A review of the epidemiology and average cost for the treatment of gunshot wounds of extremities at a single Academic Hospital in Johannesburg, South Africa

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Medicine

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Declaration

I, Reinhard Dembskey declare that this research 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.

Signature:……  ……..

Date: 06 December 2024

Abstract

Background: Prevalence of gunshot injuries in South Africa are comparable to countries at war. This places a large burden on the health care system and incurs a huge cost to the state. The aim of this study was to look at the epidemiological variables as well as the cost of gunshot wounds to extremities. The objectives were: (i) To determine the demographics and epidemiological variables of extremity gunshot injuries, (ii) to capture the type of surgery and the duration and (iii) to document the quantity and the cost of resources which were used in during the management of patients who had sustained a gunshot wound to an extremity.

Methodology: This was a cross sectional, retrospective study. Records of patients that met the inclusion criteria were reviewed from 1 July 2018 to 31 July 2022. Relevant epidemiological variables were recorded. Six cost categories were used to determine the average cost of admitted patients. The six categories were inpatient admission, anaesthetic and operative, implants, ambulatory, physio- and occupational therapy and blood bank cost. The data was statistically analysed.

Results: Seventy patients were included in the study. Descriptive statistics were used to report epidemiological variables as well as cost in the respective cost centres. As with comparable local studies, our study revealed male predominance and lower limb gunshot injuries being more common than upper limb. The average cost to treat an orthopaedic gunshot injury was R32612.32 with admission cost and implant cost being the most significant. Combined upper and lower gunshot injuries had a statistically significant higher total cost when compared to an isolated upper or lower limb gunshot injury.

Discussion: Epidemiological variables were compared to local and international studies. Surgeries done were reviewed and compared to current international standards. Costs were comparable to previous local studies on orthopaedic gunshot injuries.

Conclusion: This study re affirms the high burden of gunshot injuries on state hospitals as well as the large cost incurred to treat these injuries. The treatment at our hospital conforms to international standards and costs are comparable to other local centres. Intervention by government is still needed to attempt to reduce the prevalence of gunshot injuries.

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NOMENCLATURE

ANOVA	Analysis of Variance
ATLS	Advanced Trauma Life Support
ECG	Electrocardiogram
FBC	Full Blood Count
GSI	Gunshot injury
GSW	Gunshot wound
HJH	Helen Joseph Hospital
NHLS	National Health Laboratory Service
OT	Occupational therapy
PT	Physiotherapy
SANBS	South African National Blood Service
U and E	Urea and Electrolytes
USD	United States Dollar

CHAPTER 1
1. INTRODUCTION AND LITERATURE REVIEW

On a global perspective, gunshot wounds (GSWs) are a major cause of morbidity and mortality. In the United States, for example, more then 30 000 people are fatally wounded and over 67 000 are injured annually secondary to firearm injuries.[1] In the United Kingdom, firearm injuries increased by 30% between 1998 and 2002.[2] In Australia, another paper reports the experience of a single centre in the central Sydney business district which managed 74 patients with gunshot injuries (GSIs) over a one-year period.[3] When looking at the South African experience, the numbers are both dramatic and alarming. The United Nations and one local paper reported South Africa's firearm injury rate to be close to that of countries at war.[4,5] The United Nations rates South Africa to be the eleventh most dangerous country globally and Cape town in particular is listed as having one of the highest murder rates in the world.[4,5] A recent paper from Cape Town that utilised a single institutions trauma registry supports these earlier figures as the authors reported that 294 gunshot extremity injuries were managed at a single institution over a ten month period.[6] Despite the high prevalence of GSIs, current research in this field remains limited. Much of the research has also come from countries with a lower prevalence of GSIs compared to South Africa.

South African studies between 2017 and 2020 showed the predominance of male victims involved in shootings with 93.6%, 91.4%, 92.5% and 91.3%, respectively.[5-8] Local studies reported that the vast majority of GSWs occurred in the lower extremity with the femur being the pre-dominant bone involved and that 78.2% of victims were black.[5-8] In a 2003 study done at the GF Jooste Hospital in Cape Town, Allard and Burch[10] already demonstrated the massive burden of serious abdominal GSIs on the health sector, costing 13 times more per capita than the planned expenditure. Norberg et al.[11] looked at the cost of all gunshot related injuries that were admitted at Tygerberg Hospital in 2006 and found the average cost to be similar to Allard and Burch's findings.

Van Heukelum et al.[7] calculated an average cost of R26 292 per patient treated for orthopaedic related GSIs in 2017. Similarly, Maqungo et al.[5] showed an average cost of R24 832.43 per patient treated for orthopaedic related GSIs at Groote Schuur Hospital during 2012.

Doctors, especially orthopaedic surgeons, who work in South Africa, should be competent in the management of GSIs. Severe haemorrhage is the most common cause of death; hence, Advanced Trauma Life Support (ATLS) principles should be applied to all gunshot injured patients. More specifically, gunshots to the extremities require the early administration of antibiotics, a washout and the application of sterile dressing. The current management of specific injury areas and fractures is further discussed below.

Isolated extremity soft tissue injuries are usually managed conservatively on an outpatient basis where only a single dose of a prophylactic antibiotic/s is administered together with a wound washout and the application of a sterile dressing.[9] A recent South African study advocated the management of such injuries using this less aggressive approach.[12] Surgical intervention might be necessary in cases of severe wound contamination, large wounds, delayed treatment, multiple wounds and significant tissue devitalisation however, these cases should be assessed on a case-by-case basis.

When considering low velocity GSWs to the extremities in urban centres, from 1994 from Los Angeles reported that 9% of these gunshots involved the shoulder. In this patient group, 15% suffered a fracture requiring hospitalisation for definitive fracture management and within this subset of patients, there was a 15% incidence of a vascular injury, which commonly involved the axillary and/or subclavian arteries.[13] Low-velocity extra-articular injuries of the clavicle and scapula are usually managed conservatively. However, scapula neck fractures, where there is greater than 40 degrees of angulation or more than 1cm of displacement, are best managed by surgical stabilisation. Concerning injuries of the humeral head, these injuries commonly result in minimally displaced fracture fragments with an intact rotator cuff complex lending them amenable to conservative management. When the humeral head is comminuted, as occurs in the context of high-velocity injuries, the optimal management is delayed hemiarthroplasty when infection has been excluded.

Additional surgical indications are displaced humeral tuberosity fractures, displaced glenoid fractures, as well as intra-articular bullet fragments.[13-15]

Gunshot shaft of humerus fractures, which occur secondary to low-velocity GSWs are generally managed by wound debridement and irrigation, tetanus prophylaxis, with surgical fixation reserved for selected cases that fail a trial of conservative treatment. Selected indications for early operative management include: comminuted fractures, segmental fractures, bilateral humeral fractures, concomitant forearm fractures with a floating elbow, and fractures which extend into a joint space. Additional long bone fractures is a relative indication for early operative intervention. External fixation is necessary in the context of significant soft tissue destruction as an interim or definitive procedure. Plating or intramedullary nailing can be used as a definitive treatment once soft tissue healing has occurred.[16]

Gunshot elbow is rare. A North American study reported only 29 patients over a 10 year period. The importance of excluding a vascular injury in GSWs to the anterior elbow cannot be overemphasised and vascular imaging is regarded as mandatory even in the presence of a distal pulse.[17] External fixation is necessary in the context of significant soft tissue destruction as an interim or definitive procedure. Plating, radial head excision, olecranon excision and tricep repair as well as prosthetic replacement are additional procedures that may be needed.[18]

Gunshot forearm comprise up to 39% of upper extremity injuries.[6] Isolated ulnar fractures are managed conservatively with debridement and irrigation unless there is more than ten degrees of angulation or more than 50% of displacement. In patients where these values are exceeded, initial external fixation followed by plating with or without a bone graft is the preferred choice of treatment.

