



Radiological predictive factors for the outcome of surgically treated calcaneus fractures

Mário BAPTISTA, Rui PINTO, João TORRES

From Faculdade de Medicina da Universidade do Porto, Portugal

Calcaneus fractures are fairly common and clinically relevant due to their poor outcome. Thus, solving the controversy regarding treatment and outcome prediction should be a target. This study intends to evaluate the predictive ability of common radiologic tools for the surgical outcome of calcaneus fractures, regardless of treatment modality. 44 patients' records, with operated calcaneus fractures between 2008 and 2013, were retrospectively assessed and radiology was blindly evaluated. Patients were submitted to percutaneous or open lateral approach. No relevant correlations were found between the measurements on the plain lateral radiograph and the outcome. Fractures were also graded according to the Sanders classification. Type 4 fractures predicted the occurrence of any hazard, such as skin or pain related complications and need for secondary surgery ($p = 0.051$, odds = 14.00 [CI = 1.30-150.89]). However, it's still not possible to accurately target patients with high risk of postoperative complications. Until then, follow-up protocols should be maintained indiscriminately.

Keywords : calcaneus ; foot ; fracture ; outcome assessment ; surgery ; radiology.

INTRODUCTION

The calcaneus is the most commonly fractured bone of the tarsi and represents 1-2% of all fractures (5). It articulates with the talus through the subtalar joint complex, of which the posterior facet is

the largest and, functionally, more important articular surface. By supporting the talus, the calcaneus is of paramount importance in transmitting the body load to the ground (12,24).

Due to the complex anatomy of the calcaneus, the fracture pattern is highly variable and about seventy-five percent of these fractures have an articular compromise (5,12). This compromise has been associated with a poor functional outcome (22). Calcaneus fractures are typically produced by an axial force, as from a fall from height or a motor vehicle accident (5,22). Therefore, associated fractures of nearby bones and vertebral column are often present in these patients (6). Severe soft tissue compromise is also commonly present, being often a cause for delaying surgery (19).

There is controversy about open and percutaneous treatment of calcaneus fractures, with no consensus in the literature (20). Most authors agree that a successful anatomical reduction of the articular

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- Mário Baptista¹, MSc Graduate.
 - Rui Pinto², MD, Head of Department.
 - João Torres^{1,2}, MD, FEBOT, PhD.

¹Faculdade de Medicina da Universidade do Porto.

²Serviço de Ortopedia e Traumatologia do Centro Hospitalar de São João, E.P.E.

Correspondence : Mário Baptista, Alameda Professor Hernâni Monteiro, 4200-319 Porto, Portugal.

E-mail : mario.xb@gmail.com.

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surface is the most important goal to achieve (19,22,30). The main reasons for a poor outcome after surgical treatment are reduced joint mobility and subtalar arthritis (22,28). The latter is the major cause for disabling residual pain and may require a subtalar fusion (8,18).

Imagiology plays a preponderant part both in diagnosing and assessing the fracture pattern, therefore aiding the surgical approach selection (2,22). The plain radiograph and CT scan provide information on specific aspects of the calcaneus morphology (23,25). It's however controversial whether radiological data may or not play a role on the outcome prediction (17,20,25).

This study intends to evaluate the predictive ability of those radiological tools, for the surgical outcome of calcaneus fractures, regardless of treatment modality.

MATERIALS AND METHODS

Data was retrospectively acquired from patient's medical records. Imagiology was blindly evaluated.

All patients with a closed calcaneus fracture treated surgically between 2008 and 2013 were included (n = 49). Exclusion criteria were : primary arthrodesis

(n = 2), fracture by avulsion of the Achilles ("beak fracture") (n = 2) and polytraumatized patients admitted to an intensive care unit (n = 1). For bilateral fractures (n = 5) only the foot submitted to surgery was considered relevant for measurement and outcome evaluation. When both calcaneus were submitted to surgery (n = 2), the foot with greater articular displacement was selected.

Information on demographics, fracture mechanism, associated fractures and the surgical approach was acquired. The evaluated outcomes were : presence of skin complications (skin necrosis or soft tissue infection) ; disabling residual pain (mainly due to posttraumatic arthritis) ; need for a secondary surgery (subtalar arthrodesis or hardware removal). A general dichotomous outcome variable was encoded as the occurrence of *any hazard*, which included the need for a secondary surgery and the presence of skin or pain complications.

