The role of multidetector CT in evaluation of calcaneal fractures

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Abstract Purpose: This study aimed at evaluating the role played by multidetector computed tomography in decision making in the management of extra and intraarticular fractures of the calcaneus.

Patients and methods: Twenty-eight patients with calcaneal fractures were included. Radiographs and multidetector computed tomography were performed. Sanders classification for intraarticular fractures was used.

Results: Intraarticular involvement was found in 93.3% and extraarticular involvement in 6.7%. Mean Bohler’s angle = 13° ± 12.219. The most common fracture was Sanders type IV (40%). No statistically significant correlation was found between Sanders fractures types I, II and III and Bohler’s angle. However, a significant correlation was found concerning type IV (p = 0.013). There was a significant correlation between Sanders classification and calcaneocuboid joint involvement (p = 0.031).

Conclusion: The study showed that multidetector computed tomography is the best method for assessing and classifying calcaneal fractures, as well as delineating the fracture fragments and helping in making the pre-operative planning.

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1. Introduction

The calcaneus is the biggest and most commonly fractured of the tarsal bones. Calcaneal fractures represent only about 2% of all fractures but 60% of fractures involving the tarsal bones.

Modern calcaneal fracture classification systems depend mainly on computed tomography (CT) because of its three-dimensional nature, rather than on two-dimensional plain radiography as was used previously. The use of multidetector CT has allowed the development of classification systems that correlate with management.

The Bohler’s angle (Fig. 1) is measured between two lines drawn on radiographs of the lateral projection of the ankle.
The first line is drawn between the highest part of the anterior process connecting to the highest part of the posterior facet. The second line is drawn from the same point on the posterior facet connecting to the most superior point of the tuberosity of the calcaneus. It normally measures between 25° and 40°. Reduction of this angle has been used to determine loss of calcaneal height (3).

The Sanders classification system is the most commonly used system for describing intraarticular fractures of the calcaneus (2). It consists of four types based on the fracture line location at the posterior facet (4). Nondisplaced fractures (displacement <2 mm) are classified as type I regardless of fracture lines (Fig. 2). Types II–IV are displaced fractures with an increasing number of fracture lines and fragments. Type II fractures consist of two articular pieces from a single intraarticular fracture line and are divided into three subtypes on the basis of whether the fracture line location is lateral (IIA), central (IIB), or medial (IIIC) (Fig. 3). Medial fractures are harder to evaluate and manage surgically. Type III fractures consist of three articular pieces resulting from two fracture lines. These are subdivided into types IIIAB, IIIAC, and IIIBC (Fig. 4). Fractures with more than three intraarticular fracture lines are considered comminuted and are classified as type IV (Fig. 5).

Extraarticular calcaneal fractures fall into one of three categories depending on whether the involvement of the calcaneus is anterior, middle, or posterior. Type A fractures involve the anterior process of the calcaneus (Fig. 6). Fractures that involve the midcalcaneus or body, including the trochlear process, sustentaculum tali, and lateral process, are type B fractures. Type C extraarticular calcaneal fractures involve the posterior calcaneus, including the posterior tuberosity and the medial tubercle (2).

The aim of this study is to find a correlation between Sanders types of fractures and Bohler’s angle, as well as finding a correlation between Sanders classification and calcaneocuboid joint involvement, which are areas that were not frequently assessed by previous literature. This, in return, is expected to have an effect on decision making and management options for patients with different types of calcaneal fractures, allowing for better outcome.

2. Subjects and methods

2.1. Patients

Our study included 28 adult patients suffering from unilateral or bilateral foot injuries (26 cases unilaterally and two cases bilaterally) as a sequel of trauma (such as a road traffic accident or a fall from a height). All subjects provided informed consent for participation in this study, which was approved by the institutional ethical review board. All patients underwent history taking, X-ray and CT scanning.

The inclusion criteria were trauma patients with calcaneal fractures. Patients with previous calcaneal surgery that might have altered the normal anatomy and pregnant women were excluded from this study.

2.2. X-ray

All patients were assessed with plain radiographs, including lateral and axial Harris views of the hindfoot. An oblique view was sometimes obtained to help in visualizing the calcaneocuboid joint involvement. Then, the Bohler’s angle was measured from radiographs of the lateral projections of the foot.

2.3. CT scan

CT scan of the calcaneus was obtained with 64-channel CT scanner (Toshiba Medical Systems, Otawara, Japan). We imaged the hindfoot at a 0.625-mm collimation, a pitch of 0.5625, 130 kV, and 60 mA. The CT scan was obtained with the patient lying supine on the scanner with the knee flexed and the foot as plantigrade as the patient would allow. Reconstruction CT planes were obtained in 3 mm slice thickness. We used the ankle joint on the axial images as a reference to obtain true sagittal and coronal planes of the hindfoot. For Sanders classification, the axial and coronal images were reformatted parallel and perpendicular to the anatomic posterior facet of the sagittally reconstructed images.

