Annals of Medical Research
DOI: 10.5455/annalsmedres.2019.01.050 2019;26(5):867-72

Original Article

Comparison of radiography and computed tomography in emergency department evaluation of ankle trauma

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Abstract

Aim: The aim of this study was to compare computed tomography (CT) and radiography (XR) images of patients presented to the emergency department with ankle trauma and undergone CT imaging, and to describe the fractures for which XR is insufficient and the characteristics of these fractures.

Material and Methods: This retrospectively designed study included patients presented to the emergency department with ankle trauma between January 2016 and December 2017. Patients who had ankle trauma, who performed XR and CT imaging were included in the study. The XR and CT images were reinterpreted by a radiologist.

Results: Three hundred and sixteen patients were enrolled in the study. Of the patients, 137 (43.4%) had fracture on XR and 168 (53.2%) had fracture on CT. The most common bone fractures were detected lateral malleolus and distal tibia fractures. The sensitivity and specificity of XR in detecting fracture compared to CT were 75% and 93%, respectively. Sixty-three (20%) of the patients had two simultaneous fractures. The sensitivity and specificity of XR in detecting two simultaneous fractures were 56% and 94%, respectively. Twelve (3.8%) of the patients had distal tibial, medial malleolus and lateral malleolus fractures (trimalleolar fracture). The sensitivity and specificity of XR in detecting trimalleolar fracture were 17% and 100%, respectively.

Conclusion: XR has a low sensitivity in identifying ankle fractures. The sensitivity is much lower in cases of two simultaneous fractures and trimalleolar fractures. Therefore, CT imaging should be preferred in patients with complex ankle injuries.

Keywords: Ankle Injury; Computed Tomography; Emergency Service; Hospital; X-Ray.

INTRODUCTION

Ankle injuries are one of the most common causes of admission to the emergency department. Ankle fractures account for 9% of all fractures and have an annual incidence of approximately 122-184-100.000 (1). Ankle injuries show a bimodal distribution with peaks in young males and elderly females. The cause is high-energy trauma in the first group, while it is osteopenia and osteoporosis in the second group (2).

Early diagnosis of ankle injuries can minimize the risk of suboptimal or delayed treatment. Radiography (XR) remains the imaging standard for the evaluation of bones after trauma (3). However, ankle fractures may not be noticed on XR images due to overlapping structures, possible suboptimal position, technical and other problems. Computed tomography (CT) has a higher sensitivity and specificity than XR in the evaluation of bone structures. CT images can be more easily interpreted than XR images, even if the anatomical structure has been destroyed due to trauma. However, it is recommended that CT imaging be performed in selected cases because of its high cost and exposure to high levels of radiation (4,5).

Preoperative and postoperative comparison studies were conducted with XR for the decision of CT imaging in ankle fractures (6-8). However, there are a limited number of studies describing the fractures for which XR imaging is insufficient in the emergency department and the characteristics of these fractures. The aim of this study was to compare CT and XR images of patients presented to the emergency department with ankle trauma and undergone CT imaging, and to describe the fractures for which XR is insufficient and the characteristics of these fractures.

Received: 27.01.2019 **Accepted:** 06.03.2019 **Available online:** 28.03.2019
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MATERIAL and METHODS

This retrospectively designed study included patients presented to the emergency department of a tertiary hospital with ankle trauma between January 2016 and December 2017 following ethics committee approval. The information and radiology images of patients were obtained from the hospital database system. All patients in all age groups undergone XR and CT imaging of the ankle were included in the study. Patients who underwent imaging for non-traumatic reasons and whose XR or CT images could not be reached from the hospital database system were excluded from the study.

A standard data record form was created for the study. The demographic information of the patients, interpretations of XR and CT images, treatment modalities used for the patients and outcomes of the patients were recorded on this form. The XR and CT images were reinterpreted by a radiologist.

The evaluation of osseous structures on the XR and CT images was carried out according to the 8-item "Modified Kozaci Protocol" (Table 1) (9). Fractures that were calcaneal as an adjacent fracture, localized in the distal fibula and extra-articular were evaluated as "distal fibular fracture".

Table 1. Interpretation protocol of radiography and computed tomography images (Modified Kozaci Protocol) (9).

