

Treatment outcomes of civilian gunshot tibia fractures at a major trauma centre

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Citation: Gerafa M, Jakoet S, Van Heukelum M, Le Roux N, Van der Merwe S, Makhubalo O, Du Preez G, Burger M, Ferreira N. Treatment outcomes of civilian gunshot tibia fractures at a major trauma centre. SA Orthop J 2021;20(2):71-75. <http://dx.doi.org/10.17159/2309-8309/2021/v20n2a1>

Editor: Prof. Leonard C Marais, University of KwaZulu-Natal, Durban, South Africa

Received: July 2020

Accepted: November 2020

Published: May 2021

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Funding: No funding was received for this study.

Conflict of interest: The authors declare they have no conflicts of interest that are directly or indirectly related to this research.

Abstract

Background

The aim of this retrospective longitudinal study was to describe the overall burden and outcomes of surgically managed gunshot tibia fractures at a major trauma centre. Secondary objectives were to identify possible risk factors for complications including non-union and infection and to highlight any differences in outcomes between treatment modalities.

Methods

All consecutive patients who sustained gunshot injuries to the tibia between January 2014 and December 2017 including children and multiple gunshot injuries were considered for inclusion. Information related to patient demographics, injury characteristics, treatment information and treatment outcomes with respect to rate of fracture union and occurrence of infection were obtained from patient records. All patients with insufficient medical records were excluded.

Results

The records of 197 patients who sustained gunshot tibia fractures were reviewed. The mean follow-up was 4.1 months (interquartile range [IQR] 2.5–6.8). The majority of cases were young males (89%) with a mean age of 29.2±10.2 years. Extra-articular diaphyseal fractures were observed in the majority of cases (91%). Definitive treatment included formal debridement in theatre and plaster cast immobilisation (44%), intramedullary nail fixation (27%), circular external fixation (22%) and plate fixation (7%). The study revealed an overall fracture-related infection (FRI) rate of 11% and bone union rate of 91%. Circular external fixation showed the lowest fracture union rate (86%) and highest FRI rate (21%) of the modalities included in this study. No associations between independent risk factors and presence of complications were identified.

Conclusion

The study reports encouraging outcomes for tibia fractures caused by civilian gunshot injuries. Various definitive surgical stabilisation techniques showed high proportions of union and low burden of FRI.

Level of evidence: Level 4

Keywords: tibia, gunshot, fracture, outcome

Introduction

Trauma accounted for 8.5% of global deaths as indicated in the 2015 Global Burden of Disease study.¹ Trauma, specifically, can be classified into intentional injuries that occurred due to interpersonal or collective violence and self-inflicted injury, as well as unintentional injuries including motor vehicle collisions, falls and burns. The United Nations Office on Drugs and Crime (UNODC) has ranked South Africa (SA) 11th in terms of violence, with a homicide rate of 31.1 per 100 000 people.² A 2019 study by Zaidi et al. highlighted the high monthly load of trauma at a district hospital in the Western Cape province of South Africa in which 44.4% of trauma cases were attributed to interpersonal violence, where 7.2% of these were firearm-related.³

Insight into the South African burden of gunshot-related injuries on orthopaedic services was reported by Engelmann et al. who reviewed 294 extremity gunshot injuries seen at a tertiary trauma centre in Cape Town over an 11-month period between June 2015 and April 2016, and reported that tibia fractures accounted for the majority (42.2%) of lower extremity injuries.⁴ A retrospective study by Martin et al. reviewed 111 patients at a tertiary level hospital who had sustained 147 gunshot-induced fractures over a 12-month period. The authors reported that the majority of these injuries involved the lower extremity, and 95% of these patients inflicted with lower extremity gunshot-induced fractures required orthopaedic procedures at an average cost exceeding 13 times the annual average per patient afforded by the South African public health sector.⁵ In agreement with this, a recent study from a tertiary

hospital in South Africa reported a total of 1 449 gunshot-related orthopaedic fractures over a four-year period, resulting in a total cost of more than ZAR 50 million to the healthcare system.⁶

