A Review of Civilian Gunshot Injuries of the Extremities

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Declaration

I, Tristan Pillay, declare that this research report is my own, unaided work. It is being submitted for the Degree of Master of Medicine in the branch of Orthopaedic Surgery at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

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Dr. Tristan Pillay

On the 5th day of April 2021 in Randburg

Abstract

Introduction

Gunshot injury is a common mechanism of injury in the South African context. A previously wartime entity has found itself to have a significant presence amongst civilians. South Africa has been reported to have a 26.8 per 100 000 rate of firearm deaths, the third highest rate in the world. The quantitative and qualitative data about these injuries – that place a significant burden on the patient, healthcare system and economy – are unfortunately poorly documented. The weaponry and the associated ballistics used by civilians is poorly understood, hence the potential to cause injury also needs to be investigated. The relative paucity of data surrounding gunshot injuries to the extremity, and an appropriate classification system, requires further investigation. A novel classification system was introduced by Gugala *et al.* which has not been validated in isolated extremity gunshot injuries.

Methods

A retrospective analysis of clinical records of patients presenting to two level one trauma centres in Johannesburg was conducted to provide an epidemiological understanding of this cohort of patients including the social backdrop that may contribute to gunshot injuries in the hope of identifying areas where preventative measures may be introduced. We analysed the injuries caused by the weaponry in the community and were able to draw a few inferences with regards to ballistic properties. We also applied the classification system proposed by Gugala *et al*. to determine validity using the Cronbach's coefficient alpha and Pearson's correlation coefficient. We did statistical analyses of other associations that may be used to determine injury potential with the reported description of the event including the size of the gun, and distance from the gun.

Results

We reviewed 232 isolated Gunshot injuries to the extremities in 188 patients. This included twenty-seven cases of soft tissue injury alone, and 214 fractures. We detected an 8.6% nerve injury rate. Most of the injuries occurred in the lower limb, with a greater likelihood of fractures occurring in upper limb injury patients. The majority of patients in this series were young, otherwise healthy males with reports of some kind of illicit substance use. We found that there was a significant peak of gunshot injuries that took

place around 20h00 and the mean time to presentation of 743 minutes to the Department of Orthopaedic Surgery. We derived a poor internal consistency with a Cronbach's Coefficient Alpha value of 0.3489 and poor inter-component correlation. The statistical analysis revealed that the ballistics was unpredictable relative to the size of the gun or distance from the gun.

Conclusion

The ascertained serological and radiological parameters in conjunction with the latest literature suggests that many of these patients are appropriate for early appropriate care with- or with-out surgical intervention. There are significant social correlations that would require further investigation which may be areas for prevention. Isolated extremity injuries have been shown to requite expeditious assessment and appropriate management as we have found these injuries are debilitating and with a better understanding and further investigation, we may better prevent the injuries from occurring and streamline the management of these injuries to improve outcomes.

Acknowledgements

It is by the Grace of God that I have been afforded this privilege of furthering my education. I wish to thank my loving family for their relentless support during the compilation of this research report. I would also like to thank my supervisors, Prof Ramokgopa, Dr. Van Deventer and Dr Milner for the tremendous insight and guidance provided, particularly Dr Milner who committed herself extensively in guiding me through this process. Last but certainly not least, I extend my gratitude to my fellow orthopaedic surgery colleagues who give their utmost to treating patients on a daily basis, often in challenging circumstances.

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Nomenclature

cm	Centimetre
CHBAH	Chris Hani Baragwanath Academic Hospital
CMJAH	Charlotte Maxeke Johannesburg Academic Hospital
ft/s	Feet per Second
GSI	Gunshot Injury
m	Metre
m/s	Metres per Second
P-Value	Probability Value
PACS	Picture Archiving and Communication System
REDCap	Research Electronic Data Capture
USA	United States of America
ZAR	South African Rand
USD	United States Dollar

1. Introduction and Literature Review

1.1 Burden on Healthcare

Gunshot injury (GSI) is a common mechanism of injury in the South African context. A previously wartime entity has found itself to have a significant presence amongst civilians.(1, 2) South Africa has been reported to have a 26.8 per 100 000 rate of firearm deaths, the third highest rate in the world.(3) Locally, it was found that gun ownership by civilians outnumber state owned guns by six times.(4) Internationally, civilian firearm associated crime is increasing, with the United Kingdom experiencing a 30% increase from 1998 to 2005 alone.(5) Knowing the weapon used in the South African setting is often quite difficult, as found by Abrahams *et al.*, and unlicensed firearms are more likely to be used in violent crime over legal guns, which also makes it difficult to understand the ballistics responsible for the injuries seen in our local setting.(6)

The quantitative and qualitative data about these injuries, are unfortunately poorly documented in South Africa. In 2002, there were 127 000 non-fatal GSIs recorded per annum across the country,(7) comparatively, the Centre for Disease Control recorded a total of 58 841 non-fatal GSIs in the United States of America (USA) in the same year.(8) Groote Schuur Hospital in Cape Town has an electronic trauma health record which shows that of the 12 000 patients seen in a year, 1000 were attributed to GSIs.(9) In the USA, the recorded amount of non-fatal GSIs for each fatal GSI was 3.3 to 1.0 in 1995.(10) In 2012, one in every 1000 people within our borders fell victim to a non-fatal GSI.(3) In the USA, Gotsch *et al.* found frequent extremity injury in non-fatal GSIs comprising 46% of the assaults and 72% of unintentional injuries.(11)

Brown *et al.* found gunshot related injuries to account for 24% of all orthopaedic admissions. The literature reveals the most common gunshot associated fractures to be of the femur (22-49%); the radius, ulna or both (14-23%); the hand (18%), the humerus (10-17%) and the tibia (11-14%).[12-14] These injuries impose a significant burden on the patients, their families and the relevant health care systems. This burden is often multifaceted, taking a significant toll on the psyche, time to healing and financial losses from the inability to work, and subsequent detriment to livelihood.[15]

By 1995, Ordog *et al.* already found GSIs to cost approximately USD 1 billion per year.[16] In the USA, gunshot related medical treatment exceeds USD 2.7 billion annually – even more startling – that up to 50 000 lives are lost each year due to GSIs which almost equals the number of fatalities (59 021) in 12 years of the Vietnam war.[17, 18] In 1994, Nowotarski *et al.* reported an average cost of USD 13 140 (approximately ZAR 46 467) per patient excluding physician fees to treat civilian gunshot associated femur fractures.[19] The cost to our local healthcare system is also substantial – Peden and Van der Spuy found that it cost an average of ZAR 30 628 to treat each gunshot victim at Groote Schuur Hospital in 1998, with a total expenditure of ZAR 3.8 million, for the year.[20] More recently, Martin *et al.* reported that the average cost of treatment per patient was ZAR 24 945, the highest being ZAR 170 084, with an average hospital stay of 9.75 days at the same facility.[21]

The United Nations meeting held in 2001 advocates adequate surveillance in health care facilities to better understand the details surrounding the incident. The current data available is often a reflection of police and law enforcement agencies which might not include the 50 – 80% of victims of violence as these may not have been reported to the relevant authorities.[22]

1.2 Ballistics

Gunshot wounding is an interaction between the penetrating projectile, the anatomy of the wounded subject and the chance occurrences that determine the exact missile path.[23] There are several variables that determine the amount of injury a projectile may inflict, these variables include: the mass and velocity of the projectile, as well as the shape of the projectile, the material it is made of, the fragmentation capacity of the projectile, and the properties of the tissues that it strikes.[2, 24-29] Yaw refers to the magnitude of deviation of the bullet from its axis of trajectory which may in some cases result in tumbling of the projectile. It has also been found to be directly proportional to the severity of tissue trauma due to an increase in surface area of the bullet making contact with the patient.[25-27] Kinetic energy directly correlates to wounding capacity. It is calculated by ½ mass x velocity squared (½ mv^2), where the mass is measured in kg and velocity in m/s.[29, 30]

Many sources have referred to the wounding capacity of a weapon relative to the muzzle velocity it is able to produce. Low-velocity weapons are regarded to have a muzzle velocity of less than 2000 feet per second (ft/s), or 600 metres per second (m/s), whereas high velocity weapons have a muzzle velocity greater than 2000 ft/s.[12, 28, 29, 31] It takes an impact velocity of 150 ft/s (approximately 45 m/s) to breach the skin and 195 ft/s (approximately 60 m/s) to fracture a bone.[12, 31-34] Furthermore, some publications have differentiated between low and medium velocity weapons where a velocity above 350 m/s is considered medium. [35-37] It has been found that most civilians have low velocity weapons in the USA, however there is a paucity of data regarding the nature of weapons that South African civilians utilise mostly.[38, 39] The gun with a longer barrel is able to confine and concentrate resultant gases from ignition of gunpowder for a greater amount of time and thereby propel the projectile at a greater velocity. Distance from the gun also plays a significant role in wounding potential as the muzzle velocity has been found to decrease significantly if the distance to the target exceeds 45 metres for low velocity weapons, and 90 metres for high velocity variants.[12, 35] Most civilian injuries have been recorded at an average range of 10 metres. [16, 40]

Higher energy transfer results in greater comminution of the bone and greater disruption of soft tissue. [24, 40, 41] Brien *et al.* described several bullet types as being low velocity but high energy projectiles such as 0.40-calibre, 0.45-calibre and 0.357-calibre magnum bullets, and low energy low velocity bullet types being 0.38-calibre, 0.25-calibre and 0.22-calibre bullets.[42] Rifles, shotguns and bullets with a calibre greater than 0.38, or even bullets of low calibre but fired within close range of the patient, may be considered to cause grade three injuries as per the Gustilo-Anderson classification, with a high propensity to cause soft-tissue and bone necrosis.[42, 43] In many cases where the patient may have fled the scene, or was unaware of the specific weaponry used, it may be difficult to ascertain the muzzle velocity in question; however, Gelbart *et al.* used a wound diameter of less than 5 cm to exclude an extended zone of injury as seen in high velocity injuries.[44] It is important to note that even if the muzzle velocity and firing distance are known, the many aforementioned confounding variables in ballistics may alter the severity of an injury in a disproportionate manner. [9, 45]

