The role of 64-MDCT with 3D images in evaluation of intra-articular calcaneal fractures and management planning

Moustafa A. Kader A. Wahab a,*, Mohamed A. Ebraheim a, Ahmed Saleh b

a Radiology Department, Faculty of Medicine, El-Minia University, Egypt
b Orthopedic Department, Faculty of Medicine, El-Minia University, Egypt

Received 23 March 2015; accepted 26 May 2015
Available online 14 June 2015

KEYWORDS
64-MDCT; Intra-articular calcaneal fractures; Pretreatment planning

Abstract  Objective: The purpose of this study was to assess the usefulness of 64-multi-detector computed tomography (64-MDCT) in diagnosis, classification and pretreatment planning of intra-articular calcaneal fractures.

Subjects and methods: 40 patients presented to emergency room with ankle swelling and pain following fall from height or motor car accident. They presented from June 2013 to December 2014. Their ages ranged from 22 to 58 years (mean age 40 years). 30 cases were males and 10 were females. All patients were subjected to 64-MDCT with 3D reformatted images.

Results: A total of 44 intra-articular calcaneal fractures were found. 8 fractures were type I, 12 were of type II, 14 were of type III and 10 fractures were type IV according to Sander’s classification. Also 24 fractures were tongue type and 20 fractures were joint depression type according to Essex-Lopresti classification. 4 fractures were bilateral and 36 fractures were unilateral. 24 fractures had associated soft tissue edema. Conservative management was done on types I and IV intra-articular fractures (except one fracture), while operative treatment was done on types II and III.

Conclusion: The use of 64-MDCT with 3D images was essential in diagnosis, classification and pretreatment planning of intra-articular calcaneal fractures.

© 2015 The Authors. The Egyptian Society of Radiology and Nuclear Medicine. Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

The calcaneus is the most commonly fractured tarsal bone, representing 60–75% of all tarsal fractures in adults and accounts for approximately 2% of all fractures (1,2). The peak
incidence occurs in younger males. Most calcaneal fractures are occupational, and are caused by axial loading from a fall. The majority are displaced intra-articular fractures (60–75 percent), with a male to female ratio of 2.4:1 (3). Seventy-two percent of these fractures resulted from falls. The calcaneus is responsible for supporting the axial load from the weight of the body. It is most commonly fractured after a fall from a height in which axial loads exceed its support capacity. Modern assessment of calcaneal fractures relies heavily on multi-detector computed tomography (MDCT), which allows better visualization and characterization of fracture lines and fragment displacement. Calcaneal fractures observed at CT have been divided into intra and extra-articular fractures on the basis of subtalar joint involvement (4). The Sanders classification system for intra-articular fractures is the most commonly used system because it correlates with clinical outcomes and involves less inter-observer variability. Familiarity with the normal anatomy of the calcaneus, the classification of calcaneal fractures, and the various complications of these fractures are essential for the treatment assessment, especially if surgical intervention is required (5,6).

64-MDCT scans have been superior to other radiologic studies for the evaluation of calcaneal fractures. The pattern and extent of the fracture could be seen and treatment can be chosen on the basis of more certain knowledge of the extent of the fracture (7–9).

The aim of this study was to assess the usefulness of 64-MDCT with 3D reformatted images in diagnosis and classification of intra-articular calcaneal fractures and its value in pretreatment planning.

2. Patients and methods

This study was approved by the ethics committee of our institution during the period between June 2013 and December 2014. 40 patients presented to emergency room with ankle swelling and pain following fall from height or motor car accident. Their ages ranged from 22 to 58 years (mean age 40 years). 30 cases were males and 10 were females. All patients subjected to MDCT using 64-multislice machine (Aquilion 64; Toshiba Medical Systems Corporation, Otawara, Japan).

2.1. Technique for MDCT of the calcaneus

All patients underwent the same MDCT examination protocol using 0.5 mm collimation scanner with a gantry rotation speed of 400 ms/rotation, range of box 450–500, image thickness 0.5 mm and 0.5 mm spacing at subtalar joint and 1 mm above and below it, standard pitch factor of 0.641, reconstruction interval 0.5 mm and total exposure time 6–8 s. Each scan was obtained with a tube voltage of 120 kV and 250 mAs. Images were carried in both bone window for fracture classification and associated other bony injuries and soft tissue window for tendon entrapment and any soft tissue abnormalities.

