Missed Fractures on Emergency Room Ankle Radiographs: An Analysis of 433 Patients

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The purpose of this study was to review fractures and radiographic abnormalities that are detectable, but often overlooked, on a standard ankle radiographic series. We carried out a retrospective review of 556 consecutive ankle radiographic series obtained between June 1, 1995, and May 31, 1996. From this population, 433 complete ankle radiographic series on patients with suspected trauma were selected. The original radiologist's interpretation was compared to a two-step "gold standard" interpretation, consisting of reinterpretation by a musculoskeletal radiologist with the patient's medical and imaging records at hand, with review of discrepant cases by a consensus panel.

Eighteen studies were incorrectly interpreted at the initial reading, yielding an overall error rate of 4.2%. Fifteen of the errors were missed fractures, ankle syndesmotic widening, or incorrect classification of old fractures as acute. The rate for this type of error was 3.5%. The most commonly missed fractures were of the talus (4 patients), followed by fracture of the base of the fifth metatarsal and calcaneal stress fracture (2 cases each); tibiofibular syndesmotic injury was missed in 2 cases.

Missed fractures on ankle radiographs most commonly involved bones of the hindfoot, especially the talus. It is important to recognize these uncommon and easily missed fractures, so that a modified search pattern may result in improved accuracy of radiographic interpretation.

Key Words

Emergency medicine, methods; Fractures, diagnosis; Ankle joint, radiography; Foot, radiography

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Ankle injuries are an extremely common reason for a visit to the emergency department; up to 12% of emergency room presentations involve an ankle injury (1). Ankle radiographs make up 10% of all radiographs obtained on emergency room patients (2). Accurate characterization of these radiographs is important for guiding patient management. Although some fractures, such as malleolar fractures, are readily identified, other injuries can be more difficult to detect. The purpose of this paper is to review our experience with emergency department ankle radiographs to assess which fracture types are most often missed and how to improve diagnostic accuracy in the emergency setting.

MATERIALS AND METHODS

We retrospectively reviewed 556 consecutive ankle radiographic series obtained between June 1, 1995, and May 31, 1996, on patients from the emergency department. Studies were included only if they were a complete radiographic series, consisting of an anteroposterior (AP), lateral, and mortise view, on a patient with recent trauma and in whom no prior instrumentation or casting had been performed. Using these inclusion criteria, 41 of the 556 radiographic series were excluded for incomplete studies, 27 for casted or instrumented patients, 24 that were not ordered to evaluate trauma, and 30 studies that had missing films. In addition, one other patient was excluded as no confident gold standard could be applied (described below). As a result, 433 ankle radiographic series were reviewed from this consecutive retrospective series.

The original radiologist's interpretation was compared to a "gold standard" interpretation. The gold standard reading consisted of a two-step process, with an initial review by a musculoskeletal radiologist, who was supplied with each patient's subsequent studies, including plain radiographs, computed

tomographic (CT) scans, and magnetic resonance imaging (MRI) studies, if done; each patient's medical record was available for review. If the original interpretation and the reinterpretation were in agreement, the original interpretation was considered correct. If the original interpretation and the reinterpretation were discrepant, these images were further evaluated by four reviewers, consisting of two additional musculoskeletal radiologists and two orthopaedic surgeons specializing in foot and ankle trauma. All additional interpretations were performed independently; the results were pooled for a final consensus reading on the discrepant cases. For this study, presence or absence of soft tissue swelling was not scored. An indecisive report that mentioned an abnormality found to be present on review was counted as a true-positive, and an indecisive report that raised a question of fracture that at reinterpretation was found to be normal was counted as a false-positive.

RESULTS

Of the 433 studies, 147 were abnormal (34%). The original interpretation was correct in 129 of the abnormal studies, yielding an overall sensitivity of 88%. There was one false-positive study, yielding a specificity of 99%. Eighteen studies were incorrectly interpreted at the initial reading, yielding an overall error rate of 4.2% (Table 1). Fifteen of the errors were missed fractures, ankle syndesmotic widening, or incorrect classification of old fractures as acute. The rate for this type of error was 3.5%.

