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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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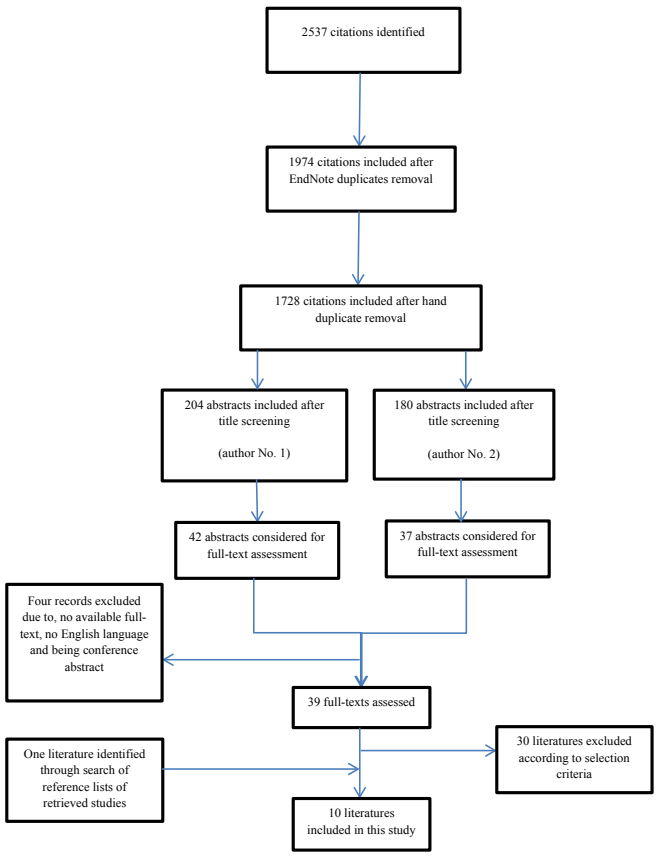

Figure 1: Flow chart of the reviewing process for diagnostic value of different image modalities in calcaneal fracture.

were excluded: [1] case-reports; [2] review studies; [3] non-research article (all type of letters, comments, and editorial); [4] cadaveric studies; [5] animal studies.

Selection procedure and data extraction

Two authors, applying the inclusion and exclusion criteria, screened all citations and abstracts and extracted all needed information from included literatures, independently. When conflicting results was seen between reviewers, a third author (senior researcher) discussed about disagreement. EndNote X7 software was used to manage review and organize screening.

The following information and data extracted: name of first author, date of publication, study objective (what authors aimed to conclude), study population, gender and mean age of population, criterion standard, imaging modality and diagnostic accuracy statistics. Finally, senior author rechecked all information of final stage table. For clarifications and more information (or unavailable full texts), we contacted with first and corresponding authors to provide additional data.

Literature quality assessment

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 measuremental 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 posteroanterior [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.

First author	Date	Country	Objective	Participants	Gender	Age	Criterion standard	Imaging modality	Diagnostic accuracy statistics							QUA-DAS
Zhang, T.	2015	China	test the value of axial view in diagnosing calcaneal fracture	140 Patients older than 18 yr with suspected calcaneal fractures	MF	39.2 yr (19-61)	CT scan	Combined calcaneal lateral and axial X-rays	Sn: 98.97%							9\
									Sp: 95.35%							
								Calcaneal single lateral X-ray	Sn: 94.85%							
									Sp: 79.07%							
Arslan, G.	2014	Turkey	determine whether calcaneal fracture severity determined by angle and facet height measurements on lateral X-ray radiographs correlate with the Sanders classification	69 patients diagnosed with calcaneal fractures and 50 individuals without calcaneal pathology as control group	MF	39 yr (18-79) cases/42 yr (19-88) controls	NS	digital lateral view X-ray images and multi planar reformatted contrast-enhanced CT images with slices measuring 1 mm			Cnl		EA-FX		IA-FX		1
									BA		42.08 ±8.8		38.9±9.48		28.62±15.73	
													P=0.186		P<0.001	
									AoG		106.04±8.22		112.8±8.16		118.94±13.08	
													P=0.003		P<0.001	
									FH (mm)		45.96±3.52		46.1±3.51		43.42±5.71	
													P=0.881		P=0.006	
									IL		21.14±4.85		18.6±3.6		18.33±5.06	
													P=0.038		P=0.003	
Isaacs, J. D.	2013	Australia	confirm the normal range for Bohler's angle and determine the angle with the highest accuracy in the diagnosis of calcaneal fractures	212 consecutive patients diagnosed with calcaneal fractures and 212 patients with normal lateral foot radiographs	MF	35.8 yr (cases)/50.9 (controls)	CT scan	Lateral radiographs		Sn	Sp	PPV	NPV	LR+	LR-	8
									BA≤15	90.6	100	100	91.4	90	0.09	
									BA≤16	92	100	100	92.6	92	0.08	
									BA≤17	95.3	100	100	95.5	95	0.05	
									BA≤18	97.2	100	100	97.2	97	0.03	
									BA≤19	98.6	100	100	98.6	99	0.01	
									BA≤20	99.5	99.1	99.1	99.5	111	0.01	
									BA≤21	100	96.7	96.8	100	30	0.01	
									BA≤22	100	95.8	95.9	100	24	0.01	
									BA≤23	100	89.2	90.2	100	9	0.01	
									BA≤24	100	84	86.2	100	6	0.01	
									BA≤25	100	81.6	84.5	100	5	0.05	