The management of isolated undisplaced radial fractures are similarly managed according to the wound characteristics however; cast immobilisation without fixation is commonly employed. Radius and ulna fractures are managed with external fixation and delayed compression plating once soft tissue healing has occurred. Severely comminuted fractures are unsuitable for plating and definitive external fixation or intra-medullary nailing may be used as an alternative.[18,19] Alternatively, a local study showed that intra- medullary nailing of radius/ulna fractures for low velocity GSWs is effective and safe.[20]

Gunshot hand injuries comprise a vast array of injury patterns and each patient needs to be assessed and managed according to the specifics of the fracture type/s. The general consensus is that in the absence of an intra-articular component, fracture displacement or bone loss, these injuries are best managed conservatively with wound debridement and irrigation followed by cast immobilisation. Immediate surgical indications are necessary when the fracture is intra-articular or when the tendons or disruption to the neurovascular system has occurred thus requiring repair.[18] In terms of the surgical management of these injuries, Kirschner wires are used, as are an array of mini plate and screw systems, and mini external fixators. [21]

When considering gunshot hip, one must consider the abdomen as being violated until proven otherwise. A high index of suspicion is necessary as to whether the hip joint is involved and the best direct radiological markers of hip joint violation are an acetabular fracture, femoral head fracture, air in the joint as well as a fracture of the intra-articular portion of the femoral neck.[18] One study went as far as to confirm the rule that any GSW occurring between the umbilicus and proximal third of the thigh should alert the attending orthopaedic surgeon to the possibility of a hip joint violation needing specific exclusion. Articular violation requires arthrotomy as does retained bullet fragments in the synovial fluid. Unstable intra-articular fractures as well as stable or unstable femoral neck fractures are best managed by internal stabilisation.

Comminuted femoral head fractures which shatter the femoral head, and thereby inherently disrupt the apical blood supply, form a specific subset of patient presentation and hip arthroplasty is the treatment of choice performed in a delayed elective manner.[22] In the case of hip joint involvement, if only small bowel contamination is present or suspected, a single dose antibiotic without formal arthrotomy is sufficient whereas large bowel contamination requires urgent arthrotomy and appropriate antibiotics. Due to the high tensile and compression forces around the proximal femur, unicortical and complete fractures require prophylactic intra-medullary nailing.[12]

Gunshot femoral shaft comprise up to 40% of extremity injuries of the lower limb.[6] Skeletal traction is indicated if definitive surgery is delayed and ultimately, as is done in the majority of cases, intramedullary nails are used.[18] All comminuted and complete fractures require surgery while unicortical fractures can be managed conservatively with a period of partial weight bearing. With large soft tissue injuries, external fixators are sometimes, albeit infrequently, used as they are fraught with high complication rates including pin tract sepsis and implant failure.[23] Brein et al.[24] proposed that extensive open injuries may be best managed with skeletal traction and serial wound debridement pending definitive intramedullary nailing once soft tissue coverage had been deemed adequate. Other papers challenge this thinking and recommend immediate reamed intramedullary nailing irrespective of the degree of soft tissue damage.[25,26] An additional benefit put forward in another study is that early intramedullary nailing lowers the incidence of pulmonary complications when compared to delayed stabilisation.[27]

Gunshot knee mandate that urgent vascular imaging be performed. Fracture fragments within the joint space and haemarthrosis on joint aspiration, indicate joint space violation and are indications for arthrotomy and joint irrigation.[18] A more recent South African study showed room for conservative treatment of intra-articular gunshots given that there is no bullet retention [28] A transversed joint space, as well as a transversed joint space with retained bullet fragments, have both been successfully treated, including successful bullet fragment removal, by arthroscopy.[29,30] Unstable injuries require internal fixation and in the context of significant soft tissue destruction, external fixators are useful.[29]

Gunshot tibial shaft are often low velocity, are associated with a grade one wound, and are un-displaced. If the wound is not large or grossly contaminated, no formal debridement is necessary however, antibiotic prophylaxis should be given. Unicortical fractures are best managed by six weeks of limited weight bearing, and prophylactic nailing is not suggested.[12] In complete, displaced or unacceptably angulated fractures or failing correction with conservative treatment, reamed nails afford the best union rate. Unreamed nails and external fixation offer a lower and comparatively similar rate of non-union while the use of external fixators is associated with more complications.[31] A single centre study in Cape Town concluded that fractures due to a GSWs with a grading of 3A or lower showed similar results in terms of infection and union when compared to other causes of open fractures managed similarly.[32] Due to poor soft tissue coverage**,** tibial plateau and pilon fractures carry with it a significant risk of wound break-down if early definitive surgery is performed. In these areas, thin wire external fixators are recommended to afford stable fixation and prevent soft tissue breakdown followed by delayed, definitive plating.[31]

Gunshot foot are managed in a similar manner to GSWs of the hand although a more conservative and definitive approach is commonly employed. In the acute setting, serial debridements are often used as the mainstay of treatment. External fixators are commonly used in the context of significant soft tissue destruction and are often definitive. Internal fixation is indicated in intra-articular injuries and where a vascular repair has been performed.[33]

The above literature review highlights the significant burden GSI's places on our health care system. This study aims to better describe this burden as well as the potential causes and costs it places on South Africa's health care budget.

1.1 Study Purpose

To collect epidemiological variables of GSI patients and to determine whether current literature suggestions for the treatment of these injuries are being followed by the HJH's Orthopaedic Department. Furthermore, to determine the cost breakdown of GSI and the ultimate cost to state.

1.2 STUDY AIM AND OBJECTIVES

Aim:

- To review the epidemiology and determine the average cost for the treatment of a GSW to an extremity at HJH.

Objectives:

1. To determine the demographics and epidemiological variables of extremity GSI's

2. To capture the type of surgery and the duration

3. To document the quantity and the cost of resources which were used in during the management of patients who had sustained a gunshot wound to the extremity

CHAPTER 2

2. METHODOLOGY

2.1 Study site: Helen Joseph Hospital (HJH)

2.2 Study design: This was a retrospective, cross-sectional study of patients who were treated for GSWs at HJH between 01 July 2018 and 31 July 2022

2.3 Data Collection

Data collection started once ethics clearance was obtained from the Human Research Ethics Committee (HREC) (Medical) of the University of the Witwatersrand (Certificate no: **M220417**, Appendix A) as well as permission from the hospital Chief Executive Officer (Appendix B). The Orthopaedic emergency admissions logbook from 01 July 2018 to 31 July 2022 was used to obtain the details of patients that were admitted with GSWs. Each patient included in the study was ascribed a unique study number to maintain patient confidentiality and anonymity. The files were obtained from the HJH filing room and reviewed. The relevant data was transcribed from each patient file onto the data collection sheet (see Appendix C). Patient information is kept completely anonymous and no patient recall was done. All the files were signed out of the filing room as they left the room and were signed back in when returned. The data capturing was done solely by the principal investigator (PI) (Dr R. Dembskey) in the Orthopaedic Department and no file left the hospital.

