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FOOT AND ANKLE

Outcomes following limb salvage after combat hindfoot injury are inferior to delayed amputation at five years

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Objectives

The surgical challenge with severe hindfoot injuries is one of technical feasibility, and whether the limb can be salvaged. There is an additional question of whether these injuries should be managed with limb salvage, or whether patients would achieve a greater quality of life with a transtibial amputation. This study aims to measure functional outcomes in military patients sustaining hindfoot fractures, and identify injury features associated with poor function.

Methods

Follow-up was attempted in all United Kingdom military casualties sustaining hindfoot fractures. All respondents underwent short-form (SF)-12 scoring; those retaining their limb also completed the American Academy of Orthopaedic Surgeons Foot and Ankle (AAOS F&A) outcomes questionnaire. A multivariate regression analysis identified injury features associated with poor functional recovery.

Results

In 12 years of conflict, 114 patients sustained 134 fractures. Follow-up consisted of 90 fractures (90/134, 67%), at a median of five years (interquartile range (IQR) 52 to 80 months).

The median Short-Form 12 physical component score (PCS) of 62 individuals retaining their limb was 45 (IQR 36 to 53), significantly lower than the median of 51 (IQR 46 to 54) in patients who underwent delayed amputation after attempted reconstruction ($p = 0.0351$).

Regression analysis identified three variables associated with a poor F&A score: negative Bohler's angle on initial radiograph; coexisting talus and calcaneus fracture; and tibial plafond fracture in addition to a hindfoot fracture. The presence of two out of three variables was associated with a significantly lower PCS compared with amputees (medians 29, IQR 27 to 43 *vs* 51, IQR 46 to 54; $p < 0.0001$).

Conclusions

At five years, patients with reconstructed hindfoot fractures have inferior outcomes to those who have delayed amputation. It is possible to identify injuries which will go on to have particularly poor outcomes.

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Keywords: Military, Calcaneal fracture, Amputation and salvage, Hindfoot, Limb salvage, Amputation, Outcome

Article focus

- What are the medium-term functional outcomes of British military casualties sustaining a hindfoot fracture in combat?
- Is it possible to determine which injury features, identifiable at time of wounding, are associated with a poor functional outcome?

Key messages

- At five years, patients with reconstructed hindfoot fractures have inferior quality-of-life outcomes compared with those requiring delayed amputation following their injury.
- Three key injury features, identifiable at time of wounding, seem to be associated with particularly poor functional

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outcomes: negative Böhler's angle on initial radiograph; combination of talar and calcaneal fracture; and combination of hindfoot and tibial plafond fracture.

Strengths and limitations

- This study provides surgeons with objective criteria to guide decision making when treating patients with severely injured hindfeet. The authors do not mandate that the presence of all three key injury variables should lead to amputation, but rather that the data provided should be used when counselling patients about their likely outcomes.
- Five-year follow-up is limited to 68% of all casualties sustaining a combat hindfoot fracture.
- At time of follow-up, patients were in their 20s and 30s. It is probable that their functional demands will be different later in life, and the benefits of limb salvage *versus* amputation at that time may change.

Introduction

The use of landmines and improvised explosive devices (IEDs) in areas of conflict can result in life-changing injuries not only to military personnel, but also to civilians.[1,2] The injuries sustained by survivors of blast and gunshot wounds vary; from traumatic amputation, to complex fractures and severe soft-tissue damage.[3,4]

The precise pattern of wounds depends on the distance of the individual from the point of detonation, whether they were on foot or in a vehicle, and whether the detonation took place in an enclosed or open space.[5] Additionally, the use of appropriate personal protective equipment (PPE) can have a significant effect on the lower limb injuries sustained.[6]

For British and American military surgeons caring for casualties from the recent conflicts, high-energy hindfoot fractures have surpassed open tibial fractures as the greatest test in terms of the salvage and reconstruction of severe lower limb injuries.[7,8] However, for surgeons working in certain African, Asian and Middle Eastern countries, these injuries have been a challenge for decades, and will likely continue to be long into the future.[9]

