AN AUDIT OF THE CAT SCAN RADIOLOGICAL REPORTING SYSTEM IN CALCANEAL FRACTURES AT CHARLOTTE MAXEKE JOHANNESBURG ACADEMIC HOSPITAL (CMJAH)

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Declaration by candidate

I, Boitumelo Khoza, student number 0103570H, declare that this Thesis / Dissertation / Research report is my own work. It is being submitted for the degree of MMed (RadD) at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

DR BOITUMELO KHOZA

On this 14TH DAY OF JULY 2025

Publications and presentations

This work has never been published.

Abstract

INTRODUCTION: Calcaneus fractures account for 1-2% of fractures. The Sanders classification system is the most used to classify intra-articular calcaneal fractures using computed tomography (CT).

AIM: To monitor the use of the Sanders classification of calcaneal fractures and thus determine the most common type of Sanders classification reported. To assess the presence of concomitant fractures in the foot and ankle. To ascertain the prevalence of calcaneal fractures and to assess the standard of the radiology reporting system in the diagnosis.

METHOD: This was a retrospective review of radiology reports in trauma patients with foot and ankle imaging at a Johannesburg based academic hospital between January 2018 and December 2019.

RESULTS: There were 316 trauma-related ankle and foot CT scans in the study period, from which it identified 72 (23%) adult patients with calcaneus fractures. Nineteen of these had bilateral calcaneal fractures. Therefore, the total number of fractures analysed further was 91, of which 72 (79%) were intra-articular and 19 (21%) were extra-articular. The Sanders classification was used in just over a third (n=25, 35%) of the radiology reports, with Sanders Type 4 fractures most observed (18/25, 72%). Most of the concomitant fractures were observed in the tarsal bones.

CONCLUSIONS: Calcaneal fractures represent a prevalent injury within the spectrum of foot and ankle trauma. Sanders classification is a valuable tool for orthopaedic surgeons in pre-operative planning and prognosis prediction for calcaneal fractures; its incorporation into routine radiological reporting practices must be consistently observed.

Keywords: Sanders classification; calcaneal fractures; CT ankle and foot

Acknowledgements

To my supervisors for helping me to make this happen.

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Computed tomography (CT)

Motor vehicle accident (MVA)

Pedestrian vehicle accident (PVA)

Picture archiving and communication system (PACS)

Standard Deviation (SD)

Introduction

1.1. Background

Calcaneal fractures are relatively uncommon and account for approximately 2% of all body fractures.[1,2] As a gold standard, CT scan is used to identify the extent of calcaneal fractures, and thus allowing optimum assessment for patient management. The treatment of such fractures and their outcome are based on several factors related to the characteristics of the fracture and the presence or absence of associated injuries.[3–5] However, calcaneal fractures are among injuries that may lead to short and long-term morbidity if not treated correctly.[5]

Most calcaneal fractures result from falls and motor vehicle accidents (MVA), which are incidents known to be associated with high-velocity axial trauma.[6,7] The most commonly associated fractures or those that occur concurrently with calcaneal fractures are near the calcaneus, including the lower leg and foot, followed by the lumbar spine.[8–10] The two most widely used classification systems to classify intra-articular calcaneal fractures are the Sanders classification based on CT imaging and the Essex-Lopresti classification based on the lateral radiograph.[11,12] The Sanders classification may be used for prognosis[13,14] and management.[15] It describes fracture line position and prognosis and does not consider the relationship between the three facets of the subtalar joint.[11] However, the Sanders classification is limited to the posterior facet of the calcaneum. The Essex-Lopresti classification can also be used for prognosis but only in cases where the fracture is identified and treated early, as its assessment lacks 3D dimensions.[16,17]

While ample research exists on the epidemiology of calcaneal fractures in various countries, data specific to South Africa is notably scarce.[6,7,18–20] Therefore, the present study aimed to analyse the recorded data of calcaneal fractures in a single trauma centre in Johannesburg, South Africa, over two years, by providing information on using the Sanders CT classification system to diagnose calcaneal fractures.

1.2. Aim of the study

The aim of the study is to determine the prevalence of calcaneal fractures in trauma patients who had foot and ankle imaging, and to monitor the use of the Sanders CT classification in assessing these fractures.

1.3. Study objectives

1) Determine the prevalence of calcaneal fractures in trauma-related CT imaging of the foot and ankle at CMJAH from January 2018 – December 2019.
2) To monitor the use of the Sanders classification of calcaneal fractures system of the foot and ankle by radiologists in radiology reports.
3) Assess the presence of associated fractures in the foot and ankle.
4) To determine the most common type of Sanders classification reported.

2. Materials and Methods

2.1. Study design and setting

A retrospective cross-sectional audit of trauma-related adult patient reports who underwent CT imaging of the foot and ankle at the Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) radiology department was performed from January 2018 to December 2019.

Charlotte Maxeke Johannesburg Academic Hospital is one of the leading teaching hospitals estimated to serve a population of 5,195,132 across three districts, namely Johannesburg Metro, Ekurhuleni, and West Rand, through its cluster hospitals.[4] It also serves the Southern African Development Community (SADC) countries and provinces such as Limpopo, Mpumalanga, and the North West.[4]

2.2. Study population

Individuals aged 18 years and older with trauma-related injuries and who underwent CT imaging of the foot and ankle were included in this study. Individuals were sent to the institution from the referral points.

2.3. Data collection

An anonymised data collection process was done by retrieving post-traumatic CT ankle and foot radiological reports from the picture archiving and communication system (PACS) analysed by radiology registrars and or consultant radiologists using a standardised data collection sheet. The data collection sheet collected demographics (sex, age); laterality; Sander's classification; mechanism of injury; associated fractures.

2.4. Data analysis and statistics

Data analysis was conducted using Stata 18 (StataCorp. 2023. Stata Statistical Software: Release 18. College Station, TX: StataCorp LLC). Descriptive statistics was used to describe the data. Normality was determined using the Shapiro-Wilk test. A $p > 0.05$ was considered for normality. Age was expressed as mean ± SD or median and IQR, depending on normality. All categorical variables were presented as frequency and percentages. Associations between concomitant fractures and laterality were determined using Chi-square/ Fisher's exact tests. A $p < 0.05$ was considered statistically significant for the associated fractures. Graphical presentation of the results was in form of bar charts and box plot.

2.5. Ethics and limitations

Permission for the study was granted by the University of the Witwatersrand Human Research Ethics Committee (Medical) (Wits HREC) (Clearance Number M220218) and the Medical Advisor Committee of Charlotte Maxeke Johannesburg Academic Hospital with the National Research Database (reference number GP_202202_077). Informed consent from patients was not required as the study was a retrospective analysis.

3. Results

3.1. Patient demographics

During the 2018-2019 review period, 394 patients underwent CT scans for ankle and foot conditions, 78 of which were unrelated to trauma with no calcaneal fracture. There were 316 patients with trauma-related fractures, with 240 non-calcaneus fractures (Figure 3.1).