1	Detection presence of fracture (cortical deterioration)
2	Determine the type (fissure, linear, fragmented, torus) and localization of fracture.
3	Measure the degree of angulation of the fracture.
4	Measure the distance of stepping-off.
5	Is there an extension of the fracture into the joint space or epiphyseal line?
6	Does the fracture include epiphyseal line? (growth plate fracture?)
7	Detect the presence of concomitant adjacent bone fracture.
8	Control of the joint space and the presence of joint dislocation.

Data Analysis

Analysis of the data collected in the study was performed using Statistical Package for the Social Sciences 21 statistical software package (IBM Corporation, IL, USA). Sensitivity, specificity, positive and negative predictive values of XR in the identification of fractures compared with CT were calculated. Dataset are reported as percentages with a 95% CI. For descriptive statistics, data obtained using Chi-square test and kappa statistics were compared.

RESULTS

Three hundred and sixteen patients were enrolled in the study. Of the patients, 91 (28.8%) were females and 225 (71.2%) were males. The mean age of the patients was 37.65±16.50 (min: 3, max: 87) years. One hundred and thirty-seven (43.4%) patients had fracture on XR and 168 (53.2%) had fracture on CT. The most common detected bone fractures were lateral malleolus and distal tibia fractures. The sensitivity and specificity of XR in detecting fracture compared to CT were 75% and 93%, respectively (AUC: 0.838, CI: 0.791-0.884) (Figure 1, Table 2).

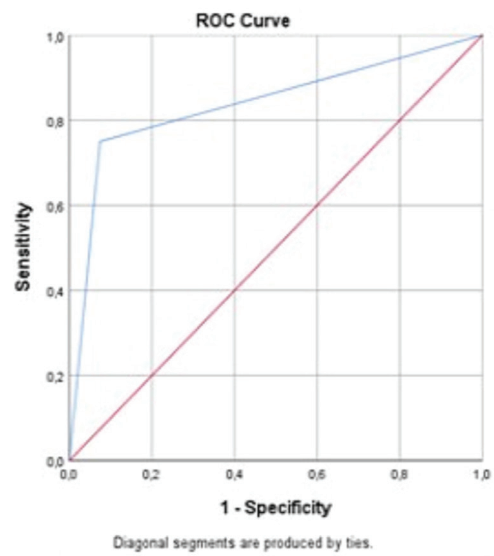

Figure 1. ROC curve showing the sensitivity and specificity ratio for x-ray to detect the ankle fractures

Table 2. Ankle fractures detected by radiography and computed tomography

Bone	XR		CT	
	(n)	%	(n)	%
Distal tibia	51	16.1	77	24.4
Medial malleolus	31	9.8	43	13.6
Distal fibula	12	3.8	18	5.7
Lateral malleolus	51	16.1	77	24.4
Talus	9	2.8	13	4.1
Calcaneus	29	9.2	38	12.0

XR: Radiography; CT: Computer Tomography

Sixty-three (20%) of the patients had two simultaneous fractures. In the group which has distal tibial fracture, 37 (46.0%) had lateral malleolus fracture, 15 (19.4%) had medial malleolus fracture, 3 (3.8%) had talus fracture and 2 (2.6%) had calcaneal fracture. Twenty-four (7.6%) of the patients had lateral and medial malleolus fractures simultaneously. The sensitivity and specificity of XR in detecting two simultaneous fractures were 56% and 94%, respectively (AUC: 0.748, CI: 0.669-0.827). Twelve (3.8%) of the patients had distal tibial, medial malleolus and lateral malleolus fractures (trimalleolar fracture). The sensitivity and specificity of XR in detecting trimalleolar fracture were 17% and 100%, respectively (AUC: 0.583, CI: 0.399-0.768).

The specificity of XR in detecting all bone fractures was 97% and higher (Table 3). The sensitivity of XR was 58% in lateral malleolus fractures, while it was 100% in distal fibula fractures. The lowest sensitivity of XR was determined in talus fractures (Figure 2). Of the talus fractures, 6 (46%) were fragmented fractures and 11 (85%) had extension of the fracture into the joint space.

