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Lung Organ Failure Score for Predicting In-Hospital Mortality after Blunt Thoracic Trauma in Indonesia: A Retrospective Validation Study

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ABSTRACT

Background: The Lung Organ Failure Score (LOFS) predicts pulmonary organ failure; its performance for in-hospital death after blunt thoracic trauma in Indonesia is uncertain.**Objective:** To evaluate LOFS discrimination and classification of in-hospital death.**Methods:** This retrospective cohort included adults with blunt thoracic trauma admitted to Dr. Mohammad Hoesin General Hospital, Palembang, Indonesia, from January 2023 to January 2025. LOFS used six-hour fluid data and operative records. Discrimination and classification accuracy were estimated. Because patient-level cross-classifications were unavailable, sensitivity analyses fitted Firth-penalized models across every joint table consistent with the observed margins.**Results:** Among 32 patients, 7 died (21.9%; 95% confidence interval [CI] 11.0–38.8). Mean LOFS was 21.00 ± 5.29 in non-survivors and 14.16 ± 3.92 in survivors (difference 6.84; 95% CI 3.15–10.53; $p < 0.001$). The area under the receiver operating characteristic curve was 0.840 (95% CI 0.553–0.957). LOFS ≥ 18 had sensitivity 85.7% (95% CI 48.7–97.4), specificity 80.0% (60.9–91.1), and negative predictive value 95.2% (77.3–99.2), matching severe thoracic injury (Abbreviated Injury Scale thorax ≥ 4) alone. Across admissible datasets, adjusted odds ratios remained above 1 after adjustment for severe head injury (12.3–64.4) or sex (14.4–143); incremental value beyond severe thoracic injury was unidentifiable.**Conclusion:** LOFS discriminated death imprecisely and, at ≥ 18 , performed no better than severe thoracic injury alone. Validation with at least 100 deaths is needed before clinical use.

1. Introduction

Injury is a leading cause of death and disability in Southeast Asia. In 2021, the member states of the Association of Southeast Asian Nations recorded an estimated 35.5 million injury cases and about 317,000 injury deaths, and road injury was the leading cause of injury death in most of them¹. In Indonesia, road trauma is dominated by motorcycles. In a recent Indonesian series, 91.8% of road-traffic brain injuries were motorcycle-related and 91.2% of riders wore no helmet². The chest is among the regions most often injured in these crashes. In a Swedish trauma population, thoracic injury was present in 32% of patients and independently increased 30-day mortality (odds ratio [OR] 1.9)³. In the TraumaRegister DGU, 45% of directly admitted major-trauma patients had thoracic injuries; about a quarter of their deaths occurred within the first hour, and organ failure dominated deaths after the sixth hour⁴.

Reported mortality after chest trauma varies with case mix and setting, partly because cohorts differ in whether they include isolated or multisystem injuries and whether they are restricted to intensive care. It is 1.9% after severe isolated blunt chest trauma in the United States⁵ and about 12% in Dutch and Japanese cohorts^{6,7}, and the pooled estimate for sub-Saharan Africa is 9%⁸. Among Dutch patients with rib fractures, 30-day mortality was 6.9% overall but 11.9% with flail chest and 14.8% with polytrauma⁹. An earlier cohort from the present center reported 15.8% mortality¹⁰. Mortality rises steeply with age^{5,11}

and with comorbidity^{6,12}. It also rises when traumatic brain injury (TBI) accompanies the chest injury¹³: in Spanish intensive care units it was 25.7% with significant TBI and 5.6% without¹⁴. Prehospital systems differ widely across Asia^{15,16}. Indonesian investigators have validated the Cipto Triage Method for emergency-department acuity assessment; this is a general triage tool rather than a trauma-team activation rule¹⁷. In a system where intensive care beds are scarce, a simple score that identifies patients at risk of respiratory failure or death at admission would directly support triage.

Blunt chest injury kills through overlapping mechanisms. The first hit is direct injury to the chest wall and lung parenchyma. In the TraumaRegister DGU, 38.1% of polytrauma patients had a lung contusion, and severe contusion tracked organ failure and sepsis¹⁸. Among propensity-matched patients with rib fractures, those with contusion had a 40% higher risk of respiratory failure and a 46% higher risk of intubation¹⁹, and a contused volume above about 20% of total lung volume identified those at greatest risk of pneumonia²⁰. A second hit follows from the systemic inflammatory response and from resuscitation. Each additional liter of crystalloid within six hours raises the odds of post-traumatic acute respiratory distress syndrome (ARDS) by 19% (high-certainty evidence)²¹, and early crystalloid volume independently predicts multiple organ dysfunction and death²². The injured brain adds a third route. ARDS develops in 7.5–19% of patients with TBI and is associated with higher mortality^{23,24}, and chest injury of AIS 4–5 worsens outcome after TBI²⁵. Once

lung failure develops after polytrauma with chest injury, mortality rises from 16.9% in adults aged 18–54 years to 67.2% in those aged 85 years or older¹¹.

