Eur J Trauma Emerg Surg (2019) 45:145–150
https://doi.org/10.1007/s00068-017-0800-z

ORIGINAL ARTICLE

Civilian cerebral gunshot wounds in rural South African patients are associated with significantly higher mortality rates than in urban patients

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Received: 20 December 2016 / Accepted: 29 May 2017 / Published online: 13 June 2017

Abstract
Introduction This study focuses on a specific and often dramatic injury, namely gunshot wounds (GSW) of the head in order to determine whether there is a discrepancy in outcome between patients who sustain their injury in a rural setting and those who sustain it in an urban setting.
Materials and methods This study involves a retrospective review of our prospectively maintained regional electronic trauma registry. All patients who sustained a cerebral GSW from January 2010 to December 2014 were reviewed.
Results During the 5-year study period, a total of 102 patients sustained an isolated cerebral GSW. Ninety-two per cent (94/102) were male and the mean age was 29 years. Ninety-four per cent (94/102) of injuries were related to interpersonal violence. Of the 102 patients in the study, 54% (55/102) were urban and were transported directly to our trauma centre. The remaining 46% (47/102) were rural and were transported to a rural district hospital prior to being referred to our trauma centre. The time of injury was available in 60% (61/102) of patients. The mean time from injury to arrival for all patients was 11 h (SD 7). The mean time from injury to arrival was significantly shorter for urban versus rural, 6 h (SD 5) and 15 h (SD 5), respectively ($p < 0.001$). The median admission GCS score was significantly lower in rural compared to urban patients ($p = 0.022$). The need for neurosurgery, need for ICU admission or length of hospital stay was not significantly different between rural and urban patients. Rural patients have a fourfold higher mortality compared with urban patients (36 vs 9%, $p = 0.001$). Amongst survivors, there was no significant difference in median length of hospital stay or mean discharge GCS.
Conclusions Cerebral GSWs are highly lethal injuries associated with significant mortality. Rural patients have a significantly longer transfer time, lower GCS on arrival and higher mortality than urban patients. Efforts should be directed at improving the pre-hospital EMS system in order to reduce delay to definitive care so that patient outcome can be optimised.

Keywords Cerebral gunshot wound · Gunshot wound of the head · Rural · Urban

Introduction

According to the Lancet commission on global surgery, surgical conditions account for approximately 30% of the global burden of disease, yet it is estimated that two-thirds of the world's population cannot access safe surgery and anaesthesia. This translates into significant preventable morbidity and mortality [1]. Globally, it has long been recognised that within countries, there are major discrepancies in access to healthcare, and urban centres tend to be better served than more rural [2–5] centres. This is especially the case in South Africa, which is classified as a low middle-income country (LMIC). The literature has also consistently shown that globally, rural trauma patients have higher mortality and worse outcome than their urban counterparts.

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Several reasons for this discrepancy have been postulated, but the literature on rural trauma outcomes in the South African context is limited. Since the advent of democracy in South Africa, substantial efforts have been made to address the deficits in rural healthcare, but much of this has been directed towards maternal health, child health and infectious diseases. Trauma is a surgical disease and has nevertheless remained a neglected epidemic [5–8]. As the AIDS pandemic is brought under control, it is expected that the burden of disease due to trauma and other surgical conditions will increasingly be recognised as a major problem. However, the capacity to deliver surgical care in rural areas in South Africa appears to have deteriorated and the burden of trauma in rural areas, their relationship between outcomes and the geographical location remains unclear. An evidence-based platform to motivate for increased attention to developing and enhancing surgical capacity in rural South Africa is thus a current priority. This study focuses on a specific and very dramatic injury, namely gunshot wounds (GSW) of the head. A cerebral GSW is a highly time-dependent injury and long delays to appropriate care exacerbate secondary brain injury [9–11]. This study was designed to examine whether any discrepancies exist in the outcomes for this injury based on whether the patient sustained the injury in a rural or an urban setting.