Table 3. The sensitivity and specificity rates of radiography to detect fractured bone

Bone	Sensitivity %	Specificity %	AUC	95% CI
Distal tibia	57	97	0.771	0.700-0.843
Medial malleolus	63	98	0.807	0.716-0.897
Distal fibula	100	98	0.990	0.980-1.000
Lateral malleolus	58	97	0.780	0.7093-0.851
Talus	30	98	0.646	0.464-0.827
Calcaneus	71	99	0.852	0.764-0.940

AUC: area under the curve, CI: confidence interval

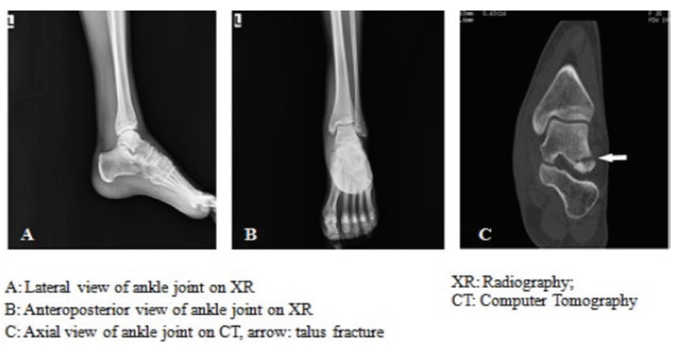

Figure 2. A 21 year-old male patient admitted to the emergency department because of falling down. He had tenderness and swelling on his ankle joint. X-ray showed no-fracture. Computed tomography scan showed a linear fracture on talus. Then, the patient was hospitalized due to tomography findings

XR showed no fracture in 179 patients (56.6%) and CT showed no fracture in 148 (46.8%) patients. The most common fracture type was linear fracture and the second most common fracture type was fragmented fracture on XR, while the most common fracture type was fragmented fracture and the second most common fracture type was linear fracture on CT (Table 4). The highest sensitivity of XR in detecting fracture type was found in cases of linear fracture. The sensitivity was calculated to be very low in fragmented, circular, avulsion and fissure fractures (Table 5).

Fourteen (4.4%) patients had tibiofibular syndesmosis diastasis and 67 (21.2%) had extension of the fracture into the joint space on XR, while 18 (5.7%) had tibiofibular syndesmosis diastasis and 115 (36.4%) had extension of the fracture into the joint space on CT (Table 6).

Forty-four (14%) of the patients were 18 years old and younger. In 13 (30%) of these patients, growth plate fracture was detected on CT. Ten (77%) of these fractures were in the tibia and 3 (23%) were in the fibula. The sensitivity of XR in detecting growth plate fractures was 54%.

The sensitivity of XR in detecting extension of the fracture into the joint space, growth plate fracture, angulation, stepping-off, and tibiofibular syndesmosis diastasis was calculated as 56% and lower (Table 7).

Eighty eight (27.8%) patients were hospitalized and 228 (72.2%) were discharged from the emergency department.

Table 4. Ankle fracture types detected by radiography and computed tomography

Fracture types	XR		CT	
	(n)	%	(n)	%
No fracture	179	56.6	148	46.8
Fissure	13	4.1	11	3.4
Linear	64	20.2	44	13.9
Circular	14	4.4	24	7.5
Fragmented	42	13.2	78	24.6
Avulsion	4	1.2	11	3.4

XR: Radiography; CT: Computer Tomography

Table 5. Sensitivity of XR in identifying the fracture type

Fracture types	Sensitivity %	Specificity %	AUC	95% CI
Fissure	9	96	0.526	0.345-0.707
Linear	55	85	0.699	0.606-0.792
Fragmented	37	94	0.659	0.582-0.736
Circular	25	97	0.833	0.478-0.744
Avulsion	9	99	0.541	0.356-0.725

XR: Radiography

Table 6. Ankle fracture characteristic detected by radiography and computed tomography

Fracture characteristics	XR		CT	
	(n)	(%)	(n)	(%)
Extension of the fracture into the joint space	67	21.1	115	36.4
Growth plate fracture	8	2.5	13	4.1
Angulation	56	17.7	73	23.1
Stepping-off	63	19.9	98	31.0
Tibiofibular syndesmosis diastasis	14	4.4	18	5.7

XR: Radiography; CT: Computer Tomography

Table 7. The sensitivity and specificity of radiography in determining the characteristics of fracture