Several scores try to capture this risk. A systematic review of prediction models for blunt chest trauma identified 22 models; most came from single-center retrospective studies at high risk of bias, and the Thoracic Trauma Severity Score (TTSS) and the Study of the Management of Blunt Chest Wall Trauma (STUMBL) score were the most widely validated externally²⁶. Their reported mortality discrimination varies. The area under the receiver operating characteristic curve (AUC) for TTSS was 0.844 in a Dutch validation cohort²⁷. The original STUMBL model was developed and externally validated for a composite of complications²⁸; a later New Zealand validation reported a mortality AUC of 0.92²⁹. The Injury Severity Score (ISS) and New Injury Severity Score (NISS) reached 0.80–0.86^{30,31}. Chest-specific scores lose accuracy in polytrauma with TBI³². Simple physiological markers such as the shock index and lactate perform comparably^{33,34}.

The Lung Organ Failure Score (LOFS) was derived by Wutzler et al. from 5892 intensive care patients in the TraumaRegister DGU who had lung contusion or laceration and an ISS of at least 16³⁵. Its target was severe pulmonary organ failure, defined as a $\text{PaO}_2/\text{FiO}_2$ ratio below 200 for at least three days, which occurred in 21.3% of patients. Seven predictor domains are scored as integers: age, sex, head injury, fluid therapy, injury severity, degree of chest trauma and surgical interventions. A total of 21 points or more marks a risk above 30%³⁵. Because LOFS combines anatomy, host factors and the intensity of early treatment, it might capture the convergence of first and second hits better than anatomical scores. Yet it has seen little use. It served as a baseline risk covariate in a trial of intraoperative ventilation³⁶, it has been criticized for ignoring the extent of contusion³⁷, and a systematic review lists it as a development-only model without external validation²⁶. The only Indonesian evaluation, from Bandung, studied ventilator use rather than death; for that outcome LOFS had a sensitivity of 85.1% and specificity of 94.4%, compared with 83.3% and 77.8% for TTSS³⁸.

Studies at our institution have evaluated the Chest Trauma Score and TTSS^{10,39,40,41}, but no study has evaluated LOFS against mortality in Southeast Asia or elsewhere. This study therefore aimed to evaluate the discrimination and classification accuracy of LOFS for in-hospital death in adults with blunt thoracic trauma at a provincial referral center in Indonesia. We also compared LOFS with its strongest single anatomical component. Finally, we quantified what the available aggregate data can and cannot establish about the independence of LOFS from other risk factors, without assuming any unobserved data.

2. Methods

Study design and setting

This was a retrospective, single-center cohort study at Dr. Mohammad Hoesin General Hospital, Palembang, South Sumatra, Indonesia. The hospital is a national referral hospital and the province's principal tertiary trauma center, and it receives direct admissions and inter-hospital transfers from district hospitals across South Sumatra. The study period ran from 1 January 2023 to 31 January 2025. The report follows the STROBE statement for cohort studies and the items of the

TRIPOD+AI statement that apply to the validation of an existing prediction score⁴².

Participants and eligibility

Patients were identified from the hospital's medical-records database using International Classification of Diseases, 10th Revision codes for thoracic injury. Eligible patients were aged 18 years or older at admission and had blunt thoracic trauma as a primary or significant secondary diagnosis requiring admission. Exclusion criteria were penetrating thoracic injury, whether isolated or concomitant; death on arrival or in the emergency department before full diagnostic evaluation, which precludes calculation of the score; pregnancy; and records insufficient to calculate LOFS or to ascertain the primary outcome. Every eligible patient in the study period was included; there was no sampling.

Variables and data collection

Two investigators independently abstracted data from electronic and paper records using a standardized form, and a senior surgeon resolved discrepancies. Demographic variables were age, sex and body mass index (weight in kilograms divided by height in meters squared). Clinical history comprised hypertension, diabetes mellitus, chronic pulmonary disease and active smoking. The mechanism of injury was recorded. Injuries were coded retrospectively with the Abbreviated Injury Scale (AIS), 2005 version, from imaging reports (chest radiography and computed tomography) and operative notes. The ISS was calculated as the sum of the squares of the highest AIS scores in the three most severely injured body regions. Severe thoracic injury was defined as AIS thorax ≥ 4 and severe head injury as AIS head/neck ≥ 3 .