Materials and methods

Clinical setting

This study was a retrospective review of a prospectively maintained regional electronic database. It was undertaken in the Pietermaritzburg Metropolitan Trauma Service (PMTS), Pietermaritzburg, South Africa. Our electronic regional trauma registry was reviewed for the 5-year period from January 2010 to December 2014. Ethics approval to maintain this database has been granted by the Biomedical Research Ethics Committee (BREC) of the University of Kwa-Zulu Natal (BE221/13 and BE 207/09). KwaZulu-Natal is located on the east coast of the country and has a population of over 11 million. Fifty per cent of the population live in the rural areas. The PMTS provides definitive trauma care to the city of Pietermaritzburg, the capital of Kwa-Zulu Natal (KZN) province. It is one of the largest trauma centres in the province and also serves as the referral centre for 19 rural hospitals within the province, with a total catchment population of over three million. The catchment area is divided into two distinct health districts. The urban district (UD) includes the city of Pietermaritzburg and the surrounding suburban areas. The rural district (RD) includes all areas outside the geographical boundaries of the city of Pietermaritzburg. In the RD, district hospitals provide basic, non-specialist healthcare. Urban patients are transported by ambulance directly to our trauma centre, while rural patients are transported to the nearest healthcare facilities within the catchment area and subsequently referred to our trauma centre. There is a chronic shortage of ambulances within the province, and delays in evacuation of victim and transportation are common [10]. Approximately 3000 trauma cases are admitted to the PMTS per annum, with over 50% being due to penetrating trauma. This is a direct reflection of the high incidence of interpersonal violence and criminal activities through the entire province.

Prehospital emergency medical service (EMS)

South Africa operates a ‘two-tier’ pre-hospital EMS system, consisting of a public sector service and a private service [8]. All the patients in this study were transported by the public sector EMS. The available literature on the pre-hospital burden of trauma in KZN suggests that the system is overwhelmed and has inadequate command and control systems. In addition, the level of training and experience of the public service EMS personnel is extremely heterogeneous. All this translates into delays in both evacuation and transportation of rural trauma patients. Once a patient has been retrieved he is usually evacuated to the nearest healthcare facility. This may not be the most appropriate facility and attempts to develop a more robust trauma system are ongoing [8].

The study

All patients who sustained a single, isolated cerebral GSW were included in this study. Those with concurrent GSWs to other body regions were excluded. Basic demographic data were reviewed. Specific information was sought regarding the geographical locations of the incident within the catchment area, as well as the time of injury, and the ambulance transport time from location of incident to our trauma centre. Patients who sustained the injury within the UD were classified as ‘urban’, while those with injuries within the RD were classified as ‘rural’ patients. Further data review included the mode of injury namely assault, suicide or accident, the types of firearm, vital signs on arrival, physical examination findings, Glasgow Coma Scale (GCS) and the final clinical outcome. The conventional classification of injury severity based on GCS was used to group all patients into three categories: mild [13–15], moderate [9–12] and severe [3–8].

Statistical analysis

Data were processed and analysed using Stata 13.0 (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP). Continuous variables were summarised using mean and standard deviation (SD). If evidence of skewing/asymmetry was found then median and interquartile range (IQR) presented instead. Differences in means of continuous variables such as age by urban/rural setting were assessed using the student's *t* test. Association between categorical variables and urban/rural setting was assessed using the Pearson Chi squared (χ^2) test or Fishers exact if expected cell count with fewer than observations. Significance cut-off used was 5%.

Results

Description of cohort

During the 5-year study period, a total of 102 patients sustained an isolated cerebral GSW. Ninety-two per cent (94/102) were males and the mean age was 29 years. Ninety-four per cent (94/102) of injuries were related to interpersonal violence (assaults). The remaining 6% (6/102) were attempted suicides, all of whom were males. Ninety-eight per cent (100/102) involved the use of low-velocity firearms (LVF), and the remaining 2% (2/102) were high-velocity firearms (HVF). Figures 1, 2 and 3 show typical CT scans of patients with a cerebral GSW.