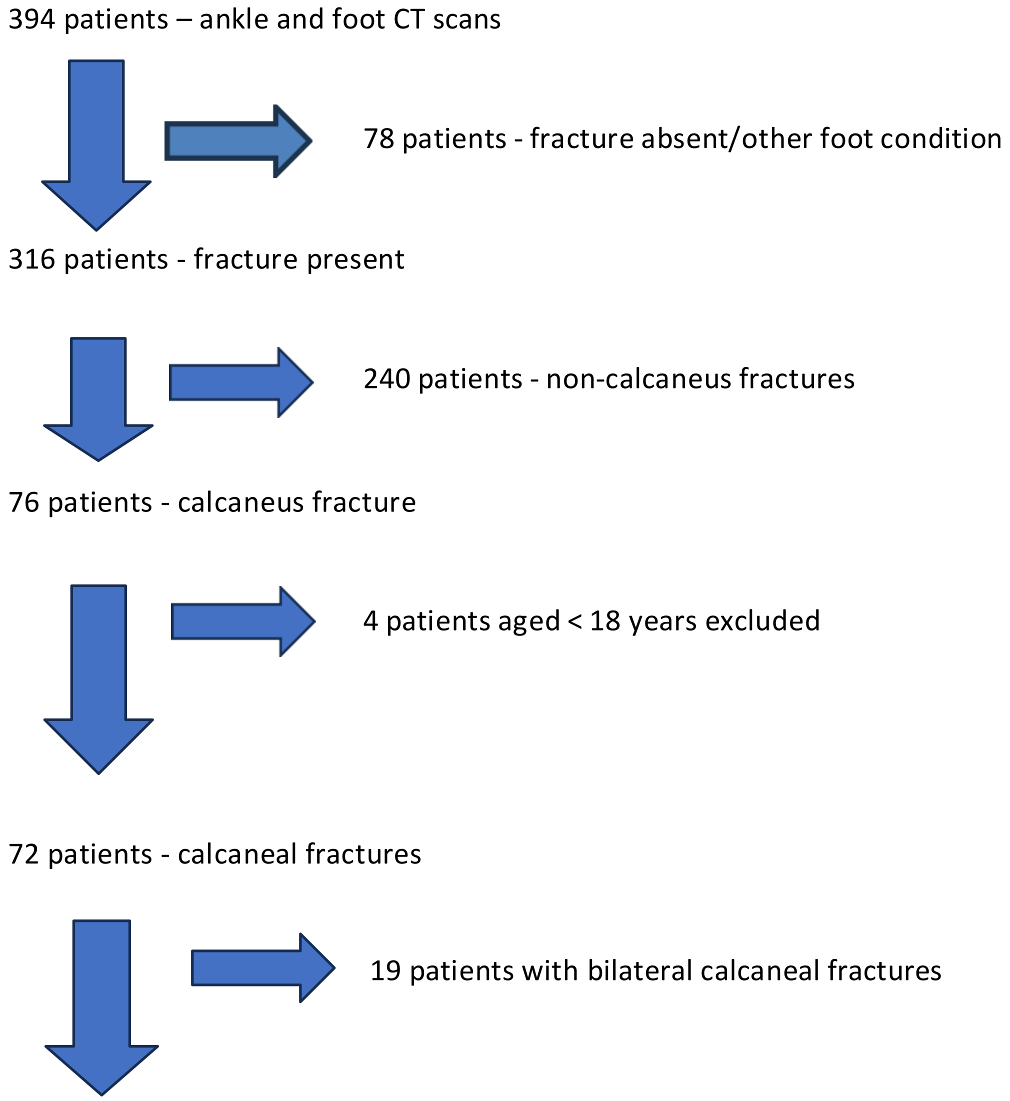

Figure 3.1. Flowchart showing how the cases were identified

Seventy-six (76) of these patients were reported to have calcaneus fractures. However, four were excluded as they were minors (<18 years), leading to a final number of 72 adult patients with calcaneal fractures (Figure 3.1).

The average age of the patients was 34.6 ± 11 years, with a minimum age of 19 and a maximum age of 75 (Figure 3.2). The gender was reported in 71/72 (99%) of the patients. There were 59/71 (83%) male patients in our study population, giving a 4:1 male-female ratio of the fractures (Figure 3.3).

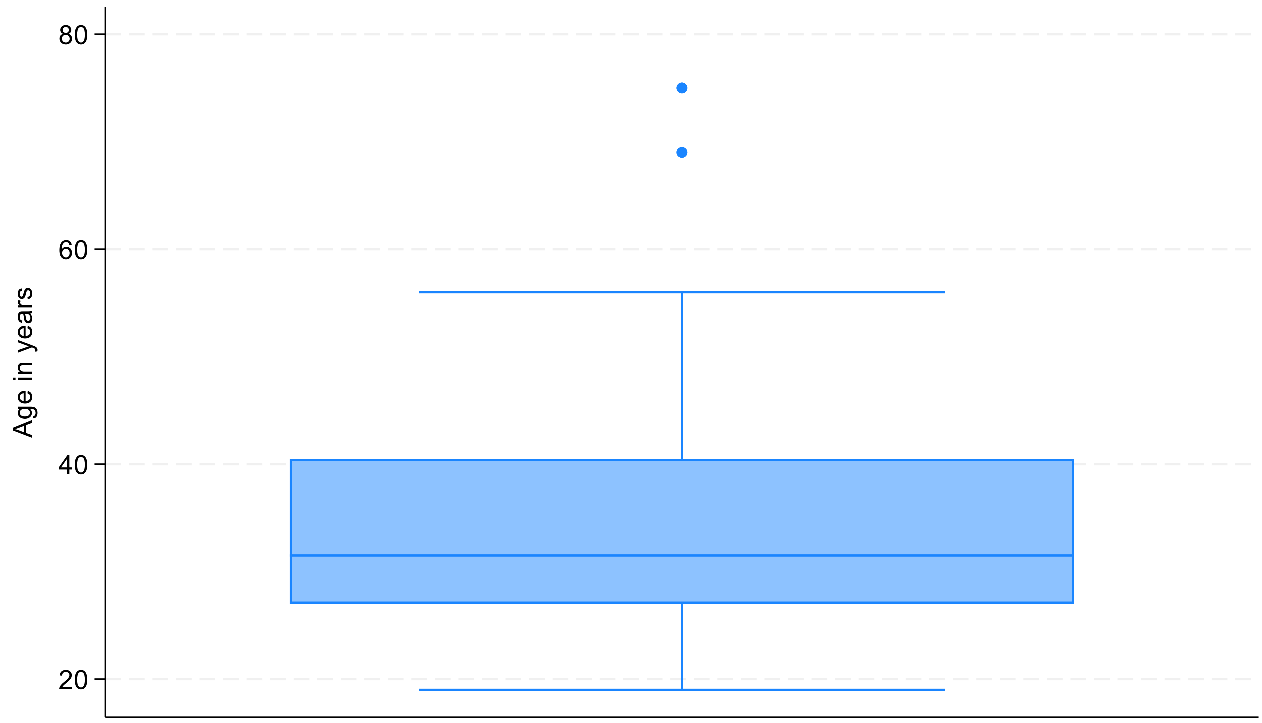

Figure 3.2: Age distribution in the patients with calcaneal fractures

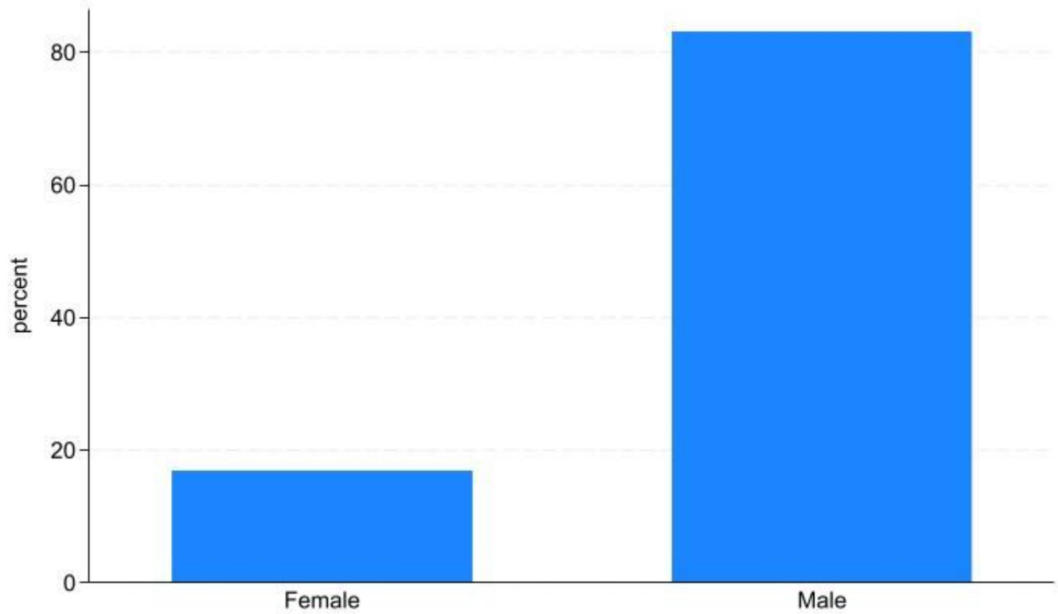

Figure 3.3. Gender distribution in the patients with calcaneal fractures

3.2. Description of fractures

Of the 72 patients, 19 of them had bilateral calcaneal fractures thus giving a total number of 91 calcaneal fractures. (Figure 3.1). Out of the 91 calcaneal fractures, 72 (79%) were intra-articular and 19 (21%) were extra-articular (Figure 3.4). The side of the foot in which the fracture occurred was reported for all 91 (100%) fractures. Fractures occurred commonly on the right foot, 50/91 (55%) and 41/91 (45%) on the left foot (Figure 3.5).