At the ankle joint, an old fracture of the fibula was incorrectly interpreted as an acute fracture in one patient, and one case of a physeal injury of the distal fibula (Salter-Harris type I) was not detected on initial radiographs. In two cases, fractures of the distal tibia, in association with other ankle fractures, were not described. Significant widening of the distal tibiofibular syndesmosis was not correctly identified in two patients.

There were four cases of missed injuries to the talus. An acute osteochondral fracture of the talar dome was not detected in two patients (Fig. 1), a sagittally oriented fracture of the talar dome was missed in one patient (Fig. 2), and fracture of the lateral process of the talus was missed in one patient (Fig. 3).

One patient had bilateral fatigue fractures of the calcaneus that were not detected on initial interpretation (Fig. 4). In one patient, avulsion of the origin of the extensor digitorum brevis was overlooked (Fig. 5). Two patients with fracture of the base of the fifth metatarsal were originally reported as having no fracture detected (Fig. 6). The other three incorrect interpretations were not related to trauma; a subtalar coalition, an intraosseous lipoma of the calcaneus, and a ganglion cyst of the distal fibula were missed in one patient each.

Delay of diagnosis occurred in only two patients. The osteochondral fracture of the talus was not correctly diagnosed until radiographs were performed at 10-day

TABLE 1

Ankle radiographic studies with incorrect interpretations at initial reading

Location	*Error (Injury Missed unless Noted)*	*Number of Cases*	*Morbidity*
Ankle			
Fibula	Old fracture called acute	1	
Fibula	Salter-Harris I fracture	1	
Syndesmosis	Widening	2	
Distal tibia	Anterior, posterior lip of tibia	2	
Talus			
	Osteochondral fracture	2	10-day delay in 1 patient
	Sagittal dome fracture	1	3-month delay in diagnosis
	Lateral process fracture	1	
Calcaneus			
Body	Stress fracture	2	
Anterior process	Extensor digitorum brevis avulsion	1	
Metatarsal			
5th metatarsal	Fracture at base	2	
Other			
Talus	Subtalar coalition	1	
Calcaneus	Intraosseous lipoma	1	
Fibula	Intraosseous ganglion	1	

Figure 1

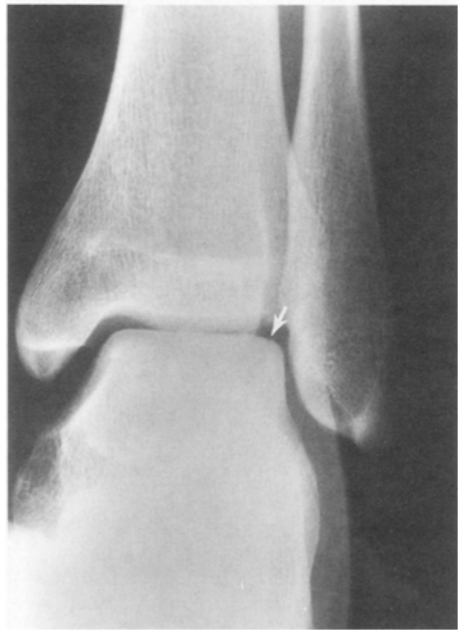

Figure 1. Osteochondral fracture of the talus. AP radiograph shows very subtle cortical stepoff (arrow), which was overlooked on initial review. Fracture was noted on follow-up radiograph.

Figure 2

Figure 2. Sagittal fracture of the body of the talus. This 56-year-old woman, who was involved in a motor vehicle accident, presented with ankle pain. Initial radiographs were normal. **Left and center,** follow-up radiographs obtained 3 months after the injury show sclerosis of the talar dome, but no definite fracture lucency is present. **Right,** CT obtained after an arthrogram/anesthetic injection clearly shows the sagittal fracture through the talar dome (arrow).

