

Clinical Predictors and Resuscitative Care Indicators of Early Mortality Among Adult Major Trauma Patients Transported by Emergency Medical Services in Thailand

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Introduction: Early identification of high-risk trauma patients in the prehospital setting is critical for optimizing emergency care and improving outcomes, particularly in resource-limited systems.

Purpose: To determine the 24-hour mortality rate and identify clinical predictors and resuscitative care indicators associated with early mortality among adult major trauma patients transported by emergency medical services (EMS) in Thailand.

Methods: A retrospective registry-based cohort study included adult patients (≥ 18 years) with major trauma transported by EMS to a tertiary trauma center in Bangkok between January 2019 and December 2024. Eligible patients were classified under Thailand Emergency Medical Triage Protocol symptom groups 21–25 with red-level severity. Data were obtained from an EMS-based trauma registry integrating prehospital and early in-hospital variables. The primary outcome was all-cause mortality within 24 hours of hospital arrival. Survival was analyzed using Kaplan–Meier methods, and predictors were identified using multivariable flexible parametric survival models.

Results: Among 197 patients, the 24-hour mortality rate was 25.9% (95% CI: 20.3–32.6). Severe neurological impairment (Glasgow Coma Scale 3–8) was independently associated with mortality (adjusted hazard ratio [aHR] 3.72, 95% CI: 1.56–8.87). Resuscitative care indicators, including chest tube insertion (aHR 6.82, 95% CI: 3.23–14.39) and central venous catheter placement (aHR 2.50, 95% CI: 1.21–5.17), were also associated with mortality and likely reflect underlying injury severity and physiological instability rather than direct causal effects. The model demonstrated good discrimination (C-statistic 0.848) and calibration.

Conclusion: One in four adult major trauma patients transported by EMS died within 24 hours of hospital arrival. Early mortality was associated with both clinical severity and resuscitative care indicators. These findings support the use of routinely available clinical variables to identify high-risk patients and inform early triage and escalation of care, while emphasizing cautious interpretation of care-related variables as markers of severity rather than modifiable risk factors.

Keywords: major trauma, emergency medical services, clinical predictors, prehospital care, resuscitative care

Introduction

Major trauma remains a significant global public health concern and is a leading cause of disability and mortality, particularly among adolescents and middle-aged adults.¹ The burden of trauma extends beyond individual health outcomes, exerting profound social and economic impacts on communities and national healthcare systems, especially in developing and middle-income countries, where trauma-related injuries can hinder overall socioeconomic development.² According to World Health Organization statistics published in 2023, Thailand reported the highest

mortality rate from accidents in Asia and the second highest globally, with road traffic accidents accounting for the majority of trauma-related deaths.³ The national mortality rate was approximately 32.7 per 100,000 population, substantially exceeding the global average of 17.4 per 100,000 population, and trauma-related costs accounted for nearly 3% of the country's gross domestic product.³

Given this substantial burden, major trauma patients require rapid, timely, and coordinated care, particularly during the prehospital phase managed by emergency medical service (EMS) systems. The concept of the “platinum 10 minutes” is frequently invoked as a guiding principle in trauma care to emphasize the importance of minimizing delays in early management; however, its practical implementation and empirical observability remain variable across EMS systems and may not be directly measurable within all operational contexts.⁴ Previous studies have demonstrated that well-functioning EMS systems can significantly reduce trauma-related mortality by facilitating early assessment, triage, stabilization, and rapid transport to appropriate trauma centers.^{5,6} Despite these advances, approximately half of major trauma patients die at the scene, and mortality continues to rise during the first 24 hours following injury if early care is delayed or suboptimal.⁷

The first 24 hours after injury represent a particularly vulnerable period in the trauma care continuum, during which outcomes are strongly influenced by both injury severity and the effectiveness of early multidisciplinary management. Reported 24-hour mortality rates vary substantially across healthcare systems. For example, Japanese emergency departments have reported a 24-hour mortality rate of 1.5% among major trauma patients,⁸ whereas rates as high as 5.75% have been reported in emergency departments in Thailand.⁹ Such variation highlights differences in trauma system organization, prehospital care capacity, and interprofessional coordination.

Several clinical and physiological factors have been consistently associated with trauma-related mortality in emergency department settings, including systolic blood pressure <90 mmHg, heart rate abnormalities, Glasgow Coma Scale (GCS) score ≤ 8 , oxygen saturation, and injury mechanism characteristics.^{9–11} However, evidence remains limited regarding early mortality among trauma patients specifically within the context of EMS systems, where prehospital decision-making, resource availability, and multidisciplinary coordination play a crucial role. Only a small number of studies have evaluated mortality outcomes among injured patients transported by EMS, with reported mortality rates as high as 45.45% in certain settings.¹² Factors associated with death in these patients include advanced age, higher injury severity assessed by the revised trauma score, and transport to hospitals with inadequate trauma care capacity.¹³

Despite the growing burden of trauma in Thailand, evidence on early mortality among EMS-transported major trauma patients remains limited, particularly studies integrating prehospital data with early in-hospital outcomes. Furthermore, while previous studies have primarily focused on physiological parameters, less attention has been given to care process-related variables that may reflect the intensity of resuscitation and underlying injury severity. In this study, selected interventions such as chest tube insertion and central venous catheter placement were considered as surrogate markers of resuscitative intensity and clinical severity rather than direct causal determinants of mortality.

Despite the substantial burden of trauma, important uncertainties remain regarding early mortality within EMS-linked trauma systems, particularly in settings where prehospital and in-hospital data are not routinely integrated. Existing studies have largely examined either physiological predictors at presentation or system-level metrics in isolation, with limited attention to how these domains interact within the early phase of care. In this context, prehospital determinants (eg, injury severity and physiological status), system processes (eg, triage and transport), and early in-hospital responses may collectively shape early mortality risk. However, the causal relationships among these components remain incompletely understood. In the present study, care process-related variables are operationalized as indicators of resuscitative intensity rather than direct measures of system performance or causal exposures, thereby providing a framework to examine early mortality while minimizing misinterpretation of procedural variables as independent determinants.

In many developing countries, including Thailand, prehospital trauma care is delivered under resource constraints, and frontline EMS teams are typically composed of paramedics and emergency nurse practitioners rather than physicians.¹⁴ These structural and workforce characteristics underscore the importance of understanding early mortality within EMS-based trauma systems, particularly during the first 24 hours after injury, when timely, coordinated, and multidisciplinary interventions are most critical.

We hypothesized that early mortality among major trauma patients is influenced not only by the severity of physiological derangement but also by the need for critical prehospital or early in-hospital interventions, which collectively reflect the burden of injury and the operational limitations of Thailand's EMS system. Therefore, this study aimed to evaluate the mortality rate and identify predictors of 24-hour mortality among adult major trauma patients transported by EMS. The findings are intended to inform multidisciplinary trauma care, assess EMS system performance, and support the development of evidence-based strategies to improve care quality, optimize resource allocation, and enhance survival outcomes in trauma systems within resource-limited settings.

Aim

This study aimed to determine the 24-hour mortality rate and identify early predictors of death that reflect both injury severity and multidisciplinary trauma care processes among adult major trauma patients transported by EMS in Thailand.

Methods

Study Design and Setting

This retrospective, single-center cohort study was conducted within the Vajira Emergency Medical Service (V-EMS) unit, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok, Thailand. V-EMS operates as a comprehensive life support (CLS)-level emergency medical service and serves as the zone leader for EMS Area 1, one of 11 EMS service areas within the Bangkok EMS system. Emergency dispatch is coordinated through the Erawan Center, which functions as the centralized EMS dispatch center for Bangkok.

The V-EMS coverage area comprises a coordinated network of six public and private hospitals that collaboratively provide emergency patient care across the region.¹ This integrated network facilitates timely prehospital response, appropriate triage, and transport to definitive care facilities within the urban trauma system.

Each V-EMS emergency response team consists of a minimum of three personnel, including a unit leader—either a paramedic or an emergency nurse practitioner (ENP)—and two emergency medical technicians. Unit leaders deliver prehospital care under both offline and online medical control protocols, in accordance with established treatment guidelines and real-time consultation with emergency physicians when required. All team leaders, paramedics, and ENPs are certified in Prehospital Trauma Life Support (PHTLS), ensuring standardized training and competency in the management of trauma patients in the prehospital setting.

Participants

Data were collected from adult patients with major trauma transported by V-EMS between January 1, 2019 and December 31, 2024. Eligible patients were identified from EMS patient care reports coded according to the Thailand Emergency Medical Triage Protocol and Criteria-based Dispatch (TEMTP-CBD), symptom groups 21–25, red code (Red 1–9). In this study, TEMTP-CBD red-level classification was used as a system-level proxy for injury severity, reflecting the highest acuity triage category within the Thai EMS system rather than an anatomical or composite severity measure.

Eligibility Criteria

Eligible patients were major trauma adult patients aged ≥ 18 years, managed by V-EMS team and coded with TEMTP-CBD symptom group 21–25, red code, and transported to the emergency department of Vajira Hospital.

Exclusion Criteria

Patients who experienced cardiac arrest at the scene or during hospital transport, those who refused treatment or hospital transfer, those who were dead at the scene, or those who had incomplete data were excluded from the study.

Data Gathering

Data were collected from two primary sources. Prehospital variables were obtained from EMS patient care reports recorded prospectively by the V-EMS team. These included sex, age, comorbidities, mechanism of injury, level of consciousness, wound type, bone injury type, hemorrhage type, injured body parts, response time, scene time, transfer

time, distance from base station to scene, distance from scene to hospital, systolic and diastolic blood pressure, heart rate, respiratory rate, oxygen saturation, body temperature, shock index, injury severity score, Glasgow Coma Scale (GCS) score, hemorrhage control, airway management, oxygen support, fluid resuscitation, and immobilization.

In-hospital treatment variables, including chest tube insertion, massive blood transfusion, central venous catheter (CVC) placement, definitive or damage control surgery, and 24-hour mortality, were abstracted retrospectively from the hospital's electronic medical record (EMR) system and verified against the Vajira EMS trauma registry. To ensure data accuracy, two independent investigators cross-checked all entries between EMS and hospital records. Discrepancies were resolved through consensus review, and additional validation was conducted by random auditing of 10% of the records to confirm consistency and completeness prior to statistical analysis.

Outcome Measures

The primary objectives of this study were to estimate the 24-hour mortality rate among adult major trauma patients transported by EMS and to identify clinical and care process-related factors predictive of early mortality.

Definitions

Major Trauma Patients

Major trauma patients were defined as individuals with life-threatening conditions requiring management according to the PHTLS guidelines, 10th edition, which emphasize the “platinum 10 minutes” principle and recommend limiting prehospital procedures to those necessary for the treatment of reversible life-threatening conditions.^{15,16} Criteria for major trauma included threatened airway or inadequate respiration (eg, tachypnea, bradypnea, hypoxia, or dyspnea); dangerous thoracic injuries (eg, open pneumothorax, flail chest, or tension pneumothorax); severe external hemorrhage or suspected internal hemorrhage; neurological abnormalities (eg, Glasgow Coma Scale score ≤ 13 , seizure, or loss of sensation or movement); penetrating injuries involving vital body regions; traumatic amputation of fingers, toes, or limbs; high-risk comorbid conditions (eg, cardiac disease, chronic obstructive pulmonary disease, or coagulopathy); and vulnerable populations, including elderly patients aged >55 years and individuals with hypothermia ($<35^{\circ}\text{C}$).

24-Hour Mortality

Twenty-four-hour mortality was defined as death occurring within 24 hours following EMS activation, measured from the time the V-EMS unit was dispatched to the scene and extending through hospital admission and the first 24 hours of in-hospital care. Patients who were found dead at the scene, experienced cardiac arrest prior to hospital arrival, or died during prehospital transport were excluded from the analysis because complete physiological and procedural data could not be obtained. Consequently, the 24-hour mortality rate reported in this study reflects mortality among patients who survived to hospital arrival.

Censored Cases

Patients who survived beyond 24 hours, were transferred to other hospitals, or had incomplete documentation regarding 24-hour outcomes were treated as right-censored observations in the survival analysis.

Event

An event was defined as death occurring within 24 hours of hospital admission in a patient transported by EMS for the first time during the study period.

TEMTP-CBD

The TEMTP-CBD code is a standardized severity classification applied at the scene based on patients' prehospital clinical presentation and symptoms. It serves as the national triage and dispatch standard in Thailand and comprises 26 symptom groups: groups 1–20 for nontrauma conditions, groups 21–25 for trauma-related conditions,¹⁷ and group 26 for emerging infectious diseases, such as coronavirus disease 2019 (COVID-19).¹⁸

Chest Tube Insertion

Chest tube insertion was defined as thoracic decompression performed for clinically suspected pneumothorax, hemothorax, or tension physiology based on prehospital or early in-hospital assessment. Central venous catheter placement was defined as insertion for hemodynamic monitoring or administration of vasoactive agents in patients with suspected circulatory instability.

These variables were recorded as early in-hospital interventions following patient arrival and were analyzed as indicators of resuscitative intensity rather than time-dependent exposures. They were not used to evaluate procedural appropriateness or timeliness but were considered surrogate markers of injury severity and physiological instability. As such, temporal ordering relative to the outcome could not be explicitly established, and these variables should be interpreted within a prognostic rather than causal framework.

Sample Size Determination

Because this was a retrospective registry-based study, no a priori sample size calculation was performed before data collection. Instead, all eligible trauma cases from 2019 to 2024 were included. A post hoc adequacy assessment was conducted to confirm that the available dataset provided sufficient precision for statistical analysis.

For descriptive reference, the theoretical minimum sample size was estimated using the formula for proportion estimation.¹⁹ With a significance level (α) of 0.05, equivalent to $Z_{\alpha/2} = 1.96$, a margin of error (d) of 0.05, and a population proportion (p) of 0.1154 based on a previous study by Siripakarn et al,²⁰ the calculated minimum sample size was 157. After adding 20% to account for incomplete data, at least 197 patients would have been required.

In addition, model development considered the ratio of outcome events to candidate predictor variables to mitigate the risk of overfitting. A parsimonious modeling strategy was applied, and only variables meeting predefined statistical and clinical criteria were retained in the final model. This approach supports the adequacy of the sample size for multivariable modeling in the present study.

Statistical Analysis

Descriptive statistics were used to summarize patient characteristics and variable distributions. Continuous variables are presented as mean $\pm$ standard deviation or median with interquartile range, as appropriate, while categorical variables are presented as frequencies and proportions. Comparisons between groups were performed using the independent *t*-test or Mann–Whitney *U*-test for continuous variables, and the chi-square test or Fisher's exact test for categorical variables.

The 24-hour mortality rate was estimated using Kaplan–Meier survival analysis and reported with corresponding 95% confidence intervals (CIs). Survival curves were stratified by clinically relevant variables, and differences between groups were assessed using the Log rank test.

Factors associated with 24-hour mortality were analyzed using flexible parametric survival models based on the Royston–Parmar approach. Univariable analyses were first conducted, and variables with $p < 0.20$ were considered for inclusion in the multivariable model. Multivariable modeling was performed to estimate adjusted hazard ratios (aHRs) with 95% CIs, applying a backward elimination strategy with a significance threshold of $p \leq 0.05$. To reduce the risk of overfitting, model development considered the ratio of outcome events to candidate predictors, and a parsimonious modeling strategy was adopted by retaining only variables with statistical significance and clinical relevance.

Model performance was evaluated in terms of discrimination and calibration. Discrimination was assessed using Harrell's C-statistic and Royston and Sauerbrei's D-statistic (including R^2_D), while calibration was evaluated using regression-based calibration analysis, including calibration plots and estimation of the calibration slope.

The Royston–Parmar flexible parametric survival model was selected in preference to the Cox proportional hazards model, as it allows flexible modeling of the baseline hazard function using restricted cubic splines, thereby providing smooth estimates of hazard and survival functions. In addition to addressing minor deviations from the proportional hazards assumption, this approach offers greater flexibility in capturing potential non-linear and time-varying hazard patterns during the early post-injury period, which is particularly relevant for modeling short-term mortality dynamics.

The proportional hazards assumption was assessed using Schoenfeld residuals; minor deviations were observed, supporting the use of a flexible parametric approach.

All statistical analyses were conducted using Stata version 18.0 (StataCorp, College Station, TX, USA). A two-sided p -value ≤ 0.05 was considered statistically significant.

Results

Patient Characteristics

Figure 1 during the study period, a total of 197 adult major trauma patients transported by EMS were included in the final analysis. The overall 24-hour mortality rate was 25.9% (95% confidence interval [CI]: 20.3–32.6), as illustrated in Figure 2. Baseline demographic characteristics, including age and sex, were comparable between survivors and non-survivors (Table 1).

Patients who died within 24 hours had a lower prevalence of documented comorbidities compared with survivors (3.9% vs 14.4%, $p = 0.045$) and were more frequently injured by blunt mechanisms (96.1% vs 70.5%, $p = 0.001$). Level of consciousness differed markedly between groups, with unresponsiveness predominating among non-survivors (78.4% vs 8.9% alert among survivors, $p < 0.001$). Several injury characteristics were also more common in the mortality group, including abrasions (54.9% vs 37.0%, $p = 0.025$), contusions (49.0% vs 25.3%, $p = 0.002$), internal hemorrhage (11.8% vs 3.4%, $p = 0.036$), head and neck injuries (60.8% vs 41.1%, $p = 0.015$), and facial injuries (54.9% vs 29.5%, $p = 0.001$).

Prehospital time intervals were largely comparable between groups. However, mean scene time was shorter among non-survivors than survivors (15.9 vs 20.1 minutes, $p = 0.040$), and a scene time exceeding 10 minutes was less frequent in the mortality group (52.9% vs 74.7%, $p = 0.004$). Physiological parameters on initial assessment were significantly worse among non-survivors, including lower systolic blood pressure (105.9 vs 129.1 mmHg, $p < 0.001$), lower diastolic blood pressure (69.5 vs 76.9 mmHg, $p = 0.036$), lower oxygen saturation (median 90% vs 97%, $p < 0.001$), lower GCS scores (80.4% with GCS < 9 vs 58.2% with GCS ≥ 13 , $p < 0.001$), and higher injury severity scores (median 32 vs 6, $p < 0.001$).

Prehospital interventions were more frequently performed among non-survivors, including endotracheal intubation (15.7% vs 1.4%, $p < 0.001$), chest tube insertion (80.4% vs 16.4%, $p < 0.001$), and CVC placement (19.6% vs 0.7%, $p < 0.001$). Oxygen supplementation was also more common in the mortality group (76.5% vs 58.2%, $p = 0.020$) (Table 1).

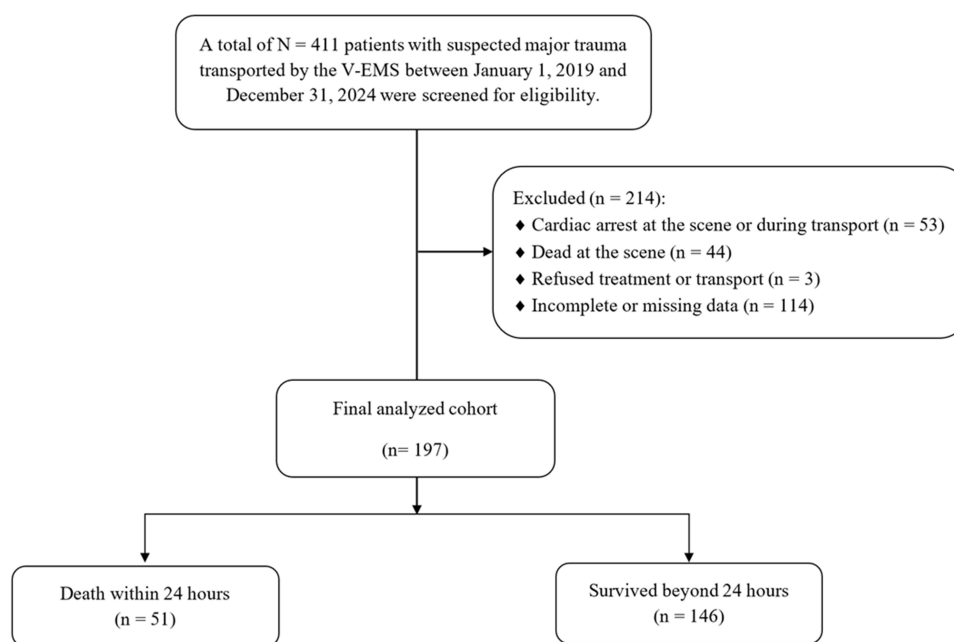


Figure 1 Study flow.

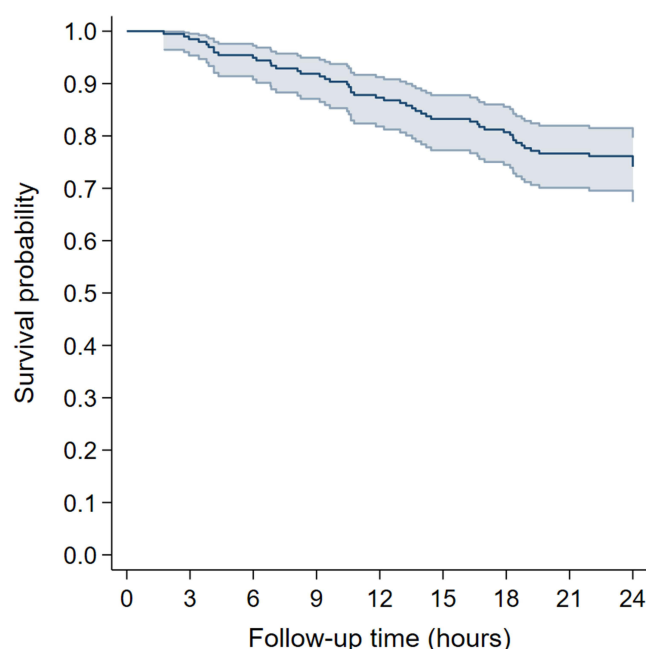


Figure 2 Kaplan–Meier survival curve illustrating hourly estimates of 24-hour mortality with 95% confidence intervals among all adult major trauma patients transported by EMS. Confidence intervals overlap at later time points and should be interpreted with caution, particularly given the decreasing number of patients at risk over time.

Mortality by Subgroups

Mortality rates stratified by clinical characteristics are presented in Table 2. Higher 24-hour mortality was observed among patients with blunt trauma compared with penetrating trauma (32.2% vs 4.4%, $p < 0.001$), those who were unresponsive compared with alert patients (54.1% vs 7.6%, $p < 0.001$), and patients with abrasions (34.2% vs 20.0%, $p =$

Table 1 Baseline Demographic Characteristics and Early Clinical Variables of Adult Major Trauma Patients Transported by EMS, Stratified by 24-Hour Mortality (n = 197)

Variables	24-Hour Mortality		p-value
	Yes (n = 51)	No (n = 146)	
Sex			
Female	16 (31.4)	37 (25.3)	0.403
Male	35 (68.6)	109 (74.7)	
Age (years)	42.78 ± 20.81	41.85 ± 20.08	0.777
< 60	36 (70.6)	115 (78.8)	0.235
≥ 60	15 (29.4)	31 (21.2)	
Comorbidities	2 (3.9)	21 (14.4)	0.045
Hypertension	1 (2.0)	9 (6.2)	0.458
Diabetes	1 (2.0)	8 (5.5)	0.451
Dyslipidemia	1 (2.0)	2 (1.4)	1.000
CKD	1 (2.0)	2 (1.4)	1.000
Others	0 (0.0)	11 (7.5)	0.069
Mechanism of injury			
Blunt	49 (96.1)	103 (70.5)	0.001
Penetrating	0 (0.0)	15 (10.3)	
Other	2 (3.9)	28 (19.2)	

(Continued)

Table 1 (Continued).

Variables	24-Hour Mortality		p-value
	Yes (n = 51)	No (n = 146)	
Consciousness			
Alert	7 (13.7)	85 (58.2)	<0.001
Verbal response	2 (3.9)	20 (13.7)	
Pain response	2 (3.9)	7 (4.8)	
Unresponsive	40 (78.4)	34 (23.3)	
Type of wounds			
Cut/Laceration	30 (58.8)	66 (45.2)	0.094
Abrasion	28 (54.9)	54 (37.0)	0.025
Contusion	25 (49.0)	37 (25.3)	0.002
Amputation	0 (0.0)	4 (2.7)	0.574
Gun shot wound	0 (0.0)	2 (1.4)	1.000
Burn	0 (0.0)	1 (0.7)	1.000
Type of bone injury			
Close fracture	14 (27.5)	46 (31.5)	0.588
Open fracture	10 (19.6)	22 (15.1)	0.449
Dislocation	1 (2.0)	5 (3.4)	1.000
Type of hemorrhage			
External stopped	19 (37.3)	68 (46.6)	0.249
External active	8 (15.7)	15 (10.3)	0.300
Internal hemorrhage	6 (11.8)	5 (3.4)	0.036
Body parts injury			
Extremity	23 (45.1)	75 (51.4)	0.441
Head/Neck	31 (60.8)	60 (41.1)	0.015
Face	28 (54.9)	43 (29.5)	0.001
Chest/Clavicle	15 (29.4)	28 (19.2)	0.128
Abdomen	9 (17.6)	14 (9.6)	0.123
Spine	9 (17.6)	13 (8.9)	0.088
Multiple injury	8 (15.7)	12 (8.2)	0.129
Pelvis	4 (7.8)	10 (6.8)	0.760
External Body Surface	3 (5.9)	9 (6.2)	1.000
Response time	7.00 ± 4.59	7.82 ± 4.46	0.262
> 8 min.	14 (27.5)	60 (41.1)	0.083
≤ 8 min.	37 (72.5)	86 (58.9)	
Scene time	15.96 ± 13.44	20.11 ± 11.88	0.040
> 10 min.	27 (52.9)	109 (74.7)	0.004
≤ 10 min.	24 (47.1)	37 (25.3)	
Transfer time	9.98 ± 7.76	8.68 ± 9.39	0.377
> 10 min.	13 (25.5)	32 (21.9)	0.601
≤ 10 min.	38 (74.5)	114 (78.1)	
Distance from base station to scene (km)	4.35 ± 4.26	3.40 ± 3.29	0.101
Distance from scene to hospital (km)	3.75 ± 2.28	3.26 ± 2.45	0.217
Systolic blood pressure (mmHg)	105.86 ± 32.43	129.07 ± 32.65	<0.001
Diastolic blood pressure (mmHg)	69.49 ± 20.31	76.92 ± 22.05	0.036
Heart rate (bpm)	87.35 ± 20.14	96.21 ± 22.89	0.015
Oxygen saturation (%)	90 (88–96)	97 (92–98)	<0.001
Respiratory rate (bpm)	20.96 ± 6.52	23.16 ± 8.37	0.090
Body temperature (°C)	36.59 ± 0.63	36.65 ± 0.64	0.569
Shock index	0.86 ± 0.28	0.79 ± 0.29	0.098

(Continued)

Table 1 (Continued).

Variables	24-Hour Mortality		p-value
	Yes (n = 51)	No (n = 146)	
Injury severe score	32 (15–49)	6 (3–16)	<0.001
< 16	13 (25.5)	98 (67.1)	<0.001
≥ 16	38 (74.5)	48 (32.9)	
Glasgow Coma Score	3 (3–6)	14 (9–15)	<0.001
13–15	7 (13.7)	85 (58.2)	<0.001
9–12	3 (5.9)	26 (17.8)	
3–8	41 (80.4)	35 (24.0)	
Hemorrhage control	19 (37.3)	71 (48.6)	0.160
Airway management	12 (23.5)	13 (8.9)	0.007
Endotracheal tube	8 (15.7)	2 (1.4)	<0.001
Oxygen support	39 (76.5)	85 (58.2)	0.020
Fluid assess	32 (62.7)	108 (74.0)	0.128
Immobilization	45 (88.2)	121 (82.9)	0.366
Chest tube insertion	41 (80.4)	24 (16.4)	<0.001
Massive blood transfusion	18 (35.3)	46 (31.5)	0.619
Central venous catheter placement	10 (19.6)	1 (0.7)	<0.001
Definite or damage control surgery	18 (35.3)	67 (45.9)	0.188

Table 2 24-Hour Mortality Rates Among Adult Major Trauma Patients Transported by EMS, Stratified by Clinical Characteristics

Factors	24-Hour Mortality		p-value
	Rate	(95% CI)	
All patients	25.89	(20.34–32.61)	
Sex			
Female	30.19	(19.71–44.47)	0.374
Male	24.31	(18.10–32.18)	
Age (years)			
< 60	23.84	(17.82–31.47)	0.202
≥ 60	32.61	(21.11–48.15)	
Comorbidities			
Yes	8.70	(2.25–30.51)	0.061
No	28.16	(22.09–35.48)	
Blunt injury (mechanism of injury)			
Yes	32.24	(25.44–40.30)	<0.001
No	4.44	(1.13–16.62)	
Consciousness			
Alert	7.61	(3.70–15.30)	<0.001
Verbal response	9.09	(2.35–31.70)	
Pain response	22.22	(6.07–63.52)	
Unresponsive	54.05	(43.22–65.65)	
Type of wounds			
Cut/Laceration			
Yes	31.25	(23.01–41.55)	0.093
No	20.79	(14.09–30.08)	

(Continued)

Table 2 (Continued).

Factors	24-Hour Mortality		p-value
	Rate	(95% CI)	
Abrasion			
Yes	34.15	(25.00–45.48)	0.027
No	20.00	(13.77–28.54)	
Contusion			
Yes	40.32	(29.34–53.57)	0.002
No	19.26	(13.55–26.98)	
Amputation			
Yes	0.00	–	0.268
No	26.42	(20.78–33.25)	
Gun shot wound			
Yes	0.00	–	0.437
No	26.15	(20.56–32.92)	
Burn			
Yes	0.00	–	0.583
No	26.02	(20.45–32.76)	
Type of bone injury			
Close fracture			
Yes	23.33	(14.54–36.19)	0.554
No	27.01	(20.37–35.28)	
Open fracture			
Yes	31.25	(18.20–50.29)	0.370
No	24.85	(18.95–32.18)	
Dislocation			
Yes	16.67	(2.53–72.69)	0.620
No	26.18	(20.53–33.03)	
Type of hemorrhage			
External stopped			
Yes	21.84	(14.53–32.07)	0.266
No	29.09	(21.55–38.55)	
External active			
Yes	34.78	(19.16–57.65)	0.299
No	24.71	(18.97–31.83)	
Internal hemorrhage			
Yes	54.55	(29.31–83.34)	0.005
No	24.19	(18.67–31.02)	
Body parts injury			
Abdomen			
Yes	39.13	(22.63–61.73)	0.144
No	24.14	(18.45–31.21)	
Chest/Clavicle			
Yes	34.88	(22.71–51.05)	0.187
No	23.38	(17.46–30.89)	
External Body Surface			
Yes	25.00	(8.83–59.16)	0.970
No	25.95	(20.24–32.90)	
Extremity			
Yes	23.47	(16.27–33.17)	0.459
No	28.28	(20.48–38.26)	

(Continued)

Table 2 (Continued).

Factors	24-Hour Mortality		p-value
	Rate	(95% CI)	
Face			
Yes	39.44	(29.17–51.77)	<0.001
No	18.25	(12.53–26.18)	
Head/Neck			
Yes	34.07	(25.34–44.78)	0.014
No	18.87	(12.61–27.70)	
Multiple injury			
Yes	40.00	(22.40–64.27)	0.085
No	24.29	(18.63–31.31)	
Pelvis			
Yes	28.57	(11.81–59.37)	0.807
No	25.68	(19.97–32.66)	
Spine			
Yes	40.91	(23.79–63.90)	0.086
No	24.00	(18.34–31.04)	
Response time			
> 8 min.	30.08	(22.80–39.03)	0.077
≤ 8 min.	18.92	(11.67–29.84)	
Scene time			
> 10 min.	39.34	(28.37–52.72)	0.002
≤ 10 min.	19.85	(14.07–27.60)	
Transfer time			
> 10 min.	25.00	(18.87–32.69)	0.693
≤ 10 min.	28.89	(17.92–44.49)	
Injury severe score			
< 16	11.71	(6.98–19.31)	<0.001
≥ 16	44.19	(34.45–55.29)	
Glasgow Coma Score			
13–15	7.61	(3.70–15.30)	<0.001
9–12	10.34	(3.46–28.74)	
3–8	53.95	(43.25–65.4)	
Hemorrhage control			
Yes	21.11	(14.02–31.08)	0.183
No	29.91	(22.18–39.55)	
Airway management (ETT)			
Yes	80.00	(52.53–96.91)	<0.001
No	22.99	(17.6–29.72)	
Oxygen support			
Yes	31.45	(24.07–40.42)	0.019
No	16.44	(9.69–27.13)	
Fluid assess			
Yes	22.86	(16.75–30.74)	0.154
No	33.33	(22.73–47.15)	
Immobilization			
Yes	27.11	(21.01–34.56)	0.410
No	19.35	(9.20–38.09)	
Chest tube insertion			
Yes	63.08	(51.53–74.6)	<0.001
No	7.58	(4.15–13.62)	

(Continued)

Table 2 (Continued).

Factors	24-Hour Mortality		p-value
	Rate	(95% CI)	
Massive blood transfusion			
Yes	28.13	(18.75–40.86)	0.586
No	24.81	(18.33–33.08)	
Central venous catheter placement			
Yes	90.91	(66.71–99.46)	<0.001
No	22.04	(16.74–28.71)	
Definite or damage control surgery			
Yes	21.18	(13.91–31.48)	0.261
No	29.46	(21.94–38.85)	

0.027), contusions (40.3% vs 19.3%, $p = 0.002$), internal hemorrhage (54.6% vs 24.2%, $p = 0.005$), facial injuries (39.4% vs 18.3%, $p < 0.001$), and head or neck injuries (34.1% vs 18.9%, $p = 0.014$).

Clinical severity and care process indicators were also strongly associated with mortality. Patients with scene time >10 minutes, injury severity score ≥ 16 , GCS <9, and those who underwent endotracheal intubation, chest tube insertion, or CVC placement had significantly higher 24-hour mortality rates (all $p < 0.05$).

Predictors of 24-Hour Mortality

Univariable survival analyses identified multiple clinical, physiological, and intervention-related factors associated with mortality within the first 24 hours (Table 3). In multivariable flexible parametric survival analysis, three independent predictors remained statistically significant (Table 4 and Figure 3a–c). A GCS score of 3–8 was associated with a higher risk of early mortality (adjusted hazard ratio [aHR] 3.72, 95% CI: 1.56–8.87, $p = 0.003$). Indicators of intensive resuscitative care were also independently associated with mortality, including chest tube insertion (aHR 6.82, 95% CI: 3.23–14.39, $p < 0.001$) and CVC placement (aHR 2.50, 95% CI: 1.21–5.17, $p = 0.013$).

Table 3 Univariable Analyses of Factors Associated with 24-Hour Mortality Among Adult Major Trauma Patients Transported by EMS

Factors	HR	(95% CI)	p-value
Sex			
Female	1.31	(0.72–2.37)	0.372
Male	1.00	Reference	
Age (years)			
< 60	1.00	Reference	0.198
≥ 60	1.49	(0.81–2.71)	
Comorbidities	0.28	(0.07–1.16)	0.080
Blunt injury (mechanism of injury)	8.43	(2.05–34.66)	0.003
Consciousness			
Alert	1.00	Reference	0.851
Verbal response	1.16	(0.24–5.60)	
Pain response	3.16	(0.66–15.21)	
Unresponsive	9.44	(4.22–21.11)	
Type of wounds			
Cut/Laceration	1.61	(0.92–2.81)	0.094
Abrasion	1.84	(1.06–3.20)	0.030

(Continued)

Table 3 (Continued).

Factors	HR	(95% CI)	p-value
Contusion	2.35	(1.35–4.07)	0.002
Amputation	–	–	NA
Gun shot wound	–	–	NA
Burn	–	–	NA
Type of bone injury			
Close fracture	0.83	(0.45–1.54)	0.556
Open fracture	1.36	(0.68–2.72)	0.381
Dislocation	0.61	(0.08–4.43)	0.627
Type of hemorrhage			
External stopped	0.72	(0.41–1.28)	0.264
External active	1.48	(0.7–3.16)	0.306
Internal hemorrhage	3.21	(1.37–7.55)	0.007
Body parts injury			
Abdomen	1.71	(0.83–3.51)	0.145
Chest/Clavicle	1.50	(0.82–2.74)	0.187
External Body Surface	0.98	(0.30–3.14)	0.968
Extremity	0.81	(0.47–1.41)	0.456
Face	2.49	(1.43–4.32)	0.001
Head/Neck	2.00	(1.14–3.51)	0.016
Multiple injury	1.93	(0.91–4.11)	0.088
Pelvis	1.13	(0.41–3.14)	0.814
Spine	1.86	(0.91–3.82)	0.091
Response time (min)			
> 8 min.	0.57	(0.31–1.06)	0.077
≤ 8 min.	1.00	Reference	
Scene time (min)			
> 10 min.	0.43	(0.25–0.75)	0.003
≤ 10 min.	1.00	Reference	
Transfer time (min)			
> 10 min.	1.13	(0.60–2.13)	0.699
≤ 10 min.	1.00	Reference	
Distance from base station to scene (km)	1.04	(0.98–1.11)	0.180
Distance from scene to hospital (km)	1.06	(0.95–1.17)	0.300
Systolic blood pressure (mmHg)	0.98	(0.97–0.99)	<0.001
Diastolic blood pressure (mmHg)	0.99	(0.97–1.00)	0.045
Heart rate (bpm)	0.99	(0.97–1.00)	0.023
Oxygen saturation (%)	0.98	(0.96–1.00)	0.027
Respiratory rate (bpm)	0.95	(0.90–1.01)	0.085
Body temperature (°C)	0.86	(0.56–1.32)	0.494
Shock index	2.08	(0.91–4.77)	0.084
Injury severe score			
< 16	1.00	Reference	
≥ 16	4.53	(2.41–8.51)	<0.001
Glasgow Coma Score			
13–15	1.00	Reference	
9–12	1.33	(0.34–5.15)	0.678
3–8	9.45	(4.23–21.12)	<0.001
Hemorrhage control	0.68	(0.38–1.20)	0.182
Airway management (ETT)	6.12	(2.85–13.13)	<0.001
Oxygen support	2.13	(1.11–4.07)	0.022

(Continued)

Table 3 (Continued).

Factors	HR	(95% CI)	p-value
Fluid assess	0.66	(0.38–1.17)	0.154
Immobilization	1.43	(0.61–3.35)	0.412
Chest tube insertion	11.80	(5.89–23.63)	<0.001
Massive blood transfusion	1.17	(0.66–2.08)	0.594
Central venous catheter placement	8.91	(4.37–18.17)	<0.001
Definite or damage control surgery	0.72	(0.40–1.27)	0.257

Table 4 Multivariable Analyses of Factors Independently Associated with 24-Hour Mortality Among Adult Major Trauma Patients Transported by EMS

Factors	Univariable Analysis			Multivariable Analysis		
	Crude HR [†] (95% CI)		p-value	Adjusted HR [‡] (95% CI)		B
Glasgow Coma Score						
13–15	1.00	Reference		1.00	Reference	0.000
9–12	1.33	(0.34–5.15)	0.678	0.77	(0.19–3.02)	–0.265
3–8	9.45	(4.23–21.12)	<0.001	3.72	(1.56–8.87)	1.313
Chest tube insertion	11.80	(5.89–23.63)	<0.001	6.82	(3.23–14.39)	1.920
Central venous catheter placement	8.91	(4.37–18.17)	<0.001	2.50	(1.21–5.17)	0.917

Notes: Variable was included in the multivariate model due to having p-value of <0.2 in the univariate analysis. [†]Crude hazard ratio estimated by flexible parametric survival models. [‡]Adjusted hazard ratio estimated by flexible parametric survival models. Constant: –3.348, R² = 0.5892, C-statistic = 0.848, D-statistic = 2.451, AIC = 226.527, BIC = 249.509.

Model Performance and Validation

Model fit indices demonstrated good overall performance, with an Akaike information criterion of 226.527 and a Bayesian information criterion of 249.509. Discrimination was strong, as indicated by a C-statistic of 0.848 and a D-statistic of 2.451. No evidence of multicollinearity was observed among the independent variables included in the

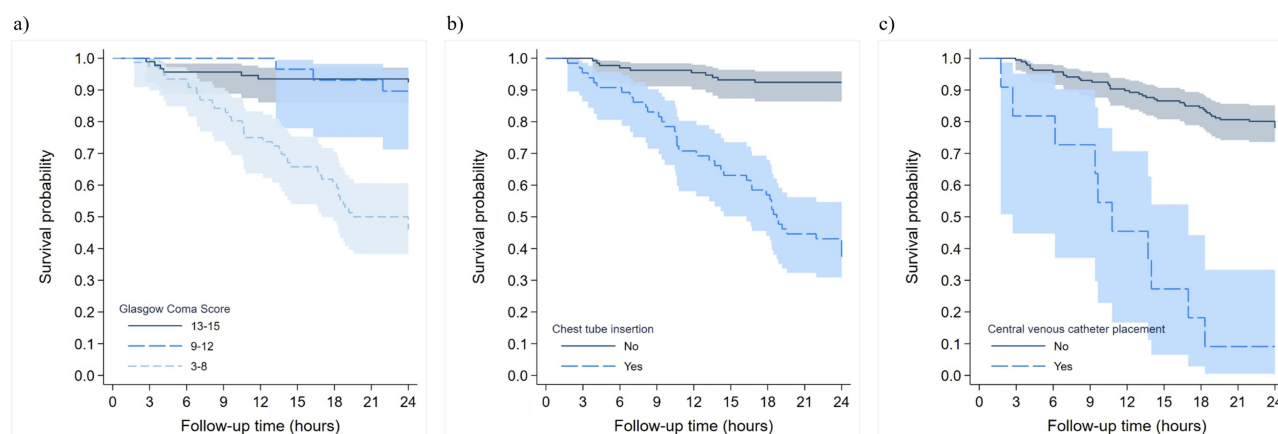


Figure 3 Kaplan–Meier survival curves depicting 24-hour mortality with 95% confidence intervals stratified by key predictive factors among adult major trauma patients transported by EMS: (a) Glasgow Coma Scale score, (b) chest tube insertion, and (c) central venous catheter placement. The observed separation between groups represents prognostic stratification and likely reflects underlying injury severity and resuscitative intensity rather than causal effects of the interventions.

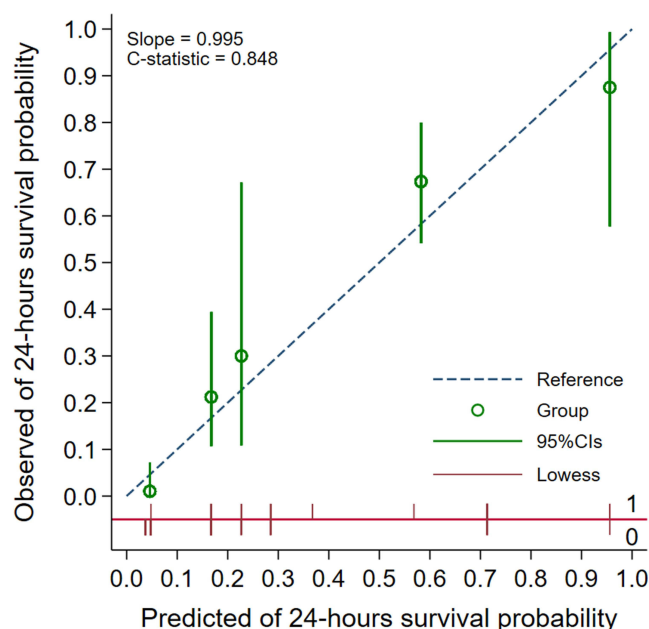


Figure 4 Calibration plot comparing predicted and observed probabilities of 24-hour mortality among adult major trauma patients transported by EMS. Calibration was assessed by grouping predicted probabilities into quantiles (eg, deciles) and comparing observed versus predicted outcomes.

final model. The coefficient of determination (R^2_D) was 0.5892, indicating that the model explained approximately 58.9% of the variability in 24-hour mortality risk.

The final prediction model can be expressed as:

$$H(t) = H_0(t) \times \text{EXP}(-3.348 - 0.265X_1 + 1.313X_2 + 1.920X_3 + 0.917X_4)$$

where X_1 represents a GCS score of 9–12, X_2 represents a GCS score of 3–8, X_3 indicates chest tube insertion, and X_4 indicates CVC placement.

The use of the Royston–Parmar flexible parametric survival model allowed for non-proportional hazard estimation and smooth survival prediction over time. Internal validation demonstrated good model calibration, with a calibration slope of 0.995 (Figure 4). Kaplan–Meier and model-based survival curves showed effective stratification of patients into low-, moderate-, and high-risk groups, with near-complete survival in the low-risk group and the lowest survival observed in the high-risk group (Figure 5).

Discussion

This study demonstrated a high 24-hour mortality rate (25.9%) among adult major trauma patients transported by emergency medical services (EMS) in Thailand. This finding reflects the substantial injury severity of the study population and underscores the critical importance of timely, coordinated emergency care across prehospital and hospital settings. The observed mortality rate is higher than those reported in developed healthcare systems, including Taiwan (12.5%) and Belgium (16.4%),²¹ as well as the United Arab Emirates (13.5%).²² Although direct comparisons across settings should be interpreted with caution due to differences in case mix, injury mechanisms, and trauma system organization, the elevated mortality observed in this study likely reflects the inclusion of patients classified strictly as major trauma, a group inherently at elevated risk for early death.

Importantly, 24-hour mortality in this study was defined from the time of EMS activation through the first 24 hours after hospital admission and included only patients who survived to hospital arrival. Patients who were found dead at the scene, experienced prehospital cardiac arrest, or died during transport were excluded because complete physiological and procedural data were unavailable. As a result, the reported mortality rate may underestimate the true burden of early trauma-related deaths at the population level. However, this approach ensured methodological consistency and enabled

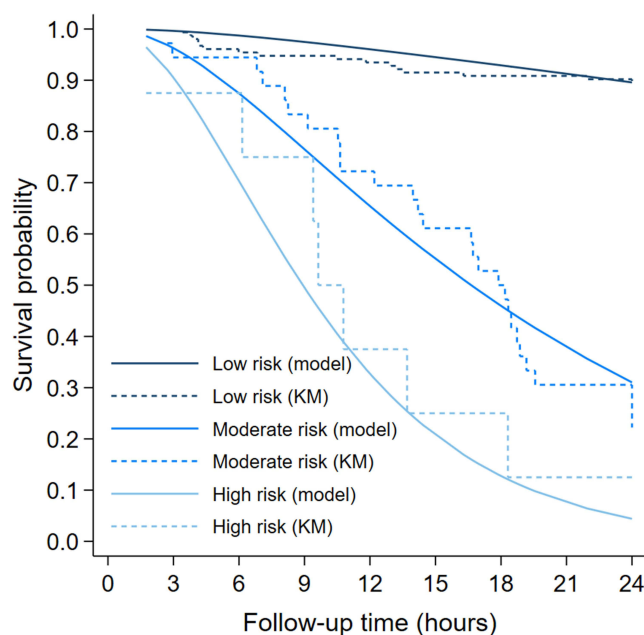


Figure 5 Comparison of predicted overall survival curves (solid lines) derived from the flexible parametric survival model and observed Kaplan-Meier survival curves (dashed lines) among adult major trauma patients transported by EMS, stratified into low-, moderate-, and high-risk groups based on the 33rd and 66th percentiles of the linear predictors Risk group stratification reflects retrospective prognostic separation rather than real-time clinical decision thresholds and should be interpreted accordingly.

robust modeling using standardized EMS and early in-hospital data, which is essential for evaluating early predictors of mortality and healthcare system performance.

This exclusion results in a survivorship-conditioned cohort, which may influence the underlying hazard structure and limit generalizability to the full trauma population. Accordingly, the findings should be interpreted as reflecting early mortality among patients who survived to hospital arrival rather than all trauma-related deaths.

Three independent predictors of 24-hour mortality were identified: GCS score, chest tube insertion, and CVC placement. A GCS score of 3–8, indicative of severe traumatic brain injury (TBI),²³ was associated with a substantially increased risk of early mortality, consistent with previous studies demonstrating the central role of neurological injury in short-term trauma outcomes.^{24–26} These findings reinforce the importance of early neurological assessment, repeated monitoring during prehospital transport, and timely transfer to trauma centers with advanced neurosurgical capability.

Although severe TBI accounted for a considerable proportion of early deaths, not all fatalities were attributable to head injury. Patients with severe thoracic, abdominal, or multisystem injuries also died within the first 24 hours, frequently due to internal hemorrhage or rapid physiological deterioration after hospital admission. The relatively low mean shock index observed in this cohort may reflect compensatory physiological responses during the prehospital phase or the effects of early EMS resuscitation, suggesting that shock index alone may underestimate early circulatory instability in patients with severe trauma.

An association between CVC placement and increased 24-hour mortality was observed; however, this relationship should not be interpreted as causal. Rather, CVC placement likely serves as a marker of underlying injury severity and hemodynamic instability, identifying patients who required invasive monitoring or aggressive resuscitation.^{27–29} Previous studies have reported that CVC insertion carries procedural risks, particularly in patients with coagulopathy, and may be associated with complications such as infection, thrombosis, or pulmonary embolism, which can contribute to adverse outcomes.^{27–29} Nonetheless, the observed association in this study is most consistent with confounding by indication, whereby more severely injured patients were more likely to require CVC placement.

Similarly, chest tube insertion was strongly associated with early mortality, with patients undergoing the procedure exhibiting a markedly higher risk of death within 24 hours. This finding contrasts with reports from intensive care unit–

based studies, such as that by Chiang et al, which did not identify chest tube insertion as an independent predictor of mortality.²⁷ Differences in study populations, clinical settings, and outcome definitions likely account for this discrepancy. Unlike ICU-based studies that include patients who have survived initial resuscitation, the present analysis focused on early mortality within the first 24 hours, a period heavily influenced by injury severity and acute physiological derangement. Chest tube insertion in this context likely reflects the presence of severe thoracic injury rather than the harmful effect of the procedure itself. Previous studies have similarly reported high short-term mortality among patients requiring chest tube insertion, emphasizing its role as a surrogate marker of severe trauma rather than an independent cause of death.³⁰

The observed associations between care process–related variables and early mortality should be interpreted with caution. Interventions such as chest tube insertion and central venous catheter placement are unlikely to be direct causal determinants of mortality; rather, they most plausibly reflect confounding by indication, whereby more severely injured and physiologically unstable patients are more likely to require invasive resuscitative procedures. Accordingly, these variables should be interpreted within a prognostic rather than causal framework and should not be considered modifiable targets for intervention. Instead, they may serve as clinically meaningful markers of high-risk patients who require early recognition, prioritized triage, and timely escalation of care.

Although this study attempts to situate early mortality within an EMS-to-hospital continuum, the observed associations likely reflect the clinical intensity of already deteriorating patients rather than discrete system-level effects.

From a systems perspective, these findings should be interpreted cautiously, as the variables included in the model primarily reflect patient-level severity and resuscitative intensity rather than direct measures of system performance or coordination. While clinical severity and system-level processes are inherently interconnected within trauma care, they are not directly interchangeable constructs. Accordingly, the present analysis does not explicitly measure system-level factors such as EMS coordination, integration, or operational performance, and any system-level implications should therefore be considered indirect and hypothesis-generating rather than confirmatory.

The observed lower prevalence of comorbidities among non-survivors is counterintuitive and may reflect a combination of younger age distribution in high-energy trauma, documentation limitations in emergency settings, or selection effects within EMS triage processes, rather than a true protective effect. Similarly, the shorter scene time observed among non-survivors may reflect rapid transport decisions in critically unstable patients rather than improved operational efficiency, highlighting the complexity of interpreting time-based metrics in high-acuity trauma care.

Importantly, the findings of this study do not support withholding indicated prehospital or early in-hospital interventions such as chest tube insertion or CVC placement. These procedures remain essential components of life-saving trauma care when clinically indicated. Instead, the observed associations highlight the need for careful patient selection, adherence to standardized procedural indications, team competency, and close post-procedural monitoring within a multidisciplinary trauma care framework.

From a healthcare systems perspective, the developed prediction model demonstrates potential utility as a prehospital and early in-hospital decision-support tool. By relying on routinely assessed clinical variables, the model may assist EMS personnel in rapidly identifying patients at high risk of early death, prioritizing transport to higher-level trauma centers, and facilitating early activation of multidisciplinary trauma teams.

From a healthcare systems perspective, the developed prediction model may provide supportive information for early risk identification; however, its implications for system-level decision-making should be interpreted with caution, as the model is derived from patient-level variables rather than direct measures of system performance.

However, the identified risk strata primarily reflect retrospective prognostic separation rather than real-time decision thresholds, and their application in clinical practice requires prospective validation. Integration of such models into digital EMS platforms or triage algorithms could support real-time clinical decision-making and resource allocation. However, external validation and implementation research are necessary before routine clinical adoption.

Limitations

This study has several limitations. First, the retrospective single-center design may limit generalizability, particularly given the heterogeneity of EMS systems across Thailand. Urban EMS units, such as the Vajira EMS system, typically

operate at a comprehensive life support level with paramedic- or ENP-led teams and access to advanced interventions, whereas rural EMS systems often function with more limited resources and personnel. These structural differences may influence prehospital assessment, intervention, and transport decisions, and multicenter studies encompassing diverse EMS contexts are warranted to enhance external validity. Second, in-hospital treatments during the emergency department or intensive care unit phase were not fully captured, which may confound observed associations. Third, outcomes of patients transferred to hospitals outside the study area could not be followed. Fourth, several potentially important predictive variables, including cardiopulmonary resuscitation, vasopressor use, and other advanced resuscitative measures, were unavailable due to data limitations. Fifth, the use of TEMTP-CBD red-level classification as a proxy for major trauma may introduce misclassification bias, as triage-based criteria may not fully correspond to standardized anatomical or composite severity measures (eg, Injury Severity Score). Sixth, the study period included the COVID-19 pandemic years (2020–2022), during which EMS operations and hospital workflows may have been disrupted. These system-level changes could have affected response times, resource availability, and early clinical management, potentially introducing residual confounding. A formal sensitivity analysis stratified by pandemic versus non-pandemic periods was not performed and warrants further investigation. Finally, some variables included in the model, such as chest tube insertion and central venous catheter placement, are hospital-based procedures and may not be directly applicable to all prehospital settings. Despite these limitations, this study provides important insights into early mortality among major trauma patients within an EMS-based trauma system in a middle-income country. The findings emphasize the critical role of multidisciplinary trauma care, early risk stratification, and integrated EMS–hospital systems in reducing preventable early deaths and improving trauma outcomes.

Conclusion

The 24-hour mortality rate among adult major trauma patients transported by EMS was 25.9%. Severe neurological impairment, reflected by a GCS score of 3–8, along with the need for invasive resuscitative interventions such as chest tube insertion and central venous catheter placement, were independently associated with early mortality. These factors should be interpreted primarily as markers of injury severity and physiological instability rather than direct measures of system performance or integration.

Furthermore, these findings are derived from a survivorship-conditioned cohort that excludes prehospital deaths; therefore, they reflect early mortality among patients who survived to hospital arrival rather than the full spectrum of trauma-related mortality.

The findings support the importance of early risk stratification and timely clinical assessment in identifying high-risk patients during the early phase of care. However, implications for system-level coordination, integration, or performance should be interpreted cautiously, as these constructs were not directly measured in the present study.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

This study was approved by the Institutional Review Board of the Faculty of Medicine Vajira Hospital, Navamindradhiraj University (COA No. 090/2568). The study was conducted in accordance with the Declaration of Helsinki. The requirement for informed consent was waived because the study used anonymized routinely collected data. Confidentiality and anonymity were strictly maintained.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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