Radiographic measurements

All radiological data was acquired by one observer and only the injured foot was measured. All measurements were obtained 3 times and the average of the values was calculated. The acquired measurements were : Böhler's angle, Gissane's angle, tibiotalar angle and talocalcaneal height, as described in Figure 1. All measurements were acquired in pre-operative lateral

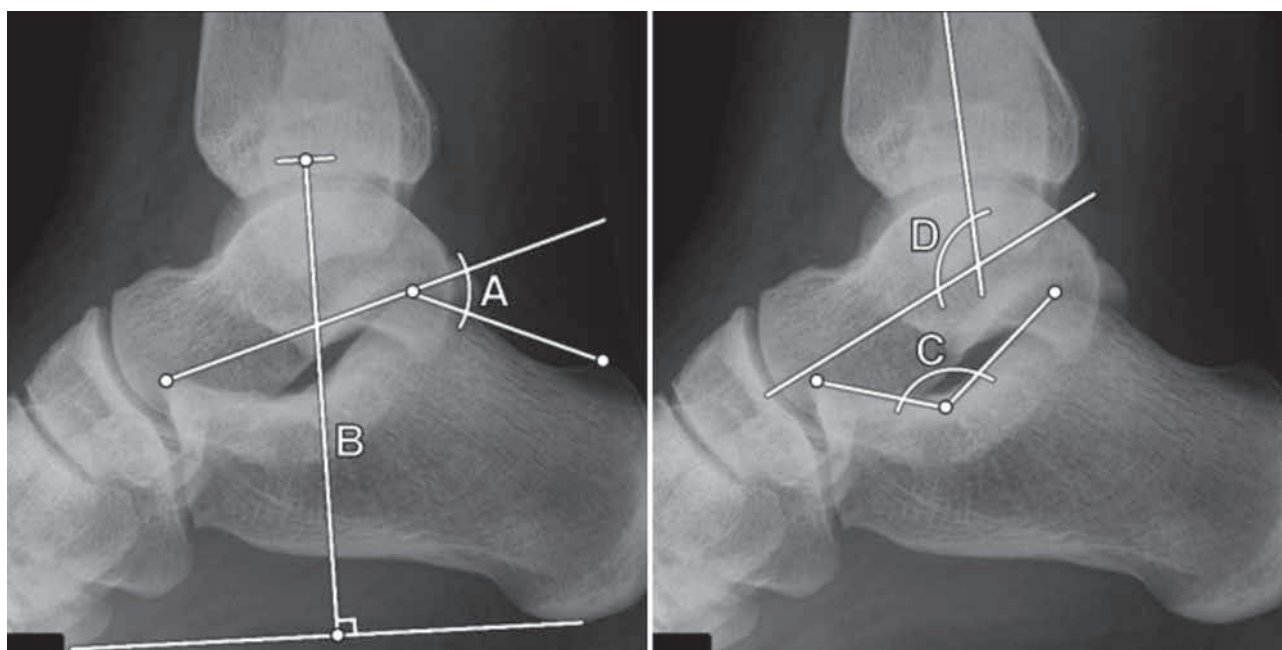


Fig. 1. — Measurements performed on the plain lateral radiograph: A. Böhler's angle. B. Talocalcaneal height. C. Gissane's angle. D. Tibiotalar angle.

radiographs. Böhler's and Gissane's angle were also measured after surgical intervention.

The Böhler's angle (2) was defined as the angle formed by the highest points of the calcaneus tuberosity, the subtalar joint and the anterior process. The difference between the post and pre-operative value was calculated (*DifBöhler*).

The Gissane's angle (10) was defined as the angle formed by the posterior facet and the line that goes from the sulcus to the tip of the anterior process of the calcaneus. The difference between the post and pre-operative value was calculated (*DifGissane*).

The tibiotalar angle (25) was defined as the angle formed by the axis of the tibia and the axis of the talus.

The talocalcaneal height (25) was defined as the distance from the *plane of support* (the line that goes from the lower point of the calcaneus to the lower point of the 5th metatarsal bone base) to the upper point of the talus.

