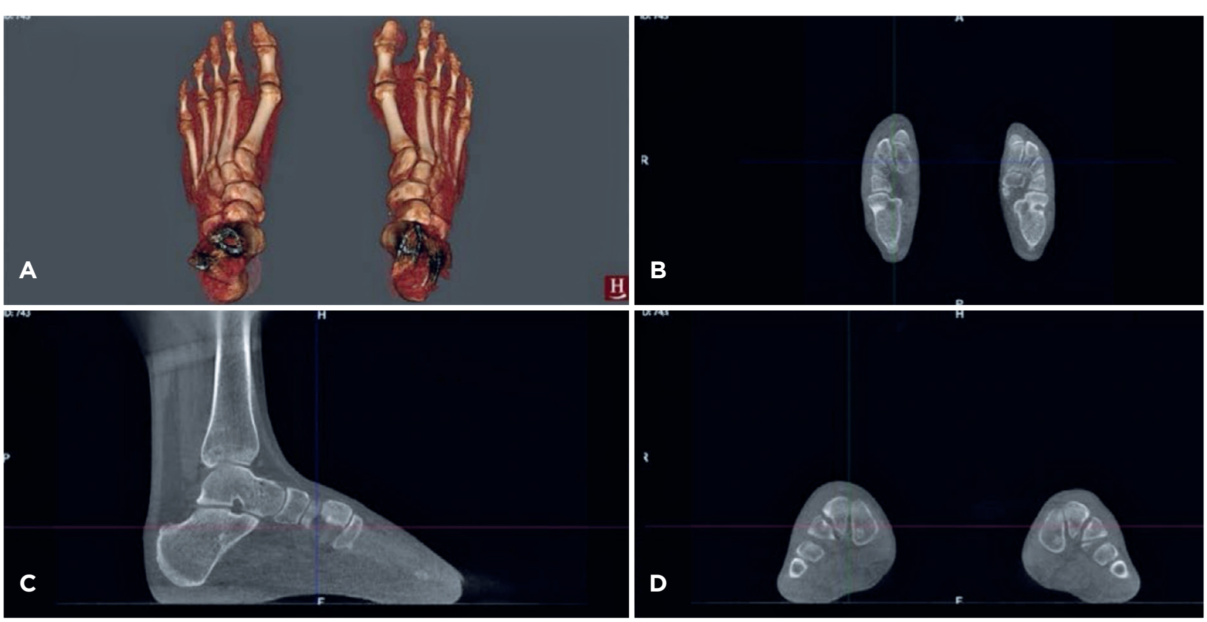

Figure 4. Normal weight-bearing computed tomography. A) 3- dimensional image of the bones; B) Axial image; C) Sagittal image; D) Coronal image.

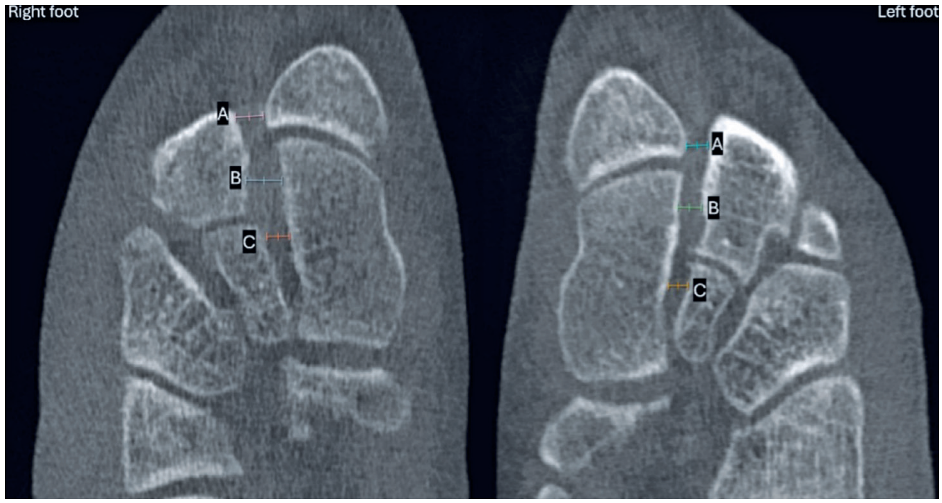

Figure 5. Weight-bearing computed tomography of a female patient with Lisfranc injury on the right foot. Axial plane of the feet. A) Distance between the first and second metatarsals (M1-M2). B) Distance between the medial cuneiform and the base of the second metatarsal (C1-M2). C) Distance between the medial and intermediate cuneiforms (C1-C2).

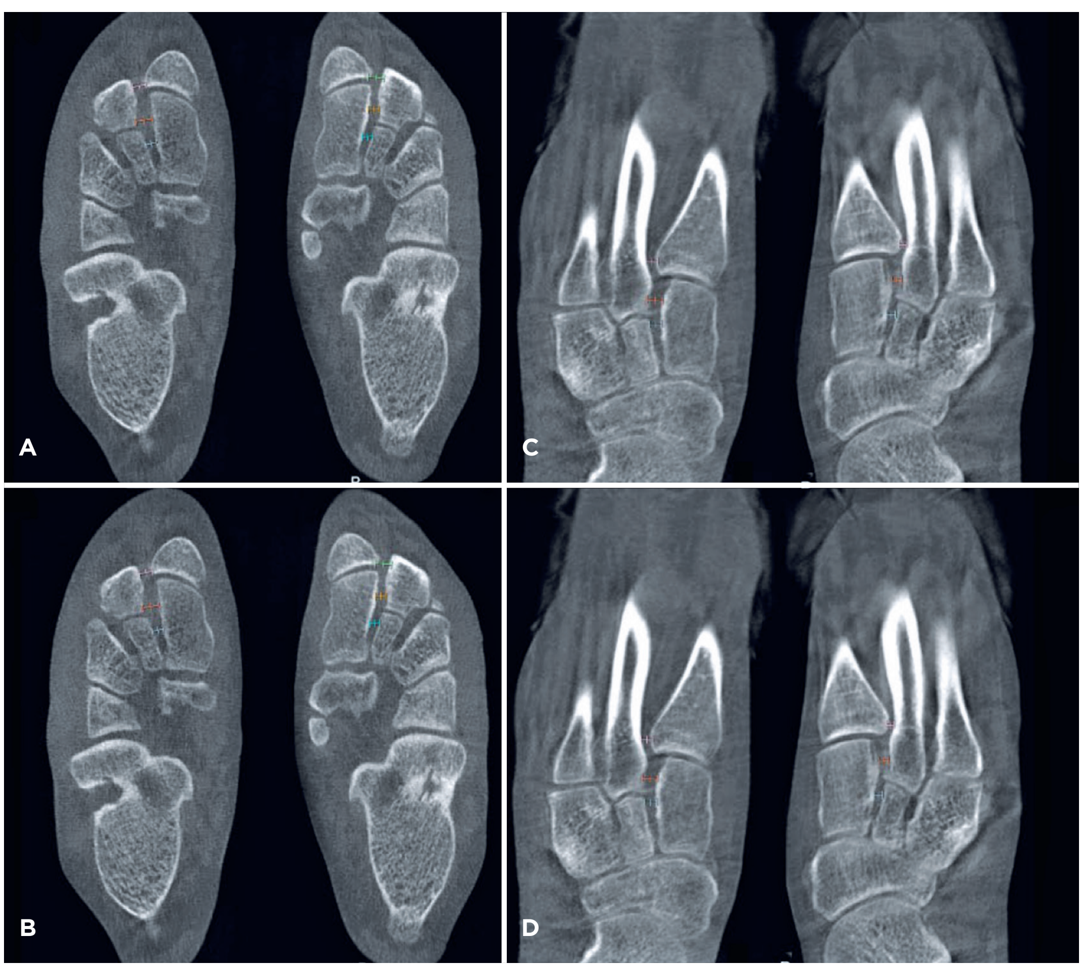

Figure 6. Weight-bearing computed tomography of a female patient with Lisfranc injury on the right foot. Axial plane of the feet. A) Sitting; B) Regular weight-bearing; C) Demi-pointe weight-bearing; and D) Pointe weight-bearing.

Table 1. Pre- and post-treatment weight-bearing computed tomography measurements C1-C2, C1-M2, M1-M2 in all protocol positions: sitting, regular weight-bearing, demi-pointe weight-bearing, pointe weight-bearing.

Pre-treatment	Sitting		Regular weight-bearing		Demi-pointe weight-bearing			
	Right	Lef;t	Right	Left	Right	Left		
C1-C2 (mm)	3.7	3;1	3.3	3	2.6	2.1		
C1-M2 (mm)	5.4	3;4	5.6	3.6	3.7	3.4		
M1-M2 (mm)	3.4	3;1	4.2	3.3	2.8	2.4		
Post-treatment	**Sitting**		**Regular weight-bearing**		**Demi-pointe weight-bearing**		**Pointe weight-bearing**	
	Right	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**
C1-C2 (mm)	3.4	3	3.6	3	2.6	2.1	2.8	2.1
C1-M2 (mm)	5.3	3;3	5.3	3.5	3.7	3.4	4.2	3.1
M1-M2 (mm)	3.2	3;1	3.8	3.4	2.8	2.4	1.9	1.4

The total return to sports was within 12 weeks; when the MRI was repeated, it showed ligament tissue healing at the Lisfranc topography (Figure 7).

At this mark, the WBCT using the same protocol adding pointe weight-bearing (Figure 8) was repeated, showing the return of the standard measurements.

Discussion

Diagnosing the pure ligamentous injury Lisfranc injury remains a complex challenge for orthopedic surgeons. While fracture-dislocations resulting from trauma are more straightforward, Lisfranc injury has a high rate of misdiagnosis and can define the return career of athletes[5,6].

The use of weight-bearing radiographs helps minimize misdiagnosis compared to the uninjured side; it can increase the measurable distance, making the diagnosis more evident[11,12].

However, the linear measurement can change depending on the foot's position, as it is based on a two-dimensional image[13-15]. Consequently, the patient's ability to bear weight on the injured side-limited by pain-can influence the measurement by changing how the patient steps and distributes weight on the foot.

The CT scan helps diagnose smaller fractures in the Lisfranc area[12,16,17]. It also helps determine whether a fracture involves articulation and how much displacement the fragment has[12]. Nonetheless, the exam is performed without weight-bearing and is effectiveineffective for diagnosing ligament injuries[13].

The MRI is an exam that can help diagnose the pure ligament injury and define the specific ligament involved[12,17]. However, it is also a non-weight-bearing exam, and the influence of this cannot be evaluated if it generates instability.

The WBCT can help evaluate the subtle Lisfranc injury[10,13]. It is faster than a normal CT scan and uses less radiation[8,13,18]. The scan can be performed with both feet simultaneously and in a weight-bearing position[13]. This allows for comparing

Figure 7. Magnetic resonance imaging after the treatment showing the ligament healing.

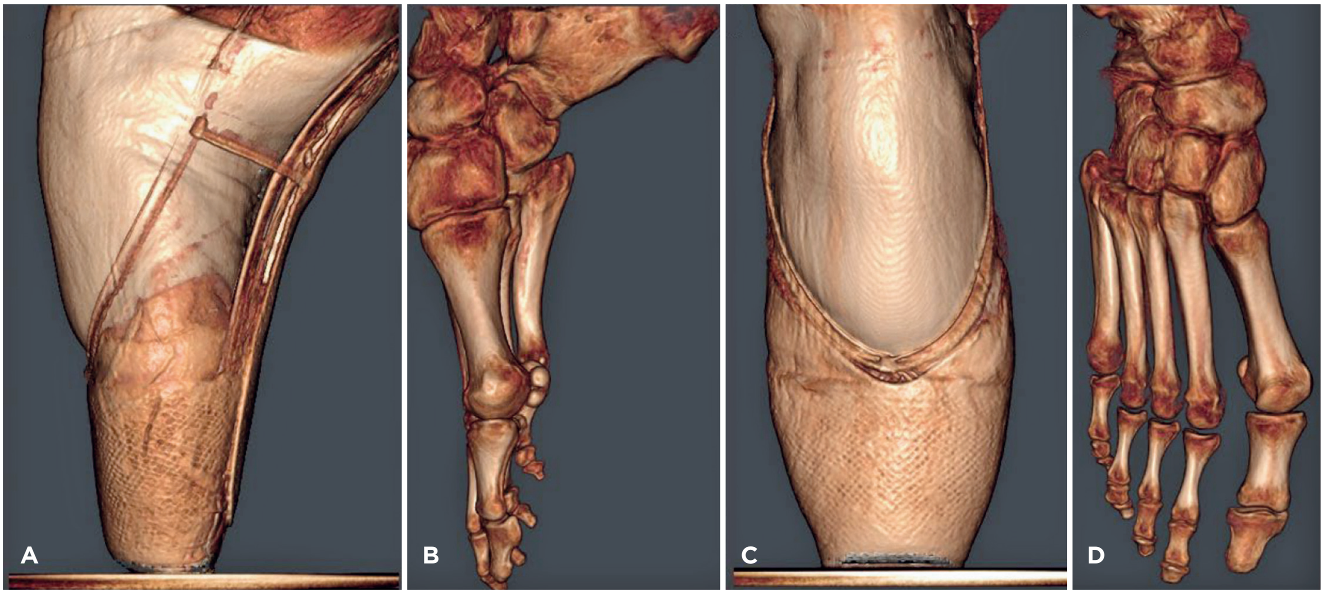

Figure 8. Pointe position weight-bearing computed tomography. A) 3- dimensional image of the foot sagittal view with pointe shoes; B) without pointe shoes; C) coronal view with pointe shoes; D) without pointe shoes.

the injured foot with the uninjured, and the weight-bearing generates a stressful position on the foot. Since the measurements are conducted in three-dimensional images, they have less influence on the feet's position on the floor[10,19]. Spirachi et al.[20] demonstrated that even in a partial weight-bearing (40 kg) WBCT can effectively diagnose the injury.

Bhimani et al.[10] describe different methods for assessing instability in the Lisfranc. They compare traditional unidimensional measurements with bi-dimensional and three-dimensional measurements. They found that the uni, bi-, and three-dimensional measurements accurately diagnose. For this reason, in our case, we chose the linear measurements similar to those used in weight-bearing radiographs.

The patient's measurements under full weight-bearing were similar in both feet, demonstrating the absence of instability in the region. To ensure that the injury would not affect her ballet practice, we performed a second scan in the full-pointe position. Even in the second position, the difference in area was similar in both feet. Since our patient did not demonstrate instability during this exam, a non-surgical approach was preferred.

To confirm the effectiveness of the non-surgical treatment, the patient underwent a new set of WBCT scans after 12 weeks of treatment. The latest measurements were similar to the previous ones, showing that the patient did not have instability, and in this case, a non-surgical treatment was appropriate. The importance of this comparison increases when the literature describes that a misdiagnosis of instability can lead to the end of an athlete's career.

Conclusion

Weight-bearing computed tomography may be a useful investigation to diagnose instability vs. stability of a pure tarsometatarsal ligament injury. When the patient does not have significant instability, non-surgical treatment with a foam walker boot combined with a midfoot support insole may be successful.

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