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Original Research Article

EMERGENCY DEPARTMENT DELAYS AND PREVENTABLE MORTALITY AMONG ADULT TRAUMA PATIENTS: A PROSPECTIVE OBSERVATIONAL COHORT STUDY WITH AN EMBEDDED CLINICAL AUDIT

Suman Rastogi[1], Sunil Bhatt[2], Takshak Shankar[3], Mukta Singh[4], Bandana Rastogi[5]

[1]Assistant Professor, Department of Emergency Medicine, Himalayan Institute of Medical Sciences, Jolly Grant, Dehradun, Uttarakhand, India.
[2]Assistant Professor, Department of Emergency Medicine, Himalayan Institute of Medical Sciences, Jolly Grant, Dehradun, Uttarakhand, India.
[3]Assistant Professor, Department of Emergency Medicine, Himalayan Institute of Medical Sciences, Jolly Grant, Dehradun, Uttarakhand, India.
[4]Associate Professor, Department of Emergency Medicine, Himalayan Institute of Medical Sciences, Jolly Grant, Dehradun, Uttarakhand, India.
[5]Junior Resident, Department of Emergency Medicine, All India Institute of Medical Sciences, Rishikesh, Uttarakhand, India.

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Corresponding Author:
Dr. Suman Rastogi,
Assistant Professor, Department of Emergency Medicine, Himalayan Institute of Medical Sciences, Jolly Grant, Dehradun, Uttarakhand, India.
Email: drsuman404@icloud.com

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ABSTRACT

Background: Delays in emergency department (ED) trauma care may contribute to avoidable mortality. Structured clinical audit can identify process gaps and opportunities to improve care. **Objective:** To evaluate preventable delays and classify potentially preventable deaths in adult trauma patients presenting to a tertiary care ED, using standardized audit methodology.

Materials and Methods: A prospective observational cohort study with an embedded clinical audit was conducted at Himalayan Hospital, Dehradun, during October 2025–September 2026. Adults aged 18–65 years presenting within 24 hours of injury and requiring trauma team activation were included. The analysis comprised 412 patients. Injury severity, intervention times, and in-hospital deaths within 30 days were assessed. A three-member expert panel classified deaths by preventability. TRISS benchmarking and multivariable logistic regression were performed.

Results: Of 412 patients, 72.3% were male and 61.2% had road traffic injuries. Median ISS was 22 (IQR 16–34). In-hospital mortality within 30 days was 18.2% (75/412). Of the deaths, 41 (54.7%) were non-preventable, 21 (28.0%) potentially preventable, and 13 (17.3%) definitely preventable. CT delay >60 minutes (OR 2.8, 95% CI 1.4–5.6; p=0.003) and operative transfer delay >90 minutes in patients with shock (OR 3.2, 95% CI 1.6–6.4; p=0.001) were associated with preventable mortality in the reported model.

Conclusion: Potentially or definitely preventable deaths accounted for 45.3% of reviewed deaths. The audit identified associations between delayed imaging or operative transfer and preventable mortality, suggesting priorities for workflow review. These observational findings require cautious interpretation because of the recruitment shortfall and limitations in risk adjustment and case-mix comparability.

Keywords: Trauma; emergency department; clinical audit; preventable mortality; treatment delay; TRISS.

INTRODUCTION

Trauma continues to be one of the foremost public health challenges worldwide, contributing significantly to morbidity, mortality, and long-term disability. The global burden of injuries encompasses substantial premature mortality and disability, making trauma care an important public health priority.[1] Road traffic collisions, falls, interpersonal violence, and penetrating injuries constitute the leading mechanisms, with low- and middle-income countries bearing a disproportionate share of this burden. In India, a multicentre review of trauma deaths has identified opportunities to prevent in-hospital mortality through improvements in care delivery.[2] The Himalayan region, with its unique geography, road infrastructure, and referral patterns, experiences a high incidence of blunt trauma from road traffic collisions and mountain falls, alongside penetrating injuries from occupational and interpersonal causes.

Despite advances in trauma systems and emergency care protocols, preventable deaths remain a pressing concern. A national evaluation by MacKenzie et al. demonstrated lower adjusted mortality among patients treated in trauma centres than among those treated in non-trauma centres.[3] A systematic review and meta-analysis by Celso et al. similarly supported the survival benefit of trauma-centre care for severely injured patients.[4] These findings support organized trauma services, although they do not establish a specific mortality effect for each emergency department process delay. Delays in diagnosis, imaging, operative intervention, and multidisciplinary coordination should therefore be evaluated directly through structured local audit.

Emergency departments (EDs) serve as the frontline of trauma care, where rapid assessment and intervention are critical determinants of survival. Advanced Trauma Life Support (ATLS) provides a systematic framework for initial assessment, resuscitation, and prioritization of life-threatening injuries.[5] Specific time thresholds for CT imaging, transfusion, and operative transfer should be defined by institutional audit protocols rather than assumed to be universal ATLS benchmarks. Registry-based process indicators can help identify departures from expected care and complement mortality review.[6] Structured audits of ED processes are therefore essential to identify delays, classify errors, and evaluate their association with patient outcomes.

Risk adjustment requires assessment of both anatomical injury severity and physiological derangement. The Injury Severity Score (ISS) provides an anatomical measure of injury burden,[7] while the Revised Trauma Score (RTS) incorporates physiological assessment.[8] The Trauma and Injury Severity Score (TRISS) methodology combines ISS, RTS, age, and injury mechanism to estimate survival probability and compare observed with expected outcomes.[9] Metrics such as the W-score, Z-score, and M-statistic support assessment of performance and case-mix comparability. When combined with expert preventability review, this approach offers a framework for evaluating trauma care.

Institution-specific analysis remains necessary to determine which ED processes require improvement. Trauma registries support standardized data collection, outcome monitoring, and continuous quality improvement, including in developing settings.[10] Himalayan Hospital (HIMS, Swami Rama Himalayan University, Dehradun) manages blunt and penetrating trauma within a regional referral setting. Conducting a structured audit in this environment provides an opportunity to generate context-specific evidence, identify system inefficiencies, and propose actionable improvements.

Evidence from organized trauma systems provides a broader context for institutional audit. Nathens et al. reported reduced injury-related mortality in association with state trauma systems,[11] while Cameron et al. documented improved survival following implementation of a statewide trauma system in Victoria.[12] Demetriades et al. examined the relationship between trauma-centre designation and mortality among severely injured patients.[13] Access to definitive care is also relevant: Haas et al. found a mortality benefit associated with direct trauma-centre transport,[14] and Sampalis et al. compared direct tertiary-centre transport with transfer from lower-level facilities.[15] Nevertheless, institutional outcome comparisons require careful risk adjustment because differences in case mix can affect mortality-based performance rankings.[16]

The present prospective observational cohort study with an embedded clinical audit evaluated adult trauma patients aged 18–65 years presenting within 24 hours of injury over 12 months. The study assessed demographics, injury severity, time-to-intervention milestones, process errors, morbidity, and mortality. A multidisciplinary panel classified deaths as non-preventable, potentially preventable, or definitely preventable. TRISS benchmarking and multivariable logistic regression were used to assess institutional outcomes and associations between ED delays and preventable mortality. By systematically quantifying delays and reviewing deaths, the study aimed to identify opportunities for workflow improvement, protocol reinforcement, and inter-specialty coordination.

MATERIALS AND METHODS

Study Design

This study was conducted as a **prospective observational cohort** with an embedded structured clinical audit. The design enabled real-time capture of trauma care processes and systematic evaluation of preventable delays and deaths.

Study Setting

The study was performed in the **Emergency Department of Himalayan Hospital (HIMS,**

Swami Rama Himalayan University, Dehradun). As a tertiary care teaching hospital and regional referral center, HIMS manages a high volume of blunt trauma (road traffic collisions, mountain road falls) and penetrating injuries, providing a representative case mix for trauma audit.

Study Period

Data were collected prospectively over a **12-month period (October 2025 – September 2026)**.

Sample Size

The planned sample size compared the proportions of potentially or definitely preventable deaths between patients with and without ED delays. Assuming proportions of 0.30 and 0.20, a two-sided significance level of 0.05, 80% power, and equal group allocation, the calculation used the following two-proportion approximation.

Using the formula for comparing two proportions:

$$n = \frac{\left(Z_{\alpha/2} + Z_{\beta}\right)^2 \cdot [p_1(1-p_1) + p_2(1-p_2)]}{(p_1 - p_2)^2}$$

Where:

- $Z_{\alpha/2} = 1.96$(for 95% CI)
- $Z_{\beta} = 0.84$(for 80% power)
- $p_1 = 0.30$(expected preventable deaths with delays)
- $p_2 = 0.20$(expected preventable deaths without delays)

Substitution yielded:

n = 290.08 per group; rounded upward to 291 per group.

The displayed approximation yielded 290.08 patients per group. Rounding upward gives 291 per group, or 582 participants in total. The protocol target was 650 participants, allowing for approximately 10% loss of analysable records. This calculation assumed equal numbers of patients in the two exposure groups.

A total of 412 patients were included in the analysis, below the planned recruitment target. The recruitment shortfall limits the precision of estimated associations and the ability to detect smaller effects. Statistical significance alone does not establish that the planned power was achieved.

Inclusion Criteria

- Adults aged 18 to 65 years.
- Acute trauma activations/admissions presenting to the Emergency Department within 24 hours of injury.
- Patients requiring trauma team activation as per institutional protocol.
- Both blunt trauma (road traffic collisions, falls from height) and penetrating injuries (assaults, stab wounds, firearm injuries) were included.

Exclusion Criteria

- Pediatric patients (<18 years).
- Geriatric patients (>65 years).
- Delayed presentations (>24 hours after injury).
- Isolated minor injuries not requiring trauma team activation (e.g., simple lacerations, isolated limb fractures without hemodynamic compromise).
- Transfers with incomplete records or missing key variables required for TRISS calculation.
- Patients who declined consent or whose legal guardians refused participation.

Data Collection and Variables

Data were collected prospectively for all eligible trauma patients using a standardized case record form designed specifically for this audit. Demographic information included age, sex, and mechanism of injury, with mechanisms categorized as road traffic accidents, falls from height, assaults, or penetrating injuries. Pre-hospital details such as transit time and EMS handoff were documented to capture delays prior to ED arrival. On presentation, physiological parameters were recorded, including Glasgow Coma Scale (GCS) and Revised Trauma Score (RTS), while anatomical severity was quantified using the Abbreviated Injury Scale (AIS) and Injury Severity Score (ISS). These baseline variables were essential for risk adjustment and TRISS methodology.

Chronological process variables included the intervals from ED arrival to trauma team assembly, eFAST, initial radiographs, whole-body CT, first blood transfusion, massive transfusion protocol (MTP) activation, and operative or ICU transfer. CT time >60 minutes and operative transfer time >90 minutes in patients with shock were treated as institutional audit thresholds. These thresholds were process indicators and should not be interpreted as universal ATLS timing requirements. Process errors assessed included airway management failures, delayed recognition of hemorrhage or tension pneumothorax, transfusion protocol deviations, imaging or reporting delays, and consultation delays.

Outcomes

Primary outcome: The principal audit outcome was the classification of trauma deaths by preventability. A three-member expert panel comprising an emergency physician, a trauma or general surgeon, and an intensivist or anesthesiologist reviewed each death and assigned one of the following categories:

- Non-preventable death (NPD): Death following injuries judged nonsurvivable after review of the anatomical injuries, physiological condition, clinical course, and available treatment options.
- Potentially preventable death (PPD): Death following severe injuries for which optimal assessment, resuscitation, and definitive treatment might have altered the outcome.
- Definitely preventable death (DPD): Death following injuries judged survivable in which the panel identified a care failure considered directly contributory to death.

Potentially and definitely preventable deaths were combined when describing the proportion of preventable deaths among all reviewed deaths.

Secondary outcomes: The study assessed mortality, process efficiency, morbidity, and system errors as follows:

- Mortality endpoints: 24-hour mortality and in-hospital mortality within 30 days of admission.

- **Process delays:** Time-to-intervention milestones including ED arrival to trauma team assembly, eFAST, radiographs, whole-body CT, massive transfusion activation, and operative transfer.
- **Morbidity measures:**
  - Massive transfusion requirements (units of PRBC, FFP, platelets within 24 hours).
  - ICU length of stay (days).
  - Ventilator-free days.
  - Complications including sepsis, acute respiratory distress syndrome (ARDS), and multiorgan dysfunction syndrome (MODS).
- **System errors:** Airway management failures, delayed recognition of hemorrhage or pneumothorax, protocol violations, imaging/reporting delays, and inter-specialty consultation lags.

Analytical Outcomes

Observed mortality was compared with TRISS-predicted mortality using the W-score, Z-score, and M-statistic. Case-mix comparability and the applicability of the reference model were considered when interpreting these comparisons. Logistic regression examined associations between ED process delays and preventable mortality; the reported model estimates are presented as odds ratios with 95% confidence intervals.

Ethical Considerations

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and the national ethical guidelines for biomedical research. Written informed consent was obtained from all participants or their legally authorized representatives at the time of enrollment, with proxy consent sought in cases where patients were incapacitated. Confidentiality was strictly maintained by anonymizing patient records and restricting access to study data. As the study was observational in nature, no experimental interventions were introduced, and clinical management was not altered. The audit process was undertaken solely for quality improvement and research purposes, with findings intended to strengthen trauma care systems.

Statistical Analysis

Data were analysed using IBM SPSS Statistics version 29.0. Continuous variables were summarised as mean ± standard deviation or median and interquartile range, according to their distribution. Categorical variables were expressed as frequencies and percentages. Where applicable, categorical comparisons used the chi-square or Fisher exact test, and continuous comparisons used the independent-samples t-test or Mann–Whitney U test. Statistical tests were two-sided, with $p<0.05$ considered statistically significant. TRISS benchmarking used the W-score, Z-score, and M-statistic. Multivariable logistic regression examined associations with preventable mortality, with odds ratios, 95% confidence intervals, and p-values reported in Table 4.

RESULTS

Baseline Characteristics

A total of 412 patients were enrolled during the study period. The mean age was 34.8 ± 12.6 years, with the majority being male (72.3%). Road traffic accidents accounted for the largest proportion of injuries (61.2%), followed by falls (21.5%), assaults (9.8%), and penetrating injuries (7.5%). The median Injury Severity Score (ISS) was 22 (IQR 16–34), reflecting a predominantly moderate-to-severe trauma cohort. The median Revised Trauma Score (RTS) at presentation was 6.2 (IQR 5.4–7.8), indicating significant physiological compromise in a subset of patients.

Table 1: Demographic and Injury Profile of Patients

Variable	Value (n=412)
Mean age (years)	34.8 ± 12.6
Male sex (%)	72.3
Mechanism of injury	RTA 61.2%, Fall 21.5%, Assault 9.8%, Penetrating 7.5
Median ISS (IQR)	22 (16–34)
Median RTS (IQR)	6.2 (5.4–7.8)

Notes: ISS = Injury Severity Score; RTS = Revised Trauma Score; RTA = Road Traffic Accident.

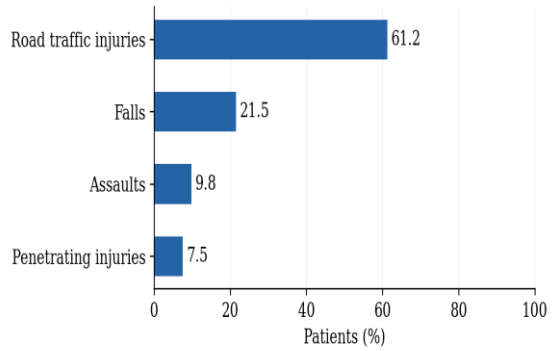


Figure 1: Reported mechanisms of injury in the trauma cohort

Figure notes: Bars show the reported percentages for each injury category. Age and injury severity scores are summarised separately in Table 1 because they use different units. Percentages and category definitions require confirmation against the study records.

Process Delays

Median recorded intervention times were 12 minutes for trauma team assembly, 18 minutes for eFAST, 24 minutes for initial radiographs, 58 minutes for whole-body CT, 32 minutes for the combined transfusion/MTP milestone, and 88 minutes for operative transfer in patients with shock (Table 2 and Figure 2). The reported delayed-case percentages are presented in Table 2; these process summaries do not by themselves establish a causal effect on mortality.

Table 2: Reported intervention times and delayed-case percentages

Intervention	Median Time (min)	Delayed Cases (%)
Trauma team assembly	12	14.6
eFAST	18	22.1
Initial X-ray	24	19.4
Whole-body CT	58	38.0
First blood unit/MTP	32	16.7
OR transfer (shock cases)	88	27.3

Notes: Times are measured in minutes from ED arrival. CT >60 minutes and operative transfer >90 minutes in patients with shock are institutional audit thresholds. Delayed-case percentages require intervention-specific eligibility denominators. eFAST = extended focused assessment with sonography for trauma; MTP = massive transfusion protocol; OR = operating room.

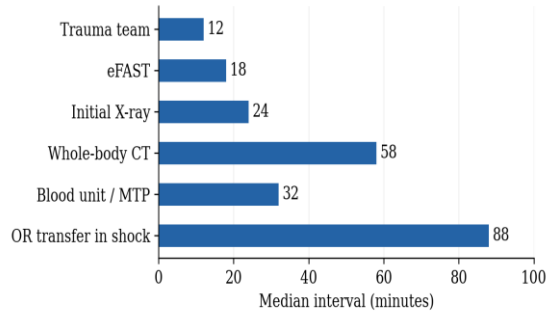


Figure 2: Reported median times to trauma interventions

Figure notes: Bars show median intervals in minutes from ED arrival. Delay percentages are displayed separately in Table 2. The applicable population varies by intervention; patients not requiring an intervention should not be included in its timing denominator. No variability measures were available for this figure.

Mortality and Preventability Review

In-hospital mortality within 30 days was reported in 75 of 412 patients (18.2%). Among the 75 deaths, 41 (54.7%) were classified as non-preventable, 21 (28.0%) as potentially preventable, and 13 (17.3%) as definitely preventable. The combined potentially and definitely preventable category comprised 34 deaths, representing 45.3% of reviewed deaths and 8.3% of the entire cohort. [Table 3 and Figure 3]

Table 3: Mortality and Preventability Classification

Category	n (%)
Non-Preventable Deaths	41 (54.7)
Potentially Preventable	21 (28.0)
Definitely Preventable	13 (17.3)
Total deaths	75 (18.2% of cohort)

Notes: Category percentages use 75 reviewed deaths as the denominator; overall mortality uses the cohort of 412 patients. Potentially and definitely preventable deaths together total 34/75 (45.3%). Preventability was assessed by a three-member expert panel.

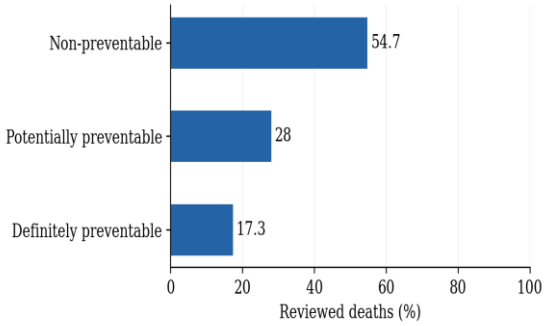


Figure 3: Mortality and Preventability Classification of Trauma Deaths (n=75)

Figure notes: Bars show percentages of the 75 reviewed deaths by preventability category. Non-preventable, potentially preventable, and definitely preventable deaths numbered 41, 21, and 13, respectively. Overall mortality is reported separately in Table 3.

Analytical Outcomes

The reported TRISS W-score was −2.1 and the Z-score was −3.4, suggesting fewer observed survivors than predicted by the reference model. The M-statistic of 0.82 indicated limited case-mix comparability with the reference population. The W- and Z-statistics therefore require cautious interpretation and do not alone establish inferior institutional performance.

In the reported multivariable model, CT delay >60 minutes was associated with higher odds of preventable mortality (OR 2.8, 95% CI 1.4–5.6; p=0.003). Operative transfer delay >90 minutes in patients with shock was also associated with higher odds (OR 3.2, 95% CI 1.6–6.4; p=0.001). Age >50 years and ISS >25 did not meet the prespecified significance threshold. The reported result for GCS <8 was at the rounded boundary (p=0.05; 95% CI 1.0–4.2), precluding a definitive significance interpretation without more precise output. [Table 4]

Table 4: Reported multivariable associations with preventable mortality

Variable	Odds Ratio (OR)	95% CI	p-value
Age >50 years	1.4	0.7–2.8	0.28
GCS <8	2.1	1.0–4.2	0.05
ISS >25	1.9	0.9–3.7	0.07
CT delay >60 min	2.8	1.4–5.6	0.003
OR delay >90 min (shock)	3.2	1.6–6.4	0.001

Notes: OR = odds ratio; CI = confidence interval; GCS = Glasgow Coma Scale; ISS = Injury Severity Score. Operative delay denotes transfer to the operating room. The exact model specification and analysis population require verification against the final statistical output.

DISCUSSION

The present study identified associations between emergency department process delays and preventable mortality in adult trauma patients. These findings address an important clinical problem within the wider global burden of injury-related mortality and disability.[1] In the Results section, potentially and definitely preventable deaths together accounted for 45.3% of reviewed deaths. Roy et al. similarly identified opportunities to prevent in-hospital trauma deaths in Indian hospitals through improvements in care delivery.[2] Comparisons of preventability percentages should nevertheless consider differences in patient selection, injury severity, and adjudication criteria.

The relevance of organized trauma care is supported by MacKenzie et al., who demonstrated lower adjusted mortality in trauma centres than in non-trauma centres.[3] Celso et al. also reported evidence supporting trauma-system development in their systematic review and meta-analysis.[4] These findings provide a context for improving care pathways at our institution. However, they do not establish a specific mortality effect for the CT and operative transfer thresholds used in this audit. The associations observed in our cohort should therefore be interpreted as findings from an observational study using institutional process measures.

A systematic approach to initial assessment and resuscitation remains central to trauma management. ATLS provides an organized framework for prioritizing life-threatening injuries,[5] while Moore et al. showed how registry data can be used to evaluate trauma-centre process performance.[6] These approaches support the assessment of imaging, transfusion, and operative pathways alongside clinical outcomes. Risk adjustment is equally important: the ISS describes anatomical injury burden,[7] the RTS incorporates physiological derangement,[8] and TRISS combines anatomical and physiological information with age and mechanism to estimate survival probability.[9] Trauma registries provide the infrastructure for consistent data collection and ongoing quality improvement.[10] Accordingly, the observed associations between delays and mortality should be considered alongside injury severity and the completeness of recorded process data.

Evidence from regional trauma systems reinforces the importance of coordinated care. Nathens et al. reported reduced injury-related mortality associated with state trauma systems,[11] and Cameron et al. documented improved survival after implementation of a statewide system in Victoria.[12] Demetriades et al. evaluated trauma-centre designation in relation to mortality among severely injured patients.[13] Haas et al. reported a mortality benefit associated with direct trauma-centre transport,[14] while Sampalis et al.

compared direct transport with transfer from lower-level facilities.[15] These studies support attention to coordination, referral pathways, and access to definitive treatment. In our institution, dedicated imaging access, coordinated transfusion pathways, and rapid surgical readiness are potential improvement measures, although this study cannot establish that any single intervention will reduce mortality.

Strengths include prospective process-data collection and multidisciplinary review of deaths. Interpretation nevertheless requires consideration of incomplete recruitment, potential selection bias, subjective preventability adjudication, and limited case-mix comparability for TRISS benchmarking. Case-mix differences can influence mortality-based institutional profiling, as demonstrated by Moore et al.[16] The study identifies priorities for local audit but does not establish the effectiveness of a specific corrective intervention.

CONCLUSION

This prospective trauma audit identified potentially or definitely preventable deaths in 34 of 75 reviewed deaths (45.3%). Delayed CT imaging and operative transfer in patients with shock were associated with preventable mortality in the reported model. These findings identify imaging access and surgical coordination as priorities for institutional review. The observational design, recruitment shortfall, potential adjudication bias, and limited TRISS case-mix comparability constrain causal and institutional performance conclusions.

Limitations

The single-centre design limits generalisability. Recruitment fell below the planned target, reducing precision and potentially limiting model stability. Consent requirements, exclusions for incomplete records, and intervention eligibility may introduce selection bias. Preventability classification involves clinical judgment; using delays both in adjudication and as model predictors may introduce incorporation bias. Delay thresholds are institutional process measures and may not be transferable to other settings. The TRISS M-statistic of 0.82 indicates limited comparability with the reference population, and regional case mix, prehospital care, and model calibration may affect benchmarking. Residual confounding and treatment-indication bias preclude causal interpretation of the observed associations.

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