Figure 3.6 demonstrates the causes of the calcaneal fracture in the 72 patients. Majority 61/72 (85%) of the patient's mechanism of injury was known. Among the 61 patients with known mechanism of injury, falls are by far the most common cause, accounting for over 85% (52/61), road traffic-related injuries (PVA and MVA) make up about 13% (8/61) and other mechanisms are rare comprising just 1.6% (1/61).

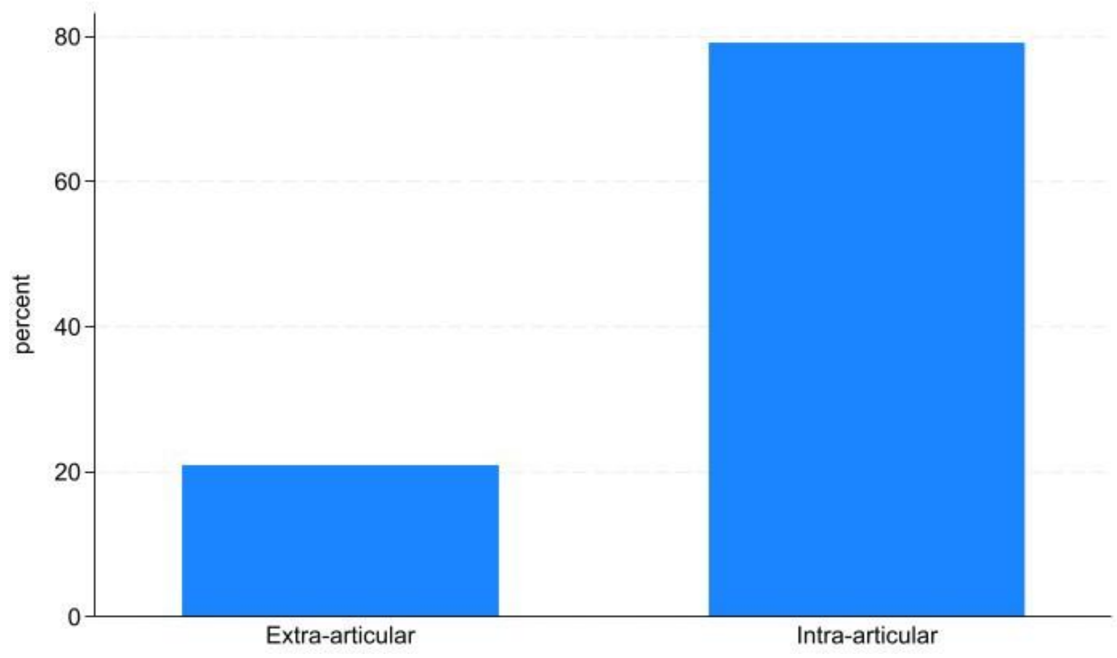

Figure 3.4. Sub-categorisation of the calcaneal fractures

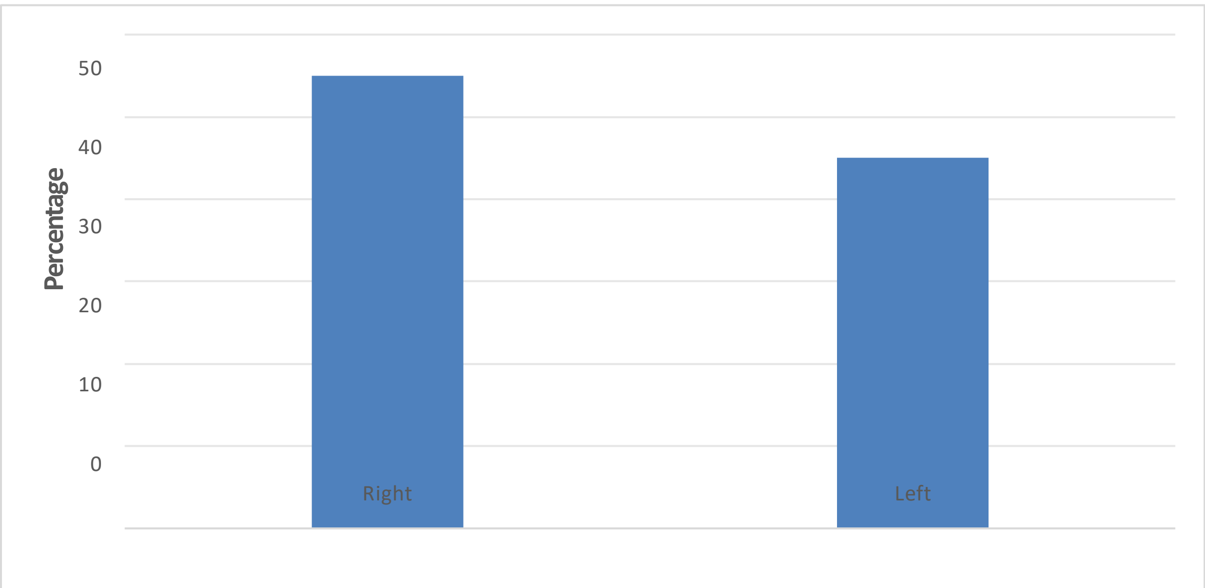

Figure 3.5. The side of calcaneal fracture occurrence

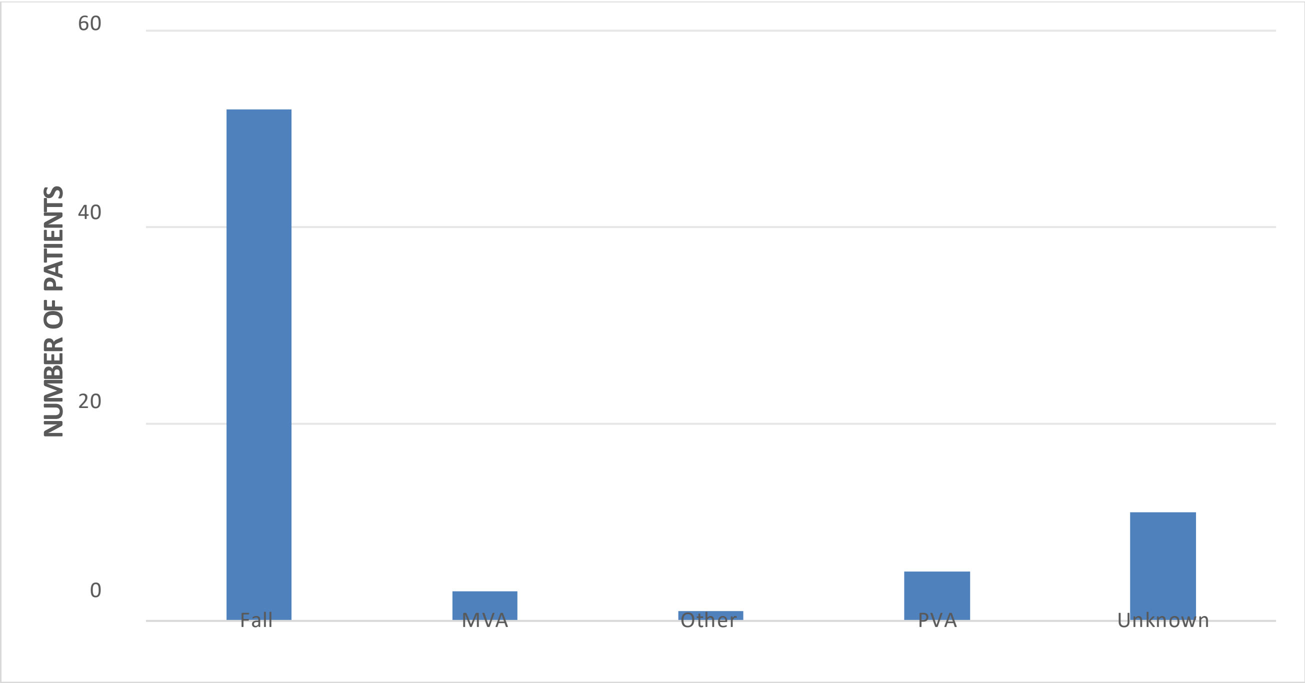

Figure 3.6. Recorded causes of the calcaneal fractures in the 72 patients

In the radiology report, the Sanders CT classification system was used in 25/72 (35%) of the intra-articular fractures, while 47/72 (65%) fractures were not classified (Figure3. 7). The majority 18/25 (72%) of the Sanders-classified fractures were Sanders Type 4; five (20%) were Sanders Type 3; one (4%) was a Sanders Type 2, and one (4%) was a Sanders Type 1 (Figure 3.8). The Type 4 Sanders were most often caused by a fall from height (13/14).