Classification of the intraarticular calcaneal fractures was obtained according to Sanders classification into:

- Type-1 fractures, in which the articular fragments were displaced less than 2 mm relative to one another.
- Type-2 fractures, in which there were two articular fragments.
- Type-3 fractures, in which there were three articular fragments.
- Type-4 fractures, in which there were four or more articular fragments.

2.4. Statistical methods

Data were statistically described in terms of mean ± standard deviation, median and range, or frequencies (number of cases).
and percentages when appropriate. For comparing categorical data, Chi-square ($\chi^2$) test was performed. Exact test was used instead when the expected frequency was less than five. McNemar test was used in paired comparisons and agreement was tested using kappa statistic. Correlation between various variables was done using Spearman rank correlation equation. A $p$ value less than 0.05 was considered statistically significant. All statistical calculations were done using computer program SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) version 15 for Microsoft Windows.

3. Results

This study included 28 patients suffering from unilateral or bilateral calcaneal fractures (30 feet) as a sequel of trauma after a fall from a height or a motor vehicle accident. Our
study included 24 males and 6 females. Their age ranged from 24 to 64 years, with mean range of 33.47 ± 9.276. The right foot was involved in 12 patients and the left foot in 18 patients. There were two patients with extraarticular fractures (6.7%) and 28 patients with intraarticular fractures (93.3%). The different distribution of the patients with intraarticular fractures was due to the different distribution of the patients with extraarticular fractures.

Fig. 3    A 35-year old female patient presented after a fall from a height. Her plain X ray and CT scan showed an intraarticular fracture (Sanders type IIB) of the right calcaneus. (a) Lateral radiograph of the right foot showed a fracture line of the calcaneus reaching the posterior facet and the inferior surface (arrows). (b) Sagittal multidetector CT scan of the right hindfoot revealed a comminuted fracture of the calcaneus extending to the subtalar joint (arrows). (c) Coronal multidetector CT scan of the right hindfoot showed a comminuted calcaneal fracture with a primary fracture line (arrows) oriented at the middle of the posterior facet of the subtalar joint. (d) Axial multidetector CT scan showed a right calcaneal fracture oriented at the middle of the subtalar joint (red arrow). Another fracture line interrupted the lateral surface (blue arrow).
fractures according to Sanders classification is shown in Table 1.

In our study, the mean Bohler’s was 13° ± 12.219. The relation between Sanders type and Bohler’s angle is shown in Table 2.

There were 20 patients (66.7%) with fractures involving the calcaneocuboid joint and 10 patients (33.3%) with fractures not involving the calcaneocuboid joint. All patients of calcaneocuboid joint involvement had an intraarticular fracture. The relation between Sanders classifications types and
A 47-year-old male patient presented after a fall from a height. His plain X-ray and CT scan showed an intraarticular fracture (Sanders type IV) of the left calcaneus and a fracture of the left distal fibula. (a) Lateral radiograph of the left foot showed a fracture of the calcaneus as well as of the distal fibula (arrows). (b) Sagittal multidetector CT scan of the left foot revealed a comminuted fracture of the calcaneus extending to the subtalar joint with interruption of the inferior aspect of the posterior surface (arrows). (c) Coronal multidetector CT scan of the left foot showed a severe comminuted calcaneal fracture involving the lateral, central, and medial aspects (arrows) of the posterior facet of subtalar joint. (d) Axial multidetector CT scan of the left foot showed a severe comminuted calcaneal fracture involving the lateral and medial surface as well as calcaneocuboid articulation (arrow).
calcaneocuboid joint involvement was significant with a p value of 0.031. The frequency and percentage of the calcaneocuboid joint involvement according to the different Sanders types is shown in Table 3.

### 4. Discussion

Calcaneal fractures are not easy to treat because of the complexity of the pathologic anatomy especially in cases of fractured posterior facet. Plain radiographs were used to assess the calcaneal fractures. Generally, oblique views can show fracture extensions into the calcaneocuboid joint. Lateral radiographs can determine whether the fractures are intraarticular or extraarticular. Bohler’s angles can be measured to help assess displacement (5).

Computed tomography has been shown to visualize more accurately the various fracture lines. Some authors believe...
the advent of CT scanning is the single most important advancement in the management of calcaneal fractures. The coronal CT images evaluate posterior facet involvement, height and width of the calcaneus. Axial CT images can also show the posterior facet, heel varus, and calcaneal widening. Sagittal reconstruction images can help assess the rotational abnormality of the posterior facet fragment, loss of height, and the calcaneocuboid joint (5).

This work included 30 feet belonging to 28 patients (two patients had bilateral injuries). Twenty-four were males and six were females, representing 80% and 20% of all patients respectively. Their mean age was 33.47 years. We observed that calcaneal fractures more commonly occurred in males than in females. This was similar to what was found by Ogawa et al. (5). The most common mode of injury was a fall from a height, representing (93.3%) which was similar to that found by Pillai et al. (6).

