African Journal of Emergency Medicine 15 (2025) 613–620

Contents lists available at ScienceDirect

African Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/afjem

ORIGINAL ARTICLE

Factors associated with mortality among patients with penetrating non-compressible torso hemorrhage in South Africa: A retrospective cohort study

Smitha Bhaumik [a,*], Adane F. Wogu [b], Lani Finck [a], Maria Jamison [a], Mengli Xiao [b], Julia Finn [a], Hendrick Lategan [c], Janette Verster [d], Shaheem de Vries [e], Craig Wylie [f], Lesley Hodson [g], Mohammet Mayet [g], Leigh Wagner [g], L'Oreal Snyders [g], Karlien Doubell [g], Elaine Erasmus [h], George Oosthuizen [c], Christiaan Rees [i], Steven G Schauer [a,j,k], Julia Dixon [a], Nee-Kofi Mould-Millman [a]

[a] University of Colorado, Department of Emergency Medicine, Academic Office 1, Mail Stop C-326, 12631 E. 17th Ave, Aurora, CO, 80045, USA
[b] Colorado School of Public Health, Department of Biostatistics and Informatics, Fitzsimons Building, 4th Floor, Mail Stop B119 13001 E. 17th Place, Aurora, CO, 80045, USA
[c] Stellenbosch University, Division of Surgery, Department of Surgical Sciences, Francie Van Zijl Drive, Parow, Cape Town, 7500, South Africa
[d] Stellenbosch University, Division of Forensic Medicine, Department of Pathology, P.O. Box 241, Cape Town 8000, South Africa
[e] Collaborative for Emergency Care in Africa, 8A Innesfree Way, Constantia, Cape Town 7806, South Africa
[f] Western Cape Government Health and Wellness, Emergency Medical Services, ESC Private Bag x 24, Bellville, Cape Town 7535, South Africa
[g] Western Cape Government Health and Wellness, P.O. Box 2060, Cape Town 8000, South Africa
[h] Stellenbosch University, Division of Emergency Medicine, Department of Family and Emergency Medicine, P.O. Box 17, Stellenbosch, Cape Town, 7599, South Africa
[i] University of Colorado, Division of Pulmonary Sciences and Critical Care Medicine, Department of Medicine, Academic Office 1, Mail Stop C-326, 12631 E. 17th Ave, Aurora, CO, 80045, USA
[j] University of Colorado, Department of Anesthesiology, Aurora, CO, USA
[k] US Army Medical Center of Excellence, JBSA Fort Sam Houston, Texas, USA

ARTICLE INFO

Keywords:
Non-compressible torso haemorrhage
Penetrating trauma
Mortality risk factors

ABSTRACT

Introduction: Non-compressible torso haemorrhage (NCTH), resulting from penetrating trauma to the chest, abdomen, or pelvis, places patients at high risk of death. The objectives of this study are to characterize the injury profile of patients with penetrating NCTH who receive care within a tiered public trauma system in South Africa and to identify factors associated with mortality.

Methods: This is a secondary analysis of clinical data collected from Sept-2021 through Dec-2023 across 6 hospitals, 4 ambulance bases, and 2 mortuaries in the Western Cape Province that form a cohesive trauma referral pathway. The study included patients age ≥18 years with penetrating NCTH who arrived at the hospital within 3 h and received blood products within 6 h of injury. NCTH was defined as Abbreviated Injury Scale (AIS) ≥ 2 to chest, abdomen or pelvis, with a systolic blood pressure ≤ 100 mm Hg. Data were analysed using multivariable logistic regression and Cox proportional hazards modelling.

Results: There were 202 patients with penetrating NCTH; median age was 29 years, 94 % male, injured by stab wounds (66 %) and gunshot wounds (31 %). Most patients (85 %) sustained injuries to the chest, 33 % to the abdomen, and 1.5 % to the bony pelvis. In a multivariable logistic regression model, elevated Triage Early Warning Score (TEWS ≥7) (OR 4.45, 95 % CI 1.58–13.90), elevated New Injury Severity Score (NISS >25) (OR 4.35, 95 % CI 1.45–16.30), anatomic injury to the abdomen/pelvis (OR 2.76, 95 % CI 1.03–7.74), and receipt of acute airway intervention (OR 4.97, 95 % CI 1.94–13.20) were significantly associated with 7-day in-hospital mortality.

Conclusion: Among patients with penetrating injuries to the torso, high triage scores, high injury severity, early airway interventions, and penetrating abdominal trauma were associated with elevated mortality risk.

* Corresponding author at: Academic Office 1, Mail Stop C-326, 12631 E. 17th Ave, Aurora, CO, USA 80045.
E-mail address: smitha.bhaumik@cuanschutz.edu (S. Bhaumik).

https://doi.org/10.1016/j.afjem.2025.02.002
Received 15 November 2024; Received in revised form 10 January 2025; Accepted 17 February 2025

African relevance

- Clinicians working within tiered trauma referral systems in Africa frequently triage patients with severe torso injuries, with the goal of identifying those who require damage control surgery and/or referral to tertiary centers to reduce mortality risk.
- In this South African population with penetrating non-compressible torso hemorrhage, the following factors were associated with mortality: high acuity at triage (Triage Early Warning Score ≥7), severe overall bodily injury severity (New Injury Severity Score > 25), presence of abdominal or pelvic trauma, and receipt of airway intervention.
- In resource-constrained African settings, earlier recognition of these factors may help trigger timely interventions to minimize morbidity and mortality for patients with penetrating non-compressible torso hemorrhage.

Background

Traumatic injuries are a significant source of morbidity and mortality worldwide, accounting for 8 % of global mortality and 10 % of years lived with disability [1]. Over 80 % of trauma deaths occur in low- and middle-income countries (LMIC), where prehospital care and trauma systems are strained and relatively underdeveloped compared to high-income nations [2]. Haemorrhage is the leading cause of trauma-related mortality, with other common aetiologies including central nervous system injury, sepsis, and multiple organ failure [3].

While haemorrhage due to extremity exsanguination can be temporized with the use of tourniquets and pressure dressings, non-compressible torso haemorrhage (NCTH) localized to the chest, abdomen, and pelvis continues to pose clinical challenges [4–6]. NCTH carries a high mortality risk in both military and civilian populations. A study of US combat fatalities in Iraq and Afghanistan found that 90 % of battlefield deaths were associated with haemorrhage, and of these, two-thirds had NCTH [7]. A review of trauma deaths in the Western Cape Province of South Africa in 2021 found haemorrhage to be the cause of death in 33 % of preventable deaths and that the most frequently injured body regions in haemorrhage deaths were the thorax and abdomen [8].

Early blood product administration and damage control surgery are the cornerstones of NCTH management [9]. Aortic cross clamping via resuscitative thoracotomy or mini-laparotomy may help temporize distal haemorrhage while supporting cerebral and coronary perfusion [10]. Recent treatment advances include the use of junctional tourniquets and specialized haemostatic materials for wound packing but these approaches have yet to be widely adopted [11,12].

Although rapid surgical haemostasis is the optimal treatment for NCTH, it is impracticable in many global settings. Clinicians in resource-constrained settings may manage NCTH patients within prolonged care health systems with frequent delays to resuscitative, definitive, and surgical care beyond what is physiologically needed for optimal outcomes [13–15]. Evaluation of NCTH patients in an African high-trauma, under-resourced, prolonged care health system may yield valuable insights into mortality predictors for NCTH in such contexts. This study adds to the existing data by evaluating associations between injury and intervention-related factors appreciable during early resuscitation, and subsequent in-hospital mortality, through use of multivariable models. Our primary objective is to identify factors that are associated with mortality among patients with penetrating NCTH managed in LMIC healthcare facilities.

Methods

Study design and setting

This study identifies risk factors for 7-day in-hospital mortality among patients with penetrating NCTH who received care within the public trauma system in the Western Cape Province of South Africa and who survived to hospital arrival.

South Africa is a middle-income country with one of the highest injury-related mortality rates in the world outside of warzones [16]. Penetrating trauma from firearms and stab wounds is the most common injury force type in this population, and the public trauma system manages an overwhelmingly large caseload of trauma patients resulting in resource constraints. Prolonged prehospital response times, limited availability of computed tomography, delays in interfacility transfer, and constrained theatre capacity pose significant challenges within these health systems [8,17]. A prior study found that trauma patients with moderate-to-severe acuity in the Western Cape experienced a median time of 3 h from injury to the first critical resuscitative intervention, and 12.5 h for interfacility ambulance transfers [18].

This is a secondary analysis of data collected from September 2021 through December 2023 for the Epidemiology and Outcomes of Prolonged Care (EpiC) study [19]. No additional data were collected for this present study beyond what was collected within EpiC. EpiC enrols patients across 12 locations in the Western Cape Province: 4 government-affiliated emergency medical service (EMS) bases, 6 public hospitals (primary, secondary, tertiary care) and 2 forensic pathology laboratories. These sites span urban, suburban and rural geographies, encompassing a cohesive trauma referral pathway. Further details regarding EpiC's methodology are separately available [14].

The study included patients age ≥18 years with NCTH from a penetrating injury who arrived at the hospital within 3 h of injury and received blood products within 6 h of injury. The 3 h cut-off was selected because many patients with torso trauma experienced delays to facility arrival, but those who arrived beyond 3 h had a much lower mortality proportion. NCTH was defined as Abbreviated Injury Scale (AIS) ≥2 (i.e., a serious injury) to chest, abdomen or pelvis, and a systolic blood pressure (SBP) ≤ 100 mm Hg based on first vitals documented by EMS or upon facility arrival. AIS severity score ranges from 1 (minimally severe anatomic injury) to 6 (maximal, non-survivable anatomic injury). The NCTH definition for this study was based on the definition provided by Morrison and adapted by the study authors given the data that were locally available [9].

Exclusion criteria included prisoners, blunt-force injuries, burns, toxicologic injuries, drownings, or envenomation. Patients with severe injuries to other anatomic regions (AIS ≥ 3) were excluded to improve the homogeneity of the study population. Patients with AIS of 6 to any anatomic region were also excluded, as this generally constitutes a non-survivable injury. Patients with NCTH who died in the prehospital setting were excluded because this study aims to identify risk factors for mortality that are identifiable by frontline clinicians working in the emergency centre (EC). This study received ethics approval with a waiver of patient informed consent by Stellenbosch University Human Research Ethics Committee (Project ID: 14866, Ethics Reference # N20/03/036).

Data collection

Data were abstracted from paper medical records into a secure online electronic database. Variables collected included: demographics, injury mechanism, vital signs, AIS scores, triage early warning score (TEWS), new injury severity score (NISS), resuscitative interventions, surgeries, hospital disposition, and cause and time of death information. The primary outcome was 7-day all-cause mortality from the time of injury; patients who sustain this primary outcome are referred to as decedents.

Time from injury to hospital arrival was calculated using the specific injury time when documented or, when missing, injury time was imputed using EMS dispatch times and/or research physician clinical judgement. Only patients with exact or estimated injury time <3 h before facility arrival were included in this analysis due to the time-sensitive nature of NCTH, to minimize survival bias. Critical resuscitative interventions were defined as those performed during the primary ambulance transport from scene, or at the first facility within the first 24 h of patient arrival, and were categorized into airway, breathing, and circulatory interventions.

TEWS was selected as the primary exposure variable for the survival analysis because it is a physiologically validated measure of severity and a core component of the South Africa Triage Scale (SATS), which is widely used in ECs across South Africa and many sub-Saharan African settings. TEWS is a numerical score that ranges from 0 to 17 and incorporates vital signs, patient mobility, and presence of trauma [20,21]. Patients with a TEWS of 7 or more are assigned the highest acuity per SATS. NISS, a measure of overall anatomic injury severity, was included as a co-variate in the multivariable model; a previous study by Lavoie et al. found a cut-point of NISS>25 to be most accurate for prediction of in-hospital mortality [22].

Statistical analysis

Continuous variables are summarized as medians with 25th and 75th interquartile range (IQR), while categorical variables are described using frequencies and percentages. Comparisons between groups for continuous variables used Mann-Whitney-Wilcoxon tests. Chi-square or Fisher's exact tests were used for categorical variables, as appropriate.

A multivariable logistic regression model assessed the risk of 7-day mortality in patients with NCTH, based on patients' demographic, injury-related, and clinical covariates. A purposeful variable selection strategy was applied to build a clinically and statistically parsimonious model [23,24]. Initially, univariable logistic regressions were fitted for each patient characteristic/variable, and covariates with a Wald test significance level of 25 % were selected for the multivariable model.

The covariates included in the univariable logistic regression were: patient age (continuous), sex, TEWS (≥7: yes/no), NISS (>25: yes/no), AIS for abdomen or pelvis (≥2: yes/no), airway intervention (yes/no), receipt of whole blood or packed red blood cells (yes/no), systolic blood pressure (>90 mmHg: yes/no), surgery within 24 h of injury (yes/no), administration of tranexamic acid (yes/no), and whether the admitting facility had surgical capability (yes/no).

In the multivariable logistic regression, an iterative approach was employed, retaining only covariates with a significance level of 5 % or those with strong clinical justification. A partial likelihood ratio test was used to compare the full and reduced models throughout this process. Covariates excluded in the univariable and multivariable modelling steps were reassessed for potential confounding effects on the risk of 7-day mortality, and those that caused more than a 20 % change in parameter estimates were reintroduced into the final model.

Based on the final selected covariates, we fitted a multivariable Cox proportional hazards (pH) model to evaluate the hazard of all-cause mortality within the 7-day follow-up, followed by adjusted survival curves [25,26]. The survival curves were plotted by TEWS group (TEWS ≥7 vs. <7) as it is the primary clinical covariate in the study. Associations between mortality risk and covariates were reported as odds ratios (ORs) with 95 % confidence intervals (95 % CI) for the logistic models, and hazard ratios (HRs) with 95 % CI for the Cox pH models. All analyses were conducted using R (version 4.3.3, R Foundation for Statistical Computing, Vienna, Austria) [27].

Results

Of 13,567 patients enrolled during the study period, 202 (1.5 %) patients sustained penetrating NCTH (Fig. 1) and met the inclusion criteria. Median age was 29.1 years with 94.1 % male patients (Table 1). 198 out of 202 (98.0 %) injuries were due to interpersonal violence. Stab wounds were the most common mechanism of injury (66.3 %), followed by gunshots (31.2 %). Most patients (84.7 %) sustained injuries to the chest, one-third (32.7 %) to the abdomen, and 1.5 % to the bony pelvis. Blood products were initiated within 1 h of injury for one-quarter of patients (28.7 %). Tranexamic acid was given to 55.4 % of patients, and freeze-dried plasma to 79.2 %. Sixteen individuals (7.8 %) received autologous blood products from the chest tube, including 13 survivors and 3 decedents ($p = 0.68$). Tube thoracostomy insertion was the most frequently provided resuscitative intervention (67.8 %). Commonly performed early resuscitative interventions are summarized at the end of Table 1. There was a total of 31 deaths (15.3 %).

Decedents had more severe physiologic derangements, characterized by a higher TEWS (median TEWS 9 [IQR 7–11]) compared to survivors (median 6 [IQR 4–8]; $p < 0.01$). Decedents also had higher overall anatomic injury severity as characterized by median NISS (42 [27-57] vs 22 [12–30]; $p < 0.01$). Decedents had comparable median SBP on arrival (SBP 82 [52–122] vs 92 [78–115] mm Hg; $p = 0.11$), and were more

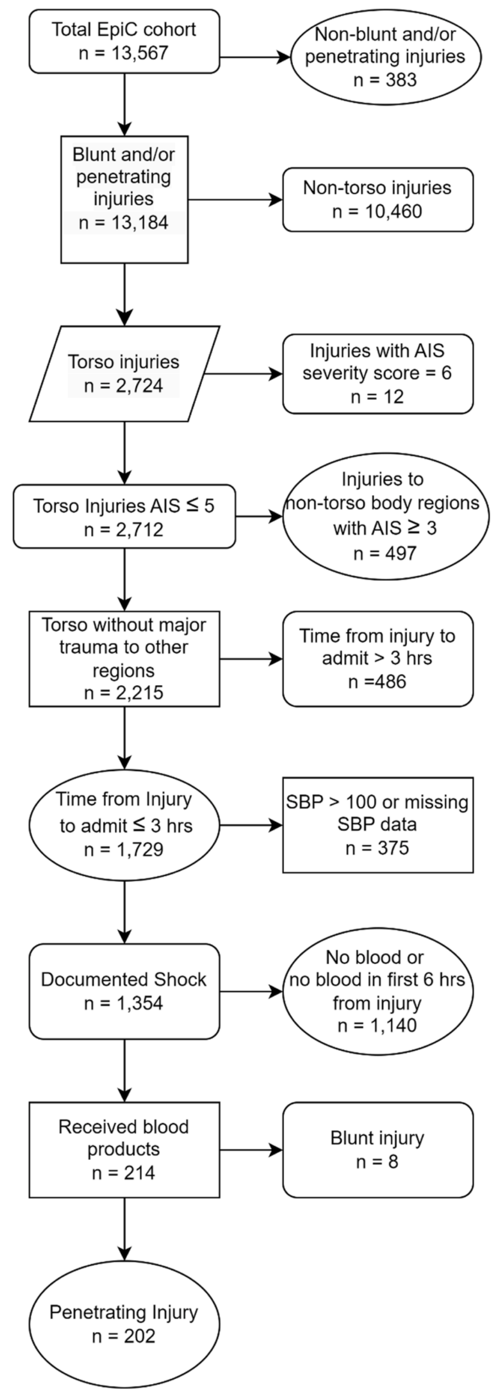

Fig. 1. Enrollment diagram.

Table 1
Comparison of survivors and decedents with penetrating NCTH.

	Total (n = 202)	Survivors (n = 171)	Decedents* (n = 31)	p-value
Age	29.1 (24.6–36.4)	29.6 (24.7–37.0)	27.9 (22.2–34.2)	0.17[d]
Male Sex	190 (94.1 %)	161 (94.2 %)	29 (93.5 %)	0.99[e]
Dominant Mechanism of Injury				0.41[e]
Stab wound	134 (66.3 %)	116 (67.8 %)	18 (58.1 %)	
Firearm	63 (31.2 %)	50 (29.2 %)	13 (41.9 %)	
Struck/hit	4 (2.0 %)	4 (2.3 %)	0 (0.0 %)	
Other	1 (0.5 %)	1 (0.6 %)	0 (0.0 %)	
First Hospital Systolic Blood Pressure	91 (76–117)	92 (78–115)	82 (52–122)	0.11[d]
First Hospital Shock Index	1.0 (0.8–1.3)	0.9 (0.8–1.3)	1.0 (0.7–1.3)	0.85[d]
Triage Early Warning Score	6 (5–8)	6 (4–8)	9 (7–11)	<0.001[d]
New Injury Severity Score	25 (14–34)	22 (12–30)	42 (27–57)	<0.001[d]
Anatomic Regions of Torso Injury				
Chest Injury[a]	171 (84.7 %)	147 (86.0 %)	24 (77.4 %)	0.28[e]
Highest Chest AIS Severity Score	3 (3–5)	3 (3–4)	5 (4–5)	<0.001[d]
Abdominal Injury[a]	66 (32.7 %)	53 (31.0 %)	13 (41.9 %)	0.32[e]
Highest Abdomen AIS Severity Score	3 (2–4)	3 (2–4)	3 (3–4)	0.20 [d]
Bony Pelvis Injury[a]	3 (1.5 %)	2 (1.2 %)	1 (3.2 %)	0.40[e]
Highest Bony Pelvis AIS Severity Score	2 (2–2)	2 (2–2)	2 (2–2)	1.0 [d]
Polytrauma[b]	37 (18.3 %)	30 (17.5 %)	7 (22.6 %)	0.68[e]
Time to First Blood (h)	1.8 (0.9–2.8)	2.1 (1.0–3.0)	0.8 (0.5–1.5)	<0.001[d]
Blood Product Receipt				<0.001[e]
<1 h of injury	58 (28.7 %)	39 (22.8 %)	19 (61.3 %)	
1–6 h of injury	144 (71.3 %)	132 (77.2 %)	12 (38.7 %)	
Blood Products and Adjuncts in First 24h				
Tranexamic Acid	112 (55.4 %)	96 (56.1 %)	16 (51.6 %)	0.79[e]
Whole Blood and/or Packed Red Blood Cells[c]	146 (72.3 %)	118 (69.0 %)	28 (90.3 %)	0.03[e]
Whole Blood from Blood Bank	18 (8.9 %)	16 (9.4 %)	2 (6.5 %)	0.60[e]
Packed Red Blood Cells	130 (64.4 %)	104 (60.8 %)	26 (83.9 %)	0.02[e]
Autologous Blood from Tube Thoracostomy	13 (6.4 %)	10 (5.9 %)	3 (9.7 %)	0.42[e]
Freeze Dried Plasma	160 (79.2 %)	137 (80.1 %)	23 (74.2 %)	0.61[e]
Total Blood Volume in First 24 h (mL)	760 (360–1520)	700 (360–1510)	1120 (650–1840)	0.03[d]
Clear Fluids Volume in First 24 h (L)	3.0 (2.0–4.5)	3.0 (2.0–4.5)	2.0 (1.0–4.5)	0.08[d]
Surgery within 24h	91 (45.0 %)	72 (42.1 %)	19 (61.3 %)	0.06[e]
Time from Facility Arrival to Surgery				<0.001[e]
<1h	10 (11.0 %)	3 (4.2 %)	7 (36.8 %)	
1–6h	44 (48.4 %)	36 (50.0 %)	8 (42.1 %)	
6 - 24h	37 (40.7 %)	33 (45.8 %)	4 (21.1 %)	
Intensive Care Unit Admission	58 (28.7 %)	52 (30.4 %)	6 (19.4 %)	0.30[e]
Airway Intervention	51 (25.2 %)	31 (18.1 %)	20 (64.5 %)	<0.001[e]
Oro-/Naso-pharyngeal Airway	1 (0.5 %)	0	1 (3.2 %)	0.02[e]
Supraglottic Airway	0	0	0	
Endotracheal tube	49 (24.3 %)	31 (18.1 %)	18 (58.1 %)	<0.001[e]
Surgical Airway	1 (0.5 %)	1 (0.6 %)	0 (0.0 %)	0.67[e]
Breathing Intervention	138 (68.3 %)	119 (69.6 %)	19 (61.3 %)	0.48[e]
Needle Decompression	4 (2.0 %)	4 (2.3 %)	0 (0.0 %)	0.39[e]
Chest Seal (Occlusive dressing applied over sucking chest wound)	4 (2.0 %)	3 (1.8 %)	1 (3.2 %)	0.59[e]
Tube thoracostomy/Chest Tube	137 (67.8 %)	118 (69.0 %)	19 (61.3 %)	0.40[e]
Circulation Intervention (Only Bleeding Control by Foley)	8 (4.0 %)	6 (3.5 %)	2 (6.5 %)	0.62[e]

[*] Decedents are defined as patients who suffer from in-hospital death within 7 days of injury
Continuous variables displayed as median (interquartile range).
[a] Defined as Abbreviated Injury Scale (AIS) Severity ≥2.
[b] Polytrauma = 2 or more body regions each with an AIS ≥2 .
[c] Includes autologous blood.
[d] Mann-Whitney-Wilcoxon test.
[e] Chi-sq or Fisher's exact test.

likely to have received blood products within 1 h of injury ($p < 0.01$). Decedents received an average of 1120 mL blood products in the first 24 h, compared to 700 mL among survivors ($p = 0.03$), noting that total volume received was likely reduced by earlier times of death. Airway interventions during acute resuscitation occurred more commonly in patients who died (64.5 % vs 18.1 %, $p < 0.01$).

Within the overall cohort, 91 patients (45 %) underwent surgery within the first 24 h. Survivors and decedents presented from scene to surgically capable hospitals with similar frequencies (79.5 % vs. 83.9 %, $p = 0.58$). Decedents were marginally more likely to have received surgery within the first 24 h (61.3 % vs 42.1 %, $p = 0.05$). Common surgeries included exploratory abdominal laparotomies (15 %), other abdominal surgeries (11 %), sternotomies, (9 %), cardiac repairs (8 %), and thoracotomies (7 %). 21 % of patients who underwent operative intervention died, compared to 11 % of patients managed non-operatively.

The primary cause of death among most NCTH decedents was haemorrhage ($n = 21$, 68 %), multiple organ failure or sepsis ($n = 5$, 16 %), other [airway, cardiac tamponade, sequelae of injury] ($n = 3$, 10 %), and catastrophic tissue destruction ($n = 2$, 6 %, one patient with injury to thoracic aorta, one with injuries to major vessel/liver/trachea). Median time from facility arrival to death was 2.1 h (IQR 0.9 - 19.8 h).

Using purposeful selection, a model was developed for predicting 7-day in-hospital mortality among patients with penetrating NCTH. The results of the univariable logistic regression models for each of the covariates included in the purposeful model selection strategy are

Table 2
Multivariable logistic regression evaluating 7-day in-hospital mortality among patients with penetrating NCTH.

Characteristic	OR (95 % C.I.)[1]	p-value
Age, years (continuous)	0.95 (0.89, 1.00)	0.06
TEWS ≥7 (yes vs. no)	4.45 (1.58, 13.90)	0.007
NISS >25 (yes vs. no)	4.35 (1.45, 16.30)	0.015
Injury to abdomen or pelvis (AIS Abdomen/Pelvis≥2) (yes vs. no)	2.76 (1.03, 7.74)	0.05
Airway Intervention (yes vs. no)	4.97 (1.94, 13.20)	<0.001

[1] Odds ratio (95 % confidence interval)
TEWS: Triage Early Warning Score; NISS: New Injury Severity Score; AIS: Abbreviated Injury Scale.

provided in the Supplementary material. The results from the multivariable logistic regression are presented in Table 2. The final model includes five risk factors, many of which can be globally assessed in the early phases of resuscitation: age, TEWS≥7 (equivalent to SATS triage of Red), severe anatomic injury score (NISS>25), presence of abdomen/pelvis anatomic injury (AIS≥2), and receipt of airway intervention. Notably, an initial TEWS≥7 was associated with 4.45 times the odds of 7-day mortality (95 % CI 1.58–13.90, $p = 0.01$). This difference can be further appreciated through visualization of the covariate-adjusted survival curve (Fig. 2). The Cox proportional hazards model confirmed the findings of the logistic regression, with TEWS≥7, NISS>25, and airway intervention associated with elevated hazard of 7-day mortality (Table 3).

Discussion

This study identified risk factors for mortality among South African patients with penetrating NCTH who received care within a tiered public trauma system in the Western Cape Province. After adjusting for age and injury severity by NISS, elevated Triage Early Warning Score (TEWS≥7) and need for intubation were significantly associated with elevated hazard of 7-day mortality in the multivariable Cox proportional hazards model. Presence of abdominopelvic trauma was significant in the multivariable logistic regression model ($p = 0.047$), but not the pH model ($p = 0.135$). This study supports the current approach to trauma

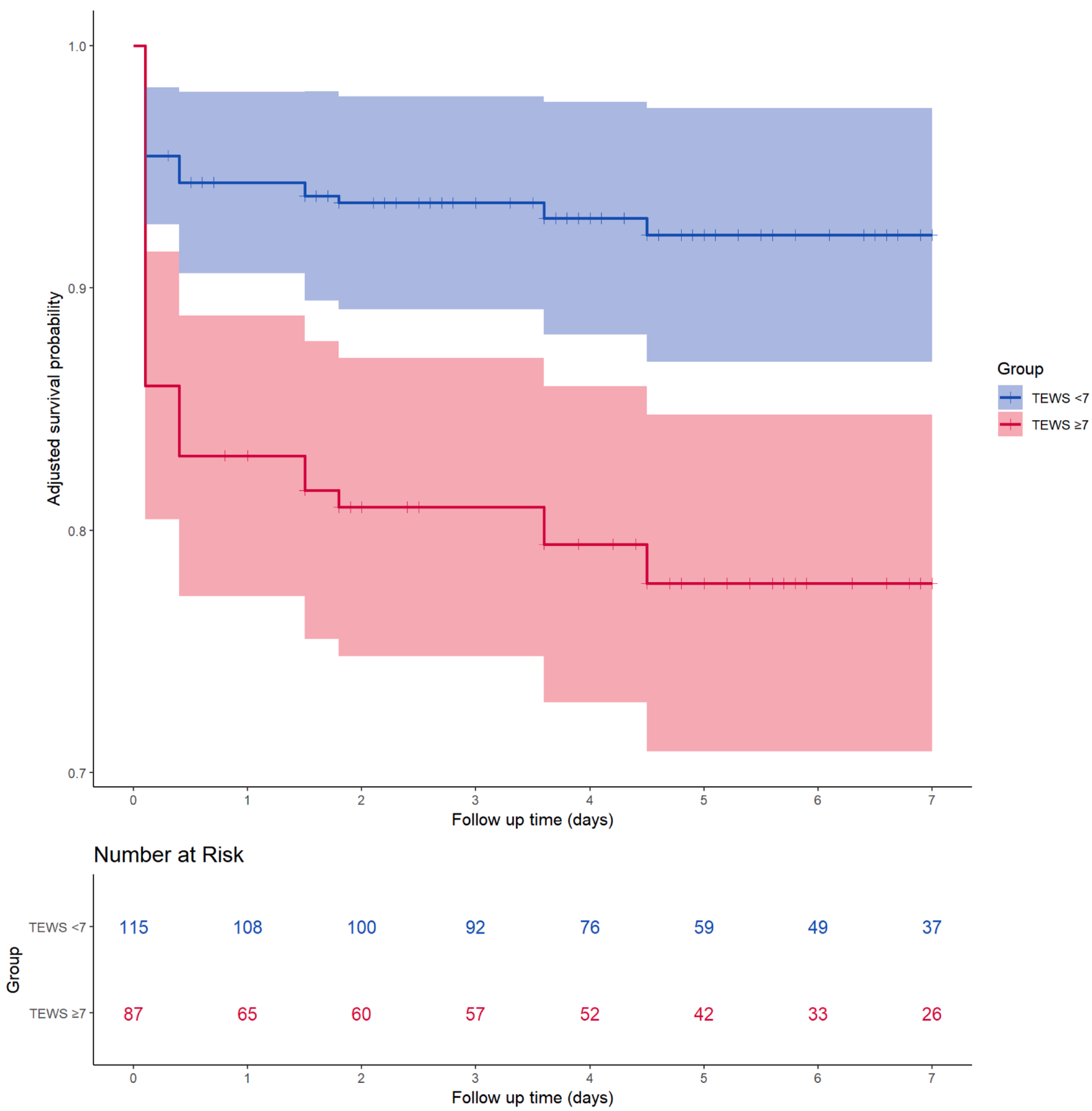

Fig. 2. Covariates-adjusted survival probability plots by TEWS group (TEWS ≥ 7 vs TEWS< 7).

Table 3
Cox proportional hazards model evaluating 7-day in-hospital mortality among patients with penetrating NCTH.

Characteristic	HR (95 % C.I.)[1]	p-value
Age, years (continuous)	0.96 (0.92, 1.00)	0.08
TEWS ≥7 (yes vs. no)	3.49 (1.41, 8.66)	0.007
NISS > 25 (yes vs. no)	3.55 (1.20, 10.60)	0.02
Injury to abdomen or pelvis (AIS Abdomen/Pelvis≥2) (yes vs. no)	1.75 (0.84, 3.64)	0.13
Airway Intervention (yes vs. no)	3.49 (1.58, 7.74)	0.002

[1] Hazard ratio (95 % confidence interval)

TEWS: Triage Early Warning Score; NISS: New Injury Severity Score; AIS: Abbreviated Injury Scale.

triage, where patients with TEWS of ≥7 are classified as high acuity and flagged for immediate stabilization. The model finding that early airway interventions are associated with mortality (even after controlling for overall injury severity) requires further investigation. It remains unclear whether need for airway intervention represents a separate and additive measure of acuity, a potential quality improvement opportunity (e.g. potential under-resuscitation prior to intubation), or a combination thereof. Lastly, it is hypothesized that the presence of penetrating abdominal trauma poses a particular treatment challenge because of limited access to computed tomography and interventional radiology in this setting.

Optimal care of the trauma patient is vital for both individual and national financial security, given this pathology commonly afflicts the working population in LMICs. For every mortality, it is estimated that there are between 10 and 50 injured survivors, half of whom develop permanent disability [28]. Within the study cohort, victims of penetrating NCTH were overwhelmingly young men injured by stab wounds or firearms. Publications from other hospital-based registries in Cape Town, Pietermaritzburg, and Johannesburg have noted a similar demographic distribution, attributable to complex socioeconomic and behavioural factors, including high rates of interpersonal violence, financial duress, and alcohol use in this subgroup [29–31]. Additionally, local epidemiologic data highlight the large overall burden of penetrating trauma in South Africa. Lutge et al. (2016) found that 27 % of all emergency room visits in KwaZulu-Natal Province (KZN) were for trauma, and of these, 19 % were due to stab wounds and 2 % due to gunshot wounds. Over 80 % of penetrating trauma visits in KZN presented to district and regional hospitals [32]. Zaidi et al. examined all cases that presented to a single district hospital EC in Western Cape over one month; 17 % visits were due to trauma, and of these, 16 % had stab wounds, and 7 % had gunshot wounds [33]. These studies suggest that the burden of penetrating trauma is substantial, with some regional variation, and that the district and regional hospitals may shoulder much of the volume.

In the present study, NCTH involved the chest most frequently, and thoracostomy tubes were commonly inserted as part of acute resuscitation. The large caseload of thoracic trauma seen across the Western Cape has led to innovative management protocols for patients with thoracostomy tubes, including early physiotherapy to promote lung re-expansion (e.g., ambulation, exercise bicycles), and use of positive end-expiratory therapy devices such as gloves or bottles [34,35]. The intercostal drains used locally rely on dry seal valves, and are rarely connected to external wall suction, allowing for increased patient mobility. Local clinicians believe this strategy enhances earlier discharge from busy and overcrowded emergency centres and enables conservation of finite resources such as wall suction and trolley beds (Dr. H. Lategan, personal communication, October 2024,). The safety and effectiveness of this practice of early mobilization remains unknown, relative to other methods used.

Some trauma centres in the Western Cape also perform autologous transfusion using the intercostal drain system, wherein pleural cavity blood is salvaged and returned intravenously (provided there is no suspicion of diaphragmatic injury and associated risk of hollow viscus contamination) [36]. Haemothorax blood is a compelling source of blood products in trauma because it is immediately available and compatible. However, its safety remains controversial. Mixing studies demonstrated accelerated coagulation when haemothorax blood was mixed with a patient's own plasma [37] In contrast, a multicentre observational study found no difference in 24 h INR or mortality when comparing patients who underwent autologous transfusion using haemothorax blood to matched controls [38]. Further research is required regarding the safety of autologous transfusion; however, this may represent a reasonable option for emergency transfusion in settings when other blood products are not available.

Among the 31 decedents in the study, half the deaths occurred within 2 h of facility arrival, and haemorrhage was the primary cause of death in most cases based on autopsy. Blood products were administered judiciously in our cohort (median 760 mL given), whereas crystalloid was given more liberally (median 3 L). High-volume crystalloid resuscitation is associated with increased odds of mortality and morbidity secondary to dilutional coagulopathy, hypothermia, increased bleeding, and acute respiratory distress syndrome [39]. Meta-analyses have found that permissive hypotension with a target mean arterial pressure of 50 mmHg may offer a survival benefit [40,41]. Additional tenets of damage control resuscitation include early identification of patients who will require massive transfusion (e.g. by using predictors of massive transfusion), transfusion of a balanced ratio of blood products or whole blood when available, and goal-directed correction of coagulopathy [42,43]. An encouraging development was that 18 patients within the study received whole blood from the blood bank at the major tertiary referral hospital. It remains unclear whether the deaths attributed to haemorrhage in our cohort were related to potential under-recognition of haemorrhagic shock, limited blood supply, delays to damage control surgery, or a combination of these factors. Annual preventable trauma death reviews, in which clinicians and public health experts across the Western Cape convene to discuss representative cases, are helping shed light on areas for quality improvement in relation to haemorrhage control [8].

Local emergency transfusion protocols in the Western Cape call for administration of freeze-dried plasma (FDP) in lieu of fresh frozen plasma (FFP) given the limited blood supply and relative affordability of FDP. FDP was administered in approximately 80 % of cases in this study. FDP is a powder form of plasma which contains coagulation factors relevant for haemorrhage control; FDP can be stored at room temperature, has 2-year shelf stability, and can be quickly reconstituted, which makes it ideal for acute trauma resuscitation [44]. Bioplasma FDP (National Bioproducts Institute, Pinetown, South Africa), a pathogen-reduced ABO-universal plasma, has been used in South Africa since 1996, with over 370,000 bottles transfused with only 48 documented adverse events, demonstrating a comparable safety profile to FFP [45,46]. More research is needed to determine the role of FDP within massive transfusion protocols. Previous studies from this area have suggested FDP has a role in early resuscitation but its optimal use-case remains unclear [44].

Tranexamic acid (TXA) was administered in only 55 % of the cohort, though all patients should have been eligible to receive it. The CRASH-2 trial found that early TXA administration reduced mortality among adult trauma patients at risk for haemorrhage [47]. TXA was implemented into Western Cape Emergency Guidelines in 2013, but compliance has been suboptimal, and reasons cited for this include medication and equipment shortages, time delays to definitive care, and clinician hesitation [48]. Further process improvement efforts may be required to promote implementation of TXA.

This study has a few limitations. First and foremost, this was not a comprehensive epidemiologic sample, as the study sites represent only a subset of the hospitals in the region. Importantly, patients who were dead on scene or who died during prehospital transport were not captured. An estimated 94 % of trauma deaths in the Western Cape occur on scene, mostly due to catastrophic injuries [49]. The risk factors for mortality identified here are applicable only to penetrating NCTH patients that survive to facility arrival. Readers must be cognizant of survival bias inherent to the sample when interpreting these results. Another limitation is the inability to determine the proportion of NCTH patients that had a surgical indication. This information was not available in the medical record, and therefore could not be abstracted for this retrospective analysis. Strengths of the study include the homogeneity of the sample – as patients with severe traumatic brain injury and other extra-thoracic injuries were purposefully excluded – along with use of multivariable analysis to adjust for relevant confounders.

In conclusion, risk factors for mortality among South African patients with penetrating non-compressible torso haemorrhage include high triage scores, early airway intervention, and presence of abdominopelvic injury. Recognition of these factors could trigger earlier actions by local clinicians (e.g., airway protocols and early blood products) and the health system (e.g., EMS bypassing or rapid transfer protocols) to help avert patient deaths. Future studies will prospectively evaluate why airway interventions and abdominopelvic injuries appear to confer elevated mortality risk and to identify what health systems interventions should be introduced. A multi-sector approach is required to address the morbidity and mortality associated with penetrating torso trauma and other traumatic conditions, including primary prevention to reduce interpersonal violence, improved trauma referral pathways, and more robust human resources and infrastructure within healthcare facilities [50]. We join local experts in advocating for a national trauma registry to help fill local evidence- and policy-gaps and to help identify opportunities for quality improvement.

CRediT authorship contribution statement

Smitha Bhaumik: Conceptualization, Methodology, Writing – original draft. **Adane F. Wogu:** Methodology, Formal analysis. **Lani Finck:** Data curation, Visualization, Formal analysis. **Maria Jamison:** Data curation, Formal analysis. **Mengli Xiao:** Methodology, Conceptualization. **Julia Finn:** Data curation, Project administration, Writing – review & editing. **Hendrick Lategan:** Funding acquisition, Resources, Writing – review & editing. **Janette Verster:** Resources, Investigation, Writing – review & editing. **Shaheem de Vries:** Resources, Project administration, Writing – review & editing. **Craig Wylie:** Resources, Investigation. **Lesley Hodson:** Resources, Investigation. **Mohammet Mayet:** Resources, Investigation. **Leigh Wagner:** Resources, Investigation. **L'Oreal Snyders:** Resources, Investigation. **Karlien Doubell:** Resources, Investigation. **Elaine Erasmus:** Resources, Investigation. **George Oosthuizen:** Supervision, Writing – review & editing. **Christiaan Rees:** Writing – review & editing. **Steven G Schauer:** Funding acquisition, Supervision, Writing – review & editing. **Julia Dixon:** Project administration, Funding acquisition, Supervision, Writing – review & editing. **Nee-Kofi Mould-Millman:** Funding acquisition, Supervision, Writing – review & editing.

Conflict of Interest

The authors declared no conflicts of interest. SGS, HJL, SdV and NM have received funding from the United States Department of Defense in the form of grants to their institutions.

Dissemination of results

Findings from this study were shared with departmental leadership in the emergency and trauma units of the participating hospitals.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi 10.1016/j.afjem.2025.02.002.

References

[1] World Health Organization. Injuries and Violence, https://www.who.int/news-room/fact-sheets/detail/injuries-and-violence; 2021 [Accessed 14 October 2024].
[2] Wong EG, Gupta S, Deckelbaum DL, Razek T, Kushner AL. Prioritizing injury care: a review of trauma capacity in low and middle-income countries. J Surg Res 2015; 193(1):217–22. https://doi.org/10.1016/j.jss.2014.08.055.
[3] Pfeifer R, Tarkin IS, Rocos B, Pape H-C. Patterns of mortality and causes of death in polytrauma patients—Has anything changed? Injury 2009;40(9):907–11. https://doi.org/10.1016/j.injury.2009.05.006.
[4] Kragh Jr JF, Walters TJ, Baer DG, Fox CJ, Wade CE, Salinas J, et al. Survival With Emergency Tourniquet Use to Stop Bleeding in Major Limb Trauma. Ann Surg 2009;249(1). https://doi.org/10.1097/SLA.0b013e31818842ba.
[5] Scerbo MH, Holcomb JB, Taub E, Gates K, Love JD, Wade CE, et al. The trauma center is too late: Major limb trauma without a pre-hospital tourniquet has increased death from hemorrhagic shock. J Trauma Acute Care Surg 2017;83(6): 1165–72. https://doi.org/10.1097/TA.0000000000001666.
[6] Chang R, Fox EE, Greene TJ, Eastridge BJ, Gilani R, Chung KK, et al. Multicenter retrospective study of noncompressible torso hemorrhage: Anatomic locations of bleeding and comparison of endovascular versus open approach. J Trauma Acute Care Surg 2017;83(1). https://doi.org/10.1097/TA.0000000000001530.
[7] Eastridge BJ, Mabry RL, Seguin P, Cantrell J, Tops T, Uribe P, et al. Death on the battlefield (2001–2011): Implications for the future of combat casualty care. J Trauma Acute Care Surg 2012;73(6). https://doi.org/10.1097/TA.0b013e3182755dcc.
[8] Dixon J, de Vries S, Fleischer C, Bhaumik S, Dymond C, Jones A, et al. Preventable trauma deaths in the Western Cape of South Africa: A consensus-based panel review. PLOS Glob Public Health 2024;4(5):e0003122. https://doi.org/10.1371/journal.pgph.0003122.
[9] Morrison JJ. Noncompressible Torso Hemorrhage. Crit Care Clin 2017;33(1): 37–54. https://doi.org/10.1016/j.ccc.2016.09.001.
[10] Brenner M, Inaba K, Aiolfi A, DuBose J, Fabian T, Bee T, et al. Resuscitative Endovascular Balloon Occlusion of the Aorta and Resuscitative Thoracotomy in Select Patients with Hemorrhagic Shock: Early Results from the American Association for the Surgery of Trauma's Aortic Occlusion in Resuscitation for Trauma and Acute Care Surgery Registry. J Am Coll Surg 2018;226(5):730–40. https://doi.org/10.1016/j.jamcollsurg.2018.01.044.
[11] Adams D, McDonald PL, Holland S, Merkle AB, Puglia C, Miller B, et al. Management of non-compressible torso hemorrhage of the abdomen in civilian and military austere environments: a scoping review. Trauma Surg Acute Care Open 2024;9(1):e001189. https://doi.org/10.1136/tsaco-2023-001189.
[12] Smith S, White J, Wanis KN, Beckett A, McAlister VC, Hilsden R. The effectiveness of junctional tourniquets: A systematic review and meta-analysis. J Trauma Acute Care Surg 2019;86(3). https://doi.org/10.1097/TA.0000000000002159.
[13] Weiser TG, Regenbogen SE, Thompson KD, Haynes AB, Lipsitz SR, Berry WR, et al. An estimation of the global volume of surgery: a modelling strategy based on available data. The Lancet. 2008;372(9633):139-44. https://doi.org/10.1016/S0140-6736(08)60878-8.
[14] Suresh K, Dixon JM, Patel C, Beaty B, del Junco DJ, de Vries S, et al. The epidemiology and outcomes of prolonged trauma care (EpiC) study: methodology of a prospective multicenter observational study in the Western Cape of South Africa. Scandinavian J Trauma, Resuscit Emerg Med 2022;30(1):55. https://doi.org/10.1186/s13049-022-01041-1.
[15] Shah B, Krishnan N, Kodish SR, Yenokyan G, Fatema K, Burhan Uddin K, et al. Applying the Three Delays Model to understand emergency care seeking and delivery in rural Bangladesh: a qualitative study. BMJ Open 2020;10(12):e042690. https://doi.org/10.1136/bmjopen-2020-042690.
[16] Prinsloo M, Mhlongo S, Dekel B, Gwebushe N, Martin L, Saayman G, et al. The 2nd Injury Mortality Survey: A national study of injury mortality levels and causes in South Africa in 2017, https://www.samrc.ac.za/sites/default/files/attachments/2022-08/The%202nd%20Injury%20Mortality%20Survey%20Report_Final.pdf; 2021 [Accessed 27 February 2025].
[17] Zhou J, Wang T, Belenkiy I, Hardcastle TC, Rouby J-J, Jiang B, et al. Management of severe trauma worldwide: implementation of trauma systems in emerging countries: China, Russia and South Africa. Critical Care 2021;25:1–10. https://doi.org/10.1186/s13054-021-03681-8.
[18] Mould-Millman N-K, Baidwan NK, Beaty B, Suresh K, Dixon JM, Patel C, et al. Prolonged casualty care: Extrapolating civilian data to the military context. J Trauma Acute Care Surg 2022;93(2S):S78–85. https://doi.org/10.1097/TA.0000000000003675.
[19] Mould-Millman NK GA, Bebarta V, Dixon JM, Schauer SG, Cunningham C, Becker TE, et al. Establishing the Epidemiology and Outcomes of Combat-Relevant Prolonged Trauma Care: A Prospective Multicenter Prehospital Pilot Study in South Africa. University of Colorado: Department of Defense, Defense Medical Research and Development Program; 2019.
[20] Twomey M, Wallis LA, Thompson ML, Myers JE. The South African triage scale (adult version) provides valid acuity ratings when used by doctors and enrolled nursing assistants. African J Emerg Med 2012;2(1):3–12. https://doi.org/10.1016/j.afjem.2011.08.014.

[21] Gottschalk S, Wood D, DeVries S, Wallis LA, Bruijns S. The Cape Triage Score: a new triage system South Africa. Proposal from the Cape Triage Group. Emerg Med J 2006;23(2):149–53. https://doi.org/10.1136/emj.2005.028332.
[22] Lavoie A, Moore L, LeSage N, Liberman M, Sampalis JS. The New Injury Severity Score: a more accurate predictor of in-hospital mortality than the Injury Severity Score. J Trauma Acute Care Surg 2004;56(6):1312–20. https://doi.org/10.1097/01.ta.0000075342.36072.ef.
[23] Hosmer Jr DW, Lemeshow S, Sturdivant RX. Applied logistic regression. John Wiley & Sons; 2013.
[24] Bursac Z, Gauss CH, Williams DK, Hosmer DW. Purposeful selection of variables in logistic regression. Source Code Biol Med 2008;3(1):1–8. https://doi.org/10.1186/1751-0473-3-17.
[25] Denz R, Klaaßen-Mielke R, Timmesfeld N. A comparison of different methods to adjust survival curves for confounders. Stat Med 2023;42(10):1461–79. https://doi.org/10.1002/sim.9681.
[26] Therneau TM, Grambsch PM. The Cox Model. Modeling Survival Data: Extending the Cox Model. Statistics for Biology and Health. New York: Springer; 2000. p. 39–77. https://doi.org/10.1007/978-1-4757-3294-8_3.
[27] The R Core Team. R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing; 2024.
[28] Gosselin RA, Spiegel DA, Coughlin R, Zirkle LG. Injuries: the neglected burden in developing countries. Bull World Health Organ 2009;87(4):246. https://doi.org/10.2471/blt.08.052290.
[29] Nicol A, Knowlton LM, Schuurman N, Matzopoulos R, Zargaran E, Cinnamon J, et al. Trauma surveillance in Cape Town, South Africa: an analysis of 9236 consecutive trauma center admissions. JAMA surgery 2014;149(6):549–56. https://doi.org/10.1001/jamasurg.2013.5267.
[30] Moodley N, Clarke D, Aldous C. Current trauma patterns in Pietermaritzburg. S Afr J Surg 2015;53(4):42–4.
[31] Bhana M, Fru P, Plani F. A long walk to freedom: the epidemiology of penetrating trauma in South Africa–analysis of 4697 patients over a six-year period at Chris Hani Baragwanath Academic Hospital. S Afr J Surg 2022;60(2):77–83.
[32] Lutge E, Moodley N, Tefera A, Sartorius B, Hardcastle T, Clarke D. A hospital-based surveillance system to assess the burden of trauma in KwaZulu-Natal Province South Africa. Injury 2016;47(1):135–40. https://doi.org/10.1016/j.injury.2015.08.020.
[33] Zaidi A, Dixon J, Rodriguez K, Raji Z, LeBeau S, De Vries S, et al. Abstract 191: the burden of acute injuries at a district hospital in the Western Cape Province of South Africa. Ann Emerg Med 2016;68(4):S75.
[34] Senekal M, Eales C. The optimal physiotherapeutic approach to penetrating stab wounds of the chest. South African J Physioth 1994;50(2):29–36.
[35] Dos Santos EdC, da Silva JdS, de Assis Filho MTT, Vidal MB, de Castro Monte M, Lunardi AC. Adding positive airway pressure to mobilisation and respiratory techniques hastens pleural drainage: a randomised trial. J Physiother 2020;66(1):19–26.
[36] Morris D. Utilisation of emergency blood in a cohort of emergency centres in Cape Town. South Africa: Dissertation. Stellenbosch University; 2017. https://scholar.sun.ac.za/server/api/core/bitstreams/2dd1f8dc-3e94-4f44-a771-12400c05c425/content [Accessed 27 February 2025].
[37] Harrison HB, Smith WZ, Salhanick MA, Higgins RA, Ortiz A, Olson JD, et al. An experimental model of hemothorax autotransfusion: impact on coagulation. Am J Surg 2014;208(6):1078–82. https://doi.org/10.1016/j.amjsurg.2014.09.012.
[38] Rhee P, Inaba K, Pandit V, Khalil M, Siboni S, Vercruysse G, et al. Early autologous fresh whole blood transfusion leads to less allogeneic transfusions and is safe. J Trauma Acute Care Surg 2015;78(4):729–34. https://doi.org/10.1097/TA.0000000000000599.
[39] Ley EJ, Clond MA, Srour MK, Barnajian M, Mirocha J, Margulies DR, et al. Emergency department crystalloid resuscitation of 1.5 L or more is associated with increased mortality in elderly and nonelderly trauma patients. J Trauma Acute Care Surg 2011;70(2):398–400. https://doi.org/10.1097/TA.0b013e318208f99b.
[40] Tran A, Yates J, Lau A, Lampron J, Matar M. Permissive hypotension versus conventional resuscitation strategies in adult trauma patients with hemorrhagic shock: a systematic review and meta-analysis of randomized controlled trials. J Trauma Acute Care Surg 2018;84(5):802–8. https://doi.org/10.1097/TA.0000000000001816.
[41] Zhang Y, Ding Y, Zheng D, Huang X, Zhang J, Liang W, et al. Comparison of Permissive Hypotension vs. Conventional Resuscitation Strategies in Adult Trauma Patients with Hemorrhagic Shock: An Updated Systematic Review and Meta-Analysis of Randomized Controlled Trials. Preprint. 2021. https://doi.org/10.21203/rs.3.rs-407033/v1.
[42] Chang R, Holcomb JB. Optimal Fluid Therapy for Traumatic Hemorrhagic Shock. Crit Care Clin 2017;33(1):15–36. https://doi.org/10.1016/j.ccc.2016.08.007.
[43] Nunez TC, Voskresensky IV, Dossett LA, Shinall R, Dutton WD, Cotton BA. Early prediction of massive transfusion in trauma: simple as ABC (Assessment of Blood cConsumption)? J Trauma Acute Care Surg 2009;66(2):346–52. https://doi.org/10.1097/TA.0b013e3181961c35.
[44] Mould-Millman NK, Wogu AF, Fosdick BK, Dixon JM, Beaty BL, Bhaumik S, et al. Association of freeze-dried plasma with 24-h mortality among trauma patients at risk for hemorrhage. Transfusion 2024;64:S155–66. https://doi.org/10.1111/trf.17792.
[45] Solheim BG, Chetty R, Flesland O. Indications for use and cost-effectiveness of pathogen-reduced ABO-universal plasma. Curr Opin Hematol 2008;15(6):612–7. https://doi.org/10.1097/MOH.0b013e32831366d3.
[46] Pusateri AE, Malloy WW, Sauer D, Benov A, Corley JB, Rambharose S, et al. Use of dried plasma in prehospital and austere environments. Anesthesiology 2022;136(2):327–35. https://doi.org/10.1097/ALN.0000000000004089.
[47] Roberts I, Shakur H, Coats T, Hunt B, Balogun E, Barnetson L, et al. The CRASH-2 trial: a randomised controlled trial and economic evaluation of the effects of tranexamic acid on death, vascular occlusive events and transfusion requirement in bleeding trauma patients. Health Technology Assessment, Clinical Governance: An International Journal 2013;17(10):1–79. https://doi.org/10.1108/cgij.2013.24818caa.005.
[48] Wiese JG, Van Hoving DJ, Hunter L, Lahri S, Bruijns SR. Poor adherence to Tranexamic acid guidelines for adult, injured patients presenting to a district, public, South African hospital. African J Emerg Med 2017;7(2):63–7. https://doi.org/10.1016/j.afjem.2017.04.006.
[49] Finn J, Dixon JM, Moreira F, Herbst C, Bhaumik S, Fleischer CL, et al. Patterns of on-scene and healthcare system trauma deaths in the Western Cape of South Africa. World J Surg 2024;48(2):320–30. https://doi.org/10.1002/wjs.12043.
[50] Hardcastle TC, Oosthuizen G, Clarke D, Lutge E. Trauma, a preventable burden of disease in South Africa: review of the evidence, with a focus on KwaZulu-Natal. South African Health Rev 2016;(1):179–89.