Diagnostic Value of Imaging Modalities for Suspected Calcaneal Fracture: A Systematic Review of Literatures

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Abstract

Background: Calcaneal fracture account as the most common tarsal bones injury. Diagnosis of fracture is based on X-rays radiological studies, but CT-scan is the most reliable tool for diagnosis of calcaneus fracture. In this study, we conducted a systematic review, which will help readers to get a better view of usefulness of different imaging modality in diagnosis of calcaneal fracture.

Methods: We conducted a systematic review based on PRISMA protocol. To find all citations, PubMed /Medline, ISI web of knowledge, EMBASE and Cochrane library databases were searched from their beginning to June 2015. Two authors, applying the inclusion and exclusion criteria, screened all citations and abstracts and extracted all needed information from included literatures, independently. In order to assess the quality of included studies, QUADAS was used.

Results: Ten literatures included in this systematic review. Sensitivity of different conventional radiographs ranged from 0% for Foot posteroanterior to 100% for Foot reversed oblique and Combined Lateral and axial calcaneal X-ray. Specificity of conventional radiographs ranged from 72% for lateral calcaneal X-ray to 100% for Lateral foot or ankle radiograph. For the CT-scan, three-dimensional (3D) shaded radiographs had highest sensitivity (90.7%) and specificity (93.9%). Four studies tried to show value of angle’s measures in diagnosis of calcaneal fracture that had different results.

Conclusions: We concluded that there are few literatures evaluating different imaging modality in diagnosis of calcaneal fracture and results are not enough to prove advantage of one modality to others. So, one study with a large population sample is needed to compare diagnostic value of different modalities.

Keywords: Diagnostic; Imaging; Calcaneal fracture; Calcaneus; Systematic review

Introduction

Calcaneal fractures account as the most common tarsal bones injury [1]. Therefore, definite diagnosis of calcaneal fracture is an important element for proper management. The main signs and symptoms of fractures are swelling and deformity. Diagnosis of fracture is based on X-rays radiological studies [2]. Two main landmark of lateral view X-ray are Böhler’s and Gissane's angles and the axial view has advantage for evaluation of Varus deformity of the calcaneus and widening of the heel [2].

Early diagnosis of fracture facilitates treatment of fracture and may reduce complications. In addition, knowing the best way of diagnosis may decrease economic burden and accelerate proper management of patients. Nowadays, CT-scan is the most reliable tool for diagnosis of calcaneus fracture [3] and CT-scan is more accurate for assessment of fracture. Detecting stress fractures of the calcaneus can be made by Technetium scans and MRI, but it is not appropriate to apply them in the acute setting [4].

Because of limited studies evaluating diagnostic value of different modalities in calcaneal fracture, we conducted a systematic review, which will help readers to get a better view of usefulness of different imaging modality.

Methods

Search strategy

We conducted a systematic review based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol [5]. To retrieve all relevant literatures, a sensitive search query consisted of terms related to calcaneus (“calcaneus”[Mesh]) combined with specific terms for fracture (“Fractures, Bone”[Mesh]), Evaluation Studies as Topic”[Mesh]) and diagnosis (“Diagnosis”[Mesh]) was used. PubMed /Medline, ISI web of knowledge, EMBASE and Cochrane library databases were searched from their beginning to June 2015 to find all citations (Updated in May 2016). Detailed search strategy results of each database are reported in supplementary appendix. There was no limitation in search of databases. In addition, a search of reference list of included studies, systematic reviews and meta-analysis was conducted in order to find missed citations.

Selection criteria

The literatures met inclusion criteria if: [1] evaluated calcaneal fracture; [2] had reported or calculable diagnostic accuracy statistics (sensitivity, specificity, positive likelihood ratio, negative likelihood ratio); [3] offered a diagnostic methodology to differentiate between fractured bone and non-fractured bone; [4] had available full text; [5] written in English language. The citations with following conditions

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We considered studies with score < 5 as low quality score 5-9 as we scored one to answer “yes” and zero to answers “no” and “unclear”. The QUADAS tool have 14 items with answers “yes”, “no” and “unclear” and Assessment of Diagnostic Accuracy Studies [6] was employed. In order to assess quality of included studies, QUADAS (Quality Assessment of Diagnostic Accuracy Studies) tool [6] was employed. QUADAS tool have 14 items with answers “yes”, “no” and “unclear” and we scored one to answer “yes” and zero to answers “no” and “unclear”. We considered studies with score < 5 as low quality score 5-9 as moderate quality and score ≥ 10 as high quality. The quality of studies assessed by two authors, applied the methodology of QUADAS tool.