Admission physiology comprised the Glasgow Coma Scale (GCS), arterial lactate and base deficit; base deficit is reported here with the sign convention of base excess. Resuscitation variables were the volume of intravenous crystalloid and colloid given within six hours of arrival in the emergency department, and the number of packed red blood cell units transfused within 24 hours. Emergency surgery was defined as an urgent, non-elective procedure for life-threatening hemorrhage, contamination or physiological instability, including laparotomy, thoracotomy and major vascular repair. The total number of operations during admission was also recorded.

Index score

LOFS was calculated for each patient according to the derivation publication³⁵. Points were assigned for each item and summed, as listed in Table 1. Not every item is available at the moment of arrival. Age, sex and the AIS-based items were taken from the initial clinical and imaging assessment, the fluid item from the volume recorded over the first six hours of care, and the surgical items from the operative record of the index admission. The score analyzed here therefore describes the first hours of care rather than the moment of arrival. The score was calculated from records abstracted after discharge, so abstractors were not blinded to the outcome; agreement between the two abstractors was not quantified. Two thresholds were examined. The first was the threshold that maximized the Youden index in these data (≥ 18), which is exploratory because it was derived in the same sample. The second was the high-risk threshold of the derivation study (≥ 21).

Table 1. Lung Organ Failure Score items, point allocation and study definitions.

Item	Points / definition
Planned surgical interventions	One (3); two or more (4)
Emergency surgery	Any (3): urgent, non-elective procedure for life-threatening haemorrhage, contamination or physiological instability
Severe thoracic injury	AIS thorax 4 (2); AIS thorax 5 (3)
Severe head injury	AIS head/neck ≥ 3 (2)
Sex	Male (2)
Intravenous fluid, first 6 h after arrival	1 point per 2 L of crystalloid and colloid
Injury Severity Score	1 point per 8 ISS points
Age	1 point per 10 years
Total score	Sum of points; the derivation study reported >30% risk of severe pulmonary organ failure at ≥ 21 points ³⁵
Injury coding	AIS 2005; ISS = sum of squares of the highest AIS in the three most severely injured regions; severe thoracic injury AIS thorax ≥ 4 ; severe head injury AIS head/neck ≥ 3
Primary outcome	In-hospital death from any cause during the index admission
Secondary outcomes	Mechanical ventilation during admission; length of hospital stay

AIS, Abbreviated Injury Scale; ISS, Injury Severity Score.

Outcomes

The primary outcome was in-hospital death from any cause during the index admission. Secondary outcomes were the need for mechanical ventilation and the length of hospital stay. Mechanical ventilation was used as a pragmatic proxy for pulmonary organ failure, the outcome for which LOFS was designed, because serial PaO₂/FiO₂ ratios were not uniformly recorded.

Study size

The study size was fixed by the number of eligible patients in the study period; no sample-size calculation preceded the study. Guidance for external validation of prediction models recommends calculating the minimum sample size from target precision for calibration, discrimination and clinical utility rather than from rules of thumb; in its worked example, 177 events were required⁴³. With seven deaths, the achieved precision is low: the 95% CI for a sensitivity of 85.7% spans 48.7 percentage points and the Hanley–McNeil half-width for an AUC of 0.840 is ± 0.194 . The study is therefore reported as a preliminary validation, and the sample size required for a definitive study is given in the Discussion.

Statistical analysis

Categorical variables are presented as counts and percentages with 95% Wilson score confidence intervals (CIs), and continuous variables as mean $\pm$ standard deviation (SD) or median with interquartile range (IQR). Normality was assessed with the Shapiro–Wilk test. Survivors and non-survivors were compared with the independent-samples *t* test, using Welch's test as a sensitivity analysis for unequal variances; with the Mann–Whitney *U* test; and with Fisher's exact test. Effect sizes were the mean difference with Hedges *g*; $r = z/\sqrt{N}$ for Mann–Whitney comparisons; the odds ratio with an exact conditional CI; the risk difference with a Newcombe CI; and Cramér's *V*.