Fig. 1 32-year old male patient presented with history of fall from height and complaining of severe pain and swelling of the Rt. ankle. (A and B) Axial and coronal MDCT scans of the right calcaneus reveal single primary fracture line located centrally relative to the posterior facet and sub-talar joint dividing the calcaneus into two articular fragments (type IIB). (C) Sagittal image shows the secondary fracture line exit through the tuberosity (arrow). (D and E) 3D images show the extent of the fracture type through subtalar (arrow in D) and through the tuberosity. Diagnosed type IIB- tongue.
The data were reconstructed into 0.75 mm slice images, resulting in a total of 400–500 slices. The threshold value for voxels was selected by threshold segmentation (−600 to 1500 HU) that was appropriate to differentiate muscles, tendons and bones. The acquired images were transferred to a separate workstation for post processing (advantage workstation, AW) with manufacturer-provided software that allowed generation of 2D and 3D images: 2D multiplanar reconstruction (MPR) in the sagittal and coronal planes as well as sagittal reformatted images of the calcaneus was prescribed for the axial images at the level of the ankle joint. Coronal images were reformatted perpendicular to the sagittal images, also in reference to the ankle joint. All images were evaluated under standard window settings for calcaneal fractures (Window level 300 HU, Window Width 1300 HU). 3D volume rendered images were done as they are essential for 1 – full extent of the fracture, 2 – relationship of the fracture to the articular surfaces and 3 – searching for displaced calcaneal fragments.

2.2. Fracture classification

Fracture classification according to Sander’s was as follows: Type I: Non-displaced fracture or displacement less than 2 mm. Type II: Fractures consisted of two articular pieces from a single intra-articular fracture line and were divided into three subtypes on the basis of whether the fracture line location is lateral (IIA), central (IIB), or medial (IIC). Type III: Fractures consisted of three articular pieces from two fracture lines. Type IV: Fracture included four or more articular fragments and was highly comminuted.

According to Lopresti classification, fractures were either tongue type fracture in which the fracture line exited the posterior aspect of the calcaneus, or the joint depression type in which the fracture line did not communicate with the tuberosity and run just posterior to the articular surface.

2.3. Management: conservative and surgical interference

Closed reduction with applied cost was done in type I fractures and most of the type IV fractures apart from the highly comminuted intra-articular types when primary subtalar arthrodesis was indicated, in which case the articular surface is determined intra-operatively to be non-reconstructable (only two cases in this study: one type III and one highly comminuted on type IV). While open reduction and internal fixation (ORIF) was done for types II and most of type III fractures. Using extensile lateral approach, standard ORIF techniques were utilized, so as to fully re-establish calcaneal length, alignment, and overall morphology. The main components of the calcaneus (anterior process, posterior tuberosity, and articular surface) were further stabilized to the plate such that at least two screws traverse each component. Final (lateral, Brodén’s and axial) fluoroscopic images were obtained, confirming the final reduction and placement of implants (see Figs. 1–5).

2.4. Follow up of patients

Included questioning the patients about pain during activity and rest, ability to walk and stand, determining the range of motion of subtalar joint. According to the method of McMster (10), noting any change in the shoe size and the...
Fig. 3  26-Year old female presented with history of fall from height and complaining of severe pain and swelling of left calcaneus. (A) Axial images reveal intra-articular fracture line with extension to involve the posterior articular facet. (B) Coronal image reveals multiple two intra-articular fracture lines (arrows) with soft tissue injury and edema involving the muscles on the medial aspect of the calcaneus namely the abductor hallucis and quadrates plantae. (C and D) Sagittal images show the secondary fracture exit through the calcaneal tuberosity (arrow on D). E, E1, F and F1-3D coronal and sagittal images reveal the primary intra-articular fracture (arrow on F1) as well as secondary fracture line that involved the tuberosity (arrow on F). Diagnosed type IIIAC- tongue.
amount of swelling in the hind foot. The different categories added to a maximum of 100 points. A score of 80–100 points was judged to be a good result, 60–79 points was a fair result and 59 points or fewer was a poor result.