Rural vs urban patients: demographics

Of the 102 patients in the study, 54% (55/102) were from the UD and were transported directly to our trauma centre. The remaining 46% (47/102) were from the RD and had initially been transported to a rural district hospital prior to being referred to our trauma centre. The time of injury was available in 60% (61/102) of patients. The mean time from injury to arrival for all patients was 11 h (SD 7). The mean time from injury to arrival was significantly shorter for UD versus RD, 6 h (SD 5) and 15 h (SD 5), respectively ($p < 0.001$). Table 1 summarises the demographics, weapons, injury pattern and the time to definitive care.

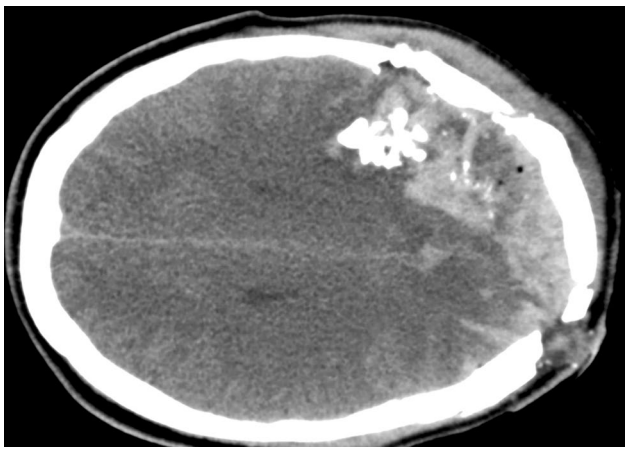

Fig. 1 Axial CT image of trans-frontal GSW

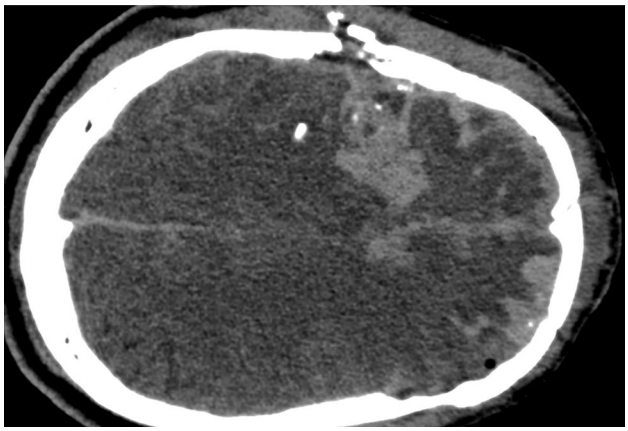

Fig. 2 Axial CT image of left temporo-parietal GSW

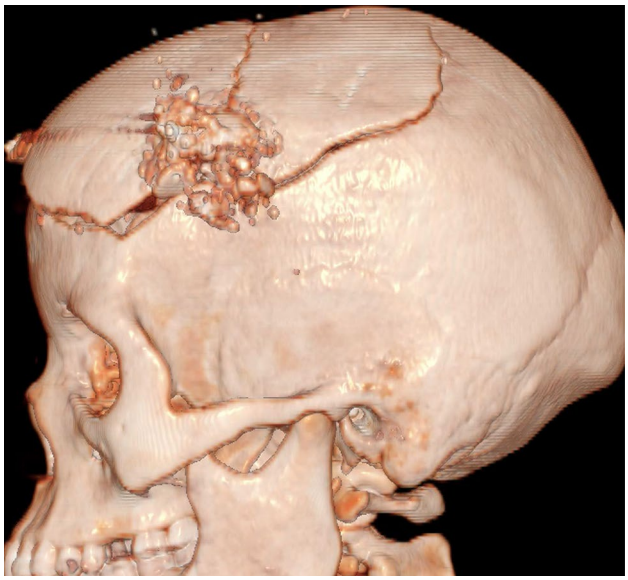

Fig. 3 3D reconstruction of left fronto-temporal GSW

Rural vs urban patients: clinical status and progress

Table 2 summarises the comparison between rural and urban patients in terms of admission clinical status and clinical progress. The median admission GCS score