The task of achieving a painless, plantigrade, functional foot, with united fractures and healed wounds, is multifaceted. The multiple articular surfaces in the hindfoot,[10] vulnerable soft-tissue envelope,[11] and tenuous blood supply all contribute to the reconstructive difficulties. Consequently, attention has focused on the technical aspects of limb salvage, with various orthopaedic and plastic surgical techniques examined for their use in increasing the potential for treating these injuries.[12]

Focusing on whether these injuries could be reconstructed, a function of technical feasibility, does not address whether they should be. The latter point examines whether, following a severe hindfoot injury, an individual would achieve a greater quality of life with a reconstructed hindfoot or the alternative of transtibial amputation. This management equipoise between amputation and reconstruction depends not only on the patient's injuries, but also on the medical facilities available to treat them. Thus, an injury seen in a British soldier evacuated to the Royal Centre of Defence Medicine in Birmingham (United Kingdom) and treated by military surgeons, will be managed very differently from the same injury treated by a civilian surgeon working in an active or former conflict zone.

This study aimed to establish patients' medium-term functional recovery following severe combat hindfoot trauma. Additionally, it sought to examine the possibility of predicting, at time of injury, which injuries may progress to a poorer eventual recovery than those with amputated limbs.

Patients and Methods

This was a retrospective telephone-based follow-up study of a previously identified case series.[7] The study was registered with, and approved by, the United Kingdom Joint Medical Command. All surviving British military casualties from the 12 years of conflict in Iraq and Afghanistan with a fracture of either the talus, calcaneus, or both, were identified.[7] Data were gathered on patients' demographics, injury details and surgical management; patients managed with a primary amputation in the first three surgical episodes were excluded. The severity of the injury was recorded using the New Injury Severity Score (NISS).[13] This considers the three most severe injuries sustained by the patient, regardless of body region. The total is calculated as the sum of the squares of the three most severe Abbreviated Injury Scale (AIS) injuries, to a maximum of 75.

Patients were contacted by telephone and invited to participate in the study. Those who consented were asked about their recovery, and whether they had undergone amputation or unplanned further surgery. Unplanned surgery was defined as surgery to address ongoing symptoms after definitive fixation and wound closure, i.e., revision fixation, removal of symptomatic metalwork, or fusion. All participants were assessed with the United Kingdom adapted second version of the Short-Form 12 (SF-12 V2) questionnaire,[14] which ranges from 0 (lowest level of health) to 100 (highest level of health). In addition, those who had retained their limb completed the American Academy of Orthopaedic Surgeons (AAOS) foot and ankle (F&A) outcomes questionnaire (range from 0 (most disability) to 100 (least disability)).[15] The AAOS F&A questionnaire was chosen as it does not require clinical assessment and can be administered over the telephone, and has been shown to correlate well with other quality-of-life outcome measures.[16]

Statistical analysis. Descriptive data are presented as medians with interquartile ranges (IQR). Statistical analysis

Table I. Analysis of characteristics of patients lost to follow-up

	Amputation (n = 28)	Limb salvage (n = 62)	Lost to FU (n = 44)
Age (yrs)			
Median	25	25	24
IQR	21 to 17	22 to 29	21 to 26
Mechanism of injury			
Blast (direct)	23	54	39
Blast (indirect)	2	1	2
GSW	3	5	2
Other	0	2	1
New Injury Severity Score			
Median	12	12	12
IQR	12 to 17	9 to 17	8 to 17
Open injury	13	19	18
Nerve injury	1	1	1
Arterial injury	4	4	1

FU, follow-up; IQR, interquartile range; GSW, gun shot wound

was performed with the use of SPSS v.23 software (IBM Corp., Armonk, New York). The chi-squared test was used to examine the relationship between dichotomous variables.

Injury features that would be available for the treating surgeon in their assessment of the severity of the hindfoot injury at time of presentation, were identified. A multivariate regression model was developed to examine whether these variables were subsequently associated with a lower AAOS F&A score in those patients retaining their limbs. A new model was fitted which included only those variables that had a statistically significant association, on multivariate comparison, with AAOS F&A outcome. The following seven variables were examined:

- Negative Böhler's angle on initial radiograph;
- Coexisting talar and calcaneal fracture;
- Fracture of the tibial plafond in addition to a hindfoot fracture;
- Fracture of the mid-foot in addition to a hindfoot fracture;
- Open fracture;
- Nerve injury;
- Vascular injury.

