Research

Penetrating injury from interpersonal violence and related haemorrhagic shock resuscitation practices in an urban South African emergency medical service

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Abstract

Introduction
Physical injury is a major cause of premature death and/or disability worldwide. South African mortality statistics indicate approximately half of all injury-related deaths were intentional, often from sharp-force injuries. Injury surveillance data for victims of penetrating injury is scarce in low- to middle-income countries with a reliance on mortality data. The aim was to provide an epidemiological description of penetrating injury and the related haemorrhagic shock resuscitation practice in a South African emergency medical service.

Methods
A prospective, observational, descriptive study was conducted in urban Cape Town. 'R' statistical computing was used. Emergency care providers voluntarily documented parameters for mechanism of injury, vital signs, intravenous fluid resuscitation and demographic information for patients with penetrating injury.

Results
Of 2884 (N) penetrating trauma cases, 143 (n) cases were sampled from providers. The chest (35.7%) and upper-limbs (31.5%) were the most common anatomy for penetrating injuries. The estimated mean crystalloid fluid volume administered for penetrating abdominal and chest injuries was 1010.6 mL and 925.3 mL respectively. A statistically significant association was observed between fluid administration and clinical indications such as systolic and diastolic blood pressure, heart rate, capillary refill time, level of consciousness estimation from the scene of the incident to the hospital after intravenous fluid administration. Most emergency medical service call outs (56%) were likely to occur between 20:00 and 02:00.

Conclusion
The intravenous fluid management by pre-hospital emergency care providers for patients with penetrating traumatic injuries, do not cohere with hypotensive resuscitative recommendations. Future research must include clinical practice guideline implementation efficacy and pre-hospital surveillance mechanisms. This study informs hospital clinician expectations for penetrating trauma care by pre-hospital providers.

Keywords:
pre-hospital emergency care; haemorrhagic shock; penetrating injury; interpersonal violence burden

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Introduction

Physical injury is a major cause of premature death and disability worldwide (1) with a greater incidence in low- to middle-income countries (LMIC) (2). Mortality statistics for South Africa indicate that approximately half of all injury-related deaths were intentionally inflicted, often as a result of sharp-force injuries (3). Pre-hospital emergency care (EC) providers are often the first medical contact for trauma patients in South Africa yet little is known about their intravenous (IV) fluid management practices and penetrating injury surveillance. This article considers the STROBE guidelines for reporting observational studies (4).

Injuries, whether unintentional or intentional, raise major public health concerns due to the potential for disability or death. Previously, it was understood that injuries were unavoidable and events random. Injury can now be viewed as a preventable cause of trauma, particularly after the introduction of injury-specific preventive measures at a primary, secondary and tertiary level (5,6). Effective primary injury preventive measures aimed at healthy people included, for example, the provision of early childhood education, family counselling to prevent violence and the mandatory use of seat belts/car seats for children (7). As a public health concern, secondary prevention emphasises the understanding and characteristics of traumatic injuries including pre-hospital care for injured persons as they relate to early diagnosis and prompt treatment of clinical manifestations, such as haemorrhagic shock. Tertiary prevention is at the level of the injury outcome and focusses on disability limitation and rehabilitation of survivors.

Studies relating to penetrating injuries have produced noteworthy findings in the management of penetrating injuries as well as demographic data (8,9). However, reports suggest that trauma-related deaths in LMIC are frequently declared in the community (10) and may heighten the EC value proposition. The 2015 injury-related mortality statistics for South Africa indicate that approximately half of all injury-related deaths were intentionally inflicted, with the majority of homicide-attributed deaths caused by sharp force injuries/stabbing, gunshot injuries or blunt-force injuries (11).

Injury prevention is a paramount concern in high income countries (HIC). However, the highest premature mortality and permanent disability due to injury are found in LMIC (4); it is these countries that have the greatest and most pressing need for injury prevention strategies. Few countries have injury surveillance systems generating reliable information on the nature and extent of injuries, most notably with non-fatal injuries and those that do are more likely to be found in HIC (7). In order to reduce the injury surveillance gap, the backbone of evidence-based injury prevention should be injury surveillance, described 'as the systematic collection, analysis, interpretation and dissemination of data on injury and its determinants' (12). Pre-hospital care facilitated by emergency medical services (EMS) may contribute 'injury determinants' in the broad sense as they potentially confound the causal chain for secondary injury. The aim of this study was to undertake a description of pre-hospital penetrating injury and related IV fluid resuscitation practices.

Methods

Research design and participant selection
A prospective, cross-sectional, observational, self-reported design was used to undertake surveillance of penetrating injury and related pre-hospital EC IV fluid therapy.

Ethical approval was granted by the Cape Peninsula University

Table 1. Study inclusion criteria

Criteria	Description	Rationale
Penetrating traumatic injury	The patient must have suffered a traumatic injury that was caused by a sharp object that may include, but is not limited to: glass objects (eg. broken bottle), sharp metal object (knife or other improvised devices), bullet(s) or any other object that has a sharp edge, excluding needles	The causes of penetrating injury are intended to be consistent with those used in related studies for comparability
Patient age	Patient is >12 years of age	Shock treatment regimens differ for children <12 years
Wound age	The wound/injury should not be older than 24 hours before patient care	Older wounds may confound the physiological responses to treatment and treatment options
Primary calls	EC providers had to be the first to provide medical care. This excludes inter-facility transfers that are classified as 'urgent'	First responder efficacy was of interest in this study. Delayed care may imply confounding sequelae
Transportation	Patients have to be transported to a medical facility. Patients that refuse transportation or are discharged in the field are not eligible for inclusion in the study	Care bundles are likely to be interrupted in cases of pre-hospital discharge
Data collection	Only one Pre-Hospital Penetrating Injury and Fluid Management Survey should be completed per patient	This is to avoid erroneous duplication of cases

of Technology (CPUT/HW-REC 2013/H28). The risk of selection bias was inherent in self-selected participation. Participants were therefore required to be registered as professionals with the Health Professions Council of South Africa (HPCSA). Practitioners from multiple urban ambulance bases had equal opportunity to participate, albeit limited by variable penetrating trauma call exposure and reporting. Clinical data was collected during February to April 2014 on an observational data collection instrument (as a focussed medical record in addition to their respective patient care record) from pre-hospital EC providers after they had treated patients with penetrating injuries. Key modular information (mechanism of injury, intent, type of injury, place of occurrence and patient demographics) from the International Classification of External Causes of Injuries (ICECI, Version 1.2) was used in the design of the data collection tool for external validity (13). The inclusion criteria are described in Table 1. Acute trauma presentations and the likelihood of shock are included. Confounding variables such as incomplete treatment and delayed health seeking are considered.

Data analysis

Non-random, purposive sampling was used. This sampling technique was due to the nature of the problem being investigated as well as the factors described in the sampling frame which included qualification type and related scope of practice. Similarly, EC providers are unaware when traumatic incidents will occur or which EC provider will respond to the emergency. Thus target sampling, quota sampling or other non-probability or probability sampling methods were unsuitable. Private EMS and EC students were excluded. Deaths on scene, deaths in ambulance and patients refusing care were excluded. A minimum response rate was not determined prospectively. Rather, the appropriateness of the sample size was calculated post facto. Additionally, to cross check the

sample size appropriateness, statistical methods using statistical task of estimation (estimating proportions) and statistical task of inference (hypothesis testing) were used.

In this study, the study population (total number of trauma cases seen by EMS during the 3-month period of the study, excluding deaths on scene, deaths in ambulance and patients refusing care) was N=2884. The actual sample size used in the study was n=143. This sample size was sufficient to estimate a proportion actually equal to 0.5 within ± 0.08, 19 times out of 20. It is also sufficient to achieve a power of nearly 80% in a one-sided test of the hypothesis $H_0 : p = p_0$ with an effect size of 0.1 and a significance level of 5% (Figure 1). Considering the study's aim, descriptive statistics was used to analyse the reported data measuring frequencies and where applicable, Pearson's chi-squared test for independence was used to test for an association between categorical variables. Critique of the data is in relation to fluid resuscitation theory and current clinical standards.

Results

Demonstrating the interpersonal violence burden for youth, 60% of (n=143) patients were in the 20–30 years age range and over 90% were in the 15–35 years age range. The mean age for patients with knife injuries in this study was 28.8 years while the mean age of patients with firearm injuries was 28.4 years. There was no statistically significant difference between the mean ages across the categories for knife, bullet or other penetrating injury (p=0.97). A majority 84.6% (121 of 143) of patients were male regardless of the type of type of penetrating injury. A statistically significant relationship between male patients and penetrating chest injuries was observed (p<0.5). A majority 43.4% (62 of 143) of patients only sustained one penetrating traumatic injury.
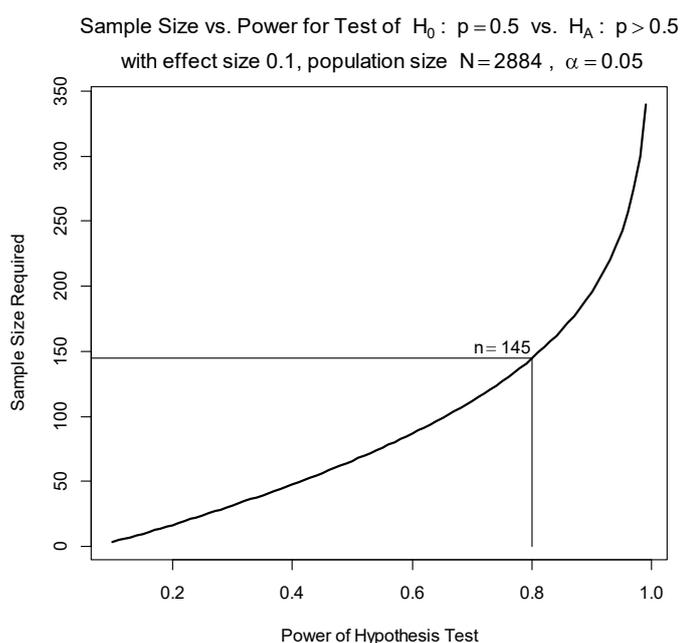

Figure 1. Sample size vs. power

No association was found between gender and the number of wounds (p=0.52). The most common penetrating injury type was knife-related (n=82) followed by bullets (n=50) and other sharp objects (n=10). One case had bullet and knife wounds. No statistically significant association between gender and type of injury was found (p=0.64). There was no statistically significant association with gender and other penetrating injury locations other than trauma to the chest (Table 2). Findings from this study indicated that the chest (35.7%, n=51), upper-limbs (31.5%, n=45) and the lower limbs (23.1%, n=33) were the most common anatomical areas for penetrating traumatic injuries. There was a significant association between gender and penetrating injuries to the chest, with chest injuries being more common in male patients (p=0.0097). No other association between gender and injury location could be found except for slight evidence that upper limb injuries are relatively more common among females (Table 2).

In this study, 77.6% (111 of 143) of all cases received IV fluid. The mean fluid volume administered to all cases was 901 mL (95% CI: 789.7–1012.2 mL). The mean volume of fluid administered to patients with penetrating abdominal injuries was 1010.6 mL (95% CI: 801.9–1219.3 mL), while mean volume of fluid administered to patients with penetrating chest injuries was 925.3 mL (95% CI: 745.8–1104.8 mL). The mean time period for which IV fluid was administered was 18.33 minutes, with the most frequent (48.9%, n=70) IV cannula bore size of 18 gauge. A comparison of vital signs (on-scene and at hospital) for patients who received IV fluid to those who did not receive was done. On-scene systolic BP is lower by an average of 28.61 units (mmHg)

Table 2. Association between injury location and gender

Injury location	Significant association with gender?	Nature of association	p-value
Chest	Yes	Chest injuries are relatively more common among males	0.0097
Pelvis and abdomen	No	No association	1
Neck, face and head	No	No association	0.70
Upper limbs	No	Slight evidence that upper limb injuries are relatively more common among females	0.074
Lower limbs	No	No association	0.82

Table 3. Comparison of vital signs (on-scene and at hospital) for patients who received IV fluid to those who did not receive IV fluid

Dependent variable	Regression coefficient on 'fluid'	p-value for significance test on coefficient	Statistical significance observed	Nature of relationship
On-scene systolic BP	-28.61	3.52×10^{-7}	Yes	On-scene systolic BP is lower by an average of 28.61 units among those who received fluid compared to those who did not
On-scene diastolic BP	-17.96	3.80×10^{-5}	Yes	On-scene diastolic BP is lower by an average of 17.96 units among those who received fluid compared to those who did not
On-scene heart rate	9.11	0.015	Yes	On-scene heart rate is higher by an average of 9.11 bpm among those who received fluid compared to those who did not
On-scene capillary refill time	1.549	2.62×10^{-8}	Yes	On-scene capillary refill time is higher by an average of 1.549 seconds among those who received fluid compared to those who did not
Hospital systolic BP	-11.71	9.03×10^{-4}	Yes	Hospital systolic BP is lower by an average of 11.71 units among those who received fluid compared to those who did not
Hospital diastolic BP	-7.79	0.023	Yes	Hospital diastolic BP is lower by an average of 7.79 units among those who received fluid compared to those who did not
Hospital heart rate	4.87	0.10	No	-
Hospital capillary refill time	1.311	3.56×10^{-7}	Yes	Hospital capillary refill time is higher by an average of 1.311 seconds among those who received fluid compared to those who did not

among those who received IV fluid compared to those who did not receive IV fluid. Similar findings were observed for systolic BP on hospital arrival (Table 3).

In relation to categorical variables, there was a statistically significant association between on-scene skin temperature and whether fluid was administered ($p=2.14 \times 10^{-6}$). Those who received fluid are more likely to have cold or cool skin temperatures. There is a statistically significant association between on-scene level of consciousness and whether fluid was administered ($p=0.0002$). Those who received fluid are more likely to have a level of consciousness assessment other than alert (ie. responsive to voice, pain or unresponsive).

Furthermore, there is a statistically significant association between hospital skin temperature and whether fluid was administered ($p=8.39 \times 10^{-7}$). Those who received fluid are more likely to have 'cold' or 'cool' skin temperatures. A statistically significant association between hospital level of consciousness and whether IV fluid was administered ($p=0.001$) as those who received IV fluid are more likely to have a level of consciousness other than alert (ie. responsive to voice, pain or unresponsive).

Parametric survival regression models were computed with each of these variables as the dependent variable and a categorical independent variable taking a value of 1 if IV fluids were administered and 0 if not (Table 4). An association between IV therapy and BP was found. If IV fluids were administered then change in systolic BP from scene to hospital was expected to be 15.53 units higher than if no fluids were administered, suggesting that administering IV fluids may cause systolic BP to rise, or mitigates its decrease. If IV fluids were administered then the change in diastolic BP from scene to hospital was expected to be 11.47 units higher than if no fluids were administered, suggesting that administering IV fluids may cause diastolic BP to rise, or mitigates its decrease.

In approximately 90% of cases (n=129), dispatch occurred within 10 minutes of the EMS call out. The time elapsed from dispatch to scene is more varied than time elapsed from call out to dispatch. The mean time taken from the time of EMS call out to hospital time (mission time) was 45.59 minutes (SD ± 15.80). Also notable is that, in relation to patient responsiveness, most cases (72.7%, n=104) were alert on scene with only a slight increase (76.9%, n=110) in the proportion of alert cases upon arrival at hospital.

Discussion

The mean age finding suggests those who are 28 years of age are at almost equal risk of stabbing or shooting injuries. Additionally, the finding of male vulnerability to penetrating chest

Table 4. Change in blood pressure and relationship with IV administration

Dependent variable	Regression coefficient on 'fluid'	p-value for significance test on coefficient	Statistically significant?	Nature of relationship
Change in systolic BP[A]	15.53	4.13×10^{-4}	Yes	If IV fluids were administered then change in systolic BP from scene to hospital was expected to be 15.53 units higher than if no fluids were administered, suggesting that administering IV fluids may cause systolic BP to rise, or mitigates its decrease
Change in diastolic BP[B]	11.47	5.97×10^{-4}	Yes	If IV fluids were administered then change in diastolic BP from scene to hospital was expected to be 11.47 units higher than if no fluids were administered, suggesting that administering IV fluids may cause diastolic BP to rise, or mitigates its decrease
Change in heart rate[C]	-2.042	0.556	No	Administering IV fluids appears to have no relationship to change in heart rate from scene to hospital
Change in capillary refill time[D]	-0.221	0.265	No	Administering IV fluids appears to have no relationship to change in capillary refill time from scene to hospital

[A]Change in systolic BP: an interval-censored variable with the lower bounds of the intervals calculated as the lower bound of hospital systolic BP intervals minus the upper bound of scene systolic BP intervals; the upper bound is calculated as the upper bound of hospital systolic BP intervals minus the lower bound of scene systolic BP intervals
[B]Change in diastolic BP: defined in a way analogous to change in systolic BP with the diastolic variables
[C]Change in heart rate: defined in a way analogous to change in systolic BP but with the heart rate variables
[D]Change in capillary refill time: defined in a way analogous to change in systolic BP but with capillary refill time variables

trauma may imply homicidal intent by the perpetrator, the caveat being that it is unknown if trauma victims were also perpetrators of violence. These results are similar to that found by Brink et al, who investigated victims of physical assault of blunt and penetrating origin (14), and Norberg et al (15), who investigated the cost of treating gunshot victims in Cape Town, South Africa (of which 59% had injuries to the chest). Chest injuries require early recognition. Special clinical interventions for chest injuries in relation to resuscitative measures, pre-operative care and surgical and non-surgical procedures may contribute to the improved outcome of the patient (16).

Gender, as an epidemiological descriptor, is associated with violence. Physical injury studied in the South African context show males at a greater risk of being a victim of injuries caused by violence (17). Male predominance among penetrating injury patients could relate to the suggestion that males are more mobile with active participation in high risk-taking activities (16). Additionally, in a framework of domestic violence (18), Abrahams et al describe males as predominant victims of public displays of gun violence as overt form of hegemonic masculinity, while women remain vulnerable behind closed doors, where guns are used to intimidate, control, hurt and kill intimate partners. Notably, this engendering of violence manifested in no association between gender and the number of injuries, inferring that surviving women are as brutalised as men (with specific regard to wound frequency); further inferring the gender neutrality of penetrating trauma of survivors. However, the association of female cases with upper arm trauma is suggestive of defensive wounding. Concrete displays of misogyny are more likely to be found with cases of femicide or longer term surveillance of serial abuse.

The age demographic finding of our study resonates with previous South African studies investigating traumatic injury (19,20). Demographic findings are of importance to stakeholders responsible for current upstream and downstream injury prevention policy and clinical guidelines and those responsible for safety promotion or violence prevention in LMIC. The consequences of non-fatal violence include post-traumatic stress disorder (21) and risk for substance misuse (22); both outside the time limits of this study.

Intravenous fluid resuscitation for trauma
Fluid resuscitation has been described as a process aimed at restoring tissue perfusion and obtaining haemodynamic stability (23). It was therefore seen as an important clinical intervention for the treatment of shock. The volume of IV fluid administered to patients with penetrating chest trauma in this study raises concerns for patient safety and the goal of mortality reduction. The greater mean volume (almost 1000 mL) administered to patients with abdominal wounds are of concern as the haemorrhage risk may be elevated with increased BP (also documented in this study) and dilution of clotting factors. The current advanced trauma life support (ATLS®) recommendations support the administration of IV crystalloid based-fluids of 1

litre for adult patients, while assessing end organ perfusion and tissue oxygenation (24). Furthermore, ATLS® guidelines addresses the potential benefit of hypotensive resuscitative or delayed IV fluid administration strategies in penetrating injuries, which may prevent additional bleeding until definitive haemorrhage control is achieved (24).

Highlighting the need for low IV crystalloid infusion in penetrating injury is of great importance as the administration of 1.5 litres or more in trauma patients was an independent risk factor for mortality (25). IV fluid volume more than 100 mL/kg leads to an increased inflammatory cytokine level and mortality (26). The debate around the choice of IV fluid type for patients with trauma is not new (27). The areas of debate have included the choice of fluid for resuscitation in the intensive care unit (28) and the role of colloids versus crystalloids in shock (29,30). Evidence from human and animal studies has led to the practice of large IV fluid volumes being discouraged (31,32). Some of these studies have found no evidence of pre-hospital IV fluid administration being beneficial and report that they may in fact be harmful when compared to studies of clinical intervention where IV fluid was withheld (38).

Evidence based practice guidelines for fluid resuscitation
Evidence based practice (EBP) guidelines have been developed for fluid management in the pre-hospital environment with an emphasis on penetrating traumatic injuries (23,32). The previous protocols for Intermediate and advanced life support do not specify the types of IV fluid to be used for trauma (39). South African emergency medicine guidelines have adopted the ATLS® approach in the management of trauma, indicating the administration of a crystalloid fluid bolus of 20 mL/kg and haemorrhage control (40). The South African Pre-hospital Clinical Practice Guideline has given structured recommendations for IV fluid resuscitation for trauma within the context of fluid type, administered volume, clinical presentation (normotensive, hypotensive, controlled vs uncontrolled haemorrhage, internal vs external haemorrhage) and clinical fluid resuscitation end-points (41).

The administration of large IV volumes may also result in isovolaemic anaemia, characterised by 'normal' blood volume but a decreased total haemoglobin concentration resulting in lower oxygen carrying capacity (42). There are cases in our study, where more than 1.5 litres of fluid was administered. This is suggestive that out-of-date HPCSA EC protocols still prevail despite the known harm for cardiac and pulmonary complications, gastrointestinal dysmotility, coagulation disturbances, and immunological and inflammatory mediator dysfunction (43). Immediate versus delayed fluid resuscitation for patients with penetrating torso trauma (with BP ≤90 mmHg) in an urban setting was investigated in an urban setting (44). Delayed aggressive fluid resuscitation for hypotensive patients until operative intervention, also known as permissive hypotension or hypotensive resuscitation is supported in the literature (44-46). Administering IV fluids appears to have no

relationship to change in heart rate or change in capillary refill time from scene to hospital (Table 2). This lack of association is confirmative of the inability of crystalloids to improve tissue perfusion (notwithstanding an elevation in volume). This study questions whether the time taken to place an IV line (time unknown) and administer fluids (mean time of over 18 minutes), results in preventable delays to hospital arrival and definitive care?

The study is limited by the narrow data collection period (a logistical limitation). Seasonal variation in frequency and nature of penetrating trauma cannot be inferred. The self-selection of participation was necessitated by limitations to existing electronic patient records. The findings may be generalisable to other large urban settings where the burden of interpersonal violence is high. Cape Town however, to be cautious, is plagued by gang-violence, weather seasonality and has more advanced practitioners than most other provinces. Also, imprecision may arise from the total number of excluded trauma cases, ie. deaths on scene, deaths in ambulance and patients refusing care.

Conclusion

This study provided a greater insight to the pre-hospital clinical presentation, demographic information and fluid management practices for penetrating trauma. The feasibility of estimating a sample post facto was conducted. The demographic profile of the patient that sustained a penetrating traumatic injury during the collection period was male, 15 to 35 years of age, and injured between the hours of 20:00 and 02:00. In determining the clinical presentation of the penetrating traumatic injury a statistically significant relationship between male patients and penetrating chest injuries was observed. Penetrating injury victims (including gunshots and stabbings) were treated more often by advanced life support compared to intermediate life support providers, however an almost even split was seen in the response to stabbings. The advanced life support response burden to gunshots was double that of the intermediate life support cases. Individuals with penetrating injuries have multi-system trauma and are more likely to be taken to a tertiary level healthcare facility with a dedicated 24-hour specialist trauma unit, implying resource intensity.

This study documents the clinical indicators and endpoints for IV fluid management by pre-hospital EC providers, for patients with penetrating traumatic injuries; but, in relation to fluid volume, does not seem to comply with current clinical recommendations for chest and abdominal injuries. The mean age of injured patients was similar to that found in previous South African epidemiological studies and therefore questions the impact of primary injury prevention programs by state and civil society. The secondary and tertiary injury prevention opportunity by EMS should therefore be harnessed.

Future research in the area of fluid resuscitation and penetrating

trauma should explore the benefits of intersecting shock management practices (through clinical practice guidelines) and injury surveillance data with place or practitioner specific qualitative research in order to uncover individual, community and health and clinical policy-related factors that could be modified to reduce morbidity and mortality and improve clinical praxis. EC is a part of the ecological perspective that emphasises the interaction between, and interdependence of, factors within and across all levels of a health problem (47). The ecological perspective highlights people's (penetrating trauma) interactions with their physical and sociocultural environments (such as EC responses) that are connected by injury surveillance endeavours of interest to EC and public health practitioners, educators and researchers. This study may shape the expectations of hospital clinicians receiving patients with penetrating trauma that are conveyed by ambulance and makes the case for EMS surveillance of trauma and trauma care as an epidemiological, forensic medicine and public health imperative (48-50).

Competing interests

All authors are EC practitioners, with professional registration with the HPCSA and upheld the General Ethical Guidelines for Health Researchers. NN and LDC served on the expert panel (on a voluntary basis) for the clinical practice guideline development in EC. Each author of this paper has completed the ICMJE conflict of interest statement.

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