Gunshot-induced tibia fractures are often associated with a myriad of complications presenting greater challenges to clinicians. Gunshots involve the transfer of blast energy to the bone and soft tissue resulting in cavitory tissue damage and a large zone of injury.⁸ Further, the risk of infection, compartment syndrome, nerve palsies, delayed union or non-union are increased due to the subcutaneous location of the tibia. Moreover, poor correlation between external wound size and degree of underlying tissue damage may lead to an underestimation of the injury severity.⁸

Several controversies regarding the management of gunshot-induced tibia fractures persist as a result of the heterogeneity of these injuries. Management of these injuries can range from conservative management to formal debridement and skeletal stabilisation either in a single setting, or as a staged approach.⁹ Advantages of temporary monolateral external fixation include bone stabilisation, and easy access for wound care.¹⁰ Conversely, problems associated with monolateral external fixation include pin-site infection and loss of stability during long-term use.¹⁰ In comparison, studies have reported the efficacy of formal debridement and internal fixation in the same sitting, demonstrating the advantages such as access to soft tissue and low risk of deep infection.¹¹ These reports add to the controversy regarding the management of gunshot-induced fractures and highlight the lack of evidence-based treatment guidelines.

The present study aims to describe the treatment outcomes of civilian gunshot tibia fractures at a major trauma centre.¹² Secondary objectives were to identify possible risk factors for complications, including non-union and fracture-related infection (FRI).

Methods

A retrospective review of clinical records and serial radiographs of all patients who sustained gunshot tibia fractures between January 2014 and December 2017 was conducted. Institutional ethics committee approval and hospital board approval was obtained prior to commencement of data collection.

Medical records of all adult and paediatric patients presenting with tibia fractures as a result of gunshot injuries in the study period were reviewed by the authors. Demographic information of all included patients was recorded, and patient records were assessed to identify the extent of soft tissue injury and presence of associated injuries. Patients that did not require surgical intervention, as well as all patients with incomplete medical records, were excluded. Tibia fractures were classified according to the Muller AO Classification¹³ as intra-articular (AO 41B-C and 43B-C), metaphyseal (AO 41A and 43A) and diaphyseal (AO 42A-C) for analysis purposes.

As per international protocol, intravenous antibiotics (cephazolin) were administered on presentation¹⁴ and the treatment modality used, as well as the timing thereof, was recorded. Temporary external fixation was used for damage control and patients with vascular injuries. For definitive management, interlocked intramedullary nailing (IMN) was used for diaphyseal tibia fractures where the soft tissue envelope was amenable to primary closure, while intra-articular and metaphyseal fractures were most often managed with plate fixation. Fine wire circular external fixation was used for metaphyseal and intra-articular fractures with extensive soft tissue damage or where delays to surgery were encountered, due to the trauma burden at our institution.

Radiographs were reviewed to determine time to radiological union based on the Radiographic Union Score for Tibia fractures

(RUST Score).¹⁵ The presence of an FRI was deemed 'suggestive' or 'confirmed' using the guidelines outlined in the consensus document of Metsemakers et al.¹⁶ Minor complications, such as the presence of cast-associated pressure sores or pin-site infections, were not recorded.

Data was analysed using STATISTICA version 13.5 (StatSoft Inc., Tulsa, OK, USA) and data is presented as means \pm standard deviations or median (interquartile range [IQR]), depending on the distribution, while categorical data is presented as frequencies and counts. Associations between risk factors, including age, sex, HIV status, injury location and delay to surgical management, and known outcomes, specifically presence of i) non-union or ii) infection, were investigated using an independent t-test or Mann-Whitney U test for continuous data, while a Pearson's chi-square test or a Fisher's exact test was used for categorical data.

Table I: Demographic information of included patients

	n=197
Age (years)	(28.8 \pm 10.4) (197)
Sex	
Male	89% (175)
Female	11% (22)
HIV status	
Positive	34% (67)
Negative	28% (56)
Unknown	38% (74)

Data is expressed as means \pm standard deviations or as frequencies, with counts indicated in parentheses.