Results

In the first electronic search of databases, 2,537 citations were identified, in which 809 citations were removed due to duplication. Title and abstract screening gave us 39 full-texts. Finally, after detailed full-text assessment, and additional search of reference lists, 10 literature included in this systematic review [7-16] (Figure 1). Among included studies, six were conducted in Europe, three in United States of America (USA), one in Asia (China) and one in Australia. Six studies evaluated value (sensitivity and specificity) of different radiographical approach and four studies had a measurement approach (assessment of angles, heights and lengths) for calcaneal fracture. Of these included studies, six had moderate quality and quality of four studies was low. We found no high-quality study evaluating diagnostic tools in calcaneal fracture. Detailed characteristics of studies are presented in Table 1.

Conventional radiography (X-ray)

Six studies evaluated diagnostic accuracy of different views of conventional radiographs [7,11-14,16]. Of these, four had moderate quality. Sensitivity of different conventional radiographs ranged from 0% for foot posterocentral [13] to 100% for foot reversed oblique and combined lateral and axial calcaneal X-ray [12,13]. Specificity of conventional radiographs ranged from 72% for lateral calcaneal X-ray [12] to 100% for lateral foot or ankle radiograph [11,16]. Just one study reported positive and negative predictive value [12].

Computed tomography scan (CT-scan)

Only two studies assessed role of CT-scan in diagnosis of calcaneal fracture [14,16]. Both studies had moderate quality, but just one of them reported sensitivity and specificity of different types of CT-scan [16]. Three-dimensional (3D) shaded radiographs had highest sensitivity (90.7%) and specificity (93.9%).

Angles

Four studies tried to show value of angle’s measures in diagnosis of calcaneal fracture in which two of them had moderate quality. Three of these worked on Böhler angle [8-10]. Two studies just showed significant difference of Böhler angle between fractured and non-fractured calcaneus [8,10]. One presented sensitivity and specificity of different amount of Böhler angle [9]. This study concluded Böhler angle of 20° or less is highly accurate in diagnosis of calcaneal fracture. Among other measurements, just tibiotalar angle and calcaneal length showed no significant difference between fractured and non-fractured calcaneus.

We identified no literature evaluating diagnostic accuracy of ultrasonography and magnetic resonance imaging (MRI).