The Spearman's correlation coefficient test was used to establish the relationship between the AAOS F&A score and SF-12 score. The threshold for significance was set at a p-value < 0.05. Böhler's angle, i.e. the radiological angle between the superior tip of the calcaneal tuberosity, and the superior edge of the anterior and posterior facets, was measured on lateral radiographs taken at the time of injury.[17] Nerve injury was defined as confirmed transection of a nerve identified at time of surgical exploration. Vascular injury was defined as arterial injury requiring surgical repair. The accuracy of statistical comparisons was calculated using a *post hoc* power analysis.

Table II. Indication for amputation (n = 28)

Indication	n (%)
Pain	19 *(68)*
Quality of life	4 *(14)*
Nonunion	2 *(7)*
Infection	2 *(7)*
Soft-tissue breakdown	1 *(3.5)*

Results

A previously reported series identified all 114 British military casualties with 134 fractured hindfeet from the conflicts in Iraq and Afghanistan.[7] A total of 77 patients (77/114, 68%) were successfully contacted and consented to participate in this follow-up study. Patients undergoing amputation, those with retained limbs, and those lost to follow-up were similar with respect to age, mechanism of injury, and associated injuries (Table I). A total of 13 of patients followed up had bilateral injuries, providing follow-up for 90 injured limbs (90/134, 67%), with a median follow-up of 64 months (IQR 52 to 80).

Following hindfoot reconstruction, 28 limbs (28/90, 31%) subsequently underwent amputation at a median of 14 months (IQR 11 to 21) from time of injury. A total of 19 limbs (19/28, 68%) had undergone at least one further unplanned operation after the initial hospital admission prior to eventual amputation. In 19 of the subsequent amputation cases (19/28, 67%), pain was cited as the predominant reason to elect for amputation, with further detail given in Table II.

In the 62 cases where the limb was retained, the median AAOS F&A score was 74 (IQR 61 to 88), with eight patients scoring a maximum 100 points. The multivariable regression analysis identified three key variables associated with a significantly poorer AAOS F&A score: negative Böhler's angle on initial radiograph; coexisting talar and calcaneal fracture; and fracture of the tibial plafond in addition to hindfoot fracture, with detail given in Table III. Whether the hindfoot fracture was open, the presence of a concurrent midfoot fracture, vascular or

Table III. Multivariable regression analysis demonstrating effect of injury variable on American Academy of Orthopaedic Surgeons Foot and Ankle (AAOS F&A) outcome score in individuals retaining their limb

Injury variable	Change in AAOS F&A score	p-value	95% confidence intervals	
			Lower limit	Upper limit
Negative Böhler's angle	-16 points	0.008	-27.8	-4.4
Coexisting talal and calcaneal fracture	-12 points	0.026	-24.3	-2.6
Tibial plafond fracture in addition to hindfoot fracture	-10 points	0.030	-20.1	-1.0