Fracture characteristics	Sensitivity %	Specificity %	AUC	95% CI
Extension of the fracture into the joint space	48	94	0.709	0.645-0.773
Growth plate fracture	54	100	0.768	0.595-0.941
Angulation	56	94	0.750	0.676-0.824
Stepping-off	49	93	0.710	0.643-0.778
Tibiofibular syndesmosis diastasis	50	98	0.742	0.592-0.891

AUC: area under the curve, CI: confidence interval

DISCUSSION

The ankle joint consists of three bones and multiple ligaments. The distal fibula and tibia are connected to each other by an interosseous membrane or syndesmosis. The posterior and anterior tibiofibular ligaments strengthen this joint. The talus articulates with the lateral malleolus and medial malleolus. The lateral and medial collateral ligament complexes connect the malleoli to the talus and calcaneus (10). Therefore, there may be fracture in multiple bones in cases of ankle injuries.

The evaluation of osseous structures in ankle injuries is usually carried out using three standard projectional XRs which are antero-posterior, latero-lateral and mortise view of the ankle (11,12). Mortis view is especially important to evaluate the position of the talus and syndesmosis (13). However, CT imaging has recently been started to be used more commonly in ankle injuries. In a study evaluating the advantages of CT compared to XR in the diagnostic assessment of acute ankle and foot trauma, it was found that three most common fractures, which cannot be detected in the ankle on XR, were posterior and medial malleolus fractures and Tillaux fractures (7). Therefore, CT imaging is recommended to evaluate fractures, their anatomical relationships, extent of comminution and intra-articular bodies in ankle injuries (4). Moreover, CT imaging has been shown to be useful in cases of dislocated fractures, fractures that may be obscure on XR due to cast, trimalleolar fractures and suprasyndesmotic fractures (6). In a study, preoperative CT was shown to significantly alter the surgical strategy in 24% of malleolus ankle fracture cases (6). In a study comparing the treatment of trimalleolar ankle fracture before and after CT, it was shown that the surgical planning, technique and approach of a surgeon frequently changed with additional information provided by CT, and that radiographs alone were insufficient to determine the characteristics of a fracture (5). In our study, the most common bone fractures were distal tibia, medial and lateral malleolus fractures. The overall sensitivity of XR in detecting ankle fractures was 75%. It was seen that the sensitivity of XR was low, especially in talus (sensitivity: 30%), medial malleolus (sensitivity: 63%) and lateral malleolus (sensitivity: 58%) fractures. Twenty percent of the patients had two simultaneous fractures, and the sensitivity of XR in detecting two simultaneous fractures was 56%. Furthermore, 3.8% of the patients had distal tibia, medial malleolus and lateral malleolus fractures simultaneously. The sensitivity of XR in detecting trimalleolar fracture was 17%. The sensitivity of XR was determined to gradually decrease in multiple fractures. This suggested that the fragments of a fractured bone may cause an error in interpreting XR images. In addition to this information, the sensitivity in detecting angulation and stepping-off of fractures was rather low (56% and 49%, respectively). In fracture types, the sensitivity in detecting other fractures was calculated to be rather low, except for linear fractures. The sensitivity of XR was 37% in the diagnosis of fragmented fractures and 25% in the diagnosis of circular fractures. These results indicate that XR is insufficient for the imaging of fracture fragments. This issue is important since it may affect the treatment decision.

In ankle injuries, different classifications have been proposed for the evaluation of fractures, clinical decision making, determination of prognosis, documentation and understanding of researches and literature. In these classifications, fractured bone, fracture localization, fracture type and extension of the fracture into the joint space are important parameters (2,14). However, XR has been reported to be insufficient for the imaging of extension of the fracture into the joint space. In a study, it was reported that while XR provided sufficient information for the surgical planning in extra-articular fractures of the distal tibia, CT was important to detect the extension of the fracture into the joint space. CT scans have been shown to provide additional information on fracture structure, resulting in a 64% change in the surgical approach planned initially (18). In a study comparing CT with XR to evaluate the extension of long bone fractures into the joint space, it was concluded that CT imaging was necessary to display the extension of the fracture into the joint space in distal femoral diaphyseal fractures and all metaphyseal fractures (17). In our study, the extension of the fracture into the joint space was detected on CT in 36.4% of the patients. The sensitivity of XR in detecting the extension of the fracture into the joint space was 48%.