1.3 Injury Severity

The severity of tissue injury depends on the efficiency of energy transfer, and naturally high velocity weaponry may infer high energy transfer resulting in a greater severity of injury. [12, 25, 46-49] A high density tissue such as bone is less able to absorb energy and will often fracture from the high energy insult. It is the transfer of energy that is proportional to injury severity. Therefore, one must be cognisant not to take muzzle velocity in isolation but more importantly – impact energy. Low velocity firearms may produce a high impact energy and greater injury.[12, 35, 50] The higher energy missiles create shockwaves that are capable of inflicting remote injury.[35] If significant fragmentation is seen clustered on radiographs, one can infer significant soft tissue injury at that site. [51] Gugala *et al.* described the parameters required for high energy injuries to occur and these include: 1) the use of a high velocity weapon fired within 90 m of the target, 2) an injury inflicted by a shotgun at a range less than 5 m; 3) the use of atypical bullets enhancing wounding potential such as hollow-point; 4) the weapon being fired repetitively into a limited area of tissue to increase the wounding size and 5) a missile creating extensive bony comminution and/or injuries producing secondary missiles such as bony fragment regardless of the firearm used.(35)

Bartlett *et al.* describes two categories of gunshot induced fractures as complete and incomplete fractures. Incomplete fractures are further subdivided into drill hole fractures, usually occurring in metaphyseal bone with the diameter of the fracture being similar to that of the bullet;(40, 52) the unicortical divot fracture which characteristically reveals a small area of bone lifted off with or without an associated fracture line extending from the divot; and lastly a chip fracture which is very rare in bullet injuries and is often the result of a narrow point impact as seen in a stab wound. (12, 26, 52-56) Complete fractures generally occur in diaphyseal bone which commonly result in single or double butterfly fractures. Some authors have also documented spiral fractures originating from the point of impact which is believed to be ascribed to a stress riser effect i.e. the bone was under load or stress at the time of impact. (12, 53, 55-58) Clinical and radiographic appearance of the entrance hole is usually a punched-out round to oval shape with a sharp bevelled edge. The exit site is generally conical in appearance with variable degrees of comminution.(26, 34, 52)

Shotguns, rifles and larger barrelled handguns are able to propel the relevant projectiles at a much greater velocity, and are able to infer a greater degree of force that is transferred to the tissues.(12, 17, 46) Greater comminution is seen in fractures attributed to these weapons. (53, 55, 59) Similarly, there is significant injury to the surrounding soft tissues, which are often the more concerning injuries to the extremities.(53)

Joint injuries are very common sites to find the bullet either as fragments or in entirety. These projectile remnants may cause injury in one of two ways, the first being mechanical trauma to the joint itself during motion causing damage to the cartilage, functional limitation in motion of the joint and discomfort for the patient, and the second being lead toxicity which may cause a local synovitis [59, 60] or systemic effect on cardiovascular, neurological, musculoskeletal and reproductive symptoms.[61]

Neurovascular injury is of utmost importance as it may determine the prognosis of the limb following injury. Hahn *et al.* found the most common physical signs of arterial injury to be diminished or absent pulses and pulsatile bleeding.[62] The literature also denotes other signs such as ischaemic pain, pallor, cold extremity, an expanding haematoma or a bruit which have been described as “hard” signs.[18, 63-68] “Soft” signs of vascular injury include history of haemorrhage, unexplained hypotension, a small stable haematoma, nerve injury, and proximity of the wound to major vascular structures.[18] Pulses however may be misleading as it may be normal in 20% of cases where lesions are observed on angiography.[63] A variety of nerve injuries may also result from a gunshot. There is a high incidence of concomitant nerve injuries with vascular injuries. Sitzmann *et al.* found this particularly more common in the upper limb, with a rate of 50%.[18, 69] Commonly the concussion zone of the injury may cause neuropraxic injury to the nerve which, in many cases, has a good chance of recovering spontaneously. [18, 70, 71]

1.4 Classification

Fractures were previously classified according to the Winquist and Hansen classification to quantify the degree of comminution.[72] It was found that 93% of low velocity gunshot related fractures fell into a grade 3 or grade 4 comminution with the remaining 7% falling into the grade 2 classification.[73] GSIs are quite complex and diverse in the local and systemic effect it may have on the patient, hence it has been particularly challenging to find an all-encompassing classification that will take into account important local and systemic parameters and provide a relative standard for the practitioner to prognosticate and treat the patient.

Long *et al.* proposed a system that consists of radiographic findings, wounding and susceptibility to infection to qualify the severity of injury. Whilst seemingly concise, the study only looked at civilian GSIs to the femoral diaphysis and did not take into consideration the overall physiological condition of the patient.[(74)]

Gustilo and Anderson formulated a classification for open fractures in general which over time has been adapted to GSIs, which from the literature, seems to be quite deficient as it tends to only give an impression of soft tissue injury and its associated infection risk. Low velocity injuries fall into the type 1 or type 2 category depending on the size of the wound, and high velocity injuries fall into the type 3 category irrespective of wound size.[(35, 75)]

Moye-Elizalde *et al.* from a total of 402 patients found the Gustilo Classification to be insufficient in classifying GSIs.[(76)] Military GSIs have also been classified by the International Committee of The Red Cross but many of our civilian injuries do not fall accurately into the same nature of injury. [(25, 46, 77)] In 2003, Gugala and Lindsey proposed a holistic classification of GSIs which was statistically validated and encapsulates the relevant ballistic and clinical characteristics of a GSI in which they reviewed 216 patients. It utilises a scoring system to better qualify and quantify the injury as outlined in Table 1.1 below. [(35, 75)]

Table 1. 1: Novel civilian gunshot injury classification system proposed by Gugala and Lindsey [35] (used with permission)

Feature	Classification
E = Energy	Missile impact energy dissipated within the target tissues HE-C = High-energy } Confirmed LE-C = Low-energy } HE-S = High-energy } Suspected LE-S = Low-energy }
V = Vital structure	V = 0, No vital structure injured V = 1, Functional damage (neuropraxia) V = 2, Structural damage of small neurovascular structures V = 3, Injury to viscera, major vessels (proximal to and including the popliteal and brachial vessels), central nervous system
W = Wound	W = 1, Nonpenetrating (grazing or blast) W = 2, Penetrating (nonexiting) W = 3, Perforating (in and out)
F = Fracture	F = 0, No bony fracture, or fracture that does not require stabilization Extraarticular (*modified Winquist and Hansen*[44]): EF = 1, Extraarticular, comminution < 25% EF = 2, Extraarticular, comminution 25–50% EF = 3, Extraarticular, comminution 50–75% EF = 4, Extraarticular, comminution > 75% or segmental defect Intraarticular, (*after Collins and Temple*[7]): IF = 1, Single capsular perforation, no extensive soft tissue damage IF = 2, Single or multiple perforations, and extensive soft tissue damage IF = 3, Open periarticular fracture with extension to articular surface IF = 4, Intraarticular fracture with dislocation or vascular or nerve injury
C = Contamination	C = 1, Relatively clean wound C = 2, Moderately contaminated wound (clothing debris) C = 3, Grossly contaminated wound (viscus, bowel content)

1.5 Problem Statement

The paucity of data regarding the effect of these injuries precludes any form of guidelines as to how these injuries should be treated. Furthermore, the nature of ballistics needs to be evaluated as well as the milieu in which these events occur.

1.6 Study Aim and Objectives

Aim:

As GSIs occur frequently in the South African population, it is important that clinicians have an adequate understanding of these injuries, and the nature of the weaponry used, to optimise patient care. Therefore, the aim of this study is to review civilian GSIs of the extremities to gain a better understanding of the ballistics involved in our population.

Objectives:

I. To determine the epidemiology, including prevalence, of GSIs to the Extremities at two academic hospitals in Johannesburg.

II. To better understand the ballistics effect of weapons used in our population of patients – including patterns of fracture, soft tissue injury and physiological effects in line with the Gugala Classification.

2. Methods & Materials

2.1. Study Design and Setting

This was an observational study in the form of a retrospective chart review of approximately 188 adult patients who presented with GSIs to the extremities at Chris Hani Baragwanath Academic Hospital (CHBAH) and Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) from 01 July 2016 to 30 September 2018, both of which are level one trauma centres. This study adheres to the STROBE guidelines for research. Clinical records and patient presentations were scrutinised to extract the relevant information regarding the epidemiology. A single investigator (Dr T. Pillay) reviewed x-rays and clinical pictures in correlation with clinical records to classify the gunshot injuries according to Gugala *et al*.

2.2. Participants

The records of adult patients with gunshot injuries to the extremities that presented to trauma casualty were reviewed. Patients' radiographs were used to analyse fracture patterns using printouts or the Picture Archiving and Communication System (PACS). Clinical records, as well as patient presentations prepared regularly by the attending units within the orthopaedic department in the form of weekly mortality and morbidity audits, were used to derive epidemiology as well as injury severity.

The Gugala classification system was used to quantify and qualify the severity of injuries seen in our population. Permission from the author to use the classification system and assess its validity in our setting was obtained (see Appendix A). The classification system takes into consideration energy transfer, vital structure injury, wounding effect, fracture characteristics and contamination of the wound.[35]

Patient Inclusion Criteria:

- Sustained GSIs to the upper and lower extremities
- Gunshot within 48 hours of presentation
- 18 years of age and older
- Polytrauma
- Gunshot hip including acetabulum
- Gunshot shoulder including clavicle and scapula

Patient Exclusion Criteria:

- Gunshot to the spine and pelvis
- Patients who were declared dead on arrival

2.3. Data Collection

Ethics clearance was obtained via the University of the Witwatersrand's Human Research Ethics Committee (Medical) (clearance certificate: M181022, see Appendix B). The relevant clearance was obtained from the CEO of CMJAH and the Medical Advisory Committee of CHBAH (see Appendix C and D, respectively).

Demographic and radiographic data, as well as relevant history and examination findings, were captured using the Research Electronic Data Capture (REDCap) Software which is password encrypted (an example of the data collection sheet is shown in Appendix E). Patients were assigned a unique study number to maintain anonymity and confidentiality throughout the study.

2.4. Data Analysis

Patient characteristics, clinical findings and classification components were described using frequencies and percentages for categorical variables. Quantile distributional diagnostic plots (qnorm) were used to determine whether numeric variables were normally distributed or non-normal. For normally distributed numeric variables, the mean and standard deviation were reported. For numeric variables with non-normal distributions, the median and interquartile range were used.