However, where the Sanders classification was not used, the radiologist described the fracture lines, extent, and displacement similar to the classification descriptors. In the conclusion of the radiology report, these fractures were thus summarized as either being non-comminuted or comminuted intra-articular fractures.

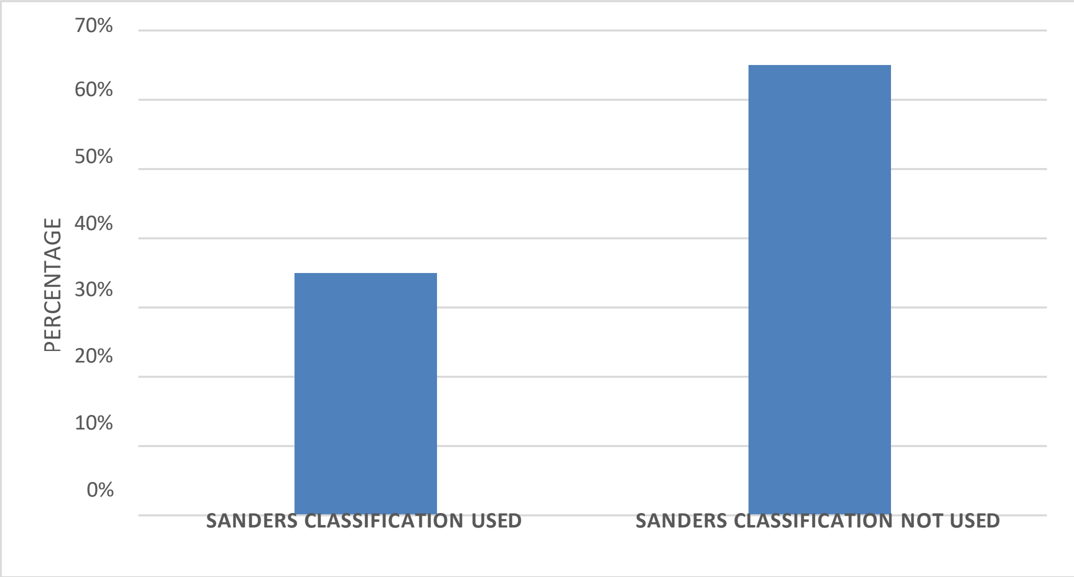

Figure 3.7. Proportion of intra-articular fractures classified using the Sanders classification system compared to those where the system was not used

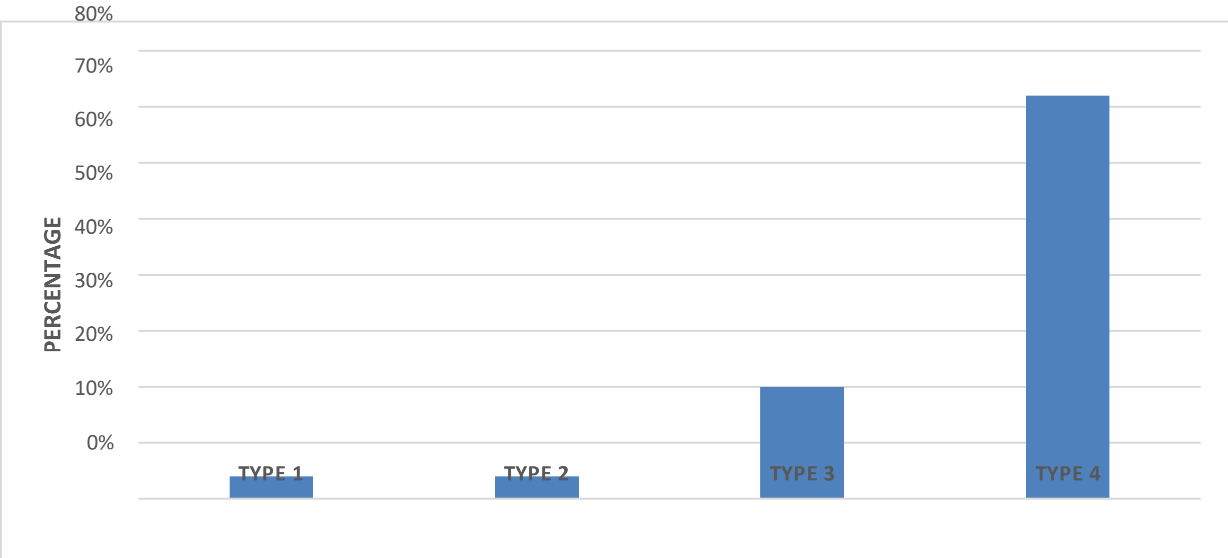

Figure 3.8. Review of the use of the Sanders classification types

3.3. Calcaneal fractures with concomitant fractures

The presence or absence of concomitant fractures was reported in all 91(100%) calcaneal fractures. Sixty (60/91) (66%) of the calcaneal fractures had no concomitant fractures. The other cohort of calcaneal fractures, 31/91 (34%), had 49 concomitant fractures. Eighteen (18/31, 58%) had one concomitant fracture; 9/31 (29%) had two concomitant fractures; 3/31 (10%) had three concomitant fractures and 1/31 (3%) had four concomitant fractures. Twenty (41%) of the 49 concomitant fractures were tarsal bone fractures; 13 (27%) were lateral malleolus fractures; nine (18%) were metatarsal fractures; five (10%) medial malleolus fractures; and two (4%) were fractures of the phalanges (Figure 3.9).