$F(3,57) = 6.95$ ($p < 0.0005$) R^2 0.27

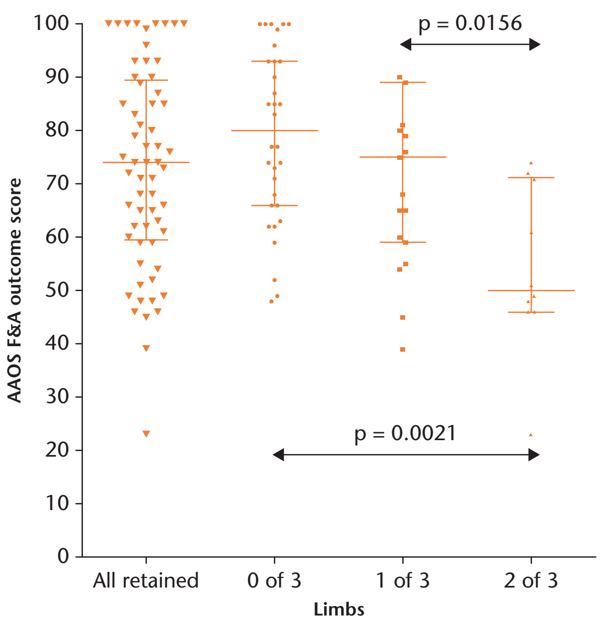

Fig. 1

Graph showing the variation in American Academy of Orthopaedic Surgeons Foot and Ankle (AAOS F&A) score depending on presence of key variables in initial injury. Key variables: negative Böhler's angle on initial radiograph; coexisting talar and calcaneal fracture; fracture of tibial plafond in addition to hindfoot fracture.

neurological injury was not associated with subsequent AAOS F&A score.

Of the 90 limbs followed up, only one possessed all three of these key variables; this limb was amputated 20 months after the injury due to the development of osteomyelitis, despite attempts to treat this deep infection surgically. Of the 62 patients retaining their limb, the median AAOS F&A score was significantly associated with the number of variables present ($p = 0.0021$, Kruskal-Wallis). In the 19 patients whose injury exhibited one variable, the AAOS F&A score was 75 (IQR 60 to 87); this reduced to a median of 50 (IQR 47 to 59) in the ten patients whose injuries featured two variables ($p = 0.0156$, Mann-Whitney), as shown in Figure 1 and Table IV. Despite the reduction in AAOS F&A score, injuries characterized by one or more of the key variables were not associated with an increased rate of amputation ($p = 0.1717$, Fisher's exact test. Power calculation 0.96).

A comparison of AAOS F&A score and SF-12 physical component score (PCS) was performed, confirming the positive correlation between AAOS F&A score and overall quality of life (Spearman's $r = 0.7277$, 95% CI 0.58 to 0.83) as shown in Figure 2.

The median SF-12 PCS of all 62 individuals retaining their limb was 45 (IQR 36 to 53): this was significantly lower than the median of 51 (IQR 46 to 54) in the 28 patients undergoing an amputation after initial salvage of their hindfoot injury ($p = 0.0351$, Mann-Whitney), as shown in Figure 3. This poorer outcome following salvage, compared with delayed amputation, is more pronounced if the salvaged limbs are grouped according to the presence of one or more of the three variables identified in the regression model. The cohort with two of three variables has a median SF-12 PCS of 29 (IQR 27 to 43), a score which is 22 points lower than that seen in patients who underwent amputation following initial salvage; this difference is statistically significant ($p < 0.0001$, Mann-Whitney; Table IV) and is represented graphically in Figure 4.

There was no difference in the SF-12 mental component score between those retaining their limb (median 44, IQR 39 to 47) and those undergoing amputation (median 39, IQR 30 to 47; $p = 0.133$, Mann-Whitney), though this comparison was underpowered (0.6).

Discussion

This study provides medium-term patient-reported outcomes for severe hindfoot injuries sustained in combat. Our results show that patients undergoing a transtibial amputation following initial salvage of their hindfoot injury have significantly higher physical outcome scores than those retaining their limb. Furthermore, our results demonstrate that three key variables, identifiable at time of injury, are associated with profoundly poorer functional outcome: negative Böhler's angle on initial radiograph; coexisting talar and calcaneal fracture; and fracture of the tibial plafond in addition to hindfoot fracture.

The three key variables identified in this study which are associated with poor functional outcome arguably equate to injury severity and complexity. It is therefore unsurprising that injuries with these variables have worse functional outcomes than those without. However, it is noteworthy that injuries with soft-tissue disruption and neurovascular compromise, typically regarded as important features of injury severity, are not associated with a poorer outcome.