The Cronbach's alpha coefficient was used to test the internal consistency of the GSI classification system among patients with GSIs of the extremities in South Africa. The effects of removing individual components from the classification system on the Cronbach's alpha coefficient were explored. We used the Pearson's correlation coefficient to examine pairwise associations between classification components. In addition, associations between the size of gun, distance from the gun, serum lactate and apposition with specific classification components (namely: energy, wound size and percentage comminution) were investigated.

Fisher's exact tests were used to compare categorical variables if any one of the cells had n<5. Two-sample Wilcoxon rank-sum (Mann-Whitney) tests were used to compare medians of numeric variables with energy (which had two categories – low versus high) and the Kruskal-Wallis equality-of-populations rank tests were used to compare medians of numeric variables with wound size and comminution (which had more than two categories).

All statistical analyses were performed using Stata version 15 (StataCorp Inc. 2017. Stata Statistical Software: Release 15. College Station, TX.).

3. Results

3.1 Epidemiology

We reviewed a total of 232 gunshot injuries in 188 patients. The male-female ratio was just under 13.5:1.0. The mean age was 32 years old, ranging from 18 to 74 years, with the most prevalent age being 24 years. Ninety-four individuals reported being employed, be it temporary or permanent work. Furthermore, 28.7% of the employed cohort of individuals were manual labourers, with a high incidence also noted amongst shop owners and those in the taxi industry i.e. 13.8 and 11.7 percent, respectively. Forty-one (21.8%) patients sustained multiple gunshots of which thirty-six (19.1%) patients sustained two GSIs and five (2.7%) patients sustained three GSIs, respectively. Of those patients that volunteered information regarding the circumstances of the injury, 21% reported that he/she was a victim of crime.

Table 3. 1: Demographic and event-related information

	Number of Patients (N)	*Percentage (%)*
Gender		
Male	175	93.09
Female	13	6.91
Reported Weapon		
Handgun/"Small"	142	75.53
Shotgun/Rifle/"Big"	8	4.26
Unknown	38	20.21
Estimated Distance from the Gun		
Less than 2m	57	30.32
2 – 6m	71	37.77
More than 6m	53	28.18
Unknown	7	3.72
Comorbidities		
Nil	163	86.70
Hypertension	5	2.66
Diabetes	3	1.60
TB (Previous or Current)	3	1.60
Other	13	6.91

Regarding the use of substances, 25% of the individuals reported no alcohol use with 47% denying tobacco use, and 85% denying use of illicit substances. However, it was only towards the end of data collection, in September 2018, that the South African government gazetted the permitted private use of cannabis. The stark majority of the patients afflicted by gunshots (88%) were otherwise medically well, with no concomitant comorbidities reported. Only 20 patients reported that they were HIV positive and a further 124 patients reported that his/her status was unknown at the time of presentation in casualty. Our national policy regarding HIV is that of voluntary counselling and testing, any subsequent testing was not reported for the sake of this study.

Monday through Wednesday revealed a fairly constant number of daily patients presenting to casualty with gunshot related injuries to the extremities – accumulatively below 27% of the total weeks GSIs. The week peaked on Saturdays – which comprised just under 25% of the total weeks GSIs (Figure 3.1). With regards to the time of injury, most patients reported being shot between 19h00 and 23h00, peaking around 20h00 (16% of daily GSIs) (Figure 3.2). Patient presentation to the Department of Orthopaedic Surgery had two peaks i.e. around 04h00 (8.6%) and a greater peak again around 09h00 (9.7%). This resulted in a mean time of patient presentation to the Department of Orthopaedic Surgery from the time of injury of 743 minutes (range: 60 – 3 870 minutes).

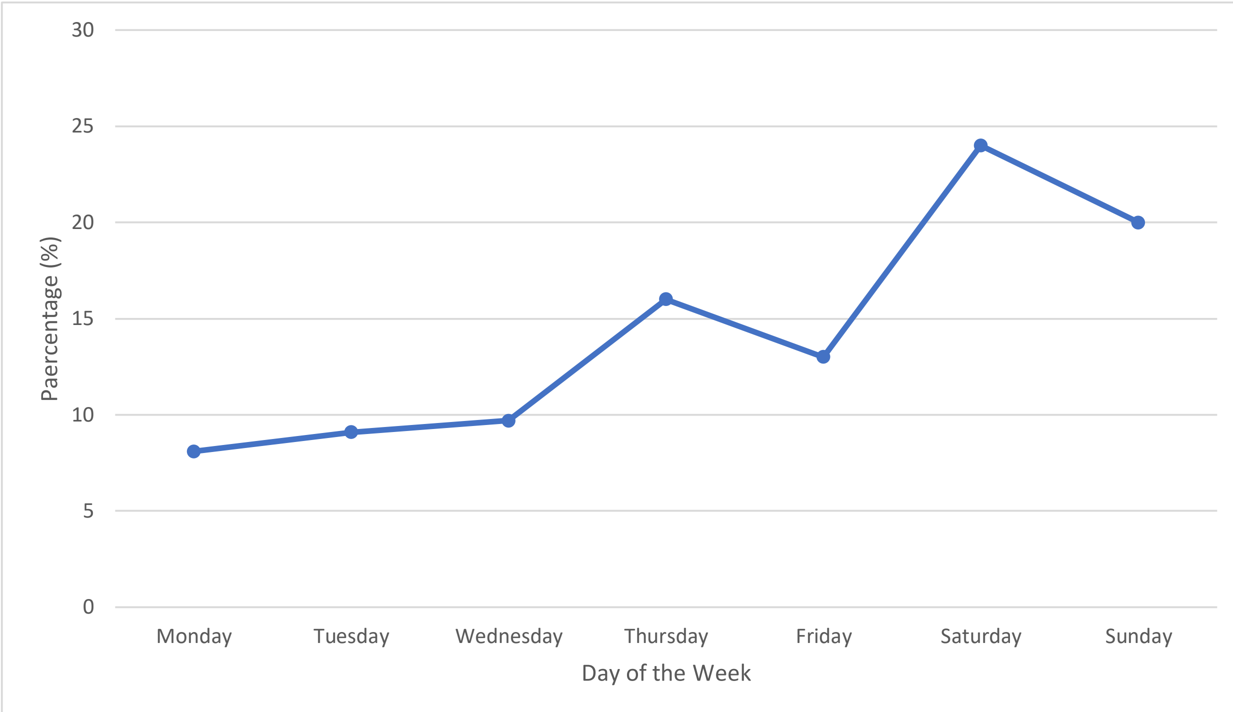

Figure 3. 1: Outline of weekly presentation of patients that sustained GSIs to the extremities

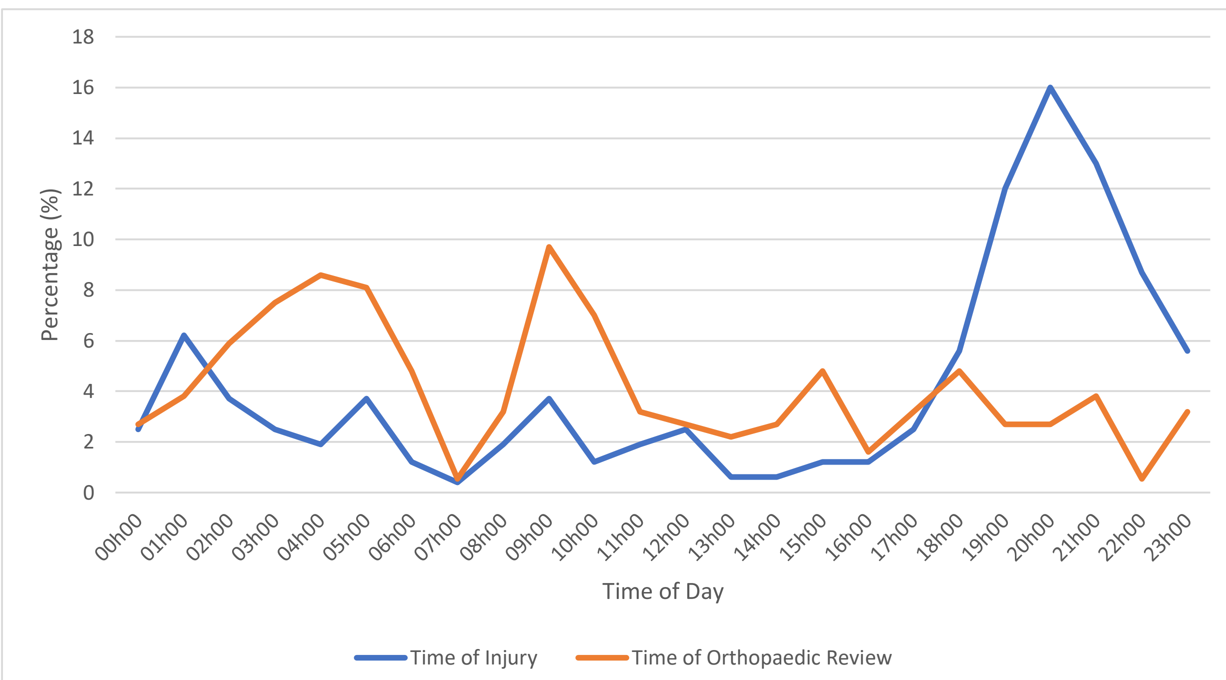

Figure 3. 2: Daily timeline of patients that sustained GSIs to the extremities

3.2 The distribution of injury

There was an even split between right and left sided injuries. The lower limb including the hip, was more frequently injured with a ratio comparative to the upper limb of

1.8:1.0. A total of 28 (12%) gunshots were soft tissue injuries in isolation with 7 (3%) of those violating the joints without concomitant fracture, 6 (2.6%) violating the knee and 1 (0.4%) violating the hip, respectively. There was a total of 214 gunshot related fractures observed (Figure 3.3).

When evaluating the wound potential, 108 (46.6%) GSIs were reported to be less than 1 cm in diameter, 114 (49.1%) GSIs greater than 1cm in diameter but less than 10 cm, and 10 (4.3%) greater than 10 cm. Contamination was confounded mostly by clothing debris as seen in 152 (65.5%) cases with the remainder reported to be relatively free of macroscopic contamination. Neurovascular injury was suspected in 29 (12.5%) cases of GSIs on clinical examination with 20 (8.6%) presenting with nerve injury and 9 (3.9%) presenting with suspected vascular injury, respectively.