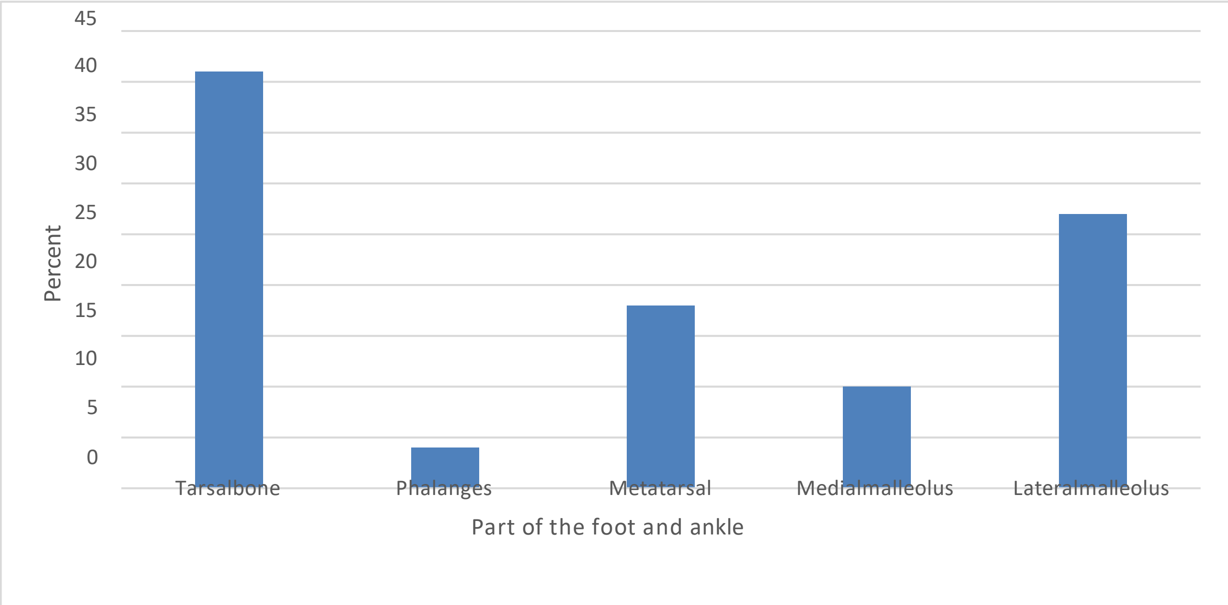

Figure 3.9. Distribution and occurrence of concomitant fractures

In the assessment of associated fractures, the most common pattern observed was tarsal (T) fractures, with a total of 18 cases (69%) on right side, bilateral side (10 cases, 59%). Tarsal-metatarsal (TM) were identified in 4 right-sided cases (15%),2 bilateral (12%), and 3 left-sided (18%). Tarsal-lateral malleolus (TLM) fractures were more common on the bilateral (2 cases, 12%) than the right (1 cases, 4%), with 1 left case (6%). Overall, tarsal fractures were the most common associated injury, particularly on the right side, while complex and multi-bone fracture patterns were less frequent. There was no statistically significant difference in the distribution of these fracture patterns between the groups (p = 0.330).

Table 3.1: Association of concomitant fractures with the laterality of calcaneal fractures

	Total	Bilateral	Left	Right		p-value
LM	1(2)	0	0	1(4)		0.330
LMMM	3(5)	2(12)	1(6)	0		
M	2(3)	0	2(12)	0		
MM	1(2)	0	1(6)	0		
P	1(2)	0	1(6)	0		
T	35(58)	10(59)	7(41)	18(69)		
TLM	4(7)	2(12)	1(6)	1(4)		
TLMMM	1(2)	1(6)	0	0		
TM	9(15)	2(12)	3(18)	4(15)		
TMM	2(3)	0	1(6)	1(4)		
TMP	1(2)	0	0	1(4)		

Evaluation of the Sanders classification through axial and coronal CT images placed parallel and perpendicular to the posterior facet of the subtalar joint (Figure 3.10).

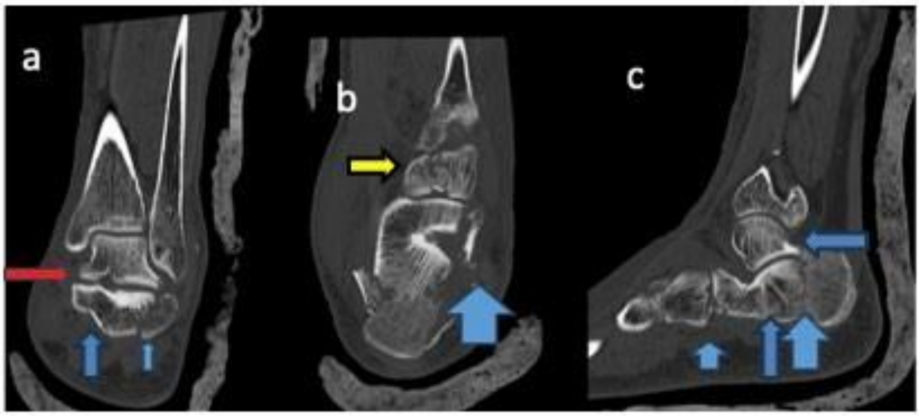

Figure 3.10. CT images (MPR) in coronal (a), axial (b), and sagittal planes (c), showing left calcaneus with multiple intra-articular fractures

(a) Fractures of the calcaneus with intra-articular extension.

(b) Multiple fractures of the calcaneus involving the posterior articular facet.

(c) Shows more than three fracture lines and was classified as Sanders Type 4 calcaneal fracture. Note concomitant fractures involving the talus (red arrow) and cuboid (yellow arrow).

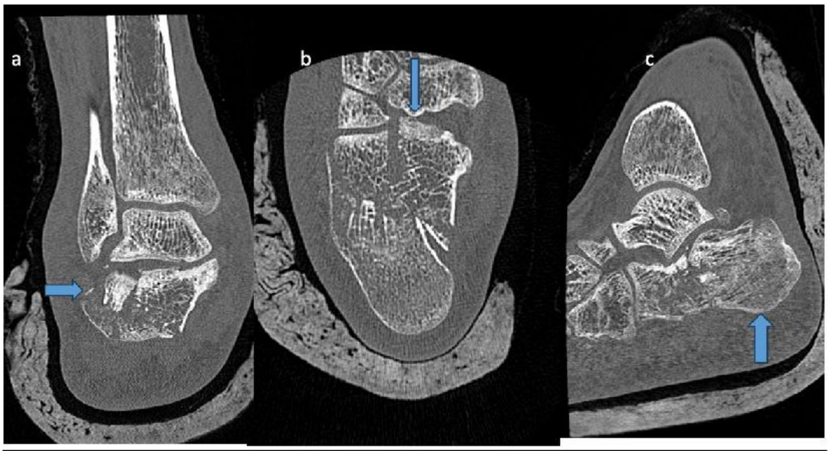

Figure 3.11. CT images (MPR) in coronal (a), axial (b), and sagittal planes (c) showing intra-articular fractures on the right

(a) Fracture of the calcaneus with intra-articular extension.

(b) Two-part fracture with one fracture line calcaneus involving the posterior articular facet. (c) Talo-calcaneus intra-articular extension. This fracture from our study was classified as Sanders Type 2 calcaneal fracture.

4. Discussion

This study identified 72 patients with an overall number of calcaneal fractures totaling 91 over two years, equating to an average of 46 fractures per year. This frequency was higher than the 12 annual fractures reported at a tertiary hospital in Brazil[21] and 39 from Saudi Arabia[22], but lower than hospitals in the United Kingdom[1] and Iran[23], pointing to geographical specificity. The average age of the study cohort was 34 years, which was in the range of previous studies.[1,21–23]

Our study showed that more males than females had fractures, with a 4:1 male-female ratio. Previous studies have repeatedly demonstrated that males have a 2.5 – 6-fold increase in the prevalence of fractures.[1,21–24] The reason for the male predominance in patients with calcaneal fractures may be lifestyle-related, as young men are more likely to be exposed to sports injuries[25] or fall.[10] Fractures to the calcaneus commonly occur with high-energy events that result in axial loading of the bone, however can also occur with any injury to the foot and ankle.[25] Falls and motor-vehicle accidents are the predominant mechanisms of injury. However, jumps onto hard surfaces, blunt or penetrating trauma, and shearing/twisting incidences may also cause injury.[18] Our study found that most calcaneal fractures were due to a fall, which aligns with other studies.[19,23] Benson et al. (2007) indicated that motor vehicle accidents needed to be severe to cause calcaneal fractures, which may often also lead to death due to injury to other body parts.[9]

Concomitant fractures often accompany calcaneal fractures.[1,8,9,26] Galluzzo et al. (2018) reported that patients with calcaneal fractures usually had other associated skeletal fractures, mainly the other tarsal bones.[28] This aligns with our study, which found that the most associated fractures were in the tarsal bones, predominantly in the midfoot.[27] This information highlights the importance of considering and evaluating the entire foot and ankle complex when assessing images and when treating calcaneal fractures, as these injuries can often involve multiple structures, as demonstrated by this current study and others.[6,18,28,30]

Thus prior to completion of the final radiology report, it is imperative for the radiology reader to look for concomitant fractures. We found in our study that there 19 patients (26.4%) had bilateral calcaneal fractures.[30]

The Sanders system is the most used classification system for intra-articular calcaneal fractures.[27] The system is based on coronal CT images. It subdivides intra-articular fractures into four types, depending on the number of fractures and the fracture line position at the posterior calcaneal facet.[13] There is prognostic importance to this classification, with Sanders Type 3 and 4 fractures having a worse prognosis in comparison to other types.[31] In our study, most of the fractures were not classified using this classification but instead most radiologists described the fracture lines and course.