Table II: Injury characteristics of included patients

	n=197
Affected side	
Left	50% (99)
Right	50% (98)
Anatomical site	
Tibia	96% (189)
Tibia and fibula	4% (7)
Tibia and patella	0.5% (1)
Intra-articular	
No	95% (187)
Yes	5% (10)
AO classification (tibia fracture)	
Diaphysis	91% (179)
42B3	71% (140)
42A3	15% (30)
42B2	5% (9)
Proximal metaphysis	8% (16)
41C2	4% (8)
41A3	4% (8)
Distal metaphysis	1% (2)
43C2	0.5% (1)
43C3	0.5% (1)

Data is expressed as frequencies with counts in parentheses.

Results

A total of 213 patients who sustained gunshot tibia injuries were reviewed. Sixteen patients who did not require surgery or had incomplete medical records were excluded. The final cohort therefore included 175 male patients (89%) and 22 female patients (11%) with a mean age of 28.8±10.4 years (Table I). Isolated tibial injuries represented 96% of cases (n=189). The majority of injuries (91%, n=179) were diaphyseal fractures while 9% (n=18) were peri-articular injuries (Table II).

Patients underwent surgery at a median of 2.0 (IQR 2.0–5.0) days following admission. The majority of fractures were managed by fixation including IMN fixation (27%, n=53), circular external fixation (22%, n=44), and plate fixation (7%, n=14) while remaining fractures were managed through formal debridement and plaster cast immobilisation (44%, n=86). Definitive soft tissue and fracture management was performed during a single theatre visit in all patients. Median length of stay in hospital was 6.0 (IQR 4.0–9.0) days. Patients were followed up for a median of 4.1 (IQR 2.5–6.8) months. Five (3%) patients were lost to follow-up prior to confirmation of union (Table III).

Table III: Treatment information of included patients

	n=197
Time delay (admission to surgery) (days)	2 (2–5) (186)
Admitted to hospital	100% (197)
Admitted to ICU	3% (6)
Temporary external fixator	8% (15)
Definitive procedure	
Debridement and plaster cast	44% (86)
Intramedullary nail	27% (53)
Circular external fixator	22% (44)
Plate fixation	7% (14)
Hospital stay (days)	6 (4–9) (186)
Follow-up (months)	4.1 (2.5–6.8) (166)
Lost to follow-up before confirming union	3% (5)

Non-missing data is reported as medians (interquartile ranges) or as frequencies, with counts indicated in parentheses. ICU: intensive care unit

Bony union was achieved in 179 patients (91%) after the initial fixation. A total of 21 patients (11%) in the entire cohort developed FRIs (Table IV). No associations between demographic or treatment-related risk factors and treatment outcomes were observed (Table V).

All definitive fixation procedures showed high proportions of union, with circular external fixators having the lowest union rate (86%). Similarly, the presence of FRI was highest in the circular fixation group (21%) (Table VI).

Discussion

The first finding of this study was the demographic sample and the predominant involvement of young males (89% male with a mean age of 29.2±10.2 years), which is similar to previous published reports on orthopaedic injuries following civilian gunshots.^{3,6,8} A recent study conducted in South Africa reported a higher rate of intentional and gang-related violence together with the use of alcohol and illegal drugs among young, gunshot-injured males.⁵ While we did not test patients for alcohol or illegal drugs in the present study, our finding, together with the previous reports, again highlights this group of individuals to be a potential target for intervention in the future.

The second important finding relates to our individualised approach to fracture management that produced an overall union

Table IV: Treatment outcomes of included patients

	n=197
Fracture healing	
Union	91% (179)
Non-union	7% (13)
Unknown	3% (5)
Fracture-related infection	
No	87% (172)
Yes	11% (21)
Unknown	2% (4)

Non-missing data is reported as medians (interquartile ranges) or frequencies, with counts indicated in parentheses. Outcomes of patients that were lost to follow-up are reported as 'unknown'.