Assessment of the 214 fractures revealed a mean shortening of 8 mm (range: 2 – 20 mm) and mean apposition of 89% (range: 70 – 95%). A total of 145 (67.8%) GSI related fractures were found to have no significant angulation, with the remainder revealing a mean angulation of 13° (range: 10 - 20°). The majority of long bone fractures affected the diaphysis (58.7%) with the remainder affecting the proximal epiphysis/metaphysis (19.2%) and distal epiphysis/metaphysis (22.1%), respectively. Sixty (31.9%) patients had blood gas mean base excess readings of -2.75 (range: -4.85 – -0.8).

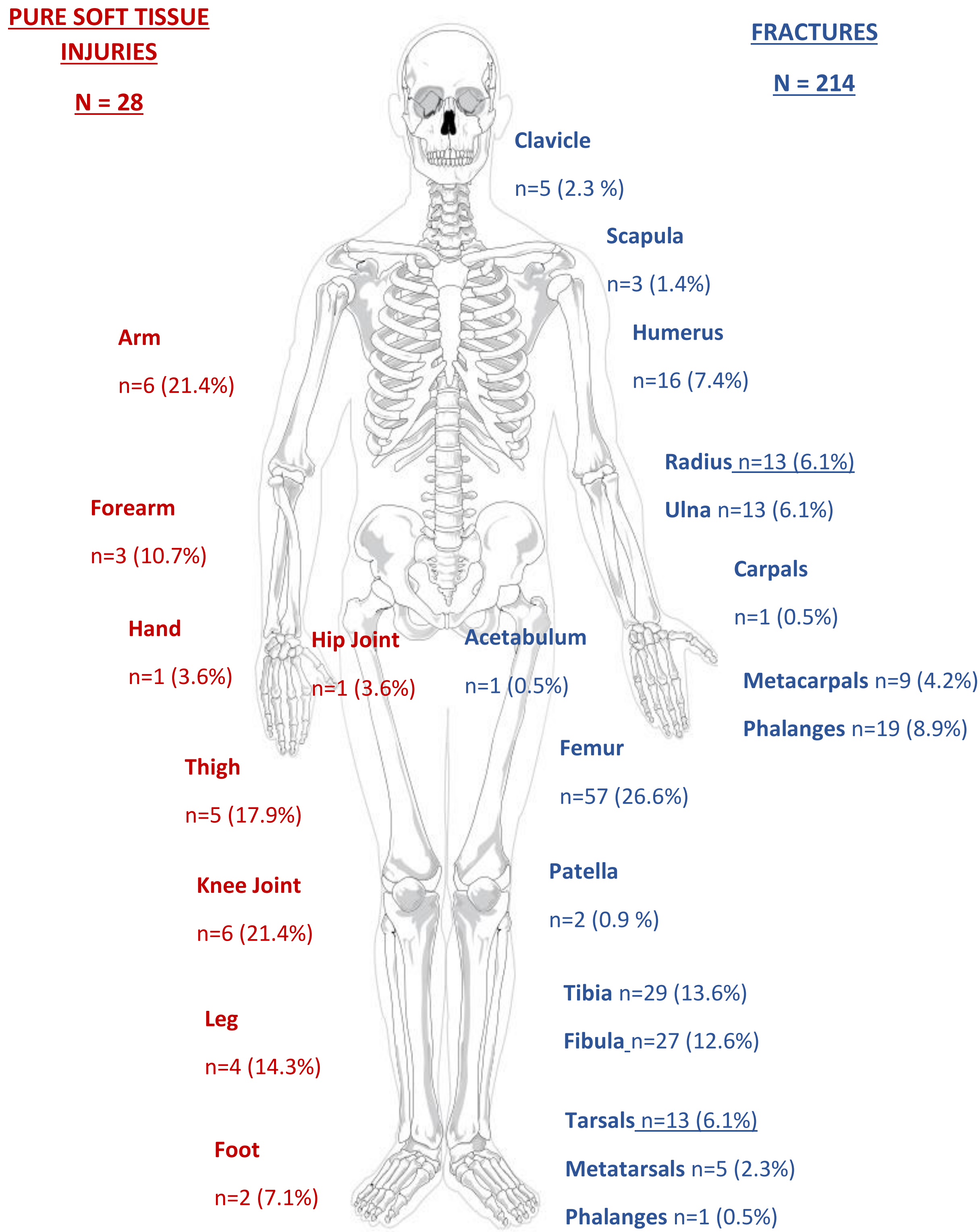

Figure 3. 3: Gunshot related injury anatomical distribution

3.3 Classification Validation

The following set of data were obtained using the Gugala classification.