Discussion

As a part of a systematic review, we aimed to address diagnostic accuracy and diagnostic value of different radiographs and tools through identification of relevant studies. Totally, 10 studies identified through search of four major databases and there were limit number of literatures evaluating diagnostic accuracy of different radiographs. In addition, we found no study with high-quality design and findings showed lack of high-quality study in assessment of diagnostic accuracy different tools in calcaneal fracture. These evidences are convincing enough that conclusions of this study are not completely reliable for clinical implication.
<table>
<thead>
<tr>
<th>First author</th>
<th>Date</th>
<th>Country</th>
<th>Objective</th>
<th>Participants</th>
<th>Imaging modality</th>
<th>Diagnostic accuracy statistics</th>
</tr>
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<tbody>
<tr>
<td>Zhang, T.</td>
<td>2015</td>
<td>China</td>
<td>Test the value of axial view in diagnosing calcaneal fractures with radiographs</td>
<td>140 Patients older than 18 yr with suspected calcaneal fractures</td>
<td>CT scan, Combined calcaneal lateral and axial X-rays</td>
<td>Sensitivity: 98.97%, Specificity: 94.85%</td>
</tr>
<tr>
<td>Arslan, G.</td>
<td>2014</td>
<td>Turkey</td>
<td>Determine whether calcaneal fractures determined by lateral X-rays and digital lateral images correlate with the Sanders classification</td>
<td>69 patients diagnosed with calcaneal fractures and 50 individuals without pathology</td>
<td>NS, Digital lateral view X-ray, Digital images and multi planar reformed contrast-enhanced CT images with slices measuring 1 mm</td>
<td>Sensitivity: 94.85%, Specificity: 79.07%</td>
</tr>
<tr>
<td>Isaacs, J. D.</td>
<td>2013</td>
<td>Australia</td>
<td>Confirm the normal range for Bohler’s angle and determine the angle with the highest accuracy in the diagnosis of calcaneal fractures</td>
<td>212 consecutive patients with calcaneal fractures with normal foot radiographs</td>
<td>CT scan, Lateral radiographs</td>
<td>Sensitivity: 98.47%, Specificity: 90.01%</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Year</td>
<td>Country</td>
<td>Methodology</td>
<td>Results</td>
<td>Reference</td>
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</table>
| Schepers, T.    | 2007 | Netherlands| Correlate the functional outcome after treatment for displaced intra-articular calcaneal fracture with plain radiography | 33 patients with unilateral calcaneal fracture | MF 46 yr (18-65) NS Weight-bearing lateral and axial view | Böhler angle 32 (25-40) Case 16 (10-40) P<0.001
|                 |      |            |                                                                              |         | Gissane angle 108 (90-125) Case 115 (80-140) P=0.023                      |
|                 |      |            |                                                                              |         | Facet inclination angle 66 (51-80) Case 54 (15-75) P<0.001                |
|                 |      |            |                                                                              |         | Tibiotalar angle 105 (94-128) Case 103 (92-110) P=0.101                  |
|                 |      |            |                                                                              |         | Talar declination angle 20 (15-28) Case 16 (10-26) P<0.001               |
|                 |      |            |                                                                              |         | Calcaneal inclination angle 23 (12-33) Case 21 (13-29) P=0.028           |
| Schepers, T.    | 2007 | Netherlands| Correlate the functional outcome after treatment for displaced intra-articular calcaneal fracture with plain radiography | 33 patients with unilateral calcaneal fracture | MF 46 yr (18-65) NS Weight-bearing lateral and axial view | Böhler angle 32 (25-40) Case 16 (10-40) P<0.001
|                 |      |            |                                                                              |         | Gissane angle 108 (90-125) Case 115 (80-140) P=0.023                      |
|                 |      |            |                                                                              |         | Facet inclination angle 66 (51-80) Case 54 (15-75) P<0.001                |
|                 |      |            |                                                                              |         | Tibiotalar angle 105 (94-128) Case 103 (92-110) P=0.101                  |
|                 |      |            |                                                                              |         | Talar declination angle 20 (15-28) Case 16 (10-26) P<0.001               |
|                 |      |            |                                                                              |         | Calcaneal inclination angle 23 (12-33) Case 21 (13-29) P=0.028           |
| Schepers, T.    | 2007 | Netherlands| Correlate the functional outcome after treatment for displaced intra-articular calcaneal fracture with plain radiography | 33 patients with unilateral calcaneal fracture | MF 46 yr (18-65) NS Weight-bearing lateral and axial view | Böhler angle 32 (25-40) Case 16 (10-40) P<0.001
|                 |      |            |                                                                              |         | Gissane angle 108 (90-125) Case 115 (80-140) P=0.023                      |
| Knight, J. R.   | 2006 | USA        | determine the use of Boehler’s angle (BA) and the critical angle of Gissane (CAG) in diagnosing calcaneus fractures in the ED | 65 patients with CT-verified calcaneus fractures and 68 ED patients with lateral foot or ankle x-rays without calcaneus fractures | N S CT scan Lateral foot or ankle radiograph Emergency physicians’ accuracy: 97.9% (97%-99%) Radiologist Sn: 98.5% Radiologist Sp: 100%
| Geusens, E.     | 2000 | Belgium    | demonstrate the statistical significance of a reversed oblique radiograph of the foot in patients with ankle or foot trauma | 100 consecutive patients who presented with a blunt trauma of ankle and/ | NS NS NS Foot posteroanterior, *Sn: 0% Foot oblique *Sn: 12.5% Foot reversed oblique *Sn: 100%
<p>| Utukuri, M. M.  | 2000 | UK         | sensitivity and specificity of the lateral view alone and lateral and axial view combined | Fifty sets of calcaneal radiographs | NS NS NS Clinical course of the patients, further radiographs and CT scans Lateral calcaneal X-ray Seniors 92.50% 86.50% 83.50% 95.50% Juniors 97.50% 72% 70% 98% Combined Lateral and axial calcaneal X-ray Seniors 100% 90% 87% 100% Juniors 97.50% 78.50% 76% 98% |</p>
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
<th>Country</th>
<th>Study Design</th>
<th>Sample Size</th>
<th>Range of Age</th>
<th>Result</th>
<th>Imaging Modality</th>
<th>Diagnostic Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tanyu, M. O.</td>
<td>1994</td>
<td>Germany</td>
<td>Value of 3D-CT imaging compared to conventional X-rays and 2D CT scans in calcaneal fracture assessment</td>
<td>23 patients with different types of acute calcaneus fractures</td>
<td>20-68 yr</td>
<td>NS</td>
<td>Nondiagnostic</td>
<td>3D-CT imaging: 16% 2D-CT scans: 0% Conventional X-rays: 44%</td>
</tr>
<tr>
<td>Richardson, M. L.</td>
<td>1992</td>
<td>USA</td>
<td>Investigate methods of estimating the calcaneus varus angle in normal and fractured hind foot and to establish normative data for each method</td>
<td>48 consecutive patients with known or suspected calcaneal fracture</td>
<td>37 yr (19-71)</td>
<td>CT scan</td>
<td>Normal feet: Axial calcaneocuboid angle 25.3±7.3 Fractured feet: 28.9±8.5</td>
<td>Moderate diagnostic value: 76% Good diagnostic value: 8% Excellent diagnostic value: 0%</td>
</tr>
<tr>
<td>Vannier, M. W.</td>
<td>1991</td>
<td>USA</td>
<td>compare the diagnostic sensitivity and specificity of 3D CT, CT slices, and plain radiography in the detection and characterization of calcaneal and pelvic fractures</td>
<td>Nineteen calcanei in 11 individuals with suspected or overt calcaneal fractures</td>
<td>NS</td>
<td>CT scan</td>
<td>Axial talocalcaneal angle 20.9±9.2</td>
<td>Excellent diagnostic value: 56% Moderate diagnostic value: 56% Good diagnostic value: 0% Excellent diagnostic value: 0%</td>
</tr>
</tbody>
</table>

