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The Accuracy of Non-Weight Bearing Plain Radiographs to Determine Associated Mid-foot Fractures in Lisfranc Injuries

Abstract

Background: Diagnosis of associated mid-foot fractures in Lisfranc injuries is important for proper treatment. We aimed to describe frequency of different types of Lisfranc injuries in surgically treated cases and to find the accuracy of non-weight bearing radiographs to determine associated mid-foot fractures.

Methods: In a retrospective study, preoperative non-weight bearing plain radiographs and CT studies of 118 surgically treated Lisfranc injuries were evaluated by 2 orthopaedic surgeons. The sensitivity and specificity of fleck sign, fractures of metatarsal bases, cuneiforms, navicular, and cuboids were calculated.

Results: Among 118 patients with the mean age of 35.0±15.7 years, most were male (77.1%). The most common type was Myerson type B (44.1 %) followed by D2 (40.7%). Fractures of the second metatarsal base (87 patients, 73.7%), the fleck signs (85 patients, 72.0 %), and fractures of the third metatarsal base (65 patients, 55.0 %) were the three most frequent injuries. Oppositely, fractures of the fifth metatarsal base (5 patients, 4.3%), middle cuneiform (14 patients, 12.0%), and navicular (15 patients, 12.7%) were the three least common associated mid-foot fractures. Plain radiographs could not show high sensitivity to distinguish associated mid-foot fractures in Lisfranc injuries with the highest for the second metatarsal base fractures (78.2%). The maximum specificity was for fractures of the first metatarsal base (100%).

Conclusion: Non-weight bearing radiographs of the foot cannot detect all associated mid-foot fractures particularly fleck sign. Therefore, preoperative CT scan is highly recommended.

Keywords: Tarsal bones, Bone fractures, Radiography, CT scan

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Introduction

Lisfranc injuries represent a wide range of injuries affecting the ligamentous and/or bony parts of the tarso metatarsal (TMT) joints. It accounts for about 0.2% of all orthopedic-related injuries [(1)]. The incidence of diagnosed Lisfranc injuries varies from 9.2 to 14 in 100,000 persons per year [(2)]; however, it is estimated that the actual incidence might be higher because of overlooked subtle Lisfranc injuries [(3)]. Lisfranc injuries are more common in the third decade of life with male/female ratio of about 2_4/1 [(4)]. Associated foot injuries were reported particularly in cases following high-energy trauma [(5)].

Non-weight bearing plain radiographs of the foot and computed tomography (CT) images are routinely used as the diagnostic tools for detecting Lisfranc injuries [(6-8)]. Weight bearing radiographs are more accurate than non-weight bearing x-rays to determine subtle Lisfranc injuries [(9, 10)]. Weight bearing radiographs cannot be requested in painful displaced Lisfranc injuries. No consensus study has been conducted to assess the diagnostic accuracy of X-ray images regarding associated mid-foot fractures attributed to the Lisfranc injuries. Therefore, this study aimed to evaluate sensitivity and specificity of non-weight bearing foot plain radiographs, as the primary diagnostic modality in the emergency department, for associated mid-foot fractures. It should be mentioned that the goal of this study was not to diagnose Lisfranc injuries. Two-dimensional (2D) & three-dimensional (3D) CT scan reconstruction images were selected as the diagnostic

method of choice to determine mid-foot fractures. Moreover, we looked through the frequency of each Myerson-modified hard castle classification by considering the recent edition with D type [11, 12].

Methods

Study design

After institutional board review and approval of the study by the ethics committee of the university, we conducted a retrospective review of all consecutive surgically treated Lisfranc injuries in the university teaching hospitals from 2015 to 2020. We included patients older than 18 years of age with availability to complete preoperative radiographic profiles. We excluded cases with pre-existing foot and ankle deformities.

Data acquisition

By reviewing the medical records, demographic features consisted of age, sex, and the injured side were collected. The Lisfranc injuries were classified based on the last version of Myerson-modified hard castle classification [11, 12] (Table 1) & (Figure 1, 2, 3, and 4).

Injuries of isolated Lisfranc ligament were categorized as D. There were no cases with D1 Lisfranc injury which is defined as the distance between medial cuneiform and second metatarsal base of 2 mm without needing surgical fixation. D2 subtype has this distance >2 mm and due to instability, they need surgical procedures [13]. Two independent orthopaedic surgeons reviewed the preoperative non-weight-bearing foot radiographs using picture archiving and communication system (PACS) to determine associated mid-foot fractures.