In some cases, rather than applying the use of the Sanders classification or describing the fracture pattern, some radiology readers opted to summarize fractures as being intra-articular or extra-articular. For intra-articular fractures ,where the Sanders Classification was used, the most common classification was Type 4, which is a severely comminuted fracture with three or more primary fracture lines and greater than 2mm of articular displacement.[12,13] This reveals a noteworthy divergence in the prevalence of fracture types compared to existing literature.

Contrary to some prior studies where Sanders Type 2 fractures were commonly reported, our findings indicate a higher incidence of Sanders Type 4.[23] The higher frequencies observed is likely secondary to the high impact of axial loading from fall from height which is the most commonly described. [32]

Analysis of our data demonstrates that calcaneal fractures, even though they may make up a small proportion of fractures, have a high impact of injury. The results of which may lead to a high rate of policy issues such as disability grant applications and qualifications and medico-legal implications.[33]

This study directed us to be able to recognize the epidemiological profile of calcaneal fractures at the institution and recognize the overall radiological reporting technique.

4.1 Limitations of the study

The study was conducted in a single hospital, thus limiting the sample size. It may not accurately represent the geographical frequencies. In addition, the study was retrospective, limiting the amount of data gathered, including patient occupation and the exact height of a fall – factors previously identified to affect the extent of the fracture.[10,34,35] Reports were completed by readers with varying levels of experience. Where applicable, findings were confirmed with a consultant. In instances where junior readers interpreted imaging independently without consultant verification, there is a potential for diagnostic variability, which may affect the consistency and reliability of the reported findings.

5. Conclusion

Calcaneal fractures represent a prevalent injury in the spectrum of foot and ankle trauma, with a preference for occurrence in the male demographic that are treated at the institution, often resulting from high-energy mechanisms such as falls. The frequency of concurrent fractures, especially in proximity, emphasises the necessity of a thorough assessment of the entire foot and ankle complex in cases of calcaneal fractures. This holistic approach is crucial for accurate diagnosis and effective treatment.

The Sanders classification system is a valuable tool for orthopaedic surgeons in pre-operative planning and prognosis prediction for calcaneal fractures. However, its incorporation into routine radiological reporting practices could possibly be consistently observed. The decision to employ this classification system in reporting may be contingent on institutional protocols. The variability in fracture descriptions, the usage and non-usage of the Sanders classification by radiologists in the radiological reporting underscores the importance of continued research to refine our understanding of these injuries and inform evidence-based treatment strategies.

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Appendix A: Ethics Clearance Certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

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DATE: 2022/05/09

REF: R14/49

PROTOCOL NO: **M220218** (This is your ethics application reference number. Please quote it in all enquiries, oral or written, relating to this study.)

PROJECT TITLE: *An audit of the CAT scan radiological reporting system in calcaneal fracture at Charlotte Maxeke Johannesburg Academic Hospital*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to Government funding of the University.

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Appendix B: Turnitin report

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Appendix C: Approved Research Protocol

An Audit of the CAT scan radiological reporting system in calcaneal fracture at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH)

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LIST OF ABBREVIATIONS

BA	Bohler's angle
BMI	Body mass index
CMJAH	Charlotte Maxeke Johannesburg Academic Hospital
CAT	Computed axial tomography
CT	Computed tomography
GA	Gissane's angle / Critical angle of Gissane
PACS	Picture Archive and Communication System

1. Rationale

The purpose of the study is to perform an audit in order to determine the incidence of calcaneal fractures in patients who received computed tomography imaging of the foot and ankle for trauma at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) between January 2018 and December 2019 in order to establish how many radiology reports were generated using the Sanders CT classification of calcaneal fractures and determine the commonest type of this classification used in order to create a standardised CT reporting template of reporting calcaneal fractures. This study may assist in:

- Allowing remote orthopaedic surgeons to make critical surgical or non-surgical management based on the report provided by radiologists if they have no access to the images.
- In order to use the same lexicon between the radiologists and orthopaedic surgeons. Saving costs and time in busy radiology departments.
- Reducing radiation dose to patients who have non operable injuries.
- Allowing an efficient reporting time when all check-lists have been addressed.
- For the orthopaedic surgeons to be cognizant about non-orthopaedic related injuries.

2. Introduction

2.1 Definition

Calcaneal fracture was initially described by Norris back in 1839 and then named by Malgaigne later in 1843 using his name (1).Due to the nature of calcaneal fractures and associated injuries, there is often substantial permanent disability related to it (2).

2.1.1 Epidemiology and prevalence.

Calcaneal fractures are uncommon, representing 1-2% of all fractures (3). However, they are debilitating injuries that pose a serious socio-economic impact due to associated residual long-term disability (4). Calcaneal fractures had a poor prognosis historically, usually because of the direct trauma and injury to the articular surfaces, calcaneal fat pads and the peroneal tendons with further resultant change in the mechanical forces acting on the ankle joint (5).

The calcaneus is the most commonly fractured foot bone, accounting for 60% of all fractures in the foot (6).Associated fractures occur in more than three quarters of patients with calcaneal fractures and most common associated fractures are in close proximity to the calcaneus (2).Other concurrent fractures are of the lumbar spine (2).

2.1.2 Risk factors

Calcaneal fractures frequently occur in younger males between the ages of 20 to 29 years (7). Annual incidence of calcaneal fractures was 16.5 in males and 6.3 in females per 100,000 (8).The young male gender of the working class as having the highest risk (9). Males were found to be at higher risk than females, with young males being among those at the highest risk. (1). Adults with a BMI of 28 or more, seldom or non-consumption of meat and its products, history of smoking, alcohol consumption, average sleep of less than seven hours per day, and a prior history of fracture are mostly risk factors causing calcaneal fractures (1).

2.1.3 Anatomy

The recognition of the calcaneus characteristics and anatomical landmarks are essential in the management guidance of the injuries. The calcaneus bone has a thin cortex with traction trabeculations that radiate from the inferior surface and compression trabeculae that converge to support the anterior and posterior articular facets, leaving a ‘’neutral triangle’’ that lies between them with sparse trabeculations (5). There are four articular surfaces of the calcaneus, three superiorly and one anteriorly. The superior surface includes the posterior, middle, and anterior facet, articulating with the talus. The posterior facet is the largest and is the primary weight bearing facet. The sustentaculum tali is an eminence on the medial aspect of the calcaneus supporting the middle articular facet (2). Anatomy of the ankle and foot consists of 26 bones, including the tibia and fibula (being the medial and lateral malleolus respectively), 7 tarsal bones (comprising of calcaneus;talus;navicular;cuboid and medial, intermediate and lateral cuneiforms) ,5 metatarsals and 14 phalanges.

2.1.4 Mechanism of injury

The primary mechanism of injury is traumatic axial loading, and the injuries are high energy (10, 11). Calcaneal fractures are caused by falls from great heights, motor vehicle accidents, and other events such as bomb blasts, skipping, tripping, and falling from a chair or stairs (12, 1). The majority of the injuries are caused by falls from great heights and motor vehicle accidents, both of which are common causes of morbidity and mortality in the suburban population (10). The lateral process of the talus is pushed into the angle of Gissane by the excessive axial force. Force is transmitted to the calcaneus when the posterior facet of the calcaneus rotates anteriorly. Following that, resistance is overcome, and a primary fracture line is re-established. The excessive axial force pushes the lateral process of the talus into the angle of Gissane. When the posterior facet of the calcaneus anteriorly rotates; force is transmitted to the calcaneus. What follows is resistance that is exceeded and then a primary fracture line results through the angle of Gissane and neutral triangle (10).

2.1.5 Types and Classification

There are two major categories of calcaneus fractures, the intra-articular, which accounts for 75% of injuries, and the extra-articular fractures, accounting for 25% of all calcaneus fractures
(2). The primary fracture line visualized in patients with intra-articular fractures is usually oblique with superomedial or superolateral fragments, occurring with and without evidence of displacement. Seen with intra-articular fractures are a shear fracture, compression fracture line, tongue type fracture and joint depression type fracture (5).

Intra-articular fractures: tend to extend through the posterior subtalar facet, while the extraarticular fractures do not extend into the subtalar joint. Account for 75% of calcaneal fractures (10).