2.5. Statistical analysis

Data entry was done by SPSS version 17 and analyzed by the same software. MDCT and its MPR images (axial, coronal and sagittal) were compared to each other and in reference to the 3D reformatted images in all planes as well as operative findings with calculation of the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy. The probability (p value) of less than 0.05 was used as a cutoff point to determine whether there is a statistically significant value for diagnosis and classification of the intra-articular calcaneal fractures.

3. Results

A total of 44 intra-articular calcaneal fractures were found. 8 fractures were type I, 12 fractures were of type II, 14 fractures were of type III and 10 fractures were type IV according to Sander’s classification. Also 24 cases were tongue type and 20 cases joint depression type according to Essex-Lopresti classification (Table 1).

24 Fractures (54.5%) had associated soft tissue edema, and 18 fractures (40.9%) were seen with muscle injuries namely abductor hallucis and quadrates plantae that were seen at the medial aspect of the calcaneus. 6 fractures (13.6%) were noted with tendon injuries, 4 of them were peroneus tendon injuries and 2 were of Achilles tendon. Necrotizing fasciitis is complication for calcaneal fracture and was seen with 2 fractures (Table 2).

As regarding the suitable plane for classification of intra-articular calcaneal fractures (types and subtypes) according to Sander’s classification, we found that the coronal reconstructed images were the most sensitive, specific and accurate with sensitivity of 95%, specificity of 80% and accuracy of 90% while the axil planes were found to be the least of all by sensitivity of 75%, specificity of 66% and 70% accuracy (Table 3).

When considering the Essex-Lopresti classification for suitable planes, the sagittal planes found to be the most sensitive,
specific and accurate by sensitivity of 98%, specificity of 95% and accuracy of 98%. Sagittal MPR images were essential in the evaluation of types of fractures according to Essex Lopresti classification; it also detected the antero-posterior extension of fracture lines, achilles tendon injury and other tarsal bone fractures. The P value was statically significant < 0.02 (Table 4).

The diagnosis of the associated soft tissue injuries was found more accurate when used the axial images than the other planes by sensitivity of 97%, specificity of 95% and accuracy of 97% (Table 5).

The benefits of 3D reformatted images were found of significant value as regarding the fracture branching and extension than the fracture classification (Table 6).

**Table 1** Types of intra-articular fractures according to Sander’s Essex Lopresti classifications.

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>According to Sander’s classification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type I</td>
<td>8</td>
<td>18.2</td>
</tr>
<tr>
<td>Type II</td>
<td>12</td>
<td>27.3</td>
</tr>
<tr>
<td>Type III</td>
<td>14</td>
<td>31.8</td>
</tr>
<tr>
<td>Type IV</td>
<td>10</td>
<td>22.7</td>
</tr>
<tr>
<td>According to Essex Lopresti classification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tongue type</td>
<td>24</td>
<td>54.55</td>
</tr>
<tr>
<td>Joint depression type</td>
<td>20</td>
<td>45.45</td>
</tr>
</tbody>
</table>

**Table 2** Regarding the associated injuries and complications of calcaneal fractures.

<table>
<thead>
<tr>
<th>Associated injuries</th>
<th>Number</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft tissue edema</td>
<td>24</td>
<td>54.5</td>
</tr>
<tr>
<td>Muscle injuries</td>
<td>18</td>
<td>40.9</td>
</tr>
<tr>
<td>Tendon injuries</td>
<td>6</td>
<td>13.6</td>
</tr>
<tr>
<td>Necrotizing fasciitis</td>
<td>2</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Fig. 5 Some steps of operative interference and post-operative evaluation: (A) Subperiosteal development of lateral flap. (B) Retractor placed after full thickness flap is developed. (C) Exposure of peroneal tendons (* peroneal brevis tendon). (D) Exposure of inferior peroneal-tendon sheath. (E) Resection of inferior peroneal-tendon sheath from lateral wall, which protects tendons and permits retraction. (F) No touch technique in which three 1.6-mm K wires are used for retraction. The lateral wall is fully exposed, and the depressed lateral-joint fragment is visualized (*). (G) Fixation of calcaneal tuberosity: simultaneous lateral to-medial force on plate (applied by surgeon’s thumb) and valgus-directed force on undersurface. (H and I) Plate in position with final lateral x-rays shows anatomic reduction of the fracture.
17 fractures were managed conservative by casting (types I and IV) apart from one fracture that was markedly comminuted needed subtalar arthrodesis, while types II and III were managed operatively by open reduction and internal fixation (26 fractures + one type IV fracture) (Table 7). By follow up of our patients, we found that 75% of type I had good results and 25% with fair results. 50% of type II fractures found with good results while 25% with fair and 25 with poor results. 50% of type III fractures found with good results while 21.5% with fair and 28.5% with poor results. Only 20% of type IV fractures were found with good results while 30% with fair and 50% with poor results (Table 8).