Table 1: Demographic features of the patients with Lisfranc Injury (n=118)

	Mean ± SD or n (%)
Age (years)	35.0 ±15.7
Gender	
Male	91 (77.1)
Female	27 (22.9)
Affected side	
Right	66 (55.9)
Left	52 (44.1)
Myerson Classification	
Type A (Total incongruity)	**9 (7.6)**
A1 (Lateralmedial)	8 (6.8)
A2 (Dorsoplantar)	1 (0.8)
Type B (Partial incongruity)	**52 (44.1)**
B1 (Medial displacement)	13 (11.0)
B1-1 (from 1st TMT* joint)	11 (9.4)
B1-2 (from proximal to 1st TMT joint)	2 (1.6)
B2 (Lateral displacement)	39 (33.1)
B2-1 (all 4 lateral rays)	20 (17.0)
B2-2 (2nd & 3rd rays)	15 (12.7)
B2-3 (4th & 5th rays)	4 (3.4)
Type C (Divergent displacement)	**9 (7.6)**
C1 (Partial)	2 (1.6)
C2 (Complete)	7 (5.9)
C2-1 (Medial column from 1st TMT joint)	5 (4.3)
C2-2 (Medial column from proximal to 1st TMT joint)	2 (1.6)
Type D2	**48 (40.7)**

*TMT: Tarso-metatarsal

They consisted of the fleck sign, intra-articular metatarsal base fractures, and fractures of 3 cuneiforms, cuboids, and navicular bones. About 3 months later, the preoperative coronal, axial, sagittal sections of 2D CT images in addition to 3D model reconstruction CT scan of all cases were reviewed by the same orthopaedic surgeons in order to diagnose aforementioned mid-foot fractures and reviewed the contradictions for an associated fracture on radiographs or CT images between the orthopaedic surgeons.

Figure 1: Homolateral total incongruity (subtype A1)

Figure 2: Dorsoplantar total incongruity (subtype A2)

Figure 3: Lateral displacement of partial incongruity with dislocation of 5th Lisfranc joint and fracture of 3rd & 4th metatarsal bones (subtype B2-3)

Statistical analysis

Gathered data were analyzed using SPSS version 16 software (SPSS Inc., Chicago, IL, USA). Continuous variables were reported as means ± standard deviations (SD), whereas the frequency and percentage were used to report the categorical variables.

The sensitivity and specificity of fleck sign, fractures in base of metatarsals, and fracture of cuneiforms, cuboid, and navicular were calculated based on the finding of CT scan as the gold standard. In order to calculate these values, each fracture found in the CT scan was labelled as true positive. If no fracture was detected in each aforementioned mid-foot bone in the CT scan, it was considered true negative.

Results

Among 118 patients with the mean age of 35.0±15.7 (range, 18-79) years, most were male (91 patients, 77.1%). Right side Lisfranc injuries (66 patients, 55.9%) were more common than the left side. The most common type was Myerson type B which was seen in 52 individuals (44.1 %) followed by D2 (48 cases, 40.7%). There were 4 cases (3.4%) in subtype of B2, defined as partial incongruity with lateral displacement of only 4th and/or 5th ray(s) with intact 1st, 2nd, and 3rd rays (Figure 3). Table 1 outlines the demographic characteristics of involved patients in addition to frequency of each type of Lisfranc injury with definitions in the parenthesis. The results of positive and negative values for different associated fractures in the mid-foot based on x-ray and CT findings are mentioned in table 2. Fractures of the second metatarsal base (87 patients, 73.7%), the fleck signs (85 patients, 72.0 %), and fractures of the third metatarsal base (65 patients, 55.0 %) were the three most frequent injuries, based on the CT scan as the gold standard. Fractures of the fifth metatarsal base (5 patients, 4.3%), middle cuneiform (14 patients, 12.0%), and navicular (15 patients, 12.7%) were the three least common associated mid-foot injuries.

The diagnostic values of plain radiographs compared to CT scan are summarized in table 3. Plain radiographs failed to show adequate sensitivity to determine associated mid-foot fractures in Lisfranc injuries with the highest value for fractures of the second metatarsal base (78.2%). The highest specificity was found for fractures of the first metatarsal base (100%).