Discrimination was quantified by the AUC, calculated as the Mann–Whitney probability that a non-survivor scores higher than a survivor, with ties counted as one half. Three 95% CIs are reported: the interval produced by the analysis software (a symmetric interval with a nonparametric standard error), the Hanley–McNeil interval, and a logit-transformed interval based on the Hanley–McNeil standard error. The last respects the 0–1 range and is treated as the primary interval because symmetric intervals are anticonservative with few events. The association between the continuous score and death is reported as the point-biserial correlation. For each threshold, sensitivity, specificity, positive and negative predictive values (PPV, NPV), likelihood ratios (log-method CIs), the diagnostic odds ratio, accuracy and the Youden index were calculated. Predictive

values at other prevalences of death were derived from Bayes' theorem, holding sensitivity and specificity fixed. For continuous admission markers, for which only medians and Mann–Whitney *p* values were available, the AUC was back-calculated from the *p* value under the untied normal approximation; because ties reduce the true AUC, these values are upper bounds. The cohort was compared with published reference proportions using one-sample exact binomial tests, with Holm adjustment across the eight comparisons, and Cohen's *h* was reported for each.

Patient-level cross-classifications between predictors were not available for this analysis. The abstracted records were summarized as cohort totals and survivor/non-survivor tables, and no joint distribution of two predictors was retained. Bivariate and multivariable questions were therefore answered by a sensitivity analysis over the space of datasets consistent with the observed marginals, and no dataset was imputed or simulated as if it had been observed. First, for characteristics reported only as cohort totals, every 2×2 table with the observed number of exposed patients, 7 deaths and 25 survivors was enumerated. For each table we computed the odds ratio (with Haldane–Anscombe correction for zero cells), Fisher's *p* and Cramér's *V*. Second, for the five binary characteristics reported separately in survivors and non-survivors, every joint table of two or three characteristics within each outcome stratum was enumerated exhaustively: 12 tables for two-predictor models and 1032 for the three-predictor model. Firth-penalized logistic regression was fitted to each table because it remains finite under the separation that small samples produce⁴⁴. Significance was assessed by penalized-likelihood-ratio tests. Third, because LOFS is an integer sum, the integer score distributions compatible with every reported statistic were identified by mixed-integer linear programming. These statistics were the group means and SDs, the Mann–Whitney *U*, the counts above 18, and a Youden index maximal at 18. The resulting distributions bounded quantities that were not reported directly: Kendall's τ -b, the DeLong standard error of the AUC and accuracy at other thresholds. Throughout, a measure whose attainable range spans the null value is reported as not identifiable from the data. A conclusion that holds in every admissible table is reported as robust.

The primary result of every bounds analysis is the unweighted attainable range. Weighting each table by its number of patient-level arrangements is reported as a secondary summary only, because it assumes that two characteristics are exchangeable within outcome strata. That assumption is implausible for LOFS and AIS thorax, since the second is a component of the first. Every Firth fit converged;

tables in which two predictors coincided perfectly were not estimable and are reported. To gauge survivorship bias, sensitivity, the predictive values and mortality were recalculated under the extreme assumptions that one to five excluded early deaths all scored below 18 or all scored 18 or more.

No values were missing for LOFS or for the primary outcome in the 32 analyzed patients, so the analysis was complete-case without imputation; records lacking a score component would have been excluded under the eligibility criteria. Calibration was not assessed, because LOFS estimates the probability of severe pulmonary organ failure, not of death, and a mortality calibration would require recalibration of the score in a larger sample. The TRIPOD+AI items concerning calibration, model updating and clinical utility therefore could not be addressed⁴².

Descriptive statistics, group comparisons and the ROC analysis were generated in IBM SPSS Statistics 25. All recomputations, bounds and figures used Python 3 with SciPy 1.18 and statsmodels 0.15. Tests were two-sided with $\alpha = 0.05$, and p values are reported to three decimal places.

Ethical approval

The study protocol was approved by the CMHC Research Center Indonesia ethics committee (approval No. 2024/8426) as a retrospective review of de-identified medical records. The requirement for individual informed consent was waived. The study was conducted in accordance with the Declaration of Helsinki.

3. Results

Participants and cohort profile

Thirty-eight patients with blunt thoracic trauma (ICD-10 thoracic injury codes) to Dr. Mohammad Hoesin General Hospital, Palembang 1 January 2023–31 January 2025: n = 38

Thirty-eight patients with blunt thoracic trauma were identified during the study period (Figure 1). Six were excluded: five were younger than 18 years and one had a concomitant penetrating thoracic injury. No patient was excluded for death in the emergency department, pregnancy or incomplete records, and LOFS and the primary outcome were complete for all 32 patients analyzed. Seven patients died in hospital (21.9%; 95% CI 11.0–38.8).