CT Classification

Sanders *et al* proposed a classification to evaluate the amount and location of fractures lines in the coronal CT scans at the level of the posterior calcaneal facet, proposing different surgical approaches accordingly (23). Type 1 is an extra-articular fracture, type 2 has one fracture line, type 3 has two fracture lines and type 4 is a highly comminuted fracture with three or more fracture lines. The position of the fracture lines is evaluated using A-C letters to describe its lateral to medial location. On this study, we chose not to apply this encoding, restricting our classification to the number of fracture lines, as described in Figure 2. For correlations and logistic regression models, Sanders type 1 and 2 have been grouped.

The coronal CT scans were evaluated by two observers. Any discrepancy was settled by consensus.

Statistical Analysis

The statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 22.0 (SPSS, Chicago, IL, USA).

A descriptive statistic of all variables was performed. To evaluate the distribution of scale variables Kolmogorov-Smirnov test was used. Only the *Time to Discharge* was not normally distributed. To correlate categorical variables the Chi-square test was used. To compare the means of parametric scale variables we used Student's Independent t-test and One-way ANOVA, according to the number of categories. To compare the distribution of unmatched groups with nonparametric

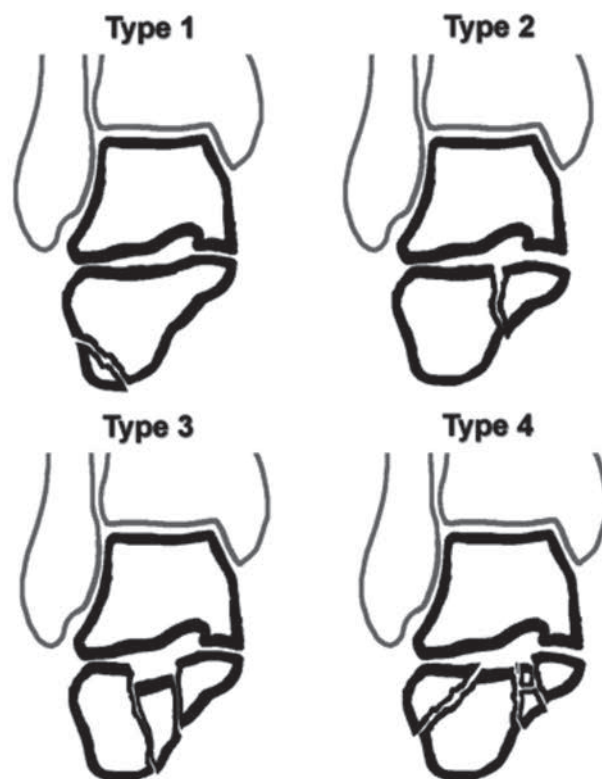


Fig. 2. — Adapted Sanders classification for calcaneus fractures in the coronal CT scan.

scale variables Mann-Whitney U test and Kruskal-Wallis test were used. To measure the strength of the linear relationship between scale variables the parametric Pearson correlation coefficient or the nonparametric Spearman correlation coefficient was calculated. To evaluate the statistical significance of the difference between the post and pre-operative measurements a Paired t-test was applied. The results of the Logistic Regression Models are presented as Odds Ratio (*odds*) with a 95% confidence interval (CI).

RESULTS

A total of 44 patients were included in the study. The average age was 48 years (range 17-73 years) and 86% were male. Female patients were older than male, with a mean of 59 years versus 46 respectively ($p = 0.045$). The right foot was injured in 52.3% of patients ($n = 23$), the left foot in 36.4% ($n = 16$) and 11.4% of patients injured both feet ($n = 5$), of whom two required bilateral surgery.