Table 1 Comparison of demographics, weapons, injury pattern and the time to definitive care between rural and urban patients with cerebral GSWs

	Rural ($N = 47$)	%	Urban ($N = 55$)	%	p value
Demographics					
Mean (SD), age (years)	30 (10)		29 (6)		0.467
Male	42	89	52	95	0.465
Female	5	11	3	5	
Weapons					
Low velocity	46	98	54	98	1.000
High velocity	1	2	1	2	
Injury					
Assaults	42	89	54	98	0.092
Suicide	5	11	1	2	
Mean (SD) time from injury (h)	15 (5)		6 (5)		<0.001

Table 2 Comparison of admission clinical status and clinical progress between rural and urban patients

	Rural ($N = 47$)	%	Urban ($N = 55$)	%	p value
Admission clinical status					
Median (IQR), heart rate (per min)	81 (60–102)		82 (71–100)		0.314
Median (IQR), systolic BP (mmHg)	125 (113–145)		121 (104–130)		0.017
Mean (SD), temperature °C	36 (1)		36 (1)		0.249
Median (IQR), admission GCS	14 (4–15)		15 (12–15)		0.022
GCS <8	13	28	7	13	0.058
GCS ≥8	34	72	48	87	
Visible brain matter	21	45	10	18	0.004
Clinical progress					
Neurosurgical procedure	14	30	17	31	0.902
Median length of stay (in days)	5 (2–8)		5 (2–6)		0.300
ICU	3	6	4	7	0.859

Table 3 Comparison of overall in-hospital mortality between rural and urban patients

	Rural ($N = 47$)	%	Urban ($N = 55$)	%	p value
Clinical outcome					
Non survivors	17	36	5	9	0.001
Survivors	30	64	50	91	
Median (IQR), length of stay (days)	5 (2–9)		5 (3–7)		0.917
Mean (SD), discharge GCS	14 (2)		14 (2)		0.698

was significantly lower in the rural patients compared to urban patients ($p = 0.022$). The need for neurosurgical procedure, ICU admission or length of hospital stay was not significantly different between rural and urban patients.

Rural vs urban patients: clinical outcome

Table 3 summarises the difference in outcome between rural and urban patients. Rural patients have a fourfold higher mortality compared with urban patients (36 vs 9%, $p = 0.001$). Amongst survivors, there was no significant difference in median length of hospital stay or mean discharge GCS. The deaths are summarised in Table 4.

Discussion

A cerebral GSW is one of the most lethal forms of traumatic brain injury [9–16]. In the civilian setting, it typically affects the young and economically active part of the population and is associated with significant morbidity and mortality [9, 10]. Over 90% of victims will die prior to reaching hospital, and a further 50% die in the resuscitation room [9, 10]. Numerous clinical factors may influence the outcome of these injuries. These include the cause of injury (suicide, assault or accident), the type of weapon, the path of the bullet and admission GCS. Our data suggest that the injury pattern is similar in the urban and rural patients. The weapons used were

Table 4 Comparison of deaths between rural and urban patients

Characteristics	Rural ($N = 17$)	%	Urban ($N = 5$)	%	p value
Demographics					
Mean age (years)	29		31		0.467
Male	17	100	5	100	0.465
Female	0	0	0	0	
Cause of death					
Structural brain injury	3	18	0	0	0.558
Nosocomial pneumonia	10	59	4	80	0.386
Other nosocomial sepsis	1	6	0	0	0.468
Unknown	3	18	0	0	0.558
Time to death					
<1 week	10	59	1	20	0.126
>1 week	7	41	4	80	

overwhelmingly low-velocity hand-guns in both groups. This implies that we have identified a group of demographically similar patients with similar injuries, yet with a discrepant outcome. This strongly suggests that the reason for the discrepancy in outcome is related to an extraneous factor and our data suggest that this factor is rural origin as opposed to urban origin of the patient. The prolonged retrieval time and delays to definitive care associated with rural trauma almost certainly account for this discrepancy in outcomes. The rapid evacuation and transfer of these patients to a specialist trauma centre capable of definitive care is essential if one wishes to achieve an optimal outcome [3–5]. In countries with mature trauma systems where patients receive timely and appropriate treatment, reasonably good clinical outcomes can be expected. This is typified by the relatively good outcome achieved in the case of US congresswoman Gabrielle Giffords who survived an assassination attempt thanks to a mature and efficient trauma system [11].