Table 1: Characteristics of studies included in the systematic review evaluating the Diagnostic Value of imaging modalities for suspected calcaneal fracture.
Conventional radiography showed a wide range of Sensitivity and specificity in diagnosis of calcaneal fracture. Although, most of studies presented a high sensitivity and specificity, but two studies showed lack of diagnostic value for some views of conventional radiography [13, 14]. Also, results demonstrated that combined lateral and axial calcaneal X-ray have higher diagnostic accuracy compared to lateral calcaneal X-ray alone. Böhler angle and Gissane's angle are two important markers of lateral X-ray [17]. Axial view is useful for assessment of calcaneal varus deformity, heel widening, step-off in the posterior facet and its relation with the sustentaculum tali [17].

CT-scan generally is considered as high sensitive and specific tools for diagnosis of fractures. In this systematic review CT-scan had used for confirmation of calcaneus fracture in most studies and only two studies evaluated importance of CT-scan in diagnosis of calcaneal fracture [14, 16]. Although, there is no strong evidences to prove importance of CT-scan, but these two studies had controversial results. Vannier et al. [16] revealed higher accuracy, sensitivity and specificity of plain radiography compared to different types of CT-scan. On contrast, Tanyu et al. [14] showed superior diagnostic value of CT-scan for calcaneal fracture.

Although, some studies assessed value of angles in diagnosis of calcaneal, but only one study presented angle cut-off points for diagnosis of calcaneal fracture. Issacs et al. [9] evaluated diagnostic value of different Böhler angles and revealed highest diagnostic value for Böhler angle of 20° or less.

The limitation of this review was that few of studies have been evaluated diagnostic value of different tools. As well as, variation in diagnostic tools and low quality studies affected the worth of results. Definitely, experiences of physician for assessment of radiograph as a confounder variable have an important role in results of studies and there was lack of information.

However, CT is considered the gold standard, but in this systematic review, we showed lack of strong evidences to confirm advantages of CT-scan. Excellence of CT-scan may be upon unreliable evidences and use of plain radiograph can decrease economic burden. We concluded there are few literatures evaluating different tools in diagnosis of calcaneal fracture and results are not enough to prove advantage of one modality to others. Therefore, one study with a large population sample is needed to compare diagnostic value of different modalities.

Conflict of interest

None

References