2.4 Selection Criteria

Inclusion Criterion:

- All patients aged 12 years and older who sustained a GSW to an extremity and admitted at HJH (patients younger than 12 years are admitted to a different hospital)

Exclusion Criteria:

- Patients with extremity GSWs with associated visceral, head or spine GSWs or injuries
- Patients that sustained GSWs to extremities that were not admitted

2.5 Data analysis

Descriptive statistics were used to describe the demographic and cost variables. Each cost variable was analysed quantitatively and the rand value reported. Continuous variables were described using means, standard deviations as well as maximum and minimum values. The cost centres were expressed as a percentage of the total cost to determine where the highest costs came from. Isolated upper limb, lower limb and combined upper and lower limb GSI costs were analysed and compared. A one-way ANOVA analysis was used to determine if a significant difference in cost existed amongst these three groups. Where differences were found, ANOVA effect sizes were used to determine practical significance. A Sheffé post hoc analysis was done to determine which pairwise differences were significant.

2.5.1 Variables for cost analysis

The following groups were used:

- Admission cost determined by length of hospital stay
- Anaesthetic and surgical/operative costs
- Orthopaedic implant cost
- Ambulatory procedures including ambulance transport cost, consulting, imaging, electrocardiograms (ECG's), blood tests, intravenous fluids
- Physiotherapy (PT)/Occupational therapy (OT)
- Blood bank services

Costs excluded were: Facility overhead costs such as utilities, cleaning services etc.

The costs were transcribed into a collection sheet (Appendix D) and calculated with assistance from the HJH finance department. All costs were calculated using the provincial gazette guidelines. In every instance where a professional fee was charged albeit for anaesthesia, surgery or in hospital consultations, the fee for a general practitioner was used with the assumption that medical officers and registrars were attending to the patients in most cases. Specialist fees are cost more and are likely be used by the hospital in some instances, hence, the calculated costs used in the calculations were under estimated in some instances.

Inpatient costs is calculated on a day's stay in hospital i.e. each day admitted cost a fixed amount. Each theatre procedure was categorised in order of severity from A to D according to the type of surgery required. An anaesthetic, surgical and facility fee was calculated and added to determine the total theatre cost.

Implant costs were calculated using the tender/procurement prices that were granted to respective companies during the data collection period. In instances where the implant company was not documented in the theatre notes, the most common company used for that specific implant was chosen with their respective price (e.g. Stryker femur intramedullary nail if no company was stated).

2.5.2 Ambulatory Costs

These costs were divided into four categories:

- Ambulance cost, if a patient was transported to hospital *via* ambulance, the assumption that most patients were brought *via* a basic life support ambulance was used
- Emergency medical consult fee, again general medical practitioner (registrar/medical officer) fee and not specialist fee was used
- In patient ambulatory fees – includes Intravenous lines, X-rays, ECG's, medication, as well as a facility fee
- National Health Laboratory Services (NHLS) costs

Allied costs were calculated per session and includes a professional and facility fee. Blood bank costs were only added when it was clearly documented in the file.

The South African National Blood Service (SANBS) pricelist is obtainable *via* their website: https://sanbs.org.za/wpcontent/uploads/2023/03/SANBS-State-Patient-Price-List-2023-2024.pdf

CHAPTER 3. RESULTS

3.1 Epidemiological variables

A total of 70 patients met the inclusion criteria. The age ranged between 16 and 59 years with a median age of 34 years. Figure 3.1 shows the sex demographic of admitted patients with males accounting for 94.3% and females for only 5.7%. Forty patients were brought to hospital *via* ambulance, 14 with personal transport and 16 unknown or not documented. The history of the event leading to a GSW is shown in Figure 3.2. The majority of cases (42.9%) are unknown, possibly due to inaccurate or incomplete history taking, while robbery constitutes the second most common reason (35.7%) for a GSI. The type of firearm used in the incident was only documented in 14 (20%) of the files, the other 80% were not documented or the patient was unsure of which gun was used.

Figure 3.3 shows the distribution of the location of the GSIs, lower limb accounted for 57.14% (n = 40), while upper limb injuries constituted 31.43% (n = 22) and both upper and lower extremity GSWs 11.43% (n = 8). Seventeen (24.3%) of the GSWs were intra articular with the knee being the most common site (n = 8), followed by the elbow (n = 4).

Only two vascular injuries were associated with the GSWs, one anterior tibial artery and one patient with both anterior tibial and peroneal artery injury, both cases were confirmed with a CT angiogram. A total of five neurological injuries were documented, one of each of the following – axillary nerve, radial nerve, median nerve, ulnar nerve and sciatic nerve.

Forty-six (65.7%) of the admitted patients required surgery and of these, 37 required some form of orthopaedic implant, the remaining admitted patients were managed non operatively with antibiotics, dressings and immobilisation where needed. The average surgical time was 104.3 minutes.