### Table 7  Type of management of the intra-articular fractures.

<table>
<thead>
<tr>
<th>Type</th>
<th>Management</th>
<th>Number of Fractures</th>
</tr>
</thead>
<tbody>
<tr>
<td>17: types I and IV</td>
<td>Conservative</td>
<td>17</td>
</tr>
<tr>
<td>fractures except one</td>
<td>Surgical</td>
<td>1</td>
</tr>
<tr>
<td>case of type IV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>underwent operative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27: types II and III</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fractures + one case</td>
<td></td>
<td></td>
</tr>
<tr>
<td>of type IV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>had subtalar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>arthrodesis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 8  The results of the follow up of the fractures.

<table>
<thead>
<tr>
<th>Type of fracture</th>
<th>Follow up results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I (8 fractures)</td>
<td>6 good (75%) 2 fair (25%)</td>
</tr>
<tr>
<td>Type II (12 fractures)</td>
<td>6 good (50%) 3 fair (25%) 3 poor (25%)</td>
</tr>
<tr>
<td>Type III (14 fractures)</td>
<td>4 good (28.5%) 5 fair (35.7%) 5 poor (35.7%)</td>
</tr>
<tr>
<td>Type IV (10 fractures)</td>
<td>2 good (20%) 3 fair (30%) 5 poor (50%)</td>
</tr>
</tbody>
</table>

### 4. Discussion

Intra-articular calcaneal fractures were the most common fracture of the tarsal bones, so better understanding of fracture patterns with MDCT scans including 3D reformatted images and modern surgical techniques had improved outcomes and lowered morbidity. So, accurate estimation of the grade and extension of calcaneal fractures played a role in planning for management and so reducing the complications (10–12).

In this study the main cause of calcaneal fractures was fall from height (FFH) representing 80% of cases and only 20% caused by motor car accidents. This was also stated by Stoller et al. (13), who considered the increased axial load caused by falling from a height and landing on the feet was the most common cause of calcaneal fractures. Motor car accidents, in which a seated passenger’s feet was pressed hard against the floor of the car, became another commonly encountered cause, however, less frequent than fall from height. This was also postulated by Berberian et al. (14), who found that the usual cause of intra-articular calcaneal fractures was FFH.

In this study we found that the (type I) intra-articular calcaneal fractures were the least and the type III was the most frequent, and this was agreed by Sanders (15) as well as Brunner et al. (2) who stated that type I was uncommon and the other types from type II to type IV were nearly similar in their percentage of occurrence.

Regarding Essex Lopresti classification that classified intra-articular fractures into tongue and joint depression types according to the direction of secondary fracture lines, the primary fracture line runs obliquely through the posterior facet forming two fragments. The secondary fracture line exited...
through the tuberosity at tongue type and just posterior to the articular facet at joint depression type. In this study we found that the tongue type fractures (24/44) were more common than joint depression type (20/44). This was not agreed by results stated by Essex–Lopresti (16) who found that the joint depression type was more common than the tongue type.