Table I. — Comparison of obtained measures with literature references

Measure	Uninjured Reference	Injured Reference (25)	Preoperative measure (min-max)	Postoperative measure (min-max)
Böhler's angle (<i>degrees</i>)	25-40 (2)	16	12 (-27-38)	18 (-17-51)
Gissane's angle (<i>degrees</i>)	120-145 (10)	113	126 (97-161)	123 (94-156)
Tibiotalar angle (<i>degrees</i>)	110 (25)	103	120 (105-141)	—
Talocalcaneal height (<i>mm</i>)	81 (25)	77	77 (64-90)	—

The major mechanism of injury was a fall from height, 89.7% ($n = 35$), followed by motor vehicle accidents, 7.7% ($n = 3$), and 2.6% of fractures was due to an ankle sprain ($n = 1$). Associated fractures were present in 18.2% of patients ($n = 8$), of which five were of nearby bones and one of the vertebral column.

Percutaneous surgery was performed in 77.3% of patients ($n = 34$) while 22.7% ($n = 10$) were submitted to an open lateral approach. The mean time from injury to surgical stabilization was 9 days.

Early skin related complications were present in 17.5% of patients ($n = 7$) and disabling residual pain was reported in 44.7% ($n = 17$). Twelve patients were elected for a secondary surgery (31.6%). Of those, nine were submitted to a hardware removal surgery (75.0%) and three to a subtalar arthrodesis (25.0%). Therefore, only 39.5% of patients ($n = 15$) were neither elected to a secondary surgery nor had any of the referred complications. Regular consultations stopped after a median of 7 months from the day of trauma. Patients elected for a secondary surgery were submitted to it after a mean of 16 months of being treated for the first time.

The measured values of this study are presented in Table I, along with a comparison to reference values in the literature. Böhler's angle measured an average of 11.9° preoperatively and 17.8° postoperatively ($p = 0.030$). The mean restored Böhler's angle was 6.1°. Gissane's angle measured an average of 125.7° preoperatively and 123.1° postoperatively ($p = 0.339$). The mean restored of this angle was -2.9°. The mean tibiotalar angle was 120.1°. Talocalcaneal height measured an average of 76.5 mm.

Only the postoperative Böhler's angle and the restored amount of it correlated significantly to skin related complications ($p = 0.004$, odds = 1.12 [CI =

1.02-1.22] and $p = 0.170$, odds = 1.06 [CI 1.01-1.12] respectively). Patients with such complications had an average postoperative Böhler's angle of 32.0° while those who didn't had an average of 14.6°. No other measurements correlated to skin complications. None of the angles or distance measured presented a significant p value for predicting disabling residual pain, need for secondary surgery nor its type. Similarly, none of the measurements predicted the occurrence of *any hazard*.

According to Sander's classification, 7.7% of fractures were classified as type 1, 7.7% as type 2, 23.1% as type 3 and 61.5% as type 4. This classification did not correlate with the treatment choice. An association between type 4 fractures and the suffering of *any hazard* was found ($p = 0.051$, odds = 14.00 [CI = 1.30-150.89]). No correlations were found regarding the need for secondary surgery or postoperative complications. None of the measurements in the plain radiograph correlated to the degree of articular displacement according to Sanders classification.

When an analysis of the variables regarding demographics, fracture specifics, associated fractures and surgical approach was performed some interesting findings were discovered. Open approaches allowed a much higher recovery of the Böhler's angle when comparing to percutaneous approaches ($p = 0.029$), restoring a mean of 16° and 3° respectively. More skin complications were reported in patients submitted to an open surgery, 56%, than in those submitted to a percutaneous surgery, 7% ($p = 0.003$, odds = 18.13 [CI = 2.59-126.72]). A correlation was also found between the delay of surgical intervention after trauma and the presence of disabling residual pain in follow-up. Patients who presented this complication had waited a mean of 6 days for surgery, while those who didn't had

Table II. — Variables significantly associated in logistic regression models

Variables	Odds Ratio [95% CI]
PostOpBöhler – Skin related complication	1.12 [1.02-1.22]
DifBöhler – Skin related complication	1.06 [1.01-1.12]
Wait Time To Surgery – Disabling residual pain	0.81 [0.68-0.97]
Open surgery – Skin related complication	18.13 [2.59-126.72]
Sanders type 4 – <i>Any Hazard</i>	14.00 [1.30-150.89]

waited a mean of 10 days ($p = 0.011$, odds = 0.81 [CI = 0.68-0.97]).

The significant odds ratio found in this study are presented in Table II.

DISCUSSION

An articular compromise in calcaneus fractures is very common and is the main cause of their poor functional outcome. As the typical patient is an adult man at working age, who risks never returning to work with full capacities due to postoperative complications, these fractures are clinically very important (22,29). As so, it is unfortunate that controversy regarding surgery criteria and methods subsists.

Böhler's and Gissane's angles are commonly used to diagnose and help evaluating calcaneus fractures (10,13). However, they cannot clearly delineate the location and extent of the fractures, as articular surfaces and anatomic references may be extremely hard to assess on the plain radiograph, especially on highly displaced fractured calcaneus (7,25). Thus, CT scanning has then become a popular tool for assessing calcaneus fractures patterns (25).

The correlation between measures on plain radiographs and the outcome is not consensual. In this study none of the preoperative measures was able to predict clinical outcomes. This finding is supported by other studies (7,17). Not only these measurements alone provide little detail about complex fractures, but also the impact of the articular conditions on the outcome may be greater after the surgery than prior to it. However, some authors have reported significant correlations for Böhler's angle, tibiotalar angle

and talocalcaneal height (4,15,25). Correlations between Gissane's angle and clinical outcomes were never found (7,14).

Of the two postoperative angles measured in this study, only Böhler's angle correlated to a clinical outcome. Higher postoperative values of this angle predicted skin related complications on the early follow-up, as did the amount of this angle restored by surgery. This finding contradicts the literature, which supports that restoration of Böhler's angle positively affects function and should be a goal to achieve for the surgeon (9,16,21). We believe that in our study this result is based on the influence of the surgical approach on this angle. Open surgery permitted greater restorations of the Böhler's angle but was also associated with more skin related complications. However, despite the high skin complication rate after open approaches, these complications do not affect the long-term clinical outcome of calcaneal fractures (9).

Sanders classification for coronal CT scan is the most widely used classification for calcaneus fractures. However, though it was originally proposed with predicting intention, divergent results are described on this matter (20,23,26). Type 4 fractures predicted the occurrence of *any hazard* during follow-up. According to this finding, Sanders classification may be helpful in targeting high risk patients during follow-up. However, a moderate inter and intra-observer variability for this classification has been reported on several studies (1,11,26). In order to promote this classification for a predictive purpose a higher inter-observer agreement is necessary, as are studies with larger samples.

The surgical window of 7-14 days post trauma is well accepted as a mean to prevent postoperative

skin infection (27). In our study, patients waited a mean of 9 days to be submitted to surgery. However, we found that the increase of this delay was a protective factor for the presence of postoperative residual pain (most likely due to posttraumatic arthritis). We hypothesized that this surgical window may also be relevant for allowing the regeneration of chondrocytes in the displaced articular surfaces and thus premature treatment might be a cause for an elevated posttraumatic arthritis rate. The association between cartilage necrosis and posttraumatic joint degeneration has been speculated by Sanders (23) and supported by an histologic study showing chondrocyte death in biopsies of the cartilage fragments (3). This finding should be further investigated as it might impose a revision of the surgical window conception.

The limitations of this study were : the reduced sample size ; its retrospective design, non-completed by contacting patients to fill functional outcomes forms ; non-evaluation of the uninjured foot ; the measurements being acquired by only one observer ; only skin and pain complications being considered, not taking into account other possible hazards.

In this study no relevant correlations between measurements in the plain radiograph and outcome were found. The difficulty of accurately applying these measurements, associated with the little information they provide, make them unlikely to predict an outcome of any kind. Nonetheless, these measurements are important interpreters of the anatomical conditions of the calcaneus. Therefore, they may have a role to play in the improvement of the surgical techniques by detecting surgery factors for the outcome and allowing a better understanding of what is worth to reconstitute in the bone's shape. Highly displaced fractures, according to the Sanders classification, can predict a generally poorer outcome and may be used by the surgeon for predicting it. The usage of common tools for the prediction of poor outcomes in calcaneus fractures is attractive and may help targeting patients who are more likely to develop postoperative complications. However, the discovery of these tools is still hampered by the lack of an inter-observer uniform fracture classification and outcome measurement. Until then, it's still

not possible to accurately target patients with high risk of postoperative complications. Thus, follow-up protocols should be maintained indiscriminately.

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