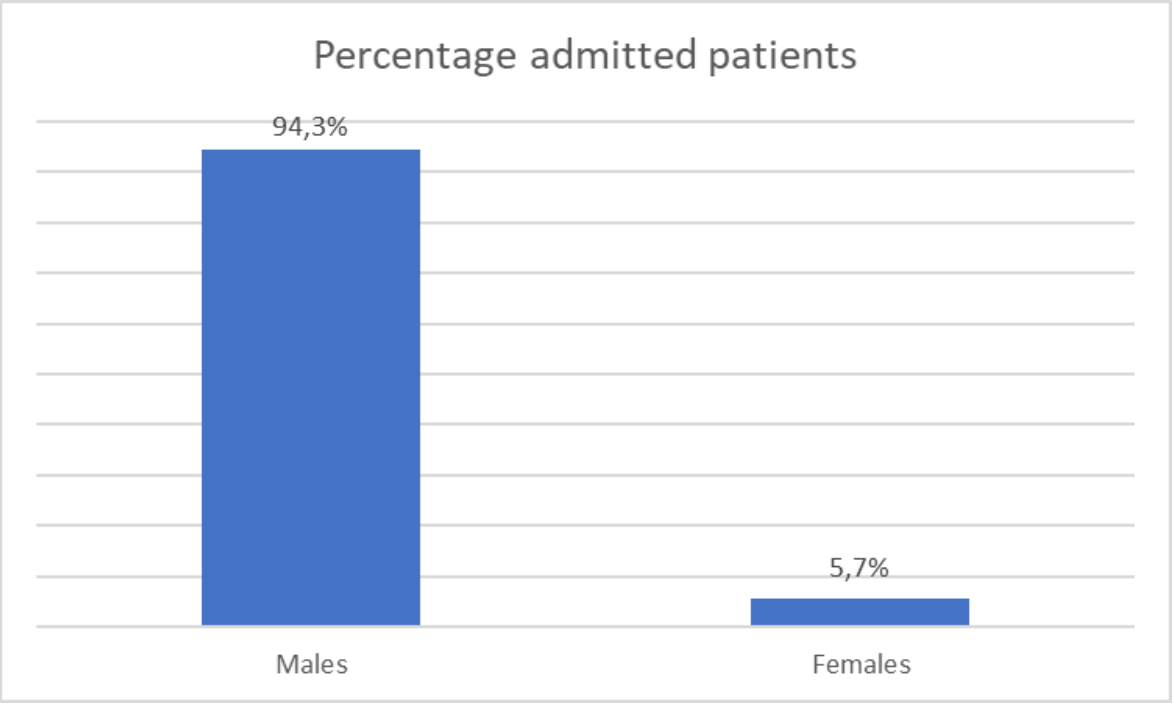

Figure 3.1: Sex demographic of admitted patients

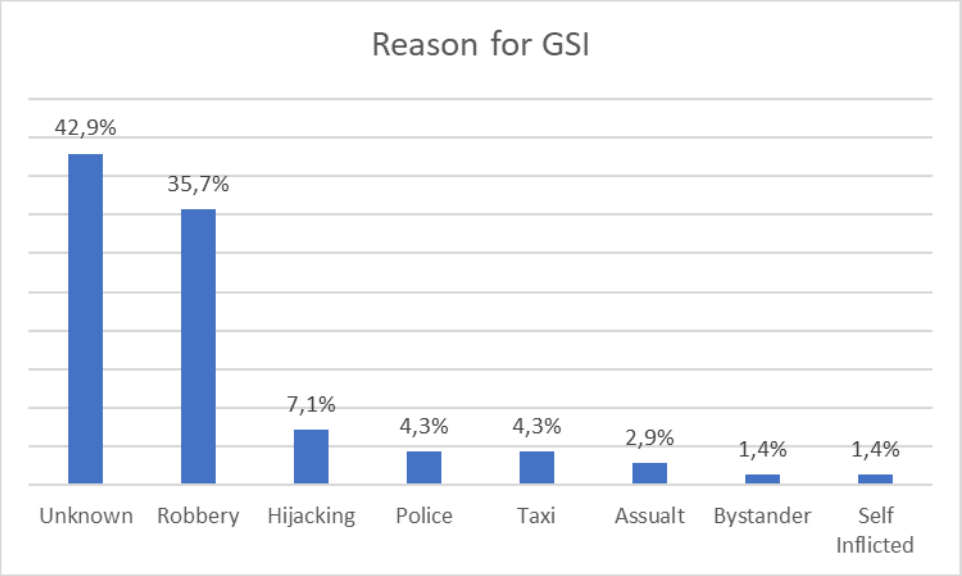

Figure 3.2: History leading to GSW

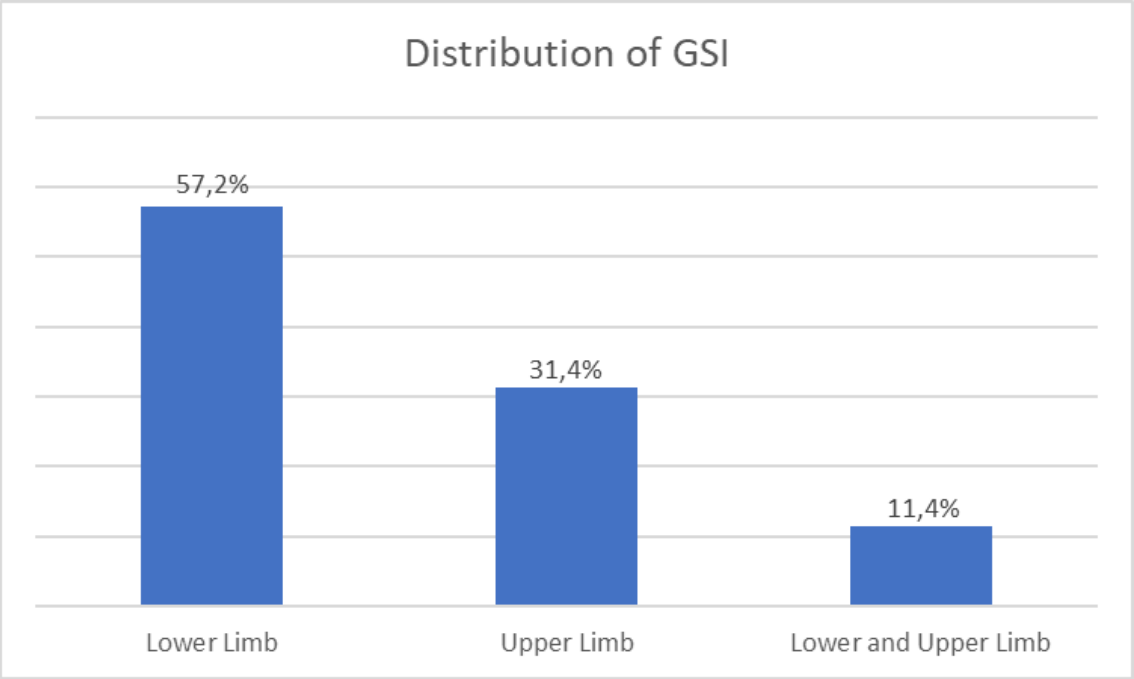

Figure 3.3: Location of GSW

3.2 Admission and Surgical Variables

The mean length of admission for all GSI's was 5.8 +/- 4.4 days with a maximum of 24 days and a minimum of 1 day. 46 patients required surgical intervention with 3 patients requiring multiple surgeries. The mean theatre time was 104.35 minutes.

68 of the 70 reviewed files had clearly documented antibiotics prescribed, with Kefzol being prescribed 85% of the time. Augmentin and Flagyl were added in the remaining cases but no clear indication was documented. The mean duration of antibiotic use was 2.4 days with a maximum of 20 days in a patient with confirmed infection requiring multiple relook debridements.

The preferred method of stabilization in the theatre was intra medullary nailing at 46.5%. This is in keeping with current literatures 'suggestion especially for shaft fractures. 3 Patients required multiple fixation methods for multiple GSI fractures.

Blood loss was not clearly documented in most cases, in fact only 7 theatre cases done (21%) had a blood loss estimate on the anaesthetic chart. The maximum blood loss estimated was 750ml with only 3 patients requiring transfusion. None of the patients admitted and not required surgery had blood transfusions.

3.3 Cost Variables

Each cost centre is discussed individually below. Table 3.1 illustrates each cost category in terms of mean, standard deviation, minimum and maximum cost, as well as the total cost.

Table 3.1: Cost centres shown in South African Rand

Cost centre	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Inpatient	R15086.26	R11485.27	R2582.00	R61968.00
Operative and Anaesthetic	R6599.73	R2334.82	R3569.00	R12385.00
Implants	R17888.97	R18639.36	R8097.00	R89350.00
Ambulatory Procedures	R4622.50	R2223.75	R1529.00	R13541.00
Physio- and Occupational Therapy	R432.00	R415.24	R216.00	R2808.00
Blood Bank	R1862.95	R3288.25	R873.00	R16164.00
TOTAL cost	**R32612.32**	**R26970.11**	**R4111.30`**	**R146741.82**

3.3.1 Inpatient admission cost

One day in hospital is calculated to be R2582 and includes a professional and facility fee. Hence a longer stay will incur a larger cost. As stated above, the mean length of admission for all GSI's was 5.8 +/- 4.4 days with a maximum of 24 days and a minimum of 1 day. Table 3.1 shows the mean cost of R15086.26 per patient.