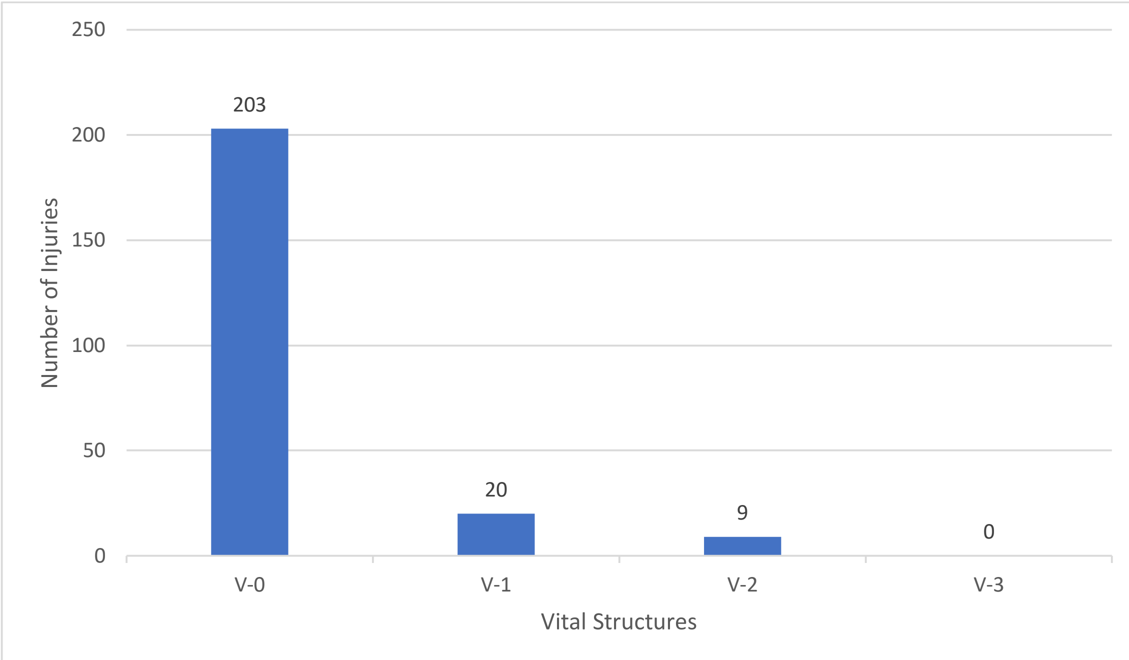

Figure 3. 4 : Gugala Classification - Vital Structure

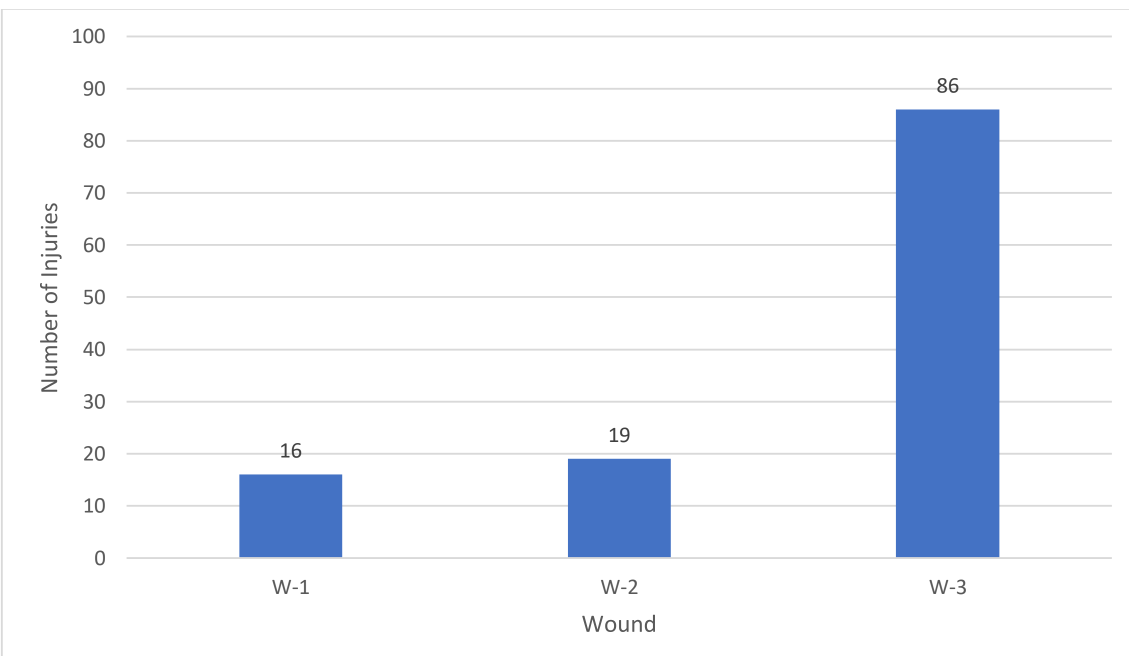

Figure 3. 5: Gugala Classification - Wound

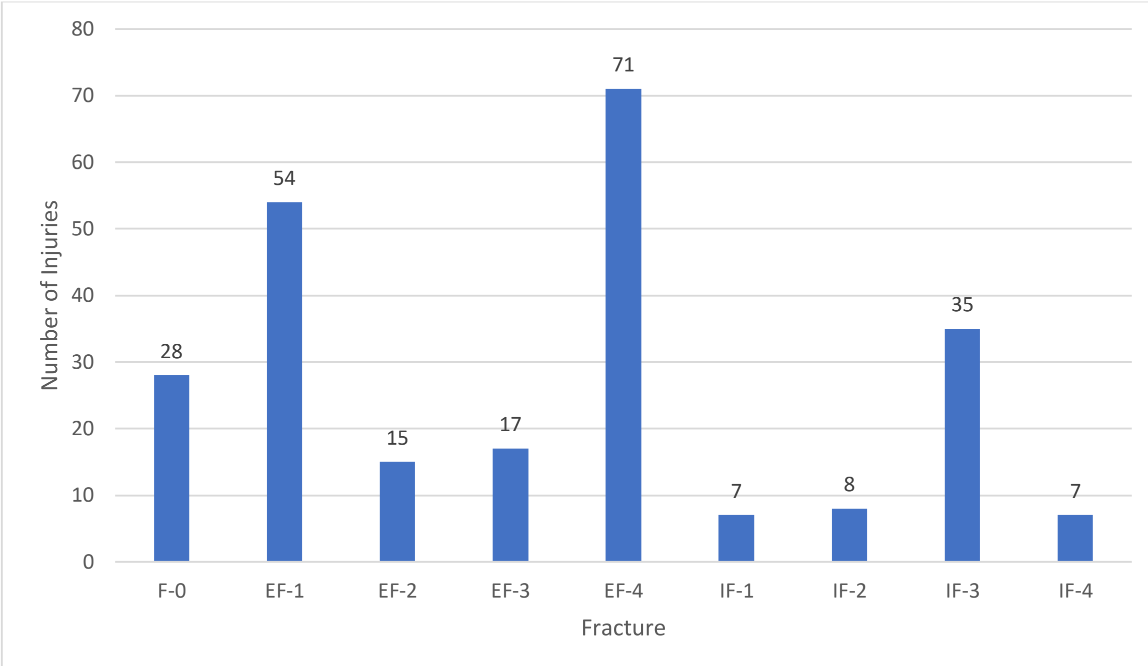

Figure 3. 6: Gugala Classification - Fracture

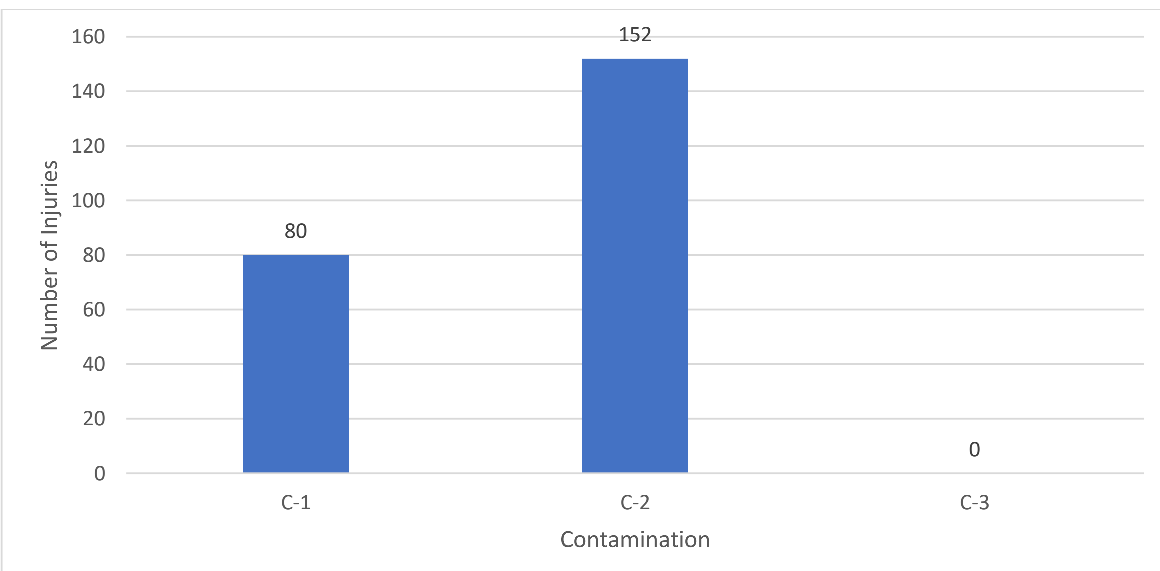

Figure 3. 7: Gugala Classification - Contamination

The internal consistency of the classification was assessed using Cronbachs coefficient alpha. We found that the classification shows poor consistency as we derived a value of 0.3869 when all classification components were included (Table 3.2). Removal of components did not yield a higher consistency co-efficient as depicted in the table below.

Table 3. 2: Cronbach Coefficient Alpha

Classification Component	***Sign***	***Item-test Correlation***	***Item-rest Correlation***	***Average Inter-item Correlation***	***Alpha after deleting the row component***
Energy (1 = low; 2 = high)	+	0.5327	0.1477	0.0985	0.3533
Vital Structures (0 –3)	+	0.5271	0.2002	0.0751	0.2888
Wound (1– 3)	+	0.5110	0.1896	0.0945	0.3429
Fracture a (0 = no fracture; 1= EF; 2 = IF)	+	0.4800	0.1337	0.1075	0.3759
Fracture b (1 – 4)	+	0.5355	0.2100	0.0902	0.3314
Contamination (1 – 3)	-	0.4706	0.1461	0.1055	0.3709
Overall Test Scale				0.0952	0.3869

Intercomponent correlation was derived using the Pearson's correlation coefficient which revealed a significant association between: Energy with Vital Structures as well as Intra-articular Fractures; Wound with Vital Structures. The only association that was significant for Extra-articular fractures was that of Intra-articular fractures. Wound had a negative association with contamination as did Extra-articular fracture with Intra-articular fracture, the latter for more obvious reasons. The associations are marked in bold in Table 3.3 below.

Table 3. 3: Pearson's Correlation Coefficient

Component — ***Pearson's correlation coefficient (p-value)*** ****p-value <0.05***

	Energy	*Vital Structures*	*Wound*	*Extra articular fracture*	*Intra articular fracture*	*Contamination*
Energy	1.0000					
Vital Structures	**0.2229 (0.0007)**	1.0000				
Wound	0.0010 (0.9884)	**0.1480 (0.0261)**	1.0000			
Extra-articular fracture	-0.0709 (0.2909)	-0.0296 (0.6594)	0.0335 (0.6189)	1.0000		
Intra-articular fracture	**0.1360 (0.0420)**	0.0408 (0.5434)	0.0554 (0.4104)	**-0.7173 (<0.0001)**	1.0000	
Contamination	0.0000 (1.0000)	-0.0927 (0.1640)	**-0.1428 (0.0323)**	-0.0179 (0.7900)	-0.0052 (0.9389)	1.0000

We also used the Fisher's exact test for small sample groups, the two sample Wilcoxon rank-sum (Mann-Whitney) test and the Kruskal-Wallis equality-of-populations rank test to compare medians. We found, as expected, that shotgun/"big" gun injuries were associated with high energy injuries (p<0.001). What is of interest to note is that handgun/"small" guns presented with both high and low energy injuries irrespective of the patient's distance from the gun at the time of the shooting.

4. Discussion

The objectives of the study were to assess the patients presenting to our level one public trauma hospitals with gunshot injuries to the extremities, to understand the social backdrop and weaponry used surrounding these events in the hope of possibly identifying areas where preventative measures can be enforced and better qualify the injury potential of these weapons. Furthermore, we looked to assess validity of a comprehensive classification system for civilian gunshots as proposed by Gugala *et* *al.* and previously validated by Brito *et al*. This is one of the largest studies on civilian gunshots focused only on extremities to date, many other studies were either performed in war zones or included gunshots to the torso. [13, 78-81] Lichte *et al*. found greater mortality in patients with injuries to the torso and head [82] however, more recently our compatriots found significant morbidity from extremity gunshots, more specifically red flagged upper limb injuries[83] which further emphasises the need to better understand these injuries. As found in our study, many of the employed patients are manual labourers, therefore the burden to his/her livelihood can be quite debilitating and is perhaps something of interest to study in the future. Our demographic profile with regards to gender and age was similar to those found by other epidemiological studies including the comparative classification validation study by Brito *et al*. [11, 75, 81, 83] The morbidity to the "young healthy patient" caused by injury not only places a burden on the patient and healthcare system, but also a significant financial burden as proved by Jakoet *et al.* where the average cost per patient was found to be ZAR 37 031 (USD 2 986) with care exceeding ZAR 280 124 (USD 22 591) in one case[81], this does not take into consideration the loss to the economy by removing that patient from the workforce in order to allow for recovery from the injury. With most of the patients in this cohort being free of co-morbidities and now found to be afflicted by GSI's, and subsequently requiring healthcare – a crude postulate would argue that perhaps the majority of this cohort wouldn't otherwise require medical services and the better prevention of such injuries would significantly decrease the burden. This point would, however, need to be proven in a scientific manner.

There is a significant correlation with alcohol use and these injuries, stricter control of which is perhaps one area to target. The identification of the time of injury is quite alarming as there is a significant peak of these injuries around the 20h00 mark, perhaps also an area where security should be enforced to a greater degree. The social backdrop regarding occupation is also interesting as there is a significant amount of injury in the public taxi industry and amongst those working in small community shops, possibly suggesting that security in these industries should be improved. We can postulate the reasons for a significant delay to orthopaedic presentation which is likely due to our local system of referral which could also explain the dual peaks. Unstable or more severely injured patients are often brought straight to casualty via ambulance however, patients that are more stable are often taken to the local clinics/regional hospitals for initial assessments and thereafter are they only referred to our level one centres should specialist care be required. Many clinics only operate during normal working hours so those with less severe injury profiles would only be referred during the day. There are also challenges of transport for these patients due to wide referral drainage areas, the evaluation of both of these confounding variables is not within the scope of this study but could be something to investigate. Nevertheless, this time to presentation must be improved, as highlighted by Engelmann *et al.*, specifically the cohort of "red flagged" upper limb injuries should be seen and treated expeditiously.(83)

The distribution of injury is similar to other epidemiological studies with lower limb gunshots being more prevalent than upper limb injuries, however upper limb gunshots result in a greater proportion of fractures as opposed to isolated joint or soft tissue injuries thus emphasising the need for expedited specialist review in these patients.(13, 18, 81, 83) GSI's to hands and feet resulted in multiple fractures from a single GSI owing to the relatively small space containing multiple bones, each classified as individual fractures according to its merit, thus possibly confounding the overall numbers classified under "Extraarticular Fracture" or "Intraarticular Fracture" groups relatively. Our rate of nerve injury at 8.6% was much on par with a similar epidemiological study in South Africa (81), however we had almost a 60:40 split between upper limb and lower limb which represents a greater lower limb prevalence than that reported in the study by Engelmann *et al.* [83] This finding, coupled with the greater potential for blood loss in these lower limb long bone fractures (52% of our cohort)[84], further emphasises the need for expeditious care for these extremity injuries. The upper limb gunshot injuries are not traditionally explored in our centre as they are mostly ascribed to neuropraxia, however based on the findings reported by Pannell *et al.*, it was discovered that those patients presenting with clinical palsies in the upper limb, often have lacerations intraoperatively, so may warrant surgical repair.[85] Furthermore, we found the blood gas parameters to be in keeping with acceptable parameters for early appropriate care.[86] The majority of our long bone fractures involving the diaphysis are biomechanically favourable for external fixation or intramedullary nailing [9, 19, 44, 87], and with the right clinical judgment one may even consider non-operative management [88, 89] – the latter may be beneficial in resource constrained environments.