Table IV. Comparison of outcome measures for primary amputees, delayed amputees and salvaged lower limb injuries

Cohort	Follow-up mths (IQR)	Median AAOS F&A score (IQR)	Median SF-12 PCS (IQR)
Initial salvage			
Retained limb	64 (52 to 80)	-	-
Overall	-	74 (61 to 88)	45 (36 to 53)
1/3 key variables* (n = 19)	-	75 (60 to 87)	-
2/3 key variables* (n = 10)	-	50 (47 to 59)	29 (27 to 43)
Delayed amputation	64 (52 to 80)	-	51 (46 to 54)

*Key variables: negative Böhler's angle on initial radiograph; coexisting talar and calcaneal fracture; fracture of tibial plafond in addition to hindfoot fracture
IQR, interquartile range; AAOS F&A, American Academy of Orthopaedic Surgeons Foot and Ankle; SF-12, Short-Form 12; PCS, physical component score

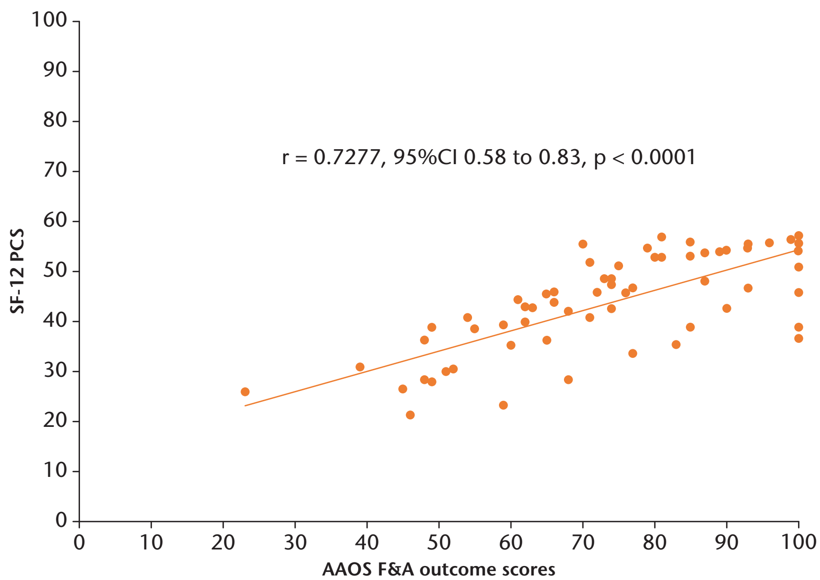

Fig. 2

Graph showing the correlation between American Academy of Orthopaedic Surgeons Foot and Ankle (AAOS F&A) score and Short-Form 12 (SF-12) physical component score (PCS). (Spearman's correlation coefficient test).

The variables used in the multivariable regression analysis were chosen as they were identifiable at the time of injury. Furthermore, they have either previously been shown to be associated with eventual outcome,[18] or were thought by the treating surgeons to be associated with poor functional outcome during routine follow-up. Associations with other injury variables, such as deep infection and wound management, have previously been discussed in the literature,[19,20] but are not identifiable at time of injury, and therefore have limited use when considering whether limb salvage should be attempted. Though wound size and location have also been examined for association with outcome,[21] these measures are subjective, and affected by the amount of debridement required during the initial procedures.

The question of whether severe hindfoot fractures sustained in combat could be salvaged successfully has previously been reported by the authors.[7] The results of this study contribute to addressing whether these injuries should be salvaged where the focus is on subsequent quality of life, rather than technical feasibility of surgical reconstruction.[22]

Previous studies have attempted to evaluate the impact of hindfoot injuries sustained in combat. Sheean et al[23] described a cohort of 122 patients, using return to duty (RTD) rates as a surrogate marker of disability. Although RTD rates have been used in several studies relating to military patients,[24,25] their use is limited by not determining the functional demands of that patient's duty, and any workplace adaptations made for them. Helgeson et al[26] described factors associated with subsequent requirement for amputation after attempted salvage of combat-related hindfoot injury, though their follow-up was limited to subjective outcome measures.