Figure 3

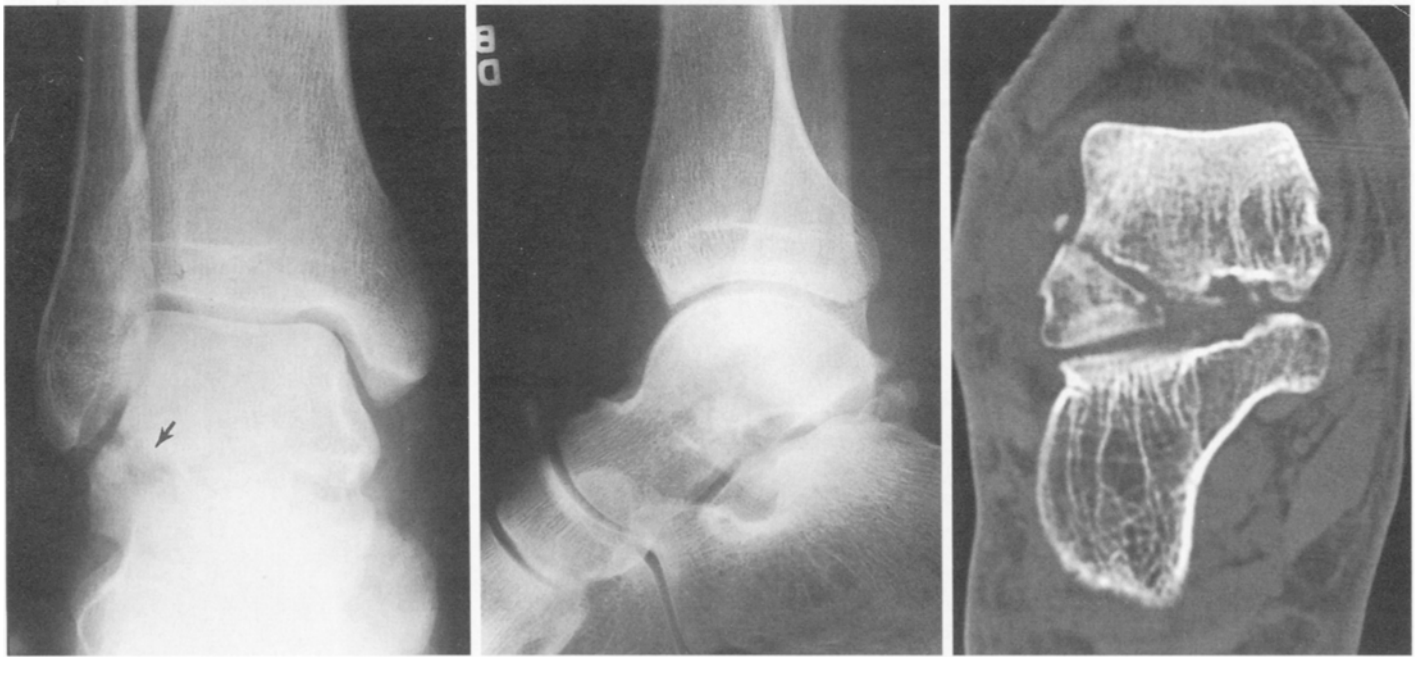

Figure 3. Fracture of the lateral process of the talus. Left, AP radiograph shows subtle, obliquely oriented lucency through the lateral aspect of the talus (arrow). **Center,** fracture not clearly visible on lateral view. Note os trigonum posterior to talus, unrelated to fracture. **Right,** coronal CT slice clearly shows the size and extent of the fracture, which involves both the fibular and subtalar articular surfaces.