Much akin to the validation study by Brito *et al.*, [75] the feasibility of the classification was determined by the investigators' ability to complete the classification system retrospectively using patient's information documented in the medical records. A single investigator (Dr T. Pillay) collected and reviewed the data. Much of the ballistics data were missing and had to be derived circumstantially based on the documented patient report from the time of the injury, specifically the size of the gun and distance from which the patient recalls being shot. In contrast to the aforementioned validation study, we excluded any gunshots to the torso, and therefore also found no visceral content contamination. Also, and in contrast, we found a significantly greater number of fractures in our cohort i.e. approximately 170 injuries *without* fracture in their cohort [75] compared to only 27 in ours. Although Brito *et al.* [75] managed to obtain good internal consistency with a Cronbach Alpha coefficient of 0.69, we had poor internal consistency, achieving a Cronbach Alpha coefficient of 0.39. The objective is to achieve at least 0.50, with a value closer to 1.00 being optimal, and above 0.70 being good. [90-92] Interestingly, when the contamination was eliminated, the Cronbach Alpha improved in their study, whilst we found the converse. Our intercomponent correlation was also poor comparatively, with only a few components showing a positive correlation. Whilst Brito *et al.* [75] derived a positive correlation between intra- and extra-articular fractures we derived a negative correlation likely ascribed to our understanding of the classification that a fracture cannot be classified as both intra- and extra-articular, whilst it seems Gugala *et al.* suggests that both may be selected in a single fracture. [35]

As expected, the ballistics from the weaponry used seems to be fairly unpredictable as evidenced by the lack of consistency when applying the aforementioned principles of impact energy to wounding potential and fractures i.e. high energy events produced low comminution and high comminution, similarly no correlation with wounding potential was established. [24, 40, 41]. Despite confirmation of smaller weapons such as hand guns – the injury potential to both bone and soft tissues was variable irrespective of the range at which the patient was shot although there are multiple variables that may alter the ballistics. [9, 45] The fracture potential is also challenging to attribute solely to the weapon used as found in our cohort where we had the greatest number of extra-articular fractures fall into the greater than 75% comminution group, followed by the less than 25% comminution group which often were simple fracture patterns, these patterns may be confounded or even solely due to a fall following the gunshot or perhaps some other blunt trauma during the time of injury. [12, 53, 55-58]

4.1 Problems and Limitations

There are several limitations of this study. Firstly, as anticipated, the study design being a retrospective review has inherent flaws, one of which was not being able to guide the data being collected, instead medical records were relied upon to gather specific data, which in a majority of cases was incomplete specifically appropriate description of the wounds i.e. only 121 of the 232 gunshot injuries had sufficient information to classify according to Gugala. There were well over 400 gunshot injuries collected however, only the 232 included in this study had sufficient data to be included in this study which limited the number of patients to be studied for bolstered statistical significance. Furthermore, some patients had to be excluded as the radiographs were not uploaded onto the PACS, and we were unable to find any other record of such, which reduced patient numbers further. As the primary investigator was not accustomed to regular use of the novel classification, there may have been intra-observer error which was not measured. Similarly, no inter-observer reliability was established.

5. Conclusion

There was an in-depth analysis of the social backdrop from which our patients present, which provided insight into guided social investigations going forward to better prevent gunshots specifically the times of injury, use of alcohol and association with the taxi industry. The unpredictability found in the retrospective analysis of the ballistics effects in civilian weapons may also pave the way for a better prospective focused ballistics assessment, with measures put into place by the authorities to enforce regulation of such weaponry. Whilst the classification system encapsulates a holistic approach to civilian gunshots, we found it to be deficient when assessing isolated gunshot injuries to the extremities. Further evaluation in a prospective review with inter-observer and intra-observer assessment is required to effectively assess the utility of this classification system.

References

1. Hennessy MJ, Banks HH, Leach RB, Quigley TB. Extremity gunshot wound and gunshot fracture in civilian practice. Clinical orthopaedics and related research. 1976(114):296-303.

2. Howland WS, Jr., Ritchey SJ. Gunshot fractures in civilian practice. An evaluation of the results of limited surgical treatment. The Journal of bone and joint surgery American volume. 1971;53(1):47-55.

3. Cuiker W SV. The Global Gun Epidemic: from Saturday Night Specials to AK47s. Santa Barbara, USA: Greenwood Publishing; 2006.

4. Chetty R. Firearm use and distribution in South Africa. In: Centre NCP, editor. Pretoria2002.

5. Mauffrey C. Management Of Gunshot Wounds To The Limbs: A Review The Internet Journal of Orthopedic Surgery. 2005;3(1).

6. Abrahams N, Jewkes R, Mathews S. Guns and gender-based violence in South Africa. SAMJ: South African Medical Journal. 2010;100:586-8.

7. Allard D, Burch VC. The cost of treating serious abdominal firearm-related injuries in South Africa. South African medical journal = Suid-Afrikaanse tydskrif vir geneeskunde. 2005;95(8):591-4.

8. Centers for Disease Control NCfIPaC. WISQUARS (Web-based Injury Statistics Query and Reporting System)|Injury Center|CDC Accessed 28 August 2018 [Available from: https://www.cdc.gov/injury/wisqars/.

9. Hilton TL, Kruger N, Wiese KR, Martin CW, Maqungo S. Gunshot tibia fractures treated with intramedullary nailing: A single centre retrospective review. SA Orthopaedic Journal. 2017;17(1).

10. Weaver LD, Hansraj KK, Idusuyi OB, Akiyama C, Ribeiro JA, Fenison AT, et al. Gunshot wound injuries. Frequency and cost analyses in south central Los Angeles. The Orthopedic clinics of North America. 1995;26(1):1-7.

11. E. Gotsch K, L. Annest J, A. Mercy J, W. Ryan G. Surveillance for fatal and nonfatal firearm-related injuries-United States2001.

12. Bartlett CS. Clinical update: gunshot wound ballistics. Clinical orthopaedics and related research. 2003(408):28-57.

13. Brown TD, Michas P, Williams RE, Dawson G, Whitecloud TS, Barrack RL. The impact of gunshot wounds on an orthopaedic surgical service in an urban trauma center. Journal of orthopaedic trauma. 1997;11(3):149-53.

14. Molinari RW, Yang EC, Strauss E, Einhorn TA. Timing of internal fixation in low-velocity extremity gunshot fractures. Contemporary orthopaedics. 1994;29(5):335-9.
15. Organisation WH. WHO Contribution to the UN Conference on Illicit Trade in Small Arms and Light Weapons. New York2001.
16. Ordog GJ, Balasubramanium S, Wasserberger J, Kram H, Bishop M, Shoemaker W. Extremity gunshot wounds: Part one--Identification and treatment of patients at high risk of vascular injury. The Journal of trauma. 1994;36(3):358-68.
17. Bartlett CS, Helfet DL, Hausman MR, Strauss E. Ballistics and gunshot wounds: effects on musculoskeletal tissues. The Journal of the American Academy of Orthopaedic Surgeons. 2000;8(1):21-36.
18. Dicpinigaitis PA, Koval KJ, Tejwani NC, Egol KA. Gunshot wounds to the extremities. Bulletin of the NYU hospital for joint diseases. 2006;64(3-4):139-55.
19. Nowotarski P, Brumback RJ. Immediate interlocking nailing of fractures of the femur caused by low- to mid-velocity gunshots. Journal of orthopaedic trauma. 1994;8(2):134-41.
20. Peden M, Van der Spuy, J. The cost of treating firearm victims. Trauma Review. 1998;6:4-5.
21. Martin C, Thiart G, McCollum G, Roche S, Maqungo S. The burden of gunshot injuries on orthopaedic healthcare resources in South Africa. SAMJ: South African Medical Journal. 2017;107:626-30.
22. Kruger J, Butchart, A., Seedat, M., Gilchrist, A. . A public health approach to violence prevention in South Africa. In: van Eeden R, Wentzel M, eds The dynamics of aggression and violence in South Africa. 1998:399-424.
23. Hollerman JJ, Fackler ML, Coldwell DM, Ben-Menachem Y. Gunshot wounds: 2. Radiology. AJR American journal of roentgenology. 1990;155(4):691-702.
24. Johnson EC, Strauss E. Recent advances in the treatment of gunshot fractures of the humeral shaft. Clinical orthopaedics and related research. 2003(408):126-32.
25. Cooper GJ, Ryan JM. Interaction of penetrating missiles with tissues: some common misapprehensions and implications for wound management. The British journal of surgery. 1990;77(6):606-10.
26. DeMuth WE, Jr., Smith JM. High-velocity bullet wounds of muscle and bone: the basis of rational early treatment. The Journal of trauma. 1966;6(6):744-55.

27. Sykes LN, Jr., Champion HR, Fouty WJ. Dum-dums, hollow-points, and devastators: techniques designed to increase wounding potential of bullets. The Journal of trauma. 1988;28(5):618-23.

28. Brien WW, Kuschner SH, Brien EW, Wiss DA. The management of gunshot wounds to the femur. The Orthopedic clinics of North America. 1995;26(1):133-8.

29. Rozen N, Dudkiewicz I. Wound Ballistics and Tissue Damage. 2011:21-33.

30. Phillips P, 3rd, Hansraj KK, Cox EE, 2nd, Ashley EM. Gunshot wounds to the hand. The Martin Luther King, Jr, General Hospital experience. The Orthopedic clinics of North America. 1995;26(1):95-108.