The distal tibiofibular syndesmosis tends to disintegrate as a result of ankle fractures and ligament injuries. If not diagnosed and treated properly, it may result in chronic instability and arthrosis. An injured syndesmosis should be evaluated very well for reduction and stabilization in accordance with the anatomy (19). The diagnosis of syndesmosis injury is made based on clinical examination and XR. In suspected cases, further investigations can be performed using CT, magnetic resonance imaging or ankle arthroscopy. However, important decisions are made by taking measurements with XR since these tests are costly and require specialty (15). However, axial CT has been reported to be much better than conventional radiography for the evaluation of syndesmosis, and in our day, some authors use CT for postoperative evaluation of reduction (21). In a study conducted on cadaveric models, the sensitivity of CT was found to be very high in minor syndesmosis injuries (20). In our study, diastasis of the tibiofibular syndesmosis was detected on CT in 6% of the patients. The sensitivity of XR in detecting diastasis compared to CT was 50%.

Growth plate fractures of the distal tibia are the second most common fractures of immature skeleton. Growth plate fractures are high-risk for secondary complications. These fractures may cause separation on the articular surface, posttraumatic arthrosis and joint destruction, and may result in asymmetric healing and deformation. In a study comparing XR with CT in growth plate fractures of the distal tibia, it was found that the sensitivity of XR was lower than 90% in fractures involving the metaphysis, while it was 64% in separation of the articular surface, 61% in dorsal formation of the articular surface, and 79% in subluxation. Again in this study, there was no misclassification in Salter-Harris (SH) type I and II, while highest misclassification rate was found in SH type III fractures (16). In our study, in which we generally evaluated growth plate fractures, 14% of the patients were 18 years old and younger. In 30% of these patients, growth plate fracture was detected on CT. Seventy-seven percent of growth plate fractures were localized in the tibia and 23% in the fibula. The sensitivity of XR in detecting growth plate fractures was 54%.

Talus is the second largest bone of the foot. Talus fractures result from high-energy traumas and are rare. However, when not diagnosed and treated properly, talus fractures lead to avascular necrosis, pseudoarthrosis, early osteoarthritis and ankle instability. Mortis view allows the anterolateral evaluation of the talus without superimposition of the lateral malleolus. However, it is not always possible to obtain a high quality XR (4). In line with the literature, talus fracture was detected on CT images in 4.1% of the patients in our study. The lowest sensitivity of XR was calculated in talus fractures among the ankle bones and found as 30%. Moreover, of the talus fractures, 46% were fragmented fracture and 85% had extension of the fracture into the joint space. Therefore, CT imaging should be considered in the case of suspicion for talus fracture.

Although calcaneal fractures are rare, in most cases, posterior joint facet involvement of the talocalcaneal joint is present. In cases of injury, the calcaneus is initially visualized with medio-lateral and axial XR. However, CT imaging is also used in the diagnosis (22). CT displays the characteristics of fracture lines and displacement of fractures better than XR (23). In a study investigating the effect of CT on final outcomes and treatment decision in calcaneus fractures, it was found that open reduction and internal fixation were performed more commonly in patients undergone CT imaging, and that intra-articular congruence was better in the postoperative period (24). In our study in which we also evaluated the calcaneal fractures as a bone adjacent to the ankle bones, 12% of the patients had calcaneal fracture and the sensitivity of XR was 71%. The sensitivity of XR in the diagnosis of calcaneal fractures was higher compared to that of the ankle bones.

CONCLUSION

In conclusion, XR has a low sensitivity in identifying ankle fractures, especially in talus fractures. The sensitivity is much lower in cases of two simultaneous fractures and trimalleolar fractures. Moreover, XR is insufficient identifying diastasis of the tibia-fibula syndesmosis, extension of the fracture into the joint space and growth plate fractures. Therefore, CT imaging should be preferred in patients with complex ankle injuries. However, more extensive studies are needed.

Limitation

In the clinical management of the patients were evaluated together x-ray images and examination findings. As our study was performed retrospectively, x-rays were interpreted without patient's examination findings.

Competing interests: The authors declare that they have no competing interest.
Financial Disclosure: There are no financial supports
Ethical approval: Antalya Training and Research Hospital Ethics Committee of Clinical Research, Date: 2019, Issue: 103

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