One of the essential requirements of a classification system is that it should be reproducible so that it can help in the assessment of data. There is a consistent, universal agreement regarding the options for treatment of intraarticular fractures of the calcaneus based on the classification of Sanders, according to which, as the fracture line moves from the lateral to medial, the operative view becomes progressively poor and the ability to obtain an accurate reduction of the fracture more difficult. This forms the basis for the prognostic value of this classification system, which has been shown to have a good correlation between the types of fracture and outcome (7).

The use of computed tomography in the diagnosis of Sanders type II and III fractures allows a more adequate surgical planning, which may lead to a better prognosis. With the exception of fractures classified as Sanders I, in which closed treatment can be used, the others preferentially have a surgical treatment. Early arthrodesis is formally indicated in type IV fractures. Surgical treatment using osteosynthesis is indicated for the rest of the fracture types (II and III) (8).

In this study, multidetector CT scan of the calcaneus was done for all cases after conventional radiography, and the patients were classified as extra and intraarticular fractures according to posterior facet affection. We had two patients with extraarticular and 28 patients with intraarticular fractures representing 6.7% and 93.3% respectively.

Using the Sanders classification 3 cases (10%) were of type I, two cases (6.7%) were of type II, 11 cases (36.7%) were of type III and 12 cases (40.0%) were of type IV. Our results do not match the result reached by Bhattacharya et al. (7). This can be explained by the fact that there is some variability and inconsistency between observers.

Bohler’s angle is described as one indicating the configuration of the calcaneus measured from radiographs of the lateral projections of the foot. It was generally believed that Bohler’s angle less than 28° should arouse suspicious of a fracture. Chen et al. got false positive abnormal cases of up to 31% if 28° is taken as the lower limit of normal and therefore suggested 20° as the lower limit (9). The Bohler’s angle is widely used in the fracture of the calcaneus. A reduction in the angle has been associated with a fracture and calcaneal fractures with a markedly reduced Bohler’s angle carry a poorer prognosis. Bohler’s angle has also been found to show no significant differences in the adult age groups, gender and side of body. However, in a study of pediatric Bohler’s angle, it was found to be less than that in adults (10).

In a study done by Ali et al. (11), no statistically significant correlation was found between Sanders types of fractures and Bohler’s angle \( \rho = 0.3108 \). This is similar to our study as regards Sanders type I \( \rho = 0.051 \), type II \( \rho = 0.655 \) and type III \( \rho = 0.898 \). However, a significant correlation was found concerning type IV \( \rho = 0.013 \). This may be explained by the fact that in this study there is a big number of type IV Sanders fractures. This indicates that the evaluation of calcaneal fractures by plain radiography only using Bohler’s angle is less sensitive than CT and may give false negative results in mildly displaced fractures and in cases with few fracture fragments.

Calcaneocuboid joint involvement in intraarticular calcaneal fractures was common and more than half showed severe injuries. In our study 20 cases (66.7%) showed calcaneocuboid joint involvement, where all cases were of the intraarticular fracture type. These included one case (5.0%) of type I, two cases (10.0%) of type II, 6 cases (30.0%) of type III and 11 cases (55.0%) of type IV. According to our results, Sanders classification allowed the prediction of the pattern of involvement of the calcaneocuboid joint \( \rho = 0.031 \) which is nearly similar to those found by Won et al. (12). This indicates that there is a significant correlation between Sanders classification and calcaneocuboid joint involvement; the higher the Sanders types, the more likely it is to involve the calcaneocuboid joint.

CT assessment is important for excluding articular surface involvement and determining the extent of the fracture. Patients with calcaneal body fractures usually have a better prognosis than those with intraarticular fractures, and management is usually conservative (13).

Only CT can give a clear understanding of the size of fragment and the number of intraarticular fracture lines. In addition, CT shows the location and plane of variable fracture lines that separate the anterolateral fragment. This guides the surgeon for the dissection necessary to visualize and treat the fracture. The precise location of the lateral wall, particularly in relation to the lateral malleolus and peroneal tendons, is much more easily appreciated with CT than with axial radiographs (13).

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<th>Table 3 Frequency and percentage of the calcaneocuboid joint involvement according to the different Sanders types.</th>
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5. Conclusion

Multidetector CT is the best method for assessing calcaneal fractures in order to decide on the management. It is thought that the scan may delineate the fracture fragments better and help in making the pre-operative planning of the fracture. However, there is a high degree of variability and inconsistency in its interpretation with only a fair to moderate agreement.
among its users. Radiologists must be familiar with injuries of the calcaneus, their anatomy, mechanisms, classification, and implications to help guide the treating physicians.

Conflict of interest

The authors have no conflict of interest to declare.

References