Table V: Demographic-, clinical- and treatment-specific risk factors for non-union and infection

Risk factor	Union* (n=179)	Non-union* (n=13)	p-value	No infection** (n=172)	Infection** (n=21)	p-value
Patient demographics						
Age (years)	28.4±10.4 (179)	32.7±10.1 (13)	0.153	28.5±10.1 (172)	32.3±10.0 (21)	0.113
Sex (% male)	88.3 (158)	100.0 (13)	0.367	87.2 (150)	100.0 (21)	0.139
HIV status						
% pos	32.4 (58)	53.9 (7)	0.263	31.4 (54)	47.6 (10)	0.197
% neg	29.6 (53)	15.4 (2)		30.8 (53)	14.3 (3)	
% unknown	38.0 (68)	30.8 (4)		37.8 (65)	38.1 (8)	
Injury characteristics						
Injury location						
% proximal	7.8 (14)	0.0 (0)	>0.999#	7.6 (13)	9.5 (2)	0.406#
% midshaft	91.6 (164)	92.3 (12)		91.9 (158)	85.7 (18)	
% distal	0.56 (1)	7.7 (1)		0.6 (1)	4.8 (1)	
Intra-articular (% yes)	5.0 (9)	7.7 (1)	0.513	5.2 (9)	4.8 (1)	>0.999
Treatment characteristics						
Time delay (days)	2.0 (2.0–5.0) (174)	3.0 (2.0–5.0) (13)	0.361	2.0 (2.0–4.0) (166)	3.0 (2.0–5.0) (21)	0.457

Non-missing data is reported as mean ± standard deviations, medians (interquartile ranges) or frequencies with counts in parentheses. *Five patients had an unknown union outcome; **Four patients had an unknown infection outcome – patients with unknown outcomes were excluded from the analysis. #Fisher's exact test for proximal and distal vs midshaft fractures

Table VI: Outcomes related to union and infection of all patients per type of definitive treatment

Definitive procedure	Union % (n)	Infection % (n)
Debridement and POP (n=86)		
Yes	93% (80)	5% (4)
No	4% (3)	92% (79)
Unknown	4% (3)	4% (3)
Intramedullary nail (n=53)		
Yes	91% (48)	13% (7)
No	6% (3)	85% (45)
Unknown	4% (2)	2% (1)
Circular fixator (n=44)		
Yes	86% (38)	21% (9)
No	14% (6)	80% (35)
Plate fixation (n=14)		
Yes	93% (13)	7% (1)
No	7% (1)	93% (13)

Data is presented as frequencies with counts indicated in parentheses. POP: plaster of Paris

rate of 91% and an FRI rate of 11%. A recent retrospective study by Metcalf et al. investigated the surgical outcome of tibia fractures managed with intramedullary nail fixation and observed a 30% non-union rate and 9% infection rate for civilian gunshot tibia fractures which was comparable to our findings.¹⁷ In terms of length of stay, the current study results (median of 6.0 days) were slightly less than that reported by Abghari et al. who investigated the outcome of civilian gunshot injuries and reported a median length of stay of 7.1 days for patients who sustained lower extremity fractures.¹⁸

There were no associations noted between the demographic or treatment-specific risk factors and the clinical outcomes. No associations between clinical outcome and HIV status were observed. Very few studies have investigated the association between HIV and bone healing and this relationship remains poorly understood and unclear. An ongoing study investigating the association between union and HIV infection is nearing completion, and should provide important information on the effect of HIV on bone healing.¹⁹

Patients in the present study waited a median of two days for surgery (IQR 2–5 days). This delay is attributed to the high burden of trauma cases at South African hospitals which hampers the ability of providing immediate surgery on admission.³ Interestingly, the delay to surgery was not associated with an increased complication rate. Kale et al. had previously reported an infection rate of 11.4% for patients with open fractures, most commonly arising from motor vehicle accidents, that received wound closure within a week of admission, compared to 77.8% for patients suffering infection when they had wound closure after two weeks, suggesting an association between delay in surgery and rate of infection.²⁰ The lack of an association in the present study could potentially be as a result of the different injury mechanism, faster median time to surgery, or the fact that all surgeries were performed in a single setting, rather than in a staged process. Ultimately, it is important to keep in mind that risk of infection is influenced by multiple factors.