Extra-articular fractures: account for about 25 - 30% of calcaneal fractures and include all fractures that do not involve the posterior facet (2).

Earlier classification system for calcaneal fractures were based on findings seen at conventional radiography and the best known of these classification is the Essex-Lopresti system (10). Modern calcaneal fracture classification systems rely on CT because of the three dimensional approach and allows better visualisation of the subtalar joint and prognostic assessment using the Sanders classification system for intra-articular fractures (10).

2.1.5.1 Essex-Lopresti classification system.

This system aided in the determination of extra-articular fractures and the intra-articular fractures which further classified into joint depression and tongue type fractures. Because conventional radiography had limited anatomy visualization, it became obsolete (10). The angle of Bohler and angle of Gissane have been used to further characterize the Essex-Lopresti classification (13).

2.1.5.2 The Sanders Classification system

The Sander classification system was developed in 1993 and is the only system that correlates with patient outcomes for prognosis, along with surgical planning and patient outcome for prognosis (5). The classification of fractures is vital because it guides the treatment of these injuries (14).

2.1.6 Imaging and Diagnosis

Imaging findings are used to diagnose and treat calcaneal fractures. For better management of calcaneal fractures, many classification systems based on computerized tomography (CT) and plain radiographic appearance have been proposed. (2) Calcaneal fractures are diagnosed with a plain radiograph and a CT scan of the ankle and foot. A lateral view is included with the plain radiograph (14).

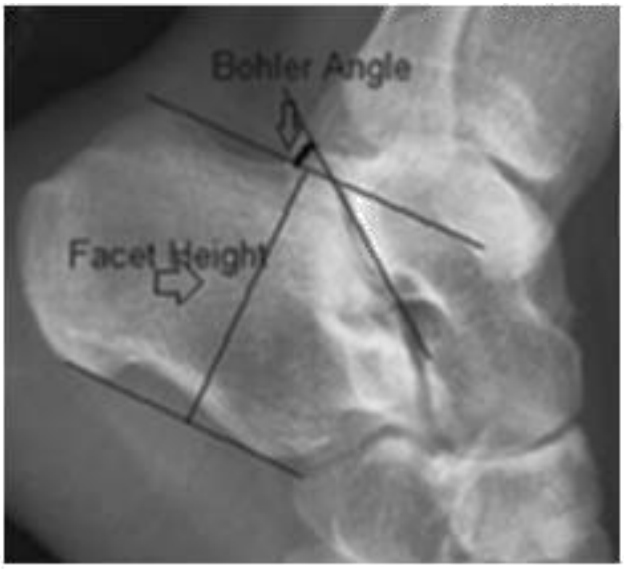

Fig. 2 The Bohler's angle and the facet height (lateral view X-ray) (11)

There are essential angles that are measured to evaluate fractures of the calcaneus. The Bohler's angle (BA) or (Angle of Bohler) is frequently assessed when evaluating the intraarticular type of fractures on a lateral plain film of the foot and ankle. Bohler's angle is the angle between the two tangent lines drawn across the calcaneus's anterior and posterior borders in the lateral view. The normal Bohler's angle is reported as an angle between 25-40 degrees (5). A Bohler's angle less than 25 degrees is suggestive of posterior facet collapse, secondary to a calcaneus fracture. A normal Bohler's angle may not preclude the presence of a fracture. The angle of Bohler can vary between the left and right foot. Variability has also been reported among different ethnic groups (12).

The BA has a high prognostic value regardless of the treatment modality (13). The critical angle of Gissane is another essential angle measured when evaluating calcaneus fractures. The angle of Gissane is assessed on a concurrent lateral view plain x-ray film. A value that exceeds 130 degrees is suggestive of a depressed posterior facet of the sub-talar joint. The Gissane angle (GA) is an angular measurement made directly inferior to the lateral process of the talus. It is formed by the intersection between the downward and upward slopes of the superior calcaneal surface. The normal value is usually between 120 – 145 degrees. An increase in this angle indicates a collapse of the posterior facet (14).

Fig. 3 The angle of Gissane and the inclination angle (lateral view X-ray) (11).

Although the severity of the deformity and the potential for sequelae from calcaneus fractures can generally be determined from radiographic studies alone, CT images represent a spectacular tool for surgical decision making. With radiography, relatively easily repaired fractures (which may be severely displaced) cannot be distinguished from those not amenable to surgical repair (10). Only CT can provide a precise definition of the size of the fragments as well as the number of fracture lines that must be identified and surgically reduced. CT also allows for better visualization of the subtalar joint and, as a result, a more accurate prognosis (10).

Multichannel helical computed tomography has shown to be important in the identification and the characterisation of the injury. The CT enables intra-articular extension of the fracture and assesses the fracture fragments. The reference is on the ankle joint on axial images to obtain true sagittal and coronal planes of the hind foot. For fracture classification, reformatted images parallel and perpendicular to the anatomical posterior facet of the sagittally reconstructed images. The Sanders classification relies on the sagitally reconstructed CT images reformat, orientated parallel and perpendicular to the posterior facet of the subtalar joint. Classified into four types, from I to IV. The sanders classification into the four types is on the basis of fracture line location at the posterior facet (11).

- Type I fractures are non-displaced.
- Type II fractures (two articular pieces) involve the posterior facet .The Type II fractures are further subdivided into Type II A, B and C depending on whether there is medial or lateral location of the fracture line.

- Type III fractures (three articular pieces) include an additional depressed middle fragment and are further subdivided into types, depending on the position and location of the fracture lines.
- Type IV fractures (four or more articular fragments) represent severely comminuted fractures.
- The type II, III and IV are further subdivided into A, B and C subtypes (medial, lateral and middle) according to fracture line localisation.

The surgical management of the injuries are divided into non operative and operative. Sanders Type I intra articular fractures and extra-articular fractures heal by conservative management ,whereas Type II and III fractures are treated surgically .Type IV fractures take a longer type top heal ,have a higher risk for complications and so are classified with the worst prognosis (15).Intra articular calcaneal fractures produce typical features ,that include loss of height due to impaction and rotation of the tuberosity fragment ,increase in width due to lateral displacement of the tuberosity fragment and disruption of the posterior facet of the subtalar joint (5). The Bohler's angle is measured on plain radiograph.

2.1.7 Associated and concurrent injuries

Calcaneal fractures are caused by high-energy causes, and as a result, concomitant injuries are common. Common injuries include lumbar spine injuries, lower extremity fractures, and foot or ankle fractures (2). There is evidence to support the link between calcaneal fractures and lumbar spine injuries, as well as a stronger link between calcaneal fractures and tibia/fibular injuries and other non-calcaneal foot injuries. Non-orthopaedic injuries have also been reported (2).

2.1.8 Treatment and Management

Demographics, co-morbidities, injury characteristics and associated injuries in patients with calcaneal fractures impact on the orthopaedic surgeon management approach (2). The management of calcaneal fractures can be surgical or non-operable. The decision is based on the amount of dislocation. Despite the fact that a CT scan can provide a better visualisation of the extent of the fracture, the number of fragments and their displacement, the amount of height loss, calcaneus and subtalar joint congruency, the decision to operate is still primarily based on plain radiographs (21). According to the European Society of Radiology, the Sanders classification is the most commonly used system because it correlates with clinical outcome and has relatively low interobserver variability. Both BA and GA are emphasized for a better outcome of operative treatment restoration (22).

3. Aim of the study

The primary goal of the study is to determine the prevalence of calcaneal fractures in trauma patients who had foot and ankle imaging. If a calcaneal fracture was present, did the radiologist report use the Sanders CT classification when assessing these fractures.

4. Study objectives

I) Primary objectives:

a) Determine the incidence of calcaneal fractures in trauma-related CT imaging of the foot and ankle at CMJAH from January 2018 – December 2019.
b) To describe the use of the Sanders classification of calcaneal fractures system of the foot and ankle by radiologists in radiology reports.

II) Secondary objectives:

a) To determine the commonest type of Sanders classification reported.
b) Assess the presence of associated fractures in the foot and ankle.