3.3.2 Operative and Anaesthetic cost

A total of 46 patients required surgical intervention and 3 patients required multiple surgeries. The mean theatre time was 104.35 minutes. The cost incurred is thus per procedure and not duration in theatre. The mean operative and anaesthetic cost was R 6599.73 per procedure, with a maximum of R 12385.00 and a minimum of R 3569.00.

3.3.3 Implant cost

A total of 37 of the operated patients required fracture stabilisation using orthopaedic implants. The mean implant cost was R17888.97 with a maximum of R89350.00 for an external ring fixator.

3.3.4 Ambulatory costs

Ambulatory cost were grouped using the above-described breakdown and the results were as

follows:

- Ambulance cost for basic life support services was R1311.00 per patient, intermediate and advanced life support paramedic teams will have a higher cost and might have been used in some cases

- The emergency consult cost which includes a practitioner and a facility fee adds to R653.00 per patient

- In hospital ambulatory fees equates to R458.00 per patient per day of admission. This is billed separately from the admission cost. Additional scans such as CT or MRI scans were not included as they are seldom done in GSI patients however, if they were done they would have incurred an additional cost.

- NHLS services: Every patient received standard admission blood tests including a FBC and U and E with an associated cost of R418.30. Additional blood tests and covid-19 swabs were added and calculated where needed.

The mean ambulatory cost per patient was R4622.50 +/- R2223.75.

3.3.5 Physiotherapy and Occupational therapy cost

Each sessions costs R216.00. Depending on the injury sustained, not all patients will require an allied consult. On the contrary, patients who had a prolonged hospital stay, especially those with a lower limb GSI may require multiple sessions. The mean cost per patient was R432.00 with a maximum of R2808.00.

3.3.6 Blood bank cost

A standard cross-match and after hours/emergency fee costs R872.63. In our sample, only three patients required a blood transfusion. The mean blood bank costs were R1862.95 with a standard deviation of R3288.25 and a maximum of R16164.00.

3.3.7 Total cost

The sum of all cost centres was used to calculate the total cost. As illustrated in Table 3.1, the mean cost was R32612.32, standard deviation of R26970.11 and a respective minimum and maximum cost of R4111.30 and R146741.82, respectively. Each cost centre is expressed as a percentage in Figure 3.4

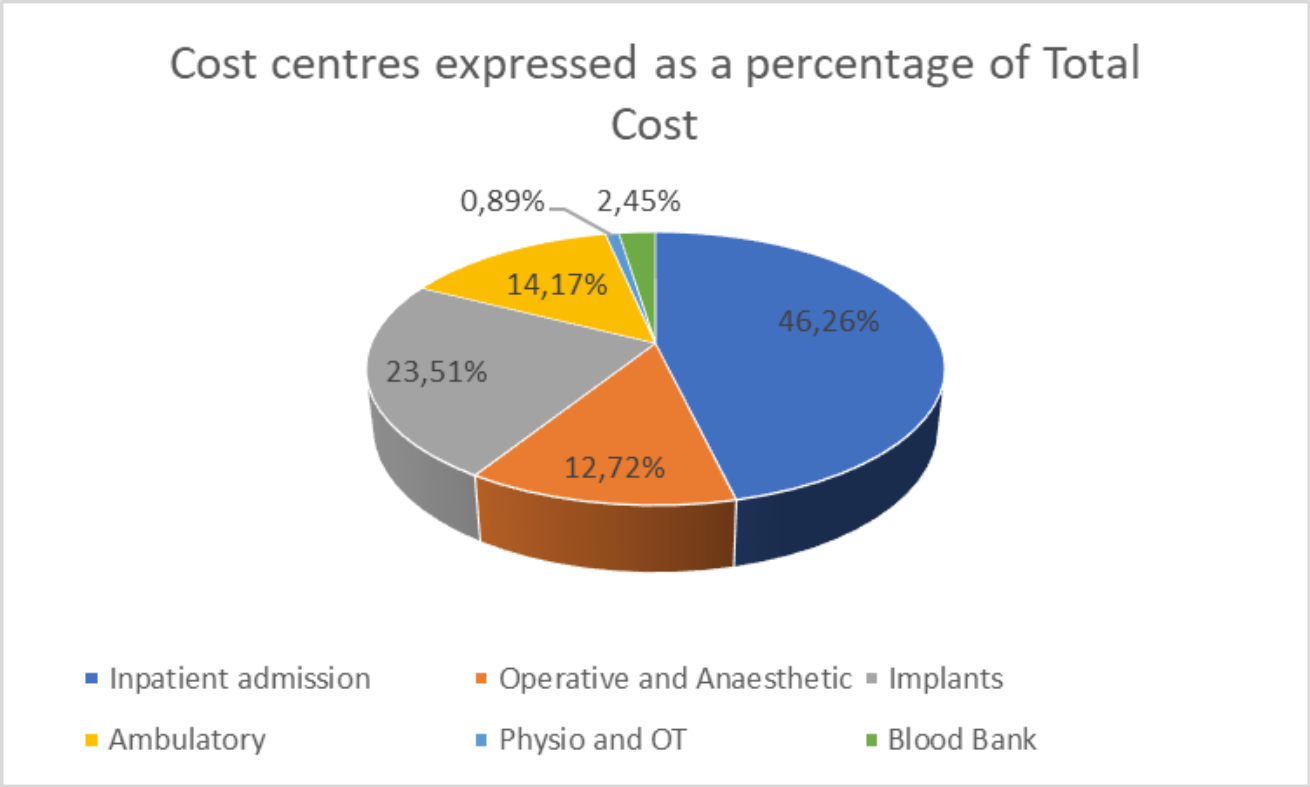

Figure 3.4: Cost centre percentage of Total Cost

Analysis was done on the cost of upper *versus* lower *versus* combined upper and limb GSI and is shown in Table 3.2. The maximum, minimum and mean of each cost centre is shown and divided between lower and upper extremity and combined injuries. The total number (n) of the various cost centres differ due to not all patients requiring surgery or implants as well as physio/OT or blood bank services. This table only provides absolute values and further analysis was done to determine if a statistical difference exists between the 3 groups and the various cost centres.