Berberian et al. (14) stated that intra-articular calcaneal fractures had poor outcomes with about 40% complication rate usually due to the associated soft tissue injuries that were common especially with comminuted fractures and related to mechanism of injury. Soft tissue injuries represented an important point to surgeons to avoid many complications, for example, bone reduction upon tendon entrapment. In this study, soft tissue edema was seen in 24 fractures (54.5%) which was not specific for fracture and usually responded to medical treatment. 18 fractures (40.9%) presented with muscle injuries, mainly abductor hallucis and quadratus plantae muscles that were located at the medial aspect of the calcaneus. These muscles form the roof of the tarsal tunnel and if not treated before reduction and treatment of the fracture, the patient may presented later on with picture similar to tarsal tunnel syndrome. This condition was due to compressive neuropathy to the tibial nerve. This compression also may be due to bone spurs associated with calcaneal fractures. Clinically, the patient presented with pain, tingling and numbness at the foot radiating to the first three toes and this was also proved by Berry et al. (17).

Regarding tendon injury, 6 fractures (13.6%) were presented with tendon injuries, 3 of them had peroneus tendon injuries and the other 3 had Achilles tendon injury. Manaster (18) stated that poor outcomes were common among patients with calcaneal fractures and may be related to complications associated with the fracture. The most important complication was the soft-tissue involvement. Tendon injury resulted from the entrapment of fibers between fracture fragments. Imaging assessment of entrapment was vital because entrapment presents an obstacle to reduction of a fracture. Necrotizing fasciitis was another complication of calcaneal fractures in patients who had not sought medical advice and with open fractures. It was noted in 2 patients (4.5%) in this study and was seen in their early stage. The reported percentage was more than our results, and Buckingham et al. (19) found that wound complications including infection were observed in up to 20% of patients, especially in those with open calcaneal fractures, who were prone to deep infection like necrotizing fasciitis even when aggressive treatment was used to prevent it.

According to Sander’s, coronal MPR plane was the most suitable MPR plane for the classification of the intra-articular calcaneal fractures especially the subtypes including the degree of displacement and site of the fracture line with sensitivity of 95%, specificity of 80% and accuracy of 90% followed by the axial and sagittal MPR planes respectively, here P value id statistically significant 0.02. So we agree with Sanders (15), who stated that axial images were used for the initial diagnosis and coronal images were the hallmark for classification. While according to Lopresti, the sagittal MPR plane was the most suitable for fracture classification with sensitivity of 98%, specificity of 95% and accuracy of 98% (1,3). To identify the associated soft tissue injuries as muscles and tendon injuries we found that the axial MPR images were the most suitable with sensitivity of 98%, specificity of 95% and accuracy of 97% and significant P value (0.02) (3,4).

In this study, the use of 3D reformatted images was essential in the fracture extension and depth, and it was more accurate (100%) than MPR images (85% accuracy). We usually start with 2D-MPR images for diagnosis and classification of the fracture then 3D reformatted images were generated and used for more data evaluation as the actual extension of the fracture in relation to the articular surface. This was also suggested by Brunner and Heeren et al. (2).

The results of the follow up of the patients in the present study revealed that, in type I fracture (8 fractures) 6 fractures showed good results (75%) and 2 fractures showed fair result (25%). In type II fracture (12 fractures) 6 fractures showed good result (50%), 3 fractures showed fair results (25%) and 3 fractures showed poor results (25%). In type III fractures (14 fractures), 4 fractures showed good results (28.5%), 5 fractures showed fair results (35.7%) and 5 fractures showed poor results (35.7%). In type IV (10 fractures) 2 fractures showed good results (20%), 3 fractures showed fair results (30%) and 5 fractures showed poor results (50%). These results were also found nearly the results of the study done by Chen et al. (20) and Basile (21).

5. Conclusion

In conclusion, MDCT with MPR and 3D reformatted images was the procedure of choice in diagnosis, classification and treatment planning of intra-articular calcaneal fractures. It provided important data that make the surgeon able to predict the fractures that will do well with closed treatment and those need open surgery and internal fixation.

Funding source

No disclosure of funding received for this work from any organization.

Authors contribution

All authors have appraised the article and actively contributed in the work.

Conflict of interest

The authors declare that there are no conflict of interest.

References

(5) Kenneth B, Jose AP, Samuel OP, Angel AG, Edgar C, Jorge AV. Department of radiological sciences, diagnostic radiology section.
University of Puerto Rico Medical Sciences Campus, RSNA, PO Box 5067, San Juan, PR 00936; 2011.