Schepers, T.	2007	Nether-lands	Correlate the functional outcome after treatment for displaced intra-articular calcaneal fracture with plain radiography	33 patients with a unilateral calcaneal fracture	MF	46 yr (18–65)	NS	Weight-bearing lateral and axial view		Cnl	Case			3
									Böhler angle	32 (25–40)	16 (−10–40) P<0.001			
									Gissane angle	108 (90–125)	113 (80–140) P=0.023			
									Facet inclination angle	66 (51–80)	54 (15–75) P<0.001			
									Tibiotalar angle	105 (94–128)	103 (92–110) P=0.101			
									Talar declination angle	20 (15–28)	16 (10–26) P<0.001			
									Calcaneal inclination angle	23 (12–33)	21 (13–29) P=0.028			
									Talocalca-neal angle	43 (32–58)	37 (23–57) P<0.001			
									Tibiocalca-neal angle	62 (45–81)	65 (35–80) P=0.011			
									Calcaneal width (mm)	40 (35–46)	46 (37–56) P<0.001			
									Calcaneal facet height (mm)	50 (43–56)	47 (38–58) P=0.001			
									Absolute foot height (mm)	81 (67–92)	77 (65–90) P<0.001			
									Calcaneal length (mm)	82 (71–93)	82 (71–92) P=0.701			
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	NS	NS	CT scan	Lateral foot or ankle radiograph	Emergency physicians' accuracy: 97.9% (97%-99%)					8
									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%					4
								Foot oblique	*Sn: 12.5%					
								Foot reversed oblique	*Sn: 100%					
Utukuri, M. M.	2000	UK	sensitivity and specificity of the lateral view alone and lateral and axial views combined	Fifty sets of calcaneal radiographs	NS	NS	Clinical course of the patients, further radiographs and CT scans	Lateral calcaneal X-ray		Sn	Sp	PPV	NPV	4
									Seniors	92.50%	86.50%	83.50%	95.50%	
									Juniors	97.50%	72%	70%	98%	
								Combined Lateral and axial calcaneal X-ray		Sn	Sp	PPV	NPV	
									Seniors	100%	90%	87%	100%	
									Juniors	97.50%	78.50%	76%	98%	

Tanyu, M. O.	1994	Germany	Value of 3D-CT imaging compared to conventional X-rays and 2D CT scans in calcaneal fracture assessment	23 patients with different types of acute calcaneus fractures	MF	20-68 yr	NS		Nondiag-nostic	Moderate diagnostic value	Good diagnostic value	Excellent diagnostic value	6
								3D-CT imaging,	16%	76%	8%	0%	
								2D-CT scans	0%	0%	80%	20%	
								Conventional X-rays	44%	56%	0%	0%	
Richardson, M. L.	1992	USA	Investigate methods of estimating the calcaneus varus angle in normal and fractured hind foot and to stablish normative data for each method	48 consecutive patients with known or suspected calcaneal fracture	MF	37 yr (19-71)	CT scan	CT scan	Normal foots	Axial calca-neocuboid angle	Axial talocalcaneal angle	Coronal talocalcaneal angle	9
										25.3±7.3	20.9±9.2	12.5±3.8	
									Fractured foots	28.9±8.5	29.2±11.3	21.8±7.6	
										P=0.05	P=0.001	P<0.001	
Vannier, M. W.	1991	USA	compare the diagnostic sensitivity and specificity of 3D CT, CT slices, and plain radiography in the detection and characterization of calcaneal and pelvic fractures	Nineteen calcanei in 11 individuals with suspected or overt calcaneal fractures	MF	NS	NS			Accuracy	Sn	Sp	5
								Plain film		96.20%	95.80%	100%	
								3D shaded		92.10%	90.70%	93.90%	
								3D depth		86.50%	87.80%	84.80%	
								CT slice		90.70%	85.70%	97.00%	
								3D volume		84.00%	79.60%	90.30%	

Date: date of publication; yr: year; M: male; F: female; NA: not applicable; P: P-value; NS: not stated; USA: United States of America; UK: United Kingdom; CT: computed tomography; Cnl: control; EA-FX: extra-articular fracture; IA-FX: intra-articular fracture; Sn: sensitivity; Sp: specificity; PPV: Positive predictive value; NPV: Negative predictive value; LR+: positive likelihood ratio; LR-: negative likelihood ratio; BA: Bohler's angle; AoG: angle of Gissane; FH: facet height; IL: inclination level;
*calculated by authors

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 of points for diagnosis of calcaneal fracture. Isaacs 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. So, one study with a large population sample is needed to compare diagnostic value of different modalities.

Conflict of interest

None

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