5. Method

5. 1 Setting

The study is going to be carried out at CMJAH CT Scan department following ethics approval

5.2 Study design

The study is a retrospective study of trauma-related patients who received CT imaging of the foot and ankle at the CMJAH radiology department between January 2018 and December 2019 period. It is a descriptive cross-sectional study. No follow up will be done.

5.3 Sample Size

The study population will comprise of patients who obtained imaging of the foot and ankle injuries between January 2018 and December 2019. The CMJAH Radiology department conducts an average of 3 foot and ankle CT scans per month. Consequently we expect to include a minimum sample of 50 patients in the study over the two year period.

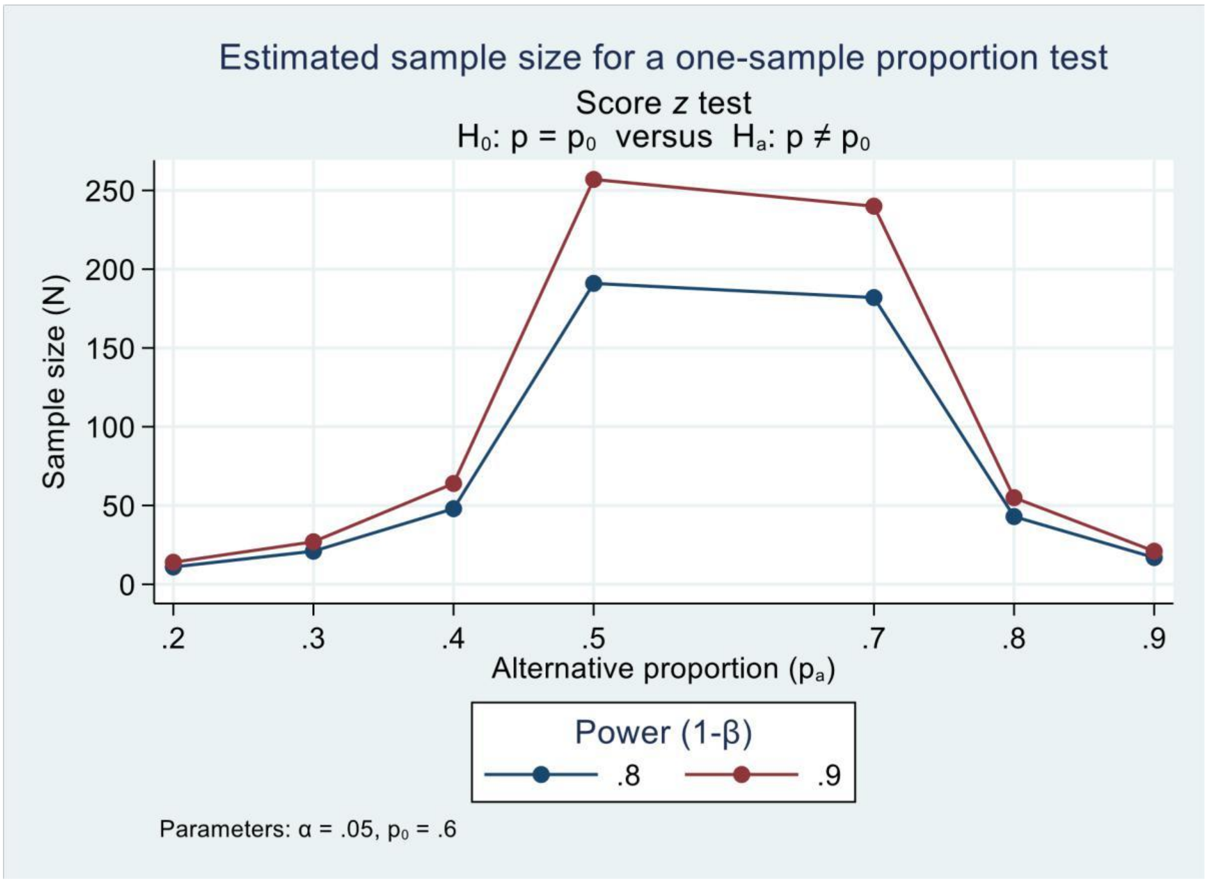

Fig 4 : Power calculation at different proportions of calcaneal fractures in imaging of the foot

Sixty percent of all foot fractures are calcaneal fractures (Liete et al 2018), Ho: p = 0.6 versus Ha: p != p0. This proportion may be different in patients imaged using CT scans as patients imaged using CT scans may have more severe injuries than those imaged using other techniques. Using the *power* command in Stata, we explored the minimum sample size required for a one-proportion sample test, with power of 0.8 or 0.9, $\alpha=0.05$ (Figure 4). We need a minimum sample of 50 to detect a difference on 0.2.

5.3.1 Inclusion criteria

i. Age 18 years and older.
ii. Unilateral or bilateral calcaneal fractures.
iii. Computed tomography (CT) scan performed on injured foot and ankle.

5.3.2 Exclusion criteria

i. Patients with CT of the foot and ankle without calcaneal fractures.
ii. Inadequate data or data that is not available.
iii. Studies not including Sanders classification.

5.4. Materials and Methods

5.4.1 Reporters

No imaging reporters will be required. The already existing Radiologist reports will be used and read from the radiology archive to assess use of Sanders classifications the primary investigator will read the reports and collect data.

5.4.2 Computers and Monitors

i) Reports will be retrieved from the Picture archiving and communication system (PACS) from the Radiology department at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH).

5.4.3 Imaging used

a) CT findings of the affected foot and ankle.

5.4.5 Measurement technique

a) Data collection from already existing radiological reports.

5.5 Data Collection

Data will be retrieved from the PACS and copied onto a DVD -R. An electronic data collection sheet will be created in Epi Data using the attached data collection tool (Appendix A) and the data will be entered. Each patient will be allocated a research number to maintain anonymity.

5.6 Validity and Confounding variables

CT as the modality of choice is a gold standard and allows the classification of calcaneal fractures to be assessed and allows a tool for patient management. The accuracy of the CT scan as a measurement tool for diagnosing calcaneal fractures will ensure internal validity of the study. Age and gender will be collected to account for sex-specific and age related differences.

5.7 Bias

There may be potential bias.

6. Data analysis and Statistics

Categorical variables will be described using frequencies and percentages. Numerical variables such as age will be described using mean and standard deviation if normally distributed, and using median and interquartile range if non-normal. Comparison of calcaneal fractures by gender will be done using chi-squared test. Mean age of patients with calcaneal fractures and those without will be compared using the Student's T test. Look at comparing how the weight of the patient had any impact or contributed to the patient sustaining the fracture.

7. Ethics

Ethics clearance will be requested from the University of the Witwatersrand's Human Research Ethics Committee (medical) and CEO permission from CMJAH.

7.1 Consent form

This is a retrospective analysis, therefore written informed consent is not feasible. Data will be anonymised.

7.2 Data safety

Patients will be assigned research numbers and identifiable information will not be used. The database will be password protected and raw data will not be shared with third parties

8. Timing

	June 2021	July	Aug	Sept	Oct	Nov	Dec	Jan 2022	Feb 2022	Mar 2022	Apr 2022	May 2022	June 2022	July 2022	Aug 2022
Literature review															
Protocol development															
Protocol Assessment															
Ethics application															
Data collection															
Data analysis															
Writing up Thesis															
Submit: marking															
Writing up paper															

9. Funding

Photocopy	R500
Printing	R500
Internet and Data	R2000
Hard drive.	R800
Travel	R1000
Total	***R4800***

10. Problems and limitations

The limitations of this study are those inherent in retrospective data analysis. The request forms received by the radiology department may have missing information on the mechanism of injury, patient demographics or indication. To mitigate this, clinical files from the hospital archives or records will be used to find missing information.

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12. Appendix A:
12.1 Data Collection Sheet

Code	Mechanism of injury			Demographics		Calcaneal Fracture		Intra-Articular Fracture		Sanders Classification										Associated Fracture Location				
	Fall from Height	Motor vehicle Accident	Other	Age	Gender	Unilateral	Bilateral	Yes	No	Type 1	Type 2			Type 3			Type 4			Phalanges	Metatarsal	Tarsal bone	Medial malleolus	Lateral malleolus
			Specify								A	B	C	A	B	C	A	B	C					