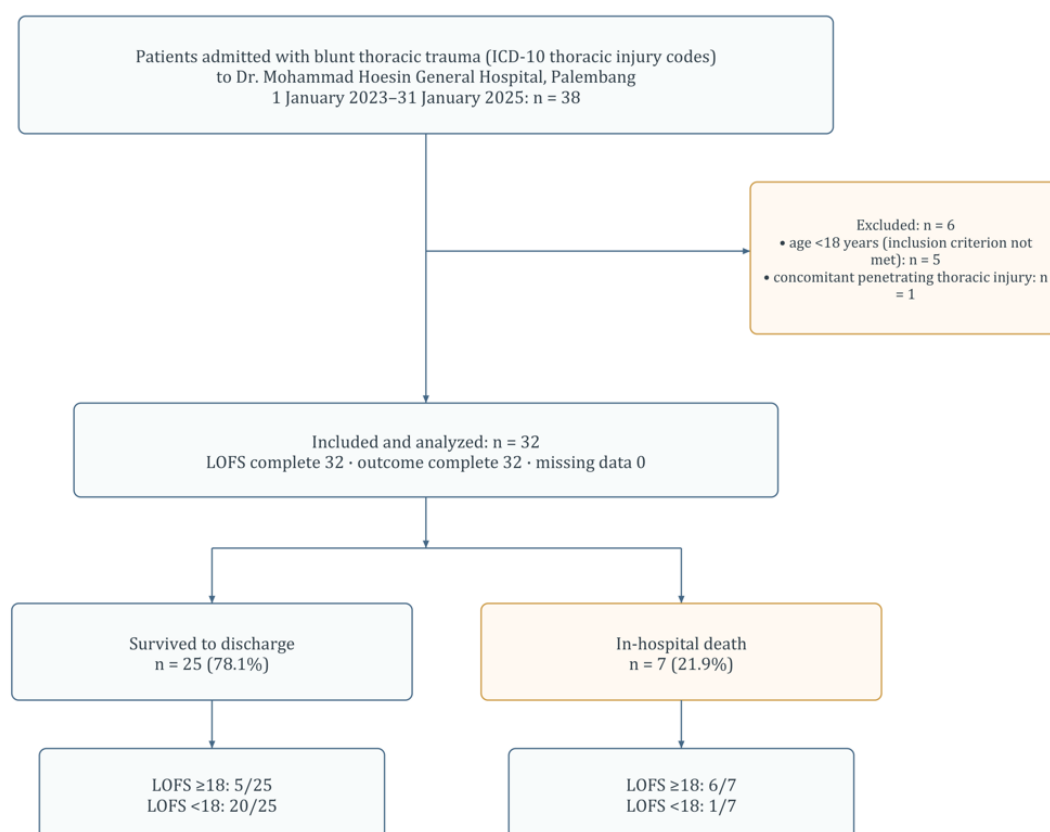


Figure 1. STROBE flow diagram of patient identification, exclusion, analysis and outcome. Counts of LOFS ≥ 18 in each outcome group are the observed classification behind Tables 4 and 5. LOFS, Lung Organ Failure Score.

Baseline characteristics are detailed in Table 2. The mean age was 45.00 ± 16.31 years and 25 patients (78.1%; 95% CI 61.2–89.0) were men. Motor-vehicle collision was the mechanism in 21 patients (65.6%). Active smoking (24 patients, 75.0%) and hypertension (16, 50.0%) were common, whereas only 2 patients (6.3%) had diabetes. On arrival, the median GCS was 13 (IQR width 6), the median lactate 3.2 mmol/L (IQR width 2.1) and the median base excess -5.0 mmol/L. The median ISS was

25.00 (IQR width 18.00). Severe thoracic injury was present in 11 patients (34.4%; 95% CI 20.4–51.7) and severe head injury in 10 (31.3%; 18.0–48.6). Twenty-four patients (75.0%) underwent an emergency operation, 22 (68.8%) had two or more surgical interventions and 15 (46.9%; 30.9–63.6) received mechanical ventilation. The median length of stay was 7 days. Eleven patients (34.4%) scored 18 points or more on LOFS.

Table 2. Baseline characteristics, management and outcome of the cohort (n = 32).