Figure 4

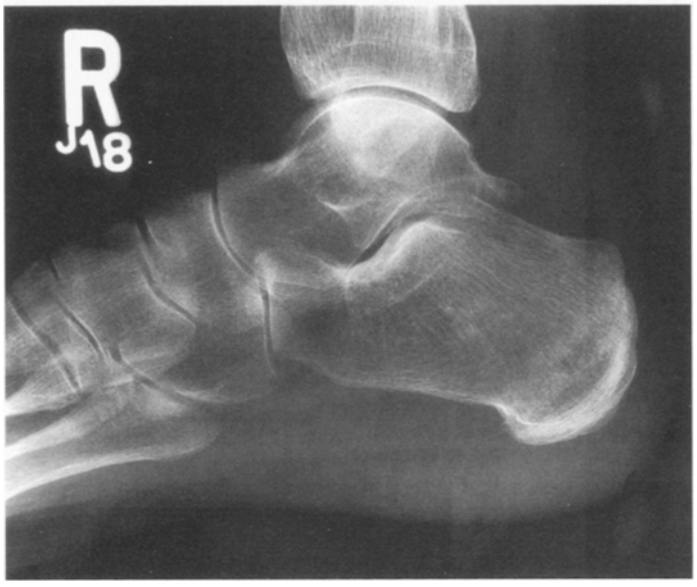

Figure 4. Calcaneal fatigue fracture. Lateral radiograph shows linear area of sclerosis anterior to the tuberosity, typical of stress or fatigue fracture. This patient had similar findings on the other calcaneus as well.

follow-up. The sagittal fracture of the talar dome was not correctly identified for 3 months, when a CT scan was ordered to evaluate the patient's ongoing symptoms.

DISCUSSION

Radiographs of the ankle are obtained to evaluate for fractures and dislocations and also to look for signs of ligamentous injury. History often is lacking, and when present, it frequently is no more than "rule out fracture." When a foot series is not ordered at the same time, there is often no indication that the patient has symptoms distal to the ankle. As can be seen from the spectrum of missed injuries in this series of radiographic studies, incorrectly interpreted injuries of the ankle joint are less common than missed injuries of the foot.

Ankle

Two cases of widening of the distal tibiofibular syndesmosis were not recognized at the time of initial interpretation. This injury can be difficult to diagnose, but it is important to identify, as it can result in the talus shifting laterally in the ankle joint, which may increase joint contact pressures (3) and, over time, can lead to osteoarthritis. The key radiographic feature of syndesmotic injury is widening of the space between the distal tibia and fibula. The clear space has been defined as the distance between the distal tibia and fibula, measured 1 cm proximal to the plafond. In both the AP and mortise views, this space should be 6 mm or less (4). In addition, the tibia and fibula should overlap on both AP and mortise views. If there is a suspicion of ligamentous injury and initial radiographs are normal, stress views can be performed to detect latent diastasis (5).

Foot

Talus

Of foot fractures, injuries to the talus were the most commonly missed in our series. The talus is the second most commonly fractured bone of the foot, surpassed only by fractures of the calcaneus (6, 7). Fifty percent of talus fractures are of the neck, whereas 50% of fractures consist of

Figure 5

Figure 5. Avulsion of the origin of extensor digitorum brevis. Left, AP radiograph shows that the ankle joint is normal, but a tiny flake of bone is present adjacent to the anterior aspect of the calcaneus (arrow). **Right,** reverse oblique view of the foot better shows the avulsion fragment (arrow). This location is where the extensor digitorum brevis muscle originates. Clinically, avulsions of this muscle resemble an ankle sprain.