Various definitive skeletal stabilisation procedures were included in this study. Formal debridement followed by cast immobilisation, as well as plate fixation, showed the optimal union and lowest infection rates in the present study. There was no association of FRI and union rates with length of stay. Minor complications, such as the presence of pressure sores, were not recorded as part of

this investigation. Obvious selection bias for cast immobilisation of stable fracture patterns, isolated fractures, low energy transfer injuries and lower grade wounds should, however, be borne in mind when interpreting these results. For this reason, no statistical analysis was performed to investigate associations between treatment modality and outcome, because this relationship would be confounded by the differences in injury characteristics which guides clinical decision-making with regard to treatment modalities. IMN fixation showed outcomes comparable to a previous publication by Hilton et al. who reported a 76.9% initial union rate following intermedullary nailing for gunshot tibia shaft fractures, with three patients developing osteomyelitis.⁸ The union rate observed in the present study for IMN was 91%.

Circular external fixation was generally reserved for patients who had complex fractures, significant soft tissue damage and delays to surgery, and showed lowest union rate when compared to other definitive fixation methods. A study conducted by Van der Walt and Ferreira however reported higher union rates of 100% using circular external fixators in their gunshot-induced tibia fracture sample.²¹ The lower union rate with the use of circular external fixation observed in the present study may be attributed to the injury characteristics and delay in treatment for patients who were managed with this fixation modality. Furthermore, circular external fixation showed the highest FRI rates when compared to other definitive fixation methods, keeping in mind that circular fixation was reserved for patients with significant soft tissue injury or delay to surgery. FRI rates were higher in the IMN group (13%) compared to plate fixation (7%), but it is important to keep in mind that nail fixation was generally reserved for diaphyseal fractures compared to plate fixation, which was typically employed for metaphyseal injuries. Unfortunately, there is very limited clinical data specifically investigating tibial plate fixation following low-energy gunshot injuries. Sitnik and Beletsky reported an 8.75% infection rate in plate fixation in an investigation of 80 patients. This series, however, only included a single gunshot wound case and is therefore not directly comparable to the result of the present study, where a 7% infection rate was observed.²² It is again important to emphasise that risk of infection is influenced by multiple factors and as such, future experimental studies, where bias is largely removed, should investigate this finding further.

The major study limitations include the retrospective design and single centre cohort which resulted in, albeit a large cohort compared to previous reports, too small a sample to detect large differences between sub-groups. The short follow-up period reported in this investigation is another limitation: we report a median follow-up time of 4.1 months, while these injuries should ideally be seen over a longer follow-up period. Lost to follow-up is however a notorious problem in our setting that has previously been described by Badenhorst et al.,²³ and we believe that the results of the study are still meaningful, regardless of this limitation. Finally, the observational nature of the study includes an inherent selection bias in the outcomes observed for the different treatment modalities used where some modalities were more likely to be used in more complex fractures than others. Subsequently, we could not comment on the risk of specific outcomes following treatment with specific devices.

Conclusion

Tibial fractures caused by civilian gunshots remain challenging injuries to manage. This study found that an individualised approach to the treatment of these fractures can produce a satisfactory union rate with minimal complications if managed during a single stage by intramedullary nails, plate fixation or cast immobilisation. While the complications were higher in patients managed with circular

external fixation, these devices were generally reserved for more severe injuries.

Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.

Ethical approval for this study was obtained from the Stellenbosch University Ethics Committee, S18/07/139.

All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

MG: Study conceptualisation, data capture, data analysis, first draft preparation, manuscript revision and approval of final manuscript
SJ: Data capture and approval of final manuscript
MvH: Data capture and approval of final manuscript
NIR: Data capture and approval of final manuscript
SvdM: Data capture and approval of final manuscript
OM: Data capture and approval of final manuscript
GdP: Data capture and approval of final manuscript
MB: Data analysis, manuscript revision and approval of final manuscript
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