31. Bartlett CS, 3rd, Hausman MR, Witschi TH. Gunshot wounds to the shoulder. The Orthopedic clinics of North America. 1995;26(1):37-53.

32. Ordog GJ, Wasserberger J, Balasubramanium S. Wound ballistics: theory and practice. Annals of emergency medicine. 1984;13(12):1113-22.

33. Amato JL, Billy LJ, Lawson NS, Rich NM. High velocity missile injury. An experimental study of the retentive forces of tissue. American journal of surgery. 1974;127(4):454-9.

34. Di Maio VJM. Gunshot Wounds: Practical Aspects of Firearms, Ballistics and Forensic Techniques. Boca Raton, FL: CRC Press; 1993.

35. Gugala Z, Lindsey RW. Classification of gunshot injuries in civilians. Clinical orthopaedics and related research. 2003(408):65-81.

36. Maqungo S. Early clinical outcomes of isolated low velocity gunshot radius fractures treated with closed reduction and locked intramedullary nailing. SA Orthopaedic Journal. 2016;15(2).

37. Dickey RL, Barnes BC, Kearns RJ, Tullos HS. Efficacy of antibiotics in low-velocity gunshot fractures. Journal of orthopaedic trauma. 1989;3(1):6-10.

38. Hampton OP, Jr. The indications for debridement of gun shot (bullet) wounds of the extremities in civilian practice. The Journal of trauma. 1961;1:368-72.

39. Russotti GM, Sim FH. Missile wounds of the extremities: a current concepts review. Orthopedics. 1985;8(9):1106-16.

40. Stefanopoulos PK, Hadjigeorgiou GF, Filippakis K, Gyftokostas D. Gunshot wounds: A review of ballistics related to penetrating trauma. Journal of Acute Disease. 2014;3(3):178-85.

41. Bowyer GW, Rossiter ND. Management of gunshot wounds of the limbs. The Journal of bone and joint surgery British volume. 1997;79(6):1031-6.

42. Brien EW, Long WT, Serocki JH. Management of gunshot wounds to the tibia. The Orthopedic clinics of North America. 1995;26(1):165-80.
43. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. The Journal of bone and joint surgery American volume. 1976;58(4):453-8.
44. Gelbart B, Aden A. Evaluation of intramedullary nailing in low-velocity gunshot wounds of the radius and ulna. SA Orthopaedic Journal. 2013;12:35-41.
45. Hollmann MW, Horowitz M. Femoral fractures secondary to low velocity missiles: treatment with delayed intramedullary fixation. Journal of orthopaedic trauma. 1990;4(1):64-9.
46. Fackler ML. Wound ballistics. A review of common misconceptions. Jama. 1988;259(18):2730-6.
47. Mendelson JA. The relationship between mechanisms of wounding and principles of treatment of missile wounds. The Journal of trauma. 1991;31(9):1181-202.
48. Fackler ML. Wound Ballistics and Soft-Tissue Wound Treatment. Techniques in Orthopaedics. 1995;10(3):163-70.
49. Seng VS, Masquelet AC. Management of civilian ballistic fractures. Orthopaedics & traumatology, surgery & research : OTSR. 2013;99(8):953-8.
50. Shepard GH. High-energy, low-velocity close-range shotgun wounds. The Journal of trauma. 1980;20(12):1065-7.
51. Fackler ML, Surinchak JS, Malinowski JA, Bowen RE. Bullet fragmentation: a major cause of tissue disruption. The Journal of trauma. 1984;24(1):35-9.
52. Huelke DF, Darling JH. BONE FRACTURES PRODUCED BY BULLETS. Journal of forensic sciences. 1964;9(4):461-9.
53. Leffers D, Chandler RW. Tibial fractures associated with civilian gunshot injuries. The Journal of trauma. 1985;25(11):1059-64.
54. Robens W, Kusswetter W. Fracture typing to human bone by assault missile trauma. Acta chirurgica Scandinavica Supplementum. 1982;508:223-7.
55. Rose SC, Fujisaki CK, Moore EE. Incomplete fractures associated with penetrating trauma: etiology, appearance, and natural history. The Journal of trauma. 1988;28(1):106-9.
56. Smith HW, Wheatley KK, Jr. Biomechanics of femur fractures secondary to gunshot wounds. The Journal of trauma. 1984;24(11):970-7.

57. Ryan JR, Hensel RT, Salciccioli GG, Pedersen HE. Fractures of the femur secondary to low-velocity gunshot wounds. The Journal of trauma. 1981;21(2):160-2.
58. Brettler D, Sedlin ED, Mendes DG. Conservative treatment of low velocity gunshot wounds. Clinical orthopaedics and related research. 1979(140):26-31.
59. Hughes JL, Vander Griend R, Bennett TL. Gunshot fractures. Unfallchirurg. 1986;89(11):515-20.
60. Sclafani SJ, Vuletin JC, Twersky J. Lead arthropathy: arthritis caused by retained intra-articular bullets. Radiology. 1985;156(2):299-302.
61. Araújo GCSd, Mourão NT, Pinheiro IN, Xavier AR, Gameiro VS. Lead Toxicity Risks in Gunshot Victims. PLOS ONE. 2015;10(10):e0140220.
62. Hahn M, Strauss E, Yang EC. Gunshot wounds to the forearm. The Orthopedic clinics of North America. 1995;26(1):85-93.
63. Borman KR, Snyder WH, 3rd, Weigelt JA. Civilian arterial trauma of the upper extremity. An 11 year experience in 267 patients. American journal of surgery. 1984;148(6):796-9.
64. Hammond DC, Gould JS, Hanel DP. Management of acute and chronic vascular injuries to the arm and forearm. Indications and technique. Hand clinics. 1992;8(3):453-63.
65. Mufti MA, LaGuerre JN, Pochaczevsky R, Kassner EG, Richter RM, Levowitz BS. Diagnostic value of hematoma in penetrating arterial wounds of the extremities. Archives of surgery (Chicago, Ill : 1960). 1970;101(5):562-9.
66. Spencer AD. The reliability of signs of peripheral vascular injury. Surgery, gynecology & obstetrics. 1962;114:490-4.
67. Brannon JK, Woods C, Chandran RE, Hansraj KK, Reyes CS. Gunshot wounds to the elbow. The Orthopedic clinics of North America. 1995;26(1):75-84.
68. Payne WK, 3rd, Gabriel RA, Massoud RP. Gunshot wounds to the thigh. Evaluation of vascular and subclinical vascular injuries. The Orthopedic clinics of North America. 1995;26(1):147-54.
69. Sitzmann JV, Ernst CB. Management of arm arterial injuries. Surgery. 1984;96(5):895-901.
70. Brien EW, Brien WW, Long WT, Kuschner SH. Concomitant injuries of the hip joint and abdomen resulting from gunshot wounds. Orthopedics. 1992;15(11):1317-9; discussion 9-20.
71. Omer GE, Jr. Injuries to nerves of the upper extremity. The Journal of bone and joint surgery American volume. 1974;56(8):1615-24.

72. Winquist RA, Hansen ST, Jr. Comminuted fractures of the femoral shaft treated by intramedullary nailing. The Orthopedic clinics of North America. 1980;11(3):633-48.
73. Wiss DA, Brien WW, Becker V, Jr. Interlocking nailing for the treatment of femoral fractures due to gunshot wounds. The Journal of bone and joint surgery American volume. 1991;73(4):598-606.
74. Long WT, Chang W, Brien EW. Grading system for gunshot injuries to the femoral diaphysis in civilians. Clinical orthopaedics and related research. 2003(408):92-100.
75. Brito SA, Gugala Z, Tan A, Lindsey RW. Statistical validity and clinical merits of a new civilian gunshot injury classification. Clinical orthopaedics and related research. 2013;471(12):3981-7.
76. Moye-Elizalde GA, Ruiz-Martinez F, Suarez-Santamaria JJ, Ruiz-Ramirez M, Reyes-Gallardo A, Diaz-Apodaca BA. [Epidemiology of gunshot wounds at Ciudad Juarez, Chihuahua General Hospital]. Acta ortopedica mexicana. 2013;27(4):221-35.
77. Coupland RM. The Red Cross classification of war wounds: the E.X.C.F.V.M. scoring system. World journal of surgery. 1992;16(5):910-7.
78. Held M, Engelmann E, Dunn R, Ahmad SS, Laubscher M, Keel MJB, et al. Gunshot induced injuries in orthopaedic trauma research. A bibliometric analysis of the most influential literature. Orthopaedics & traumatology, surgery & research : OTSR. 2017;103(5):801-7.
79. Persad IJ, Reddy RS, Saunders MA, Patel J. Gunshot injuries to the extremities: experience of a U.K. trauma centre. Injury. 2005;36(3):407-11.
80. Elachi I, Yongu W, Nahachi C, Onyemaechi N, Odatuwa-Omagbemi D, Mue D. The Pattern of Civilian Gunshot Injuries at a University Hospital in North Central Nigeria. 2015;14:87-90.
81. Jakoet MS, Burger M, Van Heukelum M, le Roux N, Gerafa M, van der Merwe S, et al. The epidemiology and orthopaedic burden of civilian gunshot injuries over a four-year period at a level one trauma unit in Cape Town, South Africa. Int Orthop. 2020.
82. Lichte P, Oberbeck R, Binnebösel M, Wildenauer R, Pape HC, Kobbe P. A civilian perspective on ballistic trauma and gunshot injuries. Scandinavian journal of trauma, resuscitation and emergency medicine. 2010;18:35.

83. Engelmann E, Maqungo S, Laubscher œ, Hoppe S, Roche S, Nicol A, et al. Epidemiology and injury severity of 294 extremity gunshot wounds in ten months: a report from the Cape Town trauma registry. SA Orthopaedic Journal. 2019;18:31-6.

84. Lee C, Porter KM. Prehospital management of lower limb fractures. Emergency Medicine Journal. 2005;22(9):660-3.

85. Pannell WC, Heckmann N, Alluri RK, Sivasundaram L, Stevanovic M, Ghiassi A. Predictors of Nerve Injury After Gunshot Wounds to the Upper Extremity. Hand (N Y). 2017;12(5):501-6.

86. Weinberg DS, Narayanan AS, Moore TA, Vallier HA. Prolonged resuscitation of metabolic acidosis after trauma is associated with more complications. J Orthop Surg Res. 2015;10:153-.