Figure 6

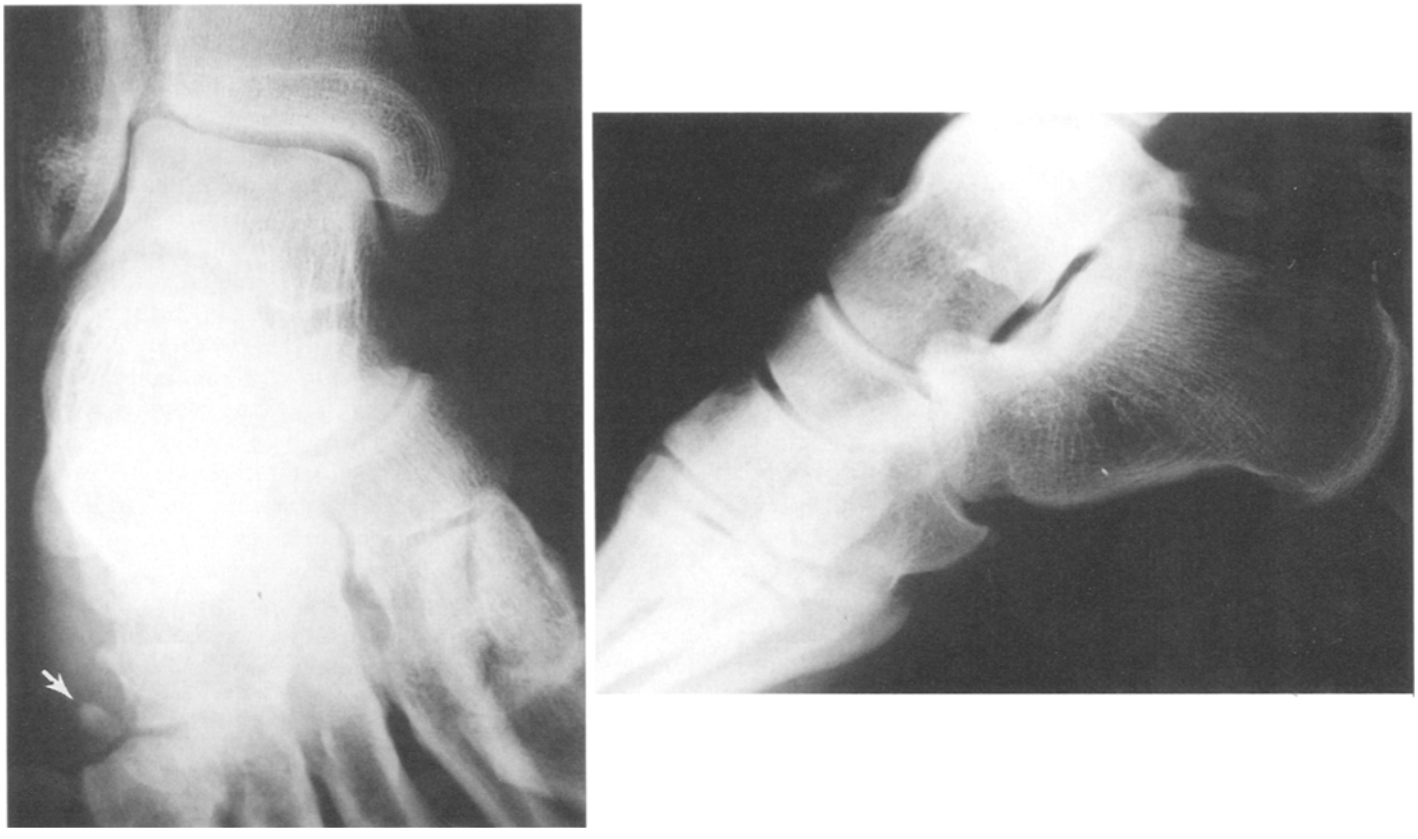

Figure 6. Fracture of the base of the fifth metatarsal. Left, AP radiograph from an ankle series shows fracture fragment arising from the base of the fifth metatarsal (arrow). **Right,** lateral radiograph from the same series fails to demonstrate the fracture. Usually, the lateral view is the best view from an ankle series for demonstrating avulsion fractures from the base of the fifth metatarsal.

other injuries, such as avulsion fractures and osteochondral injuries (8). In our series, talar neck fractures were present, but all were correctly identified at initial interpretation. The missed fractures of the talus included osteochondral impactions as well as a sagittal fracture of the talar dome and a fracture of the lateral process.

The lateral process of the talus is an important anatomic structure, with both superior and inferior articulations. The superior articulation with the fibula makes up a portion of the lateral clear space on the mortise view, and the inferior articulation constitutes the lateral third of the posterior facet of the subtalar joint. The lateral talocalcaneal ligament attaches to the lateral process (9). Fractures of the lateral process have been classified by Hawkins (10) into three types: type 1, a nonarticular chip fracture; type 2, a single large fragment involving both the superior and inferior articular surfaces; and type 3, a comminuted fracture involving both the superior and inferior surfaces. Stress fractures can occur at the lateral process (11, 12).