Characteristic	n (%) or summary	95% Wilson CI, %
Demographics		
Age, years, mean ± SD	45.00 ± 16.31	—
Male sex	25 (78.1)	61.2–89.0
Body mass index, kg/m ² , median (IQR width)	23.77 (2.56)	—
Clinical history		
Active smoker	24 (75.0)	57.9–86.7
Hypertension	16 (50.0)	33.6–66.4
Type 2 diabetes mellitus	2 (6.3)	1.7–20.1
Chronic pulmonary disease	7 (21.9)	11.0–38.8
Injury and physiology on arrival		
Motor-vehicle collision	21 (65.6)	48.3–79.6
Glasgow Coma Scale, median (IQR width)	13 (6)	—
Lactate, mmol/L, median (IQR width)	3.2 (2.1)	—
Base excess, mmol/L, median (IQR width)	−5.0 (3.5)	—
Severe thoracic injury (AIS thorax ≥4)	11 (34.4)	20.4–51.7
Severe head injury (AIS head ≥3)	10 (31.3)	18.0–48.6
Injury Severity Score, median (IQR width)	25.00 (18.00)	—
Management and hospital course		
Fluid volume, first 6 h, L, median (IQR width)	3.00 (2.00)	—
PRBC, first 24 h, units, median (IQR width)	2 (3)	—
Emergency operation	24 (75.0)	57.9–86.7
≥2 surgical interventions	22 (68.8)	51.4–82.0
Mechanical ventilation	15 (46.9)	30.9–63.6
Length of stay, days, median (IQR width)	7.00 (7.00)	—
Score and outcome		
LOFS, points, mean ± SD (pooled from group summaries)	15.66 ± 5.06	—
LOFS ≥18	11 (34.4)	20.4–51.7
In-hospital death	7 (21.9)	11.0–38.8

Medians are reported with the interquartile range expressed as its width (Q3 – Q1), as recorded. Base excess is shown with its sign (a base deficit of 5.0 mmol/L). The cohort LOFS mean and SD are computed exactly from the two group summaries. Male sex vs parity: exact binomial $p = 0.002$ (Cohen's $h = 0.59$). AIS, Abbreviated Injury Scale; CI, confidence interval; LOFS, Lung Organ Failure Score; PRBC, packed red blood cells; SD, standard deviation.

The cohort's mortality and case mix are compared with published cohorts in Table 3 and Figure 2; the comparators differ in inclusion criteria and in whether mortality was in-hospital or at 30 days, so the comparisons are descriptive. It did not differ detectably from the Japan Trauma Data Bank (12.8%; Holm $p = 0.710$), a Swedish thoracic-injury cohort (11.0%; 0.398), the pooled sub-Saharan African estimate (9.0%; 0.129)

or an earlier TTSS cohort from this hospital (15.8%; 0.999). Road-traffic injury accounted for a smaller share of injuries than in a Saudi chest-trauma series (65.6% vs 86.9%; Holm $p = 0.012$). The proportions of men (78.1% vs 76.3%) and of ventilated patients (46.9% vs 55.0%) did not differ from their comparators.

Table 3. Comparison of the cohort with published reference proportions (one-sample exact binomial tests).

Quantity	Reference population	Reference %	This cohort n/N (%)	Exact p	Holm p	Cohen's h
In-hospital mortality	Japan Trauma Data Bank, isolated chest trauma (in-hospital) ⁷	12.8	7/32 (21.9)	0.177	0.710	0.24
In-hospital mortality	Swedish trauma cohort with thoracic injury (30-day) ³	11.0	7/32 (21.9)	0.080	0.398	0.30
In-hospital mortality	Pooled sub-Saharan African chest-trauma mortality (meta-analysis) ⁸	9.0	7/32 (21.9)	0.022	0.129	0.36
In-hospital mortality	Blunt thoracic trauma, same centre, Jan 2023–Jan 2025 ¹⁰	15.8	7/32 (21.9)	0.333	0.999	0.16
Male sex	Same centre, same period ¹⁰	76.3	25/32 (78.1)	1.000	1.000	0.04
Road-traffic mechanism	Saudi chest-trauma series (road-traffic accidents) ⁴⁵	86.9	21/32 (65.6)	0.002	0.012	−0.51
Mechanical ventilation	Saudi chest-trauma series (intubation/ventilation) ⁴⁵	55.0	15/32 (46.9)	0.379	0.999	−0.16

Holm adjustment across the eight comparisons. Cohen's h : 0.2 small, 0.5 medium, 0.8 large; negative values indicate a lower proportion in this cohort. Comparisons are descriptive: inclusion criteria differ between studies.