Many surgeons would regard amputation later than the first or second procedure as a failure of salvage. However, in this study, amputation was regarded as a failure of salvage only if it was required after three procedures due to established patient management protocols. The first surgical procedure would be damage control aimed purely at saving life and, if possible, limbs, and would be limited to a washout, debridement and stabilization. Immediately upon arrival back in the United Kingdom, a second look in theatre would allow for assessment of

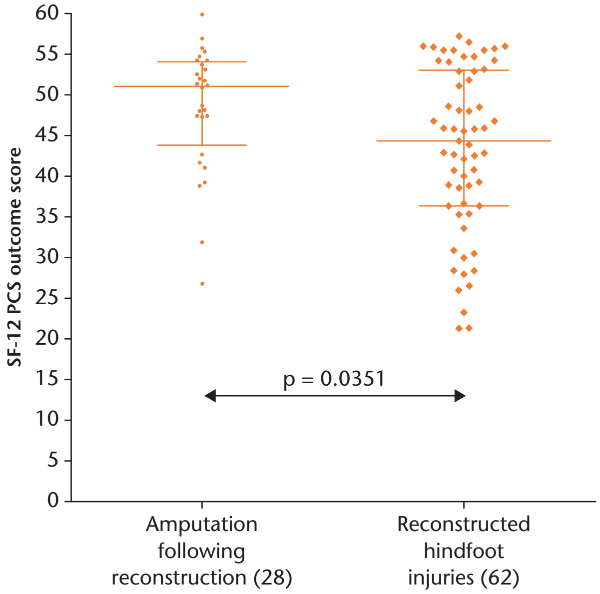

Fig. 3

Graph showing the comparison between Short-Form 12 physical component score (SF-12 PCS) outcome scores for patients with reconstructed hindfoot injuries, and those requiring amputation following attempted reconstruction.

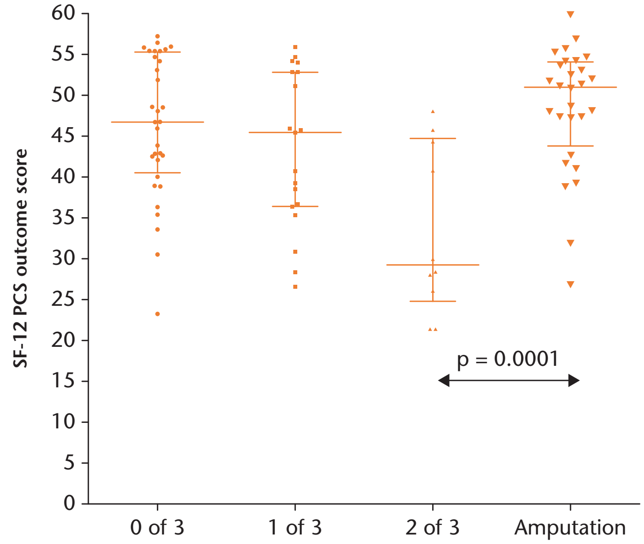

Fig. 4

Graph showing the variation in Short-Form 12 physical component (SF-12 PCS) outcome scores for those with reconstructed hindfoot injuries depending on presence of key variables in initial injury, compared with those patients requiring delayed amputation following attempted reconstruction. Key variables: negative Böhler's angle on initial radiograph; coexisting talar and calcaneal fracture; fracture of tibial plafond in addition to hindfoot fracture.

viability and operative planning. The third procedure was therefore often the definitive one, where amputation or fracture fixation for salvage would be undertaken. The period between injury and definitive operative procedure is typically one week. Using similar methodology, some authors have previously reported on outcomes in casualties sustaining a primary lower limb amputation during the same conflicts.[27] In that group, the median SF-36 PCS of transtibial amputees was 47 (IQR 42 to 55) at a mean follow-up of 40 months (range 25 to 75).

Multiple scoring systems have been developed to guide surgical decision making over amputation *versus* salvage,[28-32] though none has had their clinical use validated.[33] These scoring systems were developed in civilian populations, and though attempts have been made to translate them to a military setting,[34] their use remains unproven.[35]

It is important to address some of the non-medical confounders in assessing recovery following severe limb trauma in military patients. There is a hierarchy of combat injuries, both about financial compensation, and about the attitude of fellow service personnel and wider society. This was illustrated starkly in studies of United States veterans of the Vietnam war that revealed that bilateral transfemoral amputees reported a higher quality of life than their comrades with unilateral limb loss.[36,37] It is suspected that these financial and social factors might make injured service personnel more inclined towards amputation rather than salvage. Additionally, it is possible that the increased compensation soldiers receive for losing their limb may 'artificially' elevate scores in quality-of-life measures.