The mechanism of injury for lateral process fractures is similar to that of an ankle sprain (13), and the two entities have similar physical findings (9, 14). As a result, an ankle radiographic series is often the only ordered diagnostic imaging study, without special views of the talus. Lateral process fractures are difficult to see on the lateral radiograph and are best seen on the AP view (6). These fractures are notoriously difficult to diagnose, which may lead to increased risk of nonunion and persistent symptoms (10, 13, 15). Therefore, special attention to the lateral process on the AP and mortise views is indicated to minimize a risk in delay of diagnosis and long-term symptoms. CT allows better characterization of process fractures of the talus than does plain radiography (16–18).

Fractures of the talar dome consist predominantly of osteochondral impaction fractures, which occur during inversion of the ankle (19, 20). The fractures can occur on either the medial or lateral aspect of the dome, depending on the degree of ankle flexion at the time of inversion. With dorsiflexion, lateral dome injuries predominate, whereas with plantar flexion, medial dome injuries occur (6).

Radiographic detection of osteochondral injuries is difficult, and many are overlooked. Two cases were overlooked in our series. This happens because the planar nature of radiographs may not capture the semicircular dome impaction in tangent. CT can demonstrate osteochondral injuries (21), and MRI is very sensitive at detecting osteochondral defects. MRI has the added advantage of allowing detection of fragment detachment (22, 23).

Fractures of the body of the talus can occur, although they are much less common than fractures of the neck of the talus. These fractures are difficult to diagnose on initial radiographs. There is a high complication rate, including osteonecrosis and posttraumatic arthritis with persistent symptoms (24). Types of injuries include compression fractures of the talar dome as well as sheer fractures in the sagittal or coronal plane (25). One patient in our population had a missed talar dome fracture, with a 3-month delay in diagnosis. The fracture was finally detected by a CT study, which was ordered for the purpose of investigating the cause of the patient's persistent symptoms.

Calcaneus

The calcaneus is the most commonly injured bone of the foot (26, 27). Calcaneal fractures are divided into intra-articular and extra-articular types. Seventy-five percent of calcaneal fractures involve the articular surface (27). The main types of articular fractures, as defined by the Essex-Lopresti classification, are tongue-type fractures and joint-depression fractures (28). It is important to note that calcaneal fractures are bilateral in 5–9% of the cases (26). In 10% of cases of calcaneal fracture, there is an associated fracture of the thoracolumbar spine (29). Associated injuries of the lower extremities are common and are reported in 26-70% of cases (29–32).

A number of cases of articular calcaneal fracture were present in the study population, and all cases were correctly interpreted at initial review. Most of these patients had both ankle and foot radiographs taken at the same time. Although comprising only 25% of calcaneal fractures, extra-articular fractures of the calcaneus are more difficult to diagnose than are articular fractures. Extra-articular fractures initially overlooked in our series included fractures of the anterior process, avulsion of the origin of the extensor digitorum brevis, and fatigue fractures.

Anterior process fractures are the most common nonarticular fracture of the calcaneus and are usually related to avulsion of the bifurcate ligament (33–36). This injury constitutes 15% of all calcaneal fractures (37). The mechanism of injury is adduction with the foot in equinus position. Bifurcate ligament avulsions are more common in women (26); this prevalence may be related to the wearing of high heels, which places the foot into plantar flexion (27). On an ankle radiographic series, this fracture is visualized only on the lateral radiograph and is best seen on an oblique view of the foot (27). Compression fractures of the anterior process of the calcaneus can occur as the cuboid bone is impacted against the calcaneus during abduction of the forefoot (38) and can lead to posttraumatic arthrosis and persistent symptoms (Ref. 26; Fig. 7). However, compression fractures are less common than bifurcate ligament avulsions.