Table 3.2: Upper *versus* Lower *versus* both upper and Lower GSI

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
1. Admission cost/length of stay	Lower limb	40,00	15298,35	11916,96	1884,24	11487,12	19109,58	2582,00	61968,00
	Upper limb	22,00	11266,91	5720,80	1219,68	8730,45	13803,37	2582,00	23238,00
	Both upper and lower	8,00	24529,00	16212,94	5732,14	10974,64	38083,36	7746,00	54222,00
	Total	70,00	15086,26	11485,27	1372,75	12347,69	17824,82	2582,00	61968,00
2. Anaesthetic and operative cost	Lower limb	28,00	6968,68	2395,05	452,62	6039,98	7897,38	3569,00	12385,00
	Upper limb	10,00	4743,60	810,55	256,32	4163,77	5323,43	3569,00	5247,00
	Both upper and lower	6,00	7971,50	2193,79	895,61	5669,26	10273,74	5247,00	10494,00
	Total	44,00	6599,73	2334,82	351,99	5889,88	7309,58	3569,00	12385,00
3. Orthopaedic implant cost	Lower limb	18,00	17384,36	20828,68	4909,37	7026,50	27742,21	8096,99	89350,00
	Upper limb	7,00	14265,14	10825,11	4091,51	4253,58	24276,70	8200,00	38450,00
	Both upper and lower	5,00	24778,94	20391,23	9119,24	-540,12	50098,00	9136,60	60558,30
	Total	30,00	17888,97	18639,36	3403,07	10928,92	24849,02	8096,99	89350,00
4. Ambulatory procedures	Lower limb	40,00	4638,24	2376,17	375,71	3878,30	5398,17	1529,30	13540,70
	Upper limb	22,00	3865,23	1388,22	295,97	3249,72	4480,73	1529,30	6504,30
	Both upper and lower	8,00	6626,35	2261,12	799,43	4736,01	8516,69	4214,30	10689,30
	Total	70,00	4622,50	2223,75	265,79	4092,27	5152,74	1529,30	13540,70
5. Physio/OT cost	Lower limb	35,00	413,49	442,58	74,81	261,45	565,52	216,00	2808,00
	Upper limb	6,00	288,00	111,54	45,54	170,94	405,06	216,00	432,00
	Both upper and lower	6,00	684,00	372,04	151,88	293,57	1074,43	216,00	1080,00
	Total	47,00	432,00	415,24	60,57	310,08	553,92	216,00	2808,00
6. Blood bank services	Lower limb	18,00	1722,13	3604,14	849,50	-70,16	3514,43	872,63	16163,70
	Upper limb	6,00	872,63	0,00	0,00	872,63	872,63	872,63	872,63
	Both upper and lower	6,00	3275,70	3860,63	1576,10	-775,78	7327,19	872,63	9698,22
	Total	30,00	1862,95	3288,25	600,35	635,09	3090,80	872,63	16163,70
Total_cost	Lower limb	40,00	33774,38	26471,09	4185,45	25308,52	42240,25	4327,30	133393,85
	Upper limb	22,00	22143,76	14419,33	3074,21	15750,59	28536,94	4111,30	60400,30
	Both upper and lower	8,00	55590,59	41068,55	14519,93	21256,42	89924,76	12302,30	146741,82
	Total	70,00	32612,32	26970,11	3223,54	26181,53	39043,12	4111,30	146741,82

A one-way ANOVA was done to determine if a statistically significant difference exists between the 3 groups in any of the cost categories. A *p*-value of < 0.05 indicates a statistically significant difference between at least 2 of the groups and is shown in Table 3.3. Four cost categories had statistically significant differences between the groups. These cost categories were admission cost, anaesthetic and operative cost, ambulatory cost and total cost. Further analysis was done only on the statistically significant groups to determine the practical significance of these values. ANOVA effect sizes were calculated and shown in Table 3.4. A value of $\eta 2 = 0.01$ indicates a small effect, $\eta 2 = 0.06$ indicates a medium effect, and $\eta 2 = 0.14$ indicates a large effect. These data show a medium effect in the admission cost, ambulatory and total cost and a large effect for the anaesthetic and operative cost. The yellow highlighted values shows that a statistically significant difference exist between the groups in the admission cost, anaesthetic and operative cost, ambulatory cost and total cost.

Table 3.3: ANOVA between groups

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
1. Admission cost/length of stay	Between Groups	1036045706,45	2,00	518022853,23	4,303	0,017
	Within Groups	8065842092,92	67,00	120385702,88		
	Total	9101887799,37	69,00			
2. Anaesthetic and operative cost	Between Groups	49554148,72	2,00	24777074,36	5,495	0,008
	Within Groups	184855648,01	41,00	4508674,34		
	Total	234409796,73	43,00			
3. Orthopaedic implant cost	Between Groups	333866738,41	2,00	166933369,20	0,463	0,634
	Within Groups	9741480817,23	27,00	360795585,82		
	Total	10075347555,64	29,00			
4. Ambulatory procedures	Between Groups	44749385,82	2,00	22374692,91	5,057	0,009
	Within Groups	296461113,17	67,00	4424792,73		
	Total	341210499,00	69,00			
5. Physio/OT cost	Between Groups	517437,26	2,00	258718,63	1,535	0,227
	Within Groups	7414082,74	44,00	168501,88		
	Total	7931520,00	46,00			
6. Blood bank services	Between Groups	18216559,29	2,00	9108279,64	0,833	0,446
	Within Groups	295349439,61	27,00	10938868,13		
	Total	313565998,90	29,00			
Total_cost	Between Groups	6689017708,72	2,00	3344508854,36	5,151	0,008
	Within Groups	43500668236,03	67,00	649263705,02		
	Total	50189685944,74	69,00			

Table 3.4: ANOVA effect sizes

ANOVA Effect Sizes[a,b]				
			95% Confidence Interval	
		Point Estimate	Lower	Upper
1. Admission cost/length of stay	Eta-squared	0,11	0,00	0,25
	Epsilon-squared	0,09	-0,03	0,23
	Omega-squared Fixed-effect	0,09	-0,03	0,22
	Omega-squared Random-effect	0,05	-0,01	0,13
2. Anaesthetic and operative cost	Eta-squared	0,21	0,02	0,39
	Epsilon-squared	0,17	-0,03	0,36
	Omega-squared Fixed-effect	0,17	-0,03	0,35
	Omega-squared Random-effect	0,09	-0,01	0,21
3. Orthopaedic implant cost	Eta-squared	0,03	0,00	0,18
	Epsilon-squared	-0,04	-0,07	0,12
	Omega-squared Fixed-effect	-0,04	-0,07	0,12
	Omega-squared Random-effect	-0,02	-0,03	0,06
4. Ambulatory procedures	Eta-squared	0,13	0,01	0,27
	Epsilon-squared	0,11	-0,02	0,25
	Omega-squared Fixed-effect	0,10	-0,02	0,24
	Omega-squared Random-effect	0,05	-0,01	0,14
5. Physio/OT cost	Eta-squared	0,07	0,00	0,21
	Epsilon-squared	0,02	-0,05	0,17
	Omega-squared Fixed-effect	0,02	-0,04	0,17
	Omega-squared Random-effect	0,01	-0,02	0,09
6. Blood bank services	Eta-squared	0,06	0,00	0,23
	Epsilon-squared	-0,01	-0,07	0,18
	Omega-squared Fixed-effect	-0,01	-0,07	0,17
	Omega-squared Random-effect	-0,01	-0,03	0,09
Total_cost	Eta-squared	0,13	0,01	0,27
	Epsilon-squared	0,11	-0,02	0,25
	Omega-squared Fixed-effect	0,11	-0,02	0,25
	Omega-squared Random-effect	0,06	-0,01	0,14

a. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

b. Negative but less biased estimates are retained, not rounded to zero.

A Sheffé post hoc analysis was done to determine in which of the three categories the above cost differences exist and is illustrated in Table 3.5. A *p*-value of <0.05 is statistically significant and is highlighted in yellow. The result indicates the following:

- In the admission cost centre, there is a significant difference between upper and combined upper and lower GSI. The mean cost for upper limb GSI was R11266.91 and for combined GSI it was R24529.00.
- In the anaesthetic and operative cost centre there is a significant difference between lower and upper limb as well as upper limb and combined upper and lower limb GSI. The mean cost for upper limb was R4743.60, for lower limb R6968.68 and for combined R7971.50.
- In the ambulatory cost centre, there is a significant difference between lower and combined upper and lower GSI as well as between upper and combined upper and lower GSI. The mean cost for upper limb was R3865.23 for lower limb R4638.24 and for combined R6626.35.
- In the total cost, there is a significant difference between lower and combined upper and lower limb GSI as well as upper and combined upper and limb GSI. The mean cost for upper limb was R22143.76, for lower limb 33774.38 and for combined R55590.59.

To summarise the above findings:

- No difference exists between the 3 categories in terms of Implant cost, PT or OT cost and Blood bank costs.
- Admission cost for patients sustaining combined upper and lower limb injuries are significantly more than patients only sustaining injuries to upper limbs.
- Anaesthetic and operative cost is most expensive in the combined group but lower limb injuries costs significantly more than upper limb only GSI.
- Ambulatory costs again are most expensive in combined injuries compared to isolated upper and lower limb GSI.
- Total cost is significantly more expensive in combined injuries compared to isolated lower limb or upper limb injuries

Table 3.5: Sheffé test to determine significant difference between categories

Multiple Comparisons

Scheffe

Dependent Variable	(I) Limb	(J) Limb	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1. Admission cost/length of stay	Lower limb	Upper limb	4031,44	2912,34	0,39	-3259,61	11322,49
		Both upper and lower	-9230,65	4249,45	0,10	-19869,17	1407,87
	Upper limb	Lower limb	-4031,44	2912,34	0,39	-11322,49	3259,61
		Both upper and lower	-13262.091*	4529,93	0,02	-24602,79	-1921,39
	Both upper and lower	Lower limb	9230,65	4249,45	0,10	-1407,87	19869,17
		Upper limb	13262.091*	4529,93	0,02	1921,39	24602,79
2. Anaesthetic and operative cost	Lower limb	Upper limb	2225.079*	782,23	0,02	238,24	4211,92
		Both upper and lower	-1002,82	955,23	0,58	-3429,07	1423,43
	Upper limb	Lower limb	-2225.079*	782,23	0,02	-4211,92	-238,24
		Both upper and lower	-3227.900*	1096,50	0,02	-6012,96	-442,84
	Both upper and lower	Lower limb	1002,82	955,23	0,58	-1423,43	3429,07
		Upper limb	3227.900*	1096,50	0,02	442,84	6012,96
4. Ambulatory procedures	Lower limb	Upper limb	773,01	558,34	0,39	-624,81	2170,82
		Both upper and lower	-1988,12	814,69	0,06	-4027,69	51,46
	Upper limb	Lower limb	-773,01	558,34	0,39	-2170,82	624,81
		Both upper and lower	-2761.123*	868,46	0,01	-4935,32	-586,93
	Both upper and lower	Lower limb	1988,12	814,69	0,06	-51,46	4027,69
		Upper limb	2761.123*	868,46	0,01	586,93	4935,32
Total_cost	Lower limb	Upper limb	11630,62	6763,40	0,24	-5301,57	28562,81
		Both upper and lower	-21816,21	9868,61	0,09	-46522,31	2889,89
	Upper limb	Lower limb	-11630,62	6763,40	0,24	-28562,81	5301,57
		Both upper and lower	-33446.82727*	10519,98	0,01	-59783,62	-7110,03
	Both upper and lower	Lower limb	21816,21	9868,61	0,09	-2889,89	46522,31
		Upper limb	33446.82727*	10519,98	0,01	7110,03	59783,62

*. The mean difference is significant at the 0.05 level.

CHAPTER 4

4. DISCUSSION

The mean age of admitted patients was 34 (+/-9.33) years with males making up 94.3% of the total (see Figure 3.1). Compared to another local study there is a clear difference in terms of mean age; their mean was 26 years compared to 34 years in our study, but similarly 91.5% were male patients. GSIs to the lower limb constituted 57.14% of the total, upper limb 31.43% and combined upper and lower limb 11.43% (see Figure 3.3). This is similar to previous published local studies.[5,6] More than half (57.1%) of the injured patients were taken to hospital *via* ambulance, this adds to the cost that GSIs incur to the state. Although most are undocumented, robbery makes up 35.7% of the reason for a GSI at our health institution (see Figure 3.2). Only 20% (n = 14) of the firearms that were used in each event were documented, this could be due to patients not knowing what firearm was used, incomplete history taking or the reluctance of patients to disclose information if they were a possible assailant and do not want to give lead to any investigation, either way it will not affect the management of the patient.

Only two (2.9%) vascular and 5 (7.1%) neurological injuries were documented. No amputations due to a GSW was documented and no long-term follow-ups were done to ascertain the severity of the neurological injuries.

Of the admitted patients, 65.7% required surgery and of these patients, 80.43% required some form of orthopaedic implant. The mean waiting time from admission to surgery was 2.34 days with a mean duration of surgery lasting 104.3 minutes (minimum = 45 minutes, maximum = 370 minutes). The mean hospital stay was 5.84 days per patient with the longest being 24 days. The average stay is lower than other reported local studies however, a GSI that required visceral, head or spine surgeries was not considered.

Inpatient admission cost accounted for 46.26% of the total cost and came to R2582.00 per day. This value is higher than the value reported in a previous study at the same health institution where the authors looked at similar cost centres, although that study was concluded in 2019 with a different patient population and a different demographic with different requirements[34]. The total admission cost directly correlates with the number of days of admission i.e. a longer stay equals increased cost. The inpatient admission cost accounted for 46.26% of the total cost (see Figure 3.4). It was also statistically significantly more when comparing isolated upper limb versus combined and lower limb

GSIs. The average cost of all surgeries was R6599.73 (+/- R2334.82) and a significant cost difference exists between upper, lower and combined injuries with isolated upper limb GSI costing the least and combined upper and lower the most (see Table 3.5).

The average price per implant was R17888.97 (or USD937.7 with the current exchange rate), with the maximum being R89350.00 (see Table 3.1). Implant costs contributed 23.51% of the total cost. This average is more than a previous local study[5] which was USD667.00 (the average Rand – Dollar exchange in 2017 was 1 USD = R13.30 which equates to R8871.10)[35]. However, It is not mentioned how their implant costs were calculated or if a tender price existed and which specific implants were used. No statistically significant difference in terms of implant cost exists between upper (R14265.10) and lower (R17384.40) extremity GSIs.

Ambulatory costs comprised of the sum of the ambulance cost, the emergency consult, in hospital ambulatory cost (intravenous lines, x-rays, fluids, medications etc.) and NHLS blood tests. The mean cost was R4622.50 +/- R2223.75 and a significant difference existed between groups, again upper limb costing the least and combined injuries the most. PT and OT are charged per session at R216. The maximum in this cost centre was R2808.00. No difference existed between the groups. The mean blood bank cost was R1862.95. Prices were taken from the SANBS website. The majority of patients only required a type and screen with an emergency/after hours fee that is added to the price. Only 3 out of the 70 admitted patients required a blood transfusion. No statistical significance was noted between groups.

The mean total cost per patient was calculated by adding the cost of all six cost centres. The mean price per patient was calculated to R32612.32 with a maximum of R146741.82, which was a combined upper and lower extremity GSI (see Table 3.1). The total cost for all patients added to R2264160.26. Again, combined upper and lower limb GSI cost more than isolated upper or lower limb injuries. The average cost was higher than a previous study from Cape Town[5] which equated to R24 945.00, however; extremity injuries with additional visceral injuries were included in their study. The authors also did not mention the cost breakdown as mentioned in our study. When reviewing current literature guidelines[12-33] for the treatment of a GSI, the orthopaedic department at HJH are closely following local and international guidelines. Access to first world theatre facilities, standard international implants and surgeons and nursing staff who are being trained according to international recommendations and guidelines make treatment of GSIs at this health institution comparable to any world class trauma health institution.

4.1 LIMITATIONS

As the study design is retrospective, there were missing data from some records i.e whether a patient was crossmatched, had blood tests ordered, received physio or OT, intra operative blood loss etc, therefore some results are likely to be inaccurate and some costs likely to be under reported. Only one hospital was used for data collection and some admitted patients' files were not available in the hospital records room which lead to a smaller than desired sample size. In each instance where a professional fee was charged, the minimum cost was used using the assumption that medical officers and registrars mainly see these patients and do the operations, this will likely lead to an underestimation of the cost where a specialist fee was charged. Patients discharged from the emergency department and patients who did not have isolated extremity GSIs were excluded from the study, which will potentially underestimate the burden of GSIs.

CONCLUSION

This study supports previous studies and shows the high resource and financial impact that a GSI has on the health care system. The fact that most victims are males in their productive age means loss of productivity and increased burden in other sectors as well. Patients with extremity GSIs often need surgery and fracture stabilisation using orthopaedic implants, various cost centres add to a high total cost with various departments and personnel involved in treating a patient. The management of these injuries at HJH are according to national and international standards. Further gun regulations by government can potentially add to less GSI and an overall decreased burden on the public health sector.

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APPENDICES

Appendix A: Ethics clearance certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R49 Dr R Dembskey

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M220417

NAME: (Principal Investigator)	Dr R Dembskey
DEPARTMENT:	School of Clinical Medicine Deoartment of Surgery Division of Orthopaedic Surgery Medical School University
PROJECT TITLE:	*A review of the epidemiology and average cost for the treatment of gunshot wounds of an extremity at a single academic hospital in Johannesburg, South Africa*
DATE CONSIDERED:	2022/04/29
DECISION:	Approved unconditionally
CONDITIONS:	
NOTE:	If contact information regarding student study participants is required, please contact the Registrar's office - <Nicoleen.Potgieter@wits.ac.za>
SUPERVISOR:	Drs A Younus and B Milner; Professor A Aden
APPROVED BY:	Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2022/08/19

This Clearance Certificate is valid for 5 years from the date of approval. An extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office secretariat on the 3rd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.

I/we fully understand the conditions under which I am/we are authorized 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 submit details 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 when the study was initially reviewed. In this case, the study was initially reviewed in **April** and therefore reports and re-certification will be due in the month of **April** each year. Unreported changes to the study may invalidate the clearance given by the HREC (Medical).

Signature of Principal Investigator — Date: 22 May 2024

Appendix B: Hospital permission letter

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

Gauteng Department of Health
Helen Joseph Hospital
Enquiries: Dr. M. Mukansi
Research Committee: Chairperson
Tel :(011) 489-0306/1087
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23 March 2022

To whom it may concern

Subject: HELEN JOSEPH HOSPITAL RESEARCH COMMITTEE APPLICATION

PROTOCOL TITLE: A review of the epidemiology and average cost for the treatment of gunshot wounds of an extremity at a single Academic Hospital in Johannesburg, South Africa

Principal Investigator: Reinhard Dembskey

Ethics Clearance: Pending

Co- investigator: Reinhard Dembskey

Department: Helen Joseph Hospital

Committee Recommendations
The Committee is giving you Conditional access while awaiting the final ethical clearance certificate from the University of Witwatersrand.

It is the duty of the researcher to collect the data to the relevant department after the Research Committee approved the study.

Dr. M. Mukansi
Chairperson of HJH Ethic and Research Committee

Appendix C: Study Participant Data Summary Sheet

Title: A review of the epidemiology and outcome in gunshot wounds of extremities at a single Academic hospital in Johannesburg, South Africa

Participant number:…..... Age:…… Sex: M / F

…… …… **Pre- operative factors**

History of event: Intentional / Non – intentional / Unknown

Intentional: Police / Stranger / Known assailant / Self-inflicted / Unknown

Transport: Ambulance / Vehicle / Walked / Unknown

Isolated gunshot extremity: Yes / No

If no: Head / Neck / Chest / Abdomen / Urogenital

Type firearm: Low-velocity / High velocity / Unknown

Handgun / Shotgun / Rifle / Unknown

…… ……

Fracture

Intra-articular involvement: Yes / No

Shoulder: Clavicle / Scapula / Humeral head

Humerus: Proximal shaft / Mid-humeral shaft / Distal humeral shaft

Elbow: Humeral condyles / Olecranon / Radial head

Forearm: Radial shaft / Ulnar shaft

Wrist : Distal radius / Ulnar head / Carpal bones

Hand : Metacarpals / Phalanges

Hip: Femoral head or neck / Acetabulum

Femur: Proximal shaft / Mid-femoral shaft / Distal femoral shaft

Knee: Femoral condyles / Patella / Tibial plateau

Leg: Tibia / Fibula

Ankle: Pilon / Medial malleolus / Lateral malleolus

Foot: Talus / Calcaneus / Other Tarsal / Metatarsal / Phalanges

Associated vascular injury: No / Yes Vessel involved:…….

Associated nerve injury: No / Yes Nerve involved: ……. …….

Pre-operative use of antibiotics: No / Yes
Type:……..

Time from admission to operative intervention:..... days.

……
…….

<u>Operative parameters</u>

Number of operative procedure: 1 2 3 > 3
Number:……..

Description:……
……

Implant used:.....

Length of operative procedure (minutes): 30-60 / 60-90 / 90-120 / 120-150 / 150-180

Intra-operative blood loss (millilitres): …….

Post-operative parameters:

Use of antibiotics: No

…….. / days / Yes Type:……. X

Infection: No / Yes Pus swab result:

……..

Complications: No / Yes Describe:

…….

Length of hospital stay (days): ……

……

……

Appendix D: Data Collection sheet for costing

	6 Cost variable categories					
Participant no:	1. Admission cost/length of stay	2. Anaesthetic and operative	3. Implants	4. Ambulatory (Ambulance+ED consult +In hosp+NHLS)	5. PT/OT cost	6. Blood bank

Appendix E: National Health Research Database clearance certificate