The difficulties of giving patients with severe hindfoot injuries a realistic expectation of their likely outcome, and how this might change over their lifetime, is understood.[38] All British service personnel injured overseas are repatriated to a single unit in the United Kingdom. This centralized care has the benefit of a single team of surgeons managing these complex injuries, which allows for the accumulation of experience and the evolution of surgical techniques.

These findings indicate that it might be possible in some hindfoot injuries to identify which fractures would have an inferior functional outcome with salvage, rather than amputation. However, the authors strongly advise against the adoption of an 'algorithmic' decision-making process. These findings provide the clinician with a greater evidential basis for advising and counselling patients as to their likely outcomes with each of the two alternative treatment strategies.[39]

The heterogeneous nature of these fractures, combined with ipsilateral or more proximal injuries and personal preference, mandates an individualized approach to each patient. The relatively low R^2 coefficient achieved by the multivariable regression model clearly shows that these variables are only describing about a third of the factors influencing recovery. When considering surgical options, subjective assessment of both the injury and patient by an experienced reconstructive surgical team and rehabilitation specialists will continue to be fundamental in advising patients of the treatment options and likely recovery.[40]

The findings of this study appear to be consistent with the recently reported results of the Outcomes After Severe

Distal Tibia, Ankle, and/or Foot Trauma: Comparison of Limb Salvage Versus Transtibial Amputation trial (OUTLET), a prospective, observational multicentre study of North American civilian patients.[41,42] There were 410 patients in the limb salvage group and 87 in the transtibial amputation group who completed the Short Musculoskeletal Function Assessment (SMFA) at 18 months. Patients with reconstructed severe distal tibia, and/or mid- or hindfoot injuries reported significantly poorer scores across most SMFA domains, particularly mobility, compared with those treated with transtibial amputation.

There are weaknesses in this study. Follow-up was only available for 68% of the patients with hindfoot fractures from Iraq and Afghanistan, although those lost to follow-up appeared to be similar to those included, in terms of demographics and injury severity. The loss of follow-up of a third of the patients relates to the mobile and migrant nature of a young military population, especially those who have sustained a life-changing injury. Furthermore, the R^2 coefficient of the multivariable regression analysis suggests an incomplete understanding of the causes behind patients' poor functional outcome. The use of the AAOS F&A scoring system appears to have a ceiling, as clearly shown in Figure 2, with respect to measuring recovery in a small number of servicemen, and this might limit its use in this population of patients.

Nearly all of these patients were reporting on their quality of life when still in their 20s and 30s. It is possible that the superior outcome scores in the amputee cohort might be reversed in favour of the salvage group when these patients are in their 60s and 70s. The size of the cohort of patients precluded any evaluation of associations between outcome scores and age or time to follow-up.

It is inappropriate to apply these findings directly to civilian trauma patients due to the differences in mechanisms of injury and patient demographic. Though civilian hindfoot fractures are considered a high-energy injury, the massive soft-tissue damage, gross contamination and comminution seen in military patients, who are almost exclusively young men injured because of blast and gunshot injuries, distinguishes the two cohorts. However, the 'could' *versus* 'should' management dilemma of these injuries is relevant to all surgeons treating victims of blast and gunshot wounds, and this equipoise will vary depending on the environment in which the patient is being treated.

Despite these weaknesses, this work provides medium-term patient-reported outcome measures for patients sustaining severe hindfoot fractures in combat, and identifies key variables at time of injury to assist surgical decision making and patient counselling. The clear finding that there is a group of patients with hindfoot injuries that are technically salvageable, but who might have a superior outcome with a transtibial amputation, should be recognized by all surgeons managing these challenging injuries.

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- T. Stevenson: Data collection.
- I. D. Sargeant: Surgical oversight, data collection.
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Conflict of Interest Statement
- None declared