Figure 4: Complete divergent displacement (subtype C2-1)

Table 2: Distribution of radiological findings according to X-ray and CT images

X-ray Findings	CT findings		Total
	Negative (%)	Positive (%)	
Fleck Sign			
Negative	25 (75.8)	35 (41.2)	60
Positive	8 (24.2)	50 (58.8)	58
Total	33 (100)	85 (100)	118*
Medial Cuneiform Fracture			
Negative	75 (97.4)	21 (52.5)	96
Positive	2 (2.6)	19 (47.5)	21
Total	77 (100)	40 (100)	117
Middle Cuneiform Fracture			
Negative	98 (95.2)	11 (78.6)	109
Positive	5 (4.8)	3 (21.4)	8
Total	103 (100)	14 (100)	117
Lateral Cuneiform Fracture			
Negative	86 (95.6)	25 (92.6)	111
Positive	4 (4.4)	2 (7.4)	6
Total	90 (100)	27 (100)	117
Cuboid Fracture			
Negative	72 (94.7)	17(40.5)	89
Positive	4 (5.3)	25 (59.5)	29
Total	76 (100)	42 (100)	118*
Navicular Fracture			
Negative	100 (97.1)	12 (80.0)	112
Positive	3 (2.9)	3 (20.0)	6
Total	103 (100)	15 (100)	118*
Fracture of the first metatarsal base			
Negative	76 (100)	17 (41.5)	93
Positive	0 (0)	24 (58.5)	24
Total	76 (100)	41 (100)	117
Fracture of the second metatarsal base			
Negative	22 (73.3)	19 (21.8)	41
Positive	8 (26.7)	68 (78.2)	76
Total	30 (100)	87 (100)	117
Fracture of the third metatarsal base			
Negative	44 (84.6)	27 (41.5)	71
Positive	8 (15.4)	38 (58.5)	46
Total	52 (100)	65 (100)	117
Fracture of the fourth metatarsal base			
Negative	58 (96.7)	29 (50.9)	87
Positive	2 (3.3)	28 (49.1)	30
Total	60 (100)	57 (100)	117
Fracture of the fifth metatarsal base			
Negative	109 (97.3)	2 (40)	111
Positive	3 (2.7)	3 (60)	6
Total	112 (100)	5 (100)	117

*One patient presented to our center with Splint therefore we only could diagnose the presence of fleck sign, and C1-M1 joint subluxation.

Discussion

The recent study tried to assess the diagnostic accuracy of non-weight bearing radiographs of the foot for finding associated mid-foot fractures. Associated fractures of the mid-foot in Lisfranc injuries are important not only for diagnostic purposes such as a fleck sign indicative of unstable Lisfranc injury, but also for planning the treatment. Associated mid-foot fractures should be approached accurately to prevent subsequent instabilities, secondary deformities, and arthritis. Comminuted intraarticular fractures of the metatarsal bones can change surgical plan from reduction and fixation to arthrodesis [14]. Also, cuboid fractures, particularly nutcracker fractures, accompanying Lisfranc injuries may result in shortening of lateral column of foot with the final forefoot abduction deformity [15], if treated inappropriately.

Lisfranc joint consisted of bony and intercalating ligamentous structures maintaining the mid-foot stability. Usually, the overt diastases or fracture dislocations of the TMT joints are not missed, but the main challenge is diagnosis of subtle Lisfranc injuries [16]. Based on the new edition of Myerson-modified Hardcastle classification [12], subtle low-energy Lisfranc injuries are classified as D type. We had 48 (40.7%) cases of D2 Lisfranc injury, the second most common type. Previous studies believed that subtle Lisfranc injuries usually occur following low-energy impact [17-19]; however, Pourmorteza and Vosoughi declared that the fleck sign, avulsion fracture of Lisfranc ligament, indicative of Lisfranc instability could be detected in the patients following both high- and low-energy trauma [2]. Therefore, a high index of clinical suspicion is needed to diagnose the Lisfranc injuries regardless of the severity of the trauma. Foot pain with tenderness, plantar echymosis, painful bony prominence on the medial aspect of first metatarsal bones or dorsal of mid-foot, obvious deformities, severe acute swelling with possible compartment syndrome may indicate Lisfranc injuries [13, 20]. Fleck sign presented in 58/118 plain non-weight bearing radiographs of the foot but in 85/118 CT scans (sensitivity: 58.8% & diagnostic accuracy: 63.6). Hence, non-weight bearing X-ray of the foot may not show all low-energy Lisfranc injuries with avulsion of Lisfranc ligament.

Besides diagnostic purposes, to establish the best treatment approach, an orthopaedic surgeon ought to know the detailed characteristics of Lisfranc injuries shortly following the insult. Delayed and improper treatment may lead to post-traumatic osteoarthritis, flatfoot deformity, and persistent pain [1, 21, 22]. The previous studies agree that the CT scan is a noninvasive diagnostic tool to detect Lisfranc high-energy injuries [23, 24]. Three-dimensional CT scan provides a broad assessment of different features of fracture dislocation of the Lisfranc [25]. It is found that weight bearing CT may be the greatest utility to define subtle injuries of Lisfranc joint particularly by comparing bilateral feet [26], but all centers are not equipped with pedCAT™, weight-bearing CT imaging scanner [27].

A weight bearing X-ray is not often requested on arrival because of tremendous pain and inability of the patients to stand without support. Ponkilainen et al. reported that the sensitivity of weight bearing radiographs of the foot are not more than non-weight bearing ones [28]; however, particularly for subtle Lisfranc injuries, weight bearing radiographs should be requested to show clearly the diastasis between medial cuneiform and second metatarsal base in order to prevent possible missed diagnosis [9]. Sometimes, it is more practical to take weight bearing radiographs of the foot after several days with lower pain intensity.

Although previous studies tried to calculate the distance between bones in the medial column of the foot for ligamentous Lisfranc instability by reviewing bilateral weight bearing radiographs of the feet, in the recent study we used non-weight bearing CT images as the main diagnostic tools to determine associated mid-foot fractures. By studying the preoperative radiographs and CT scan images of surgically treated Lisfranc

injuries, the X-ray images failed to show appropriate sensitivities to become a screening tool for associated mid-foot fractures in Lisfranc injuries. We cannot rely on plain radiographs of the foot to detect fleck sign (sensitivity, 58.8%). Sensitivities of plain radiographs of the foot to determine associated fractures of cuneiform bones and the navicular were the least. Fractures of medial column of foot may be indicative of intercuneiform or naviculocuneiform instabilities. Non-weight bearing radiographs, particularly oblique view, are useful to diagnose fractures of the fifth metatarsal base. Rankine et al. supposed that the TMT joint, especially the second metatarsal bone, injury cannot be precisely detected in plain radiographs, as the bases of the first and the second metatarsal bones overlap and the joint tilted obliquely on the 45º oblique and dorsoplantar views, respectively [29, 30]. Notably, studies have shown that the diagnostic yields of X-ray images are not associated with experience of radiologists or surgeons [28, 31].

This research has several limitations such as ignoring MRI as the diagnostic tool to determine possible Lisfranc ligament ruptures. Also, due to small number of cases in each type of Lisfranc injury, accuracy of radiographic variables could not be assessed for different types. The other limitation is that if we had had preoperative weight-bearing radiographs of the patients to compare with CT scan, the results might change. Strong points of our study are reviewing an acceptable number of cases with different types of Lisfranc injury and studying the radiographs by two orthopedic surgeons.

In conclusion, non-weight bearing radiographs of the foot cannot detect all associated midfoot fractures, particularly fleck sign as an indicative of Lisfranc instability in subtle injuries. Therefore, preoperative CT scan is highly recommended. Also, it is suggested to conduct another study to compare weight-bearing radiographs of the foot with CT images, of course if the patient, particularly with high-energy trauma, can tolerate standing without support on arrival to the emergency department.

Table 3: Diagnostic values of plain radiographs compared to CT scan

Radiological Findings	Sensitivity (95% CI*)	Specificity (95% CI*)
Fleck Sign	58.8(47.6-69.4)	75.8(57.7-88.9)
Medial Cuneiform Fracture	47.5(31.5-63.9)	97.4(90.9-99.7)
Middle Cuneiform Fracture	21.4(4.7-50.8)	95.1(89.0-98.4)
Lateral Cuneiform Fracture	7.4(0.9-24.3)	95.0(89.-98.8)
Cuboid Fracture	59.5(43.3-74.4)	94.7(87.1-98.6)
Navicular Fracture	20.0(4.33-48.1)	97.1(91.7-99.4)
Fracture of the first metatarsal base	58.5(42.1-73.7)	**100(95.3-100.0)**
Fracture of the second metatarsal base	**78.2(68.0-86.3)**	73.3(54.1-87.7)
Fracture of the third metatarsal base	58.5(45.6-70.6)	84.6(71.9-93.1)
Fracture of the fourth metatarsal base	49.1(35.6-62.7)	96.7(88.5-99.6)
Fracture of the fifth metatarsal base	60.0(14.7-94.7)	97.3(92.4-99.4)

*CI: Confidence Interval

Declarations

Ethical Approval ID:

This study was performed after the approval of the study by the ethical committee of Shiraz University of Medical Sciences in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Approval ID IR.SUMS.MED.REC.1399.617

Availability of data and materials:

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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