Figure 7

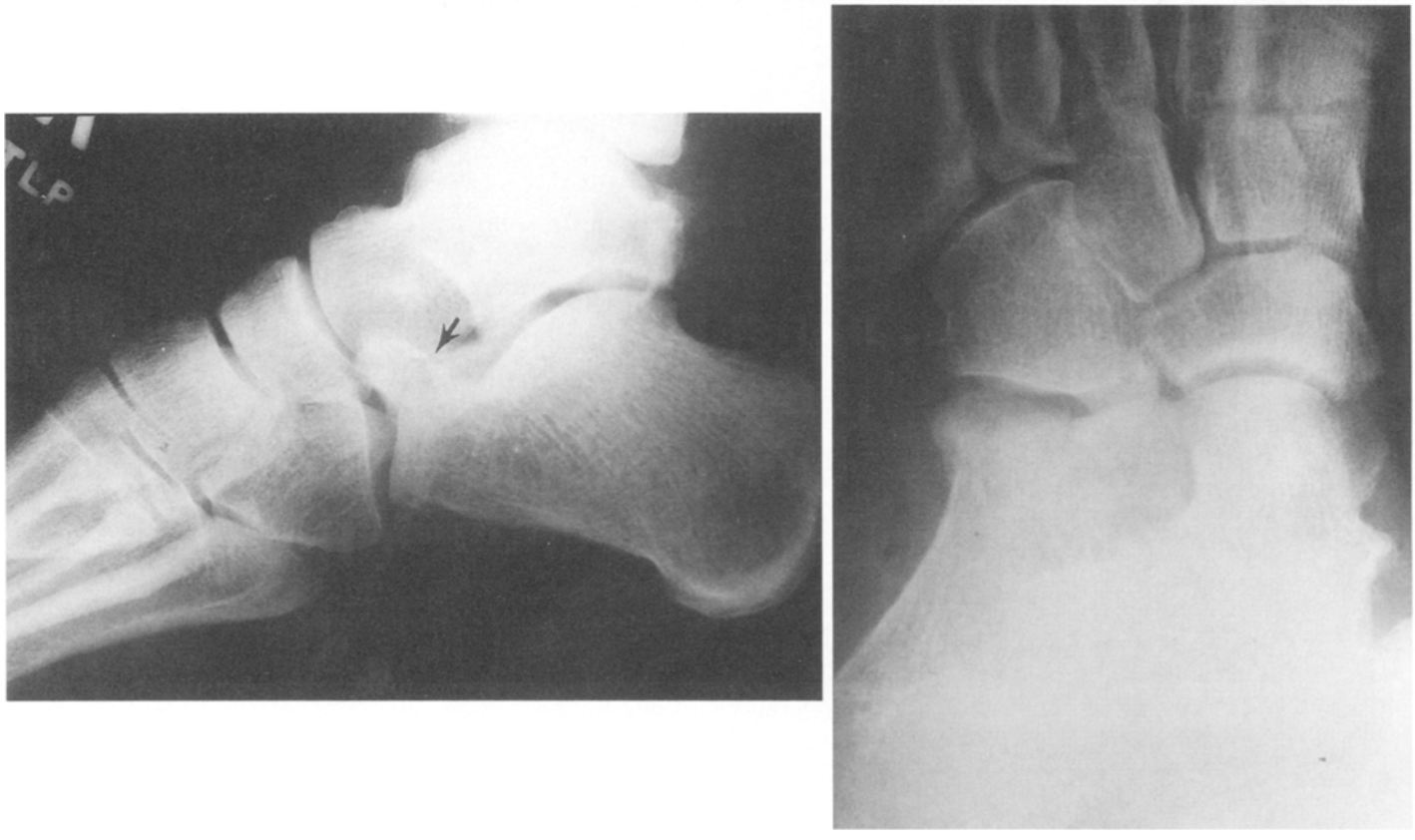

Figure 7. Impaction fracture of the anterior process of the calcaneus. Left, lateral radiograph shows a fracture of the anterior process of the calcaneus (arrow), extending to the calcaneocuboid joint. **Right,** oblique radiograph of the foot better shows the articular stepoff of the calcaneocuboid joint. This fracture is due to impaction of the calcaneus on the cuboid bone and differs from the avulsion of the anterior process related to bifurcate ligament traction.