87. Tejan J, Lindsey RW. Management of civilian gunshot injuries of the femur. A review of the literature. Injury. 1998;29 Suppl 1:Sa18-22.

88. Engelmann EWM, Roche S, Maqungo S, Naude D, Held M. Treating fractures in upper limb gunshot injuries: The Cape Town experience. Orthopaedics & traumatology, surgery & research : OTSR. 2019;105(3):517-22.

89. Nguyen MP, Prayson N, Vallier HA. Low-velocity Gunshot Injuries to the Femur: What Is the Utility of Stabilizing Incomplete Fractures? The Journal of the American Academy of Orthopaedic Surgeons. 2019;27(18):685-9.

90. Cronbach LJ. Coefficient alpha and the internal structure of tests. Psychometrika. 1951;16(3):297-334.

91. Cronbach LJ, Gleser GC, Nanda H, Rajaratman N. The dependability of behavioral measurements : Theoryofgeneralizability for scores and profiles. New York: Wiley; 1972.

92. Nunnally JC. Psychometric theory. New York: McGraw-Hill; 1978.

Appendices

Appendix A: Permission letter – use of the Gugala Classification System

utmb Health
Orthopaedic Surgery
& Rehabilitation

School of Medicine
ORTHOPAEDIC SURGERY & REHABILITATION
301 University Blvd.
Galveston, Texas 77555-0165
O 409.747.5700 F 409.747.5715
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Nov 27, 2018

To Whom It May Concern:

As per email request from Dr. Tristan Pillay, we, Ronald W. Lindsey, MD and I, as authors of the New Civilian Gunshot Classification initially published in Clinical Orthopaedic & Related Research in 2003, and subsequently in 2013, formally grant permission for Dr. Tristan Pillay to use the classification for his research, providing routine referencing the published papers on the subject.

Sincerely yours,

Ronald W. Lindsey, MD,
Professor and Chair

Zbigniew Gugala, MD, PhD
Associate Professor
Distinguished Teaching Professor

Appendix B: Human Research Ethics Committee (Medical) Clearance Certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Dr T Pillay

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M181022

NAME: (Principal Investigator)	Dr T Pillay
DEPARTMENT:	School of Clinical Medicine Department of Orthopaedic Surgery Medical School University
PROJECT TITLE:	A review of civilian gunshot injuries of the extremities
DATE CONSIDERED:	26/10/2018
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr S van Deventer & B Milner; Prof MT Ramokgopa
APPROVED BY:	Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	26/11/2018

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on 3rd floor, Phillip V Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.
I/We fully understand the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date of the meeting when the study was initially reviewed. In this case, the study was initially reviewed in **October** and will therefore reports and re-certification will be due early in the month of **October** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

28 November 2018
Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix C: CMJAH Clearance

GAUTENG PROVINCE

HEALTH

REPUBLIC OF SOUTH AFRICA

CHARLOTTE MAXEKE JOHANNESBURG ACADEMIC HOSPITAL

Enquiries:
Ms. N. Mzila
Office of the Clinical Director
Email:Nolwazi.Mzila@gauteng.gov.za
Tell: (011): 488-4812
02 October 2018

Dear Dr. T. Pillay

STUDY TITTLE: A Review of Civilian Gunshot Injuries of the Extremities.

Permission to conduct the above mentioned study is provisional approved. Your study can only commence once Ethics approval is obtained. Please forward a copy of your Ethics Clearance Certificate as soon as the study is approved by the Ethics Committee for the CEO's office to give you the final approval to conduct the study.

Supported / ~~not supported~~

Dr. M.I. Mofokeng
Clinical Director
DATE: 2/10/2018

Approved / not approved

Bogoshi

Ms. G. Bogoshi
Chief Executive Officer
DATE: 02.10.2018

Appendix D: CHBAH Clearance

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

MEDICAL ADVISORY COMMITTEE

CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

PERMISSION TO CONDUCT RESEARCH

Date: 18th September 2018

TITLE OF PROJECT:

A Review of Civilian Gunshot Injuries of the Extremities.

UNIVERSITY: Witwatersrand

Principal Investigator: Dr T Pillay

Department: Orthopaedics

Supervisor : Prof Ramokgopa / Dr S Van Deventer

Permission Head Department (where research conducted): Yes

The Medical Advisory Committee recommends that the said research be conducted at Chris Hani Baragwanath Academic Hospital. The CEO / management of Chris Hani Baragwanath Academic Hospital is accordingly informed and the study is subject to:-

- Permission having been granted by the Committee for Research on Human Subjects of the University of the Witwatersrand.
- The Hospital will not incur extra costs as a result of the research being conducted on its patients within the hospital
- The MAC will be informed of any serious adverse events as soon as they occur
- Permission is granted for the duration of the Ethics Committee Approval.

....
Recommended
(On behalf of the MAC)
Date: 20/09/2018

....
Approved/Not Approved
Hospital Management
Date: 05 10 2018

Appendix E: Data Collection Tool

University of Witwatersrand
Orthopaedics Department

Study Number:

Patient Sticker

Date:

Time:

Registrar:

MO/Intern:

Patient Name:

Hospital Number:

Age:

Patient Phone Numbers:

1)
2)
3)

Main Complaint :

Time of Injury :

Size of Gun:

- ☐ Handgun/ "small"
- ☐ Shotgun/Rifle/"big"
- ☐ Unknown

- ☐ Confirmed
- ☐ Suspected

Distance from Gun:

- ☐ <2m
- ☐ 2-6m
- ☐ > 6m

Past Medical History:

- ☐ Diabetes
- ☐ Epilepsy
- ☐ Asthma
- ☐ Rheumatic Fever/ Heart Dx
- ☐ TB
- ☐ Hypertension
- ☐ Other:

- ☐ Allergies_________________

Medication:

RVD ☐ Positive ☐Negative

☐Unknown CD4:______

☐HAART

Past Surgical History:

Social History:

Residence Location:

Handedness:

Occupation:

Alcohol:

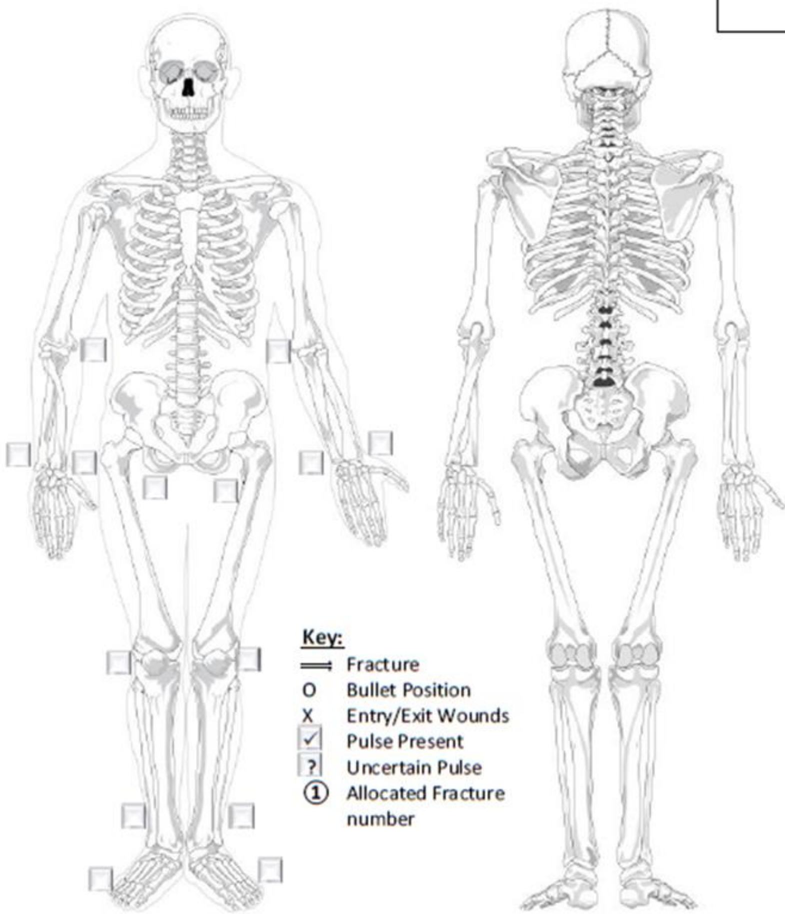
Tobacco: Pack years:

Narcotics:

University of Witwatersrand
Orthopaedics Department

Patient Sticker

Examination:



(Note: multiple fractures may have a number allocated for ease of reference)

MSK: (Including soft tissues, compartments, sensation, motor and vascular findings)

Look: Feel: Move:

Vitals

BP: / HR:

SpO_2: FiO_2: RR:

Temp: HGT:

General: ______________________

____

☐ Petechiae: ______________

Weight: _____ kg

Height: _____ m

BMI: ______ kg/m^2

CVS

JVP: Neck Veins:

S_1 S_2 Murmur:

Gallop:

Respiratory:

Signs of Respiratory Distress:

- ☐ Accessory Muscle Use
- ☐ Paradoxical Breathing
- ☐ Chest Wall Recessions
- ☐ Other: ______________

Chest Rise:

Air Entry:

Added Sounds:

Percussion:

Abdominal:

- ☐ Ecchymosis
- ☐ Scars: ________

Palpation:

☐ Bowel Sounds

CNS:

GCS: __/15 Motor: __/6

Verbal: __/5 Eye: __/4

Pupils:

☐ Moving All Limbs Equally:

If not, describe:

Investigations:

Initial ABG:

Time:

pH:

PaO_2:

$PaCO_2$:

Hb:

Hct:

Lactate:

Bicarb:

BE:

Urine Dipstix:

CXR:

Blood Reference:

Fracture/s No.: ①

Pattern (*):

Length(mm):

Angulation (°):

Rotation (°):

Apposition (%):

Classification:

Comminution (if applicable) and No.

eg ① next to appropriate option:

- ☐ <25 % Circumference
- ☐ 25 – 50 % Circumference
- ☐ 50 – 75% Circumference
- ☐ 75 – 100% Circumference or segmental bone loss

*Examples of Fracture Patterns:

Simple: Transverse, Spiral or Oblique

Wedge: Spiral, Bending or Multifragmentary

Comminuted: use adjacent

Signature:

HPCSA Number: