Test file: Risk Factors for Mortality and the Impact of Targeted Emergency Interventions in Emergency Surgical Trauma Patients

Authors: Siti Nurfatimah Mohd Shahpudin[1], Wei Zhang[2], Jingjing Yuan[3*]
Affiliations:
[1] Department of Biomedical Sciences, Advanced Medical and Dental Institute, Universiti Sains Malaysia
[2] The Sixth People's Hospital of Shanghai Jiao Tong University School of Medicine, Shanghai, China
[3] Department of Anesthesiology, Perioperative Medicine, and Pain Management, The First Affiliated Hospital of Zhengzhou University, Henan, China
***Corresponding Author:**
Jingjing Yuan, Email: yjingjing_99@163.com

Abstract

Background: Traumatic injury remains a leading cause of death globally, particularly within the first hours after the event. Identifying specific risk factors for mortality in emergency surgical trauma patients and evaluating the efficacy of time-sensitive emergency interventions are critical for improving survival. This study aimed to analyze independent predictors of 24-hour and 30-day mortality in patients undergoing emergency trauma surgery and assess the effect of protocolized emergency measures. Methods: A retrospective analysis was conducted on 2,315 consecutive adult patients who underwent emergency surgical intervention for trauma at a tertiary academic trauma center between January 2020 and December 2023. Data were extracted from electronic health records, surgical logs, and trauma registries. Variables analyzed included demographic data, injury characteristics (mechanism, Injury Severity Score [ISS]), physiological parameters on admission (hypotension, Glasgow Coma Scale [GCS], hypothermia, acidosis), time intervals (pre-hospital time, door-to-operating room), specific interventions (prehospital tourniquet, emergency department thoracotomy [EDT], massive transfusion protocol [MTP] activation), and surgical procedures performed. Primary outcomes were 24-hour and 30-day all-cause mortality. Statistical analysis involved univariate comparisons and multivariate logistic regression. Results: The overall 30-day mortality rate was 13.4% (311/2315), with 65.3% of these deaths (203/311) occurring within the first 24 hours. Multivariate analysis identified six independent risk factors for 24-hour mortality: 1) Penetrating trauma to the torso (Adjusted Odds Ratio [aOR] 3.8, 95% CI 2.7–5.4), 2) Admission systolic blood pressure <90 mmHg (aOR 3.5, 95% CI 2.5–4.9), 3) Admission Glasgow Coma Scale score ≤8 (aOR 3.0, 95% CI 2.2–4.2), 4) Injury Severity Score ≥25 (aOR 2.9, 95% CI 2.0–4.1), 5) Presence of concurrent traumatic brain injury and hemorrhagic shock (aOR 6.2, 95% CI 4.1–9.3), and 6) Age ≥65 years (aOR 2.2, 95% CI 1.6–3.1). Protocolized emergency interventions showed a significant protective effect: Activation of an in-house Massive Transfusion Protocol within 15 minutes of arrival was associated with a 35% reduction in 24-hour mortality in shocked patients (aOR 0.65, 95% CI 0.48–0.88), and a door-to-operating room time of <60 minutes for patients in extremis was independently associated with survival (aOR for mortality 0.70, 95% CI 0.52–0.94). Conclusion: Mortality in emergency surgical trauma is multifactorial, with physiological derangement at admission, high-energy injury patterns, and advanced age being key non-modifiable risk factors. However, mortality can be significantly

mitigated by systems-based, protocol-driven emergency responses, particularly the rapid control of hemorrhage through expedited surgery and goal-directed massive transfusion. These findings underscore the vital importance of pre-hospital care coordination, in-hospital trauma team efficiency, and adherence to time-critical surgical and resuscitation protocols.

Keywords: Trauma Mortality; Risk Factors; Emergency Surgical Procedures; Hemorrhagic Shock; Damage Control Surgery; Massive Transfusion; Trauma Systems.

1. Introduction

Trauma represents a formidable global public health challenge, accounting for over 4.4 million deaths annually and constituting nearly 8% of all mortality worldwide [1]. The epidemiological pattern of trauma mortality is classically described as trimodal: immediate deaths at the scene from unsurvivable injuries, early deaths occurring within minutes to hours from potentially reversible conditions like massive hemorrhage or airway compromise, and late deaths occurring days to weeks later from complications like sepsis or multiple organ failure [2]. For emergency surgical teams, the focus is squarely on preventing the second peak—early deaths—through rapid identification and aggressive correction of life-threatening physiology [3].

Despite significant advances in trauma systems, resuscitation science, and surgical techniques, mortality rates for severely injured patients requiring emergency surgery remain substantial. A critical component of improving outcomes is the precise delineation of which patient-specific and care-delivery factors most strongly predict death. While factors like the Injury Severity Score (ISS) and admission hypotension are known to correlate with poor outcomes, their relative weight and interaction in a contemporary cohort undergoing immediate surgery require ongoing evaluation [4]. Furthermore, understanding the specific impact of time-critical emergency interventions—such as emergency department thoracotomy, ultra-early massive transfusion, and ultra-fast-track to the operating room—on these high-risk patients is essential for refining clinical protocols and resource allocation [5].

This study aimed to perform a comprehensive analysis of a large, recent cohort of emergency surgical trauma patients to: 1) identify independent patient and injury characteristics associated with 24-hour and 30-day mortality, and 2) evaluate the association between specific, protocolized emergency department and surgical interventions and survival outcomes, with the goal of informing more effective and targeted acute trauma care pathways.

2. Methods

2.1 Study Design and Setting

A single-center, retrospective cohort study was conducted at an American College of Surgeons-verified Level I trauma center with an annual volume of over 3,500 trauma admissions. The study was approved by the hospital’s Institutional Review Board with a waiver of informed consent due to its retrospective, observational nature.

2.2 Study Population

The study included all consecutive adult patients (age ≥ 18 years) who presented directly from the scene of injury and underwent an emergency surgical procedure (defined as an operation in a main operating room or emergency department within 2 hours of arrival) for traumatic injury between January 1, 2020, and December 31, 2023. Emergency procedures included exploratory laparotomy, thoracotomy, vascular repair, major orthopedic fixation (e.g., pelvic packing, external fixation), and intracranial hematoma evacuation. Patients transferred from other facilities, those undergoing delayed or elective procedures, or those with isolated burns were excluded.

2.3 Data Collection and Variables

Data were extracted from a prospectively maintained trauma registry and supplemented with detailed manual review of electronic health records, anesthesia records, and surgical reports. Collected variables were grouped into several domains:

Demographics and Comorbidities: Age, sex, pre-existing anticoagulant use, and major comorbidities (e.g., cardiovascular disease, cirrhosis).
Injury Characteristics: Mechanism (blunt vs. penetrating), body region injured (head/neck, chest, abdomen/pelvis, extremities), and the calculated Injury Severity Score (ISS).
Physiological Status on Admission: Systolic blood pressure (SBP), Glasgow Coma Scale (GCS) score, core temperature, and base deficit or lactate level when available. Hypovolemic shock was defined as SBP < 90 mmHg and/or base deficit ≥ 6 mEq/L.
Pre-hospital and In-hospital Timelines: Pre-hospital time (injury to ED arrival), door-to-first-imaging (ultrasound/CT) time, door-to-operating room (OR) time, and ED length of stay.
Emergency Interventions:
Resuscitative: Pre-hospital tourniquet application, emergency department resuscitative thoracotomy (EDRT), time to activation of the Massive Transfusion Protocol (MTP, defined as >10 units of packed red blood cells in 24 hours), and time to first transfusion.
Surgical: Primary surgical procedure performed and use of damage control surgery (DCS) principles (abbreviated laparotomy/thoracotomy with planned reoperation).
Outcomes: Primary outcomes were 24-hour mortality and 30-day all-cause mortality. Secondary outcomes included total hospital length of stay, ICU length of stay, and volumes of blood products transfused in the first 24 hours.

2.4 Statistical Analysis

Continuous variables were reported as medians with interquartile ranges (IQR) and compared using the Mann-Whitney U test. Categorical variables were reported as frequencies and percentages and compared using the Chi-square or Fisher's exact test. To identify independent risk factors for mortality, all variables with a p-value < 0.10 in univariate analysis were entered into a backward stepwise multivariate logistic regression model. Results were reported as adjusted odds ratios (aOR) with 95% confidence intervals (CI). A two-tailed p-value < 0.05 was considered statistically significant. All analyses were performed using Stata/MP software version 18.0.

3. Results

3.1 Patient Characteristics

During the study period, 2,315 patients met the inclusion criteria. The median age was 44 years (IQR 28–62), and 73.5% were male. Blunt trauma accounted for 68.1% of injuries (primarily motor vehicle collisions and falls), and penetrating trauma for 31.9% (gunshot wounds and stab wounds). The median ISS was 21 (IQR 14–29). Upon admission, 21.6% of patients were hypotensive (SBP < 90 mmHg), and 18.2% had a severe traumatic brain injury (TBI, defined as GCS ≤ 8).

3.2 Mortality Outcomes and Univariate Associations

The overall 30-day mortality rate was 13.4% (n=311). Among non-survivors, 65.3% (n=203) died within the first 24 hours. In univariate analysis, non-survivors (both at 24-hours and 30-days) were significantly older, had higher ISS, and were more likely to present with hypotension, low GCS, hypothermia (<35°C), and a base deficit ≥ 6 mEq/L (all p<0.001). Penetrating torso trauma was strongly associated with 24-hour mortality (p<0.001). A delay in door-to-OR time beyond 90 minutes was significantly more common in non-survivors (p<0.01).

3.3 Multivariate Analysis of Mortality Risk Factors

The final multivariate model for 24-hour mortality identified six independent risk factors (Table 1):

1. Concurrent Severe TBI (GCS ≤8) and Hemorrhagic Shock: This combination carried the highest risk (aOR 6.2, 95% CI 4.1–9.3).
2. Penetrating Torso Trauma: aOR 3.8 (95% CI 2.7–5.4).
3. Admission Hypotension (SBP <90 mmHg): aOR 3.5 (95% CI 2.5–4.9).
4. Admission Severe TBI (GCS ≤8): aOR 3.0 (95% CI 2.2–4.2).
5. High Injury Severity (ISS ≥25): aOR 2.9 (95% CI 2.0–4.1).
6. Age ≥65 years: aOR 2.2 (95% CI 1.6–3.1).

For 30-day mortality, the same factors were significant, with the addition of pre-existing cirrhosis (aOR 2.8, 95% CI 1.5–5.2) and development of early sepsis (within 72 hours, aOR 3.1, 95% CI 2.0–4.8).

3.4 Impact of Emergency Interventions on Survival

The analysis of emergency care processes revealed several significant associations:

Massive Transfusion Protocol (MTP): In patients presenting with hemorrhagic shock (SBP<90 or BD≥6), activation of the in-house MTP within 15 minutes of arrival was associated with a 35% reduction in the odds of 24-hour mortality (aOR 0.65, 95% CI 0.48–0.88) compared to later or no activation.

Time to Operating Room: For the subgroup of patients in extremis (cardiopulmonary resuscitation on arrival or post-EDRT), a door-to-OR time of less than 60 minutes was an independent predictor of survival (aOR for mortality 0.70, 95% CI 0.52–0.94).

Damage Control Surgery (DCS): The use of DCS principles in patients with an ISS >25 was associated with a lower 24-hour mortality compared to attempts at definitive repair (22% vs. 38%, p=0.015).

Pre-hospital Tourniquet: For patients with major limb trauma, documented pre-hospital tourniquet application was associated with a lower rate of admission in profound shock (15% vs. 32%, $p<0.01$) and a non-significant trend towards lower 24-hour mortality.

4. Discussion

This large contemporary study reinforces that mortality in emergency surgical trauma is driven by a lethal synergy of anatomical injury severity and physiological derangement, particularly the combination of traumatic brain injury and hemorrhagic shock. The finding that this combination conferred a sixfold increase in odds of early death highlights a critical pathophysiological crossroads where competing priorities—brain perfusion versus hemostasis—create immense clinical challenges [6].

Our results confirm the persistent, powerful prognostic value of classic "hard signs" at admission: hypotension and a depressed level of consciousness [7]. These are not merely markers of injury but direct indicators of failing physiology that must trigger the highest level of trauma team response and resource mobilization. The strong independent risk associated with penetrating torso trauma underscores the lethality of injuries to central vascular and visceral structures, demanding a low threshold for rapid surgical exploration [8].

Importantly, this analysis moves beyond identifying risk to demonstrating the measurable impact of systematic emergency interventions. The survival benefit associated with ultra-early MTP activation (<15 minutes) provides robust, real-world evidence supporting the "blood-first" resuscitation strategy for hemorrhagic shock, aligning with military and civilian guidelines emphasizing balanced transfusion and minimizing crystalloid [9, 10]. The critical importance of minimizing time to surgical hemorrhage control is quantified by the survival advantage linked to a door-to-OR time under 60 minutes for the most critical patients. This benchmark serves as a key performance indicator for trauma system efficiency, integrating pre-hospital notification, in-hospital team readiness, and operating room access [11].

The protective association of Damage Control Surgery in the severely injured validates its role in interrupting the "lethal triad" (hypothermia, acidosis, coagulopathy) and prioritizing physiological restoration over anatomical completeness [12]. Furthermore, the observed benefit of pre-hospital tourniquets adds to the growing body of literature supporting their widespread, protocolized use for compressible extremity hemorrhage [13].

Limitations: This study has limitations inherent to its retrospective, single-center design. Unmeasured confounders, such as variations in pre-hospital advanced life support or specific surgical techniques, may influence outcomes. The observational nature can demonstrate association but not prove causation for the interventions studied. Generalizability may be limited to similar high-volume, resource-rich trauma centers.

Clinical and Systems Implications: The findings have direct implications for practice and system

design:
1. Triage and Triage: Patients presenting with hypotension + low GCS + torso penetrating mechanism should be flagged for immediate, simultaneous mobilization of the MTP and the operating room team.
2. Protocol Enforcement: Institutions should audit and enforce compliance with time-based metrics for MTP activation and OR access for unstable patients.
3. Pre-hospital Integration: Trauma systems should strengthen training and protocols for pre-hospital hemorrhage control (tourniquets, junctional devices) and early, accurate patient notification to the receiving hospital.
4. Future Research: Prospective studies are needed to refine resuscitation endpoints (e.g., viscoelastic testing vs. conventional labs) in this population and to develop predictive models that integrate real-time physiological and laboratory data to guide intervention.

5. Conclusion

Early mortality in emergency surgical trauma patients is predominantly determined by the severity of physiological insult—specifically hemorrhagic shock and severe traumatic brain injury—upon admission, compounded by high-energy injury mechanisms and advanced age. While these patient and injury factors are non-modifiable, their fatal trajectory can be altered by highly coordinated, protocol-driven emergency care. The rapid institution of hemostatic resuscitation through immediate massive transfusion protocols and expeditious surgical hemorrhage control via damage control techniques are critical, evidence-based interventions that significantly improve survival odds. These results argue for continued investment in trauma system infrastructure, pre-hospital care partnerships, and unwavering adherence to time-sensitive clinical protocols to salvage the most critically injured patients.

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