Another injury of the anterior aspect of the calcaneus that is easily overlooked or misinterpreted is avulsion of the origin of the extensor digitorum brevis muscle (39). The extensor digitorum brevis originates from the anterior and lateral aspect of the calcaneus and can be avulsed in a mechanism similar to that for avulsions of the bifurcate ligament. Differentiating the two can be difficult, but if the fracture is visualized on a lateral radiograph, the injury is more likely to be a bifurcate avulsion (35), whereas the avulsion of extensor digitorum brevis is best seen on an AP view of the ankle low over the calcaneus.

Fractures related to repetitive stress in the setting of normal bone mineralization are called fatigue fractures (27). These commonly occur in the calcaneus, either just deep to the calcaneal tuberosity or within the cancellous bone deep to the posterior facet of the subtalar joint. These fractures were visible only on the lateral radiograph. It is important to search for areas of bone sclerosis as a clue for repetitive bone injury.

Metatarsals

Fractures of the base of the fifth metatarsal are common injuries, and from an ankle radiographic series, they are usually detectable only on the lateral radiograph. They are often at the edge of the film. These fractures are commonly overlooked when included as part of an ankle radiographic series, but if appropriate history is present directing a search to the base of the fifth metatarsal, the fractures are easy to detect.

It is important to remember that two different fractures occur at the base of the fifth metatarsal: avulsion fractures and transverse fractures of the proximal shaft of the metatarsal (called a "Jones fracture") (27, 40). The avulsion fracture occurs during inversion of the foot and is due to traction by both the peroneus brevis tendon and the lateral cord of the plantar aponeurosis; the aponeurosis is probably the more important structure responsible for the avulsion (41). The less common Jones fracture was described by Sir Robert Jones, detailing his own fracture (42). This fracture is more serious than the avulsion fracture, with a higher delayed or nonunion rate and often requiring surgical intervention (43, 44). Both of the examples in our series were avulsion fractures of the metatarsal base.

There are limitations to our study. The main limitation has to do with the "gold standard." One could argue that reinterpretation, even by multiple observers, is not an independent standard to an initial interpretation. However, the study was of consecutive patients with ankle radiographs, and moreover, no other good gold standard exists that does not bias the sample by selecting patients with more severe disease than is actually present in the population. We believe that reinterpretation, with all additional radiographic and clinical data at hand, is adequate. Despite the consecutive series, there is the possibility of bias in our sample. If the reinterpretation was normal and concordant with the initial reading, and the patient did not return for follow-up, the case was considered normal. It is possible that some patients with positive findings, missed initially and on review by the musculoskeletal radiologist, could have gone elsewhere for follow-up care. Given the demographics of our practice, we feel that the number of cases that fall into this category is small.

CONCLUSION

On ankle radiographs, injuries to the hindfoot are more commonly missed than ankle pathology. Special attention should be given to the talus, with a dedicated search for the less common fracture of the lateral process, as well as for osteochondral injuries of the dome or the uncommon but more severe sagittal dome fracture. Calcaneal avulsion fractures are common and are more difficult to diagnose than the typical calcaneal body fracture, both clinically and radiographically. Attention should be paid to the anterior aspect of the calcaneus. Fractures of the base of the fifth metatarsal can be seen on the lateral ankle radiograph; this area should be scrutinized for possible fracture.

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Reviewer's Commentary

In the routine of the emergency department, the radiologist commonly sees ankle and foot radiographs. Often, the patients have been screened by only a nurse or clerk before they are referred for radiographs. This practice results in a large number of negative examinations that tend to bias all interpreters before they actually inspect an ankle or foot study. When I was on-call in my first week of emergency room coverage, I was told by the senior resident that "knees are always normal," a statement that is certainly close to reality if you do not inspect the knee radiographs very carefully. The same can be said for ankle and foot radiographs. This paper serves as a valuable wake-up call, reminding us to pay careful attention to these studies and to scrutinize them specifically for these particular injuries, which we are prone to miss.

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