Trauma in South Africa has been described as the malignant epidemic. Despite the advent of democracy the levels of trauma in the country have remained stubbornly high. Of major concern is that a great deal of this trauma is interpersonal [9–16]. In addition, interpersonal violence as a mechanism of trauma in South Africa is not restricted to urban conurbations but is also common in rural areas, as is shown in this audit. In other countries interpersonal violence is very much a feature of urban areas rather than rural ones [3–5].

Although we have shown that suicide attempts were more common in the rural population, the pattern of injury is largely similar to the urban population, with low-velocity firearms being the most common weapon used. A cerebral GSW is a highly time-dependent injury. Delays in appropriate treatment exacerbate secondary brain injury. Prolonged extraction and transfer times will translate into worse outcomes. The international literature has consistently shown that injuries sustained in rural areas are associated with higher mortality and worse outcome rates than the equivalent injury sustained in an urban setting [3–5]. Esposito et al. from Washington demonstrated that the crude mortality rate for trauma patients in rural settings was three times that of patients from urban areas [2]. Similarly Gomez et al. from Ontario showed that there was a threefold increase in mortality among patients injured in regions with limited access to specialised trauma care. There are many potential explanations for these observed discrepancies, which include differences in the quality of pre-hospital care, delays in transport and prolonged extraction times [4].

KwaZulu-Natal is the largest and most populous province of South Africa and has a population of over 11 million people of whom half reside in rural areas [7, 8]. Although a pre-hospital emergency medical service (EMS) exists, it less well organised than comparable services in high-income countries (HIC) and it is relatively under resourced [7, 8]. Our data have shown that the mean transport time for rural patients were significantly longer than their urban counter part. Moreover, rural patients tend to have a lower GCS on arrival. This is most likely related to prolonged extraction and transfer times, which exacerbate secondary brain injury due to hypoxia, hypotension and hypoglycaemia.

Rural patients have a fourfold increase in mortality compared with their urban counterparts. There were two main causes of death in this study. Early deaths (within 1 week) are likely to reflect the severity of the underlying brain injury whilst late deaths (beyond 1 week) are usually reflective of death due to nosocomial sepsis. This is especially relevant in our developing world setting where resources for specialised rehabilitation facilities are lacking. Furthermore, although not statistically significant, early deaths appeared to be more common in rural patients.

While cynics may argue that the 'devil of distance' is difficult to overcome, investing in the reorganisation of the EMS to improve rural extraction and retrieval times has been shown to improve outcome in rural trauma patients [13]. Literature from HIC also shows that the implementation of a rural trauma network results in improved outcomes for rural patients [14, 15]. While the reasons behind the higher mortality rate for rural trauma patients are certainly multifactorial, efforts should be directed towards improving the EMS. This will hopefully ensure more rapid transfer of rural trauma patients to a centre capable of delivering appropriate care and improve patient outcomes.

Conclusions

Cerebral GSWs are highly lethal injuries associated with significant mortality. Rural patients have a significantly longer transfer time, lower GCS on arrival and higher mortality. Efforts should be directed at improving the pre hospital EMS system in order to reduce delay to definitive care so that patient outcome can be optimised.

Compliance with ethical standards

Conflict of interest We received no funding for this research and have no conflicts of interest to declare.

Ethical approval We have the necessary ethical approval for this study from the Biomedical Research Committee (BREC) of the University of KwaZulu-Natal (BCA221/13). We have ethics approval to keep and use this database (BE 207/09, 221/13).

Author contributions VYK: analysis and drafting. GLL: design of data capture instrument. JLB, Database maintenance and data retrieval. JO: data cleaning and reference management. BS: statistics. PB: drafting, reference checking. DLC: senior author, general supervision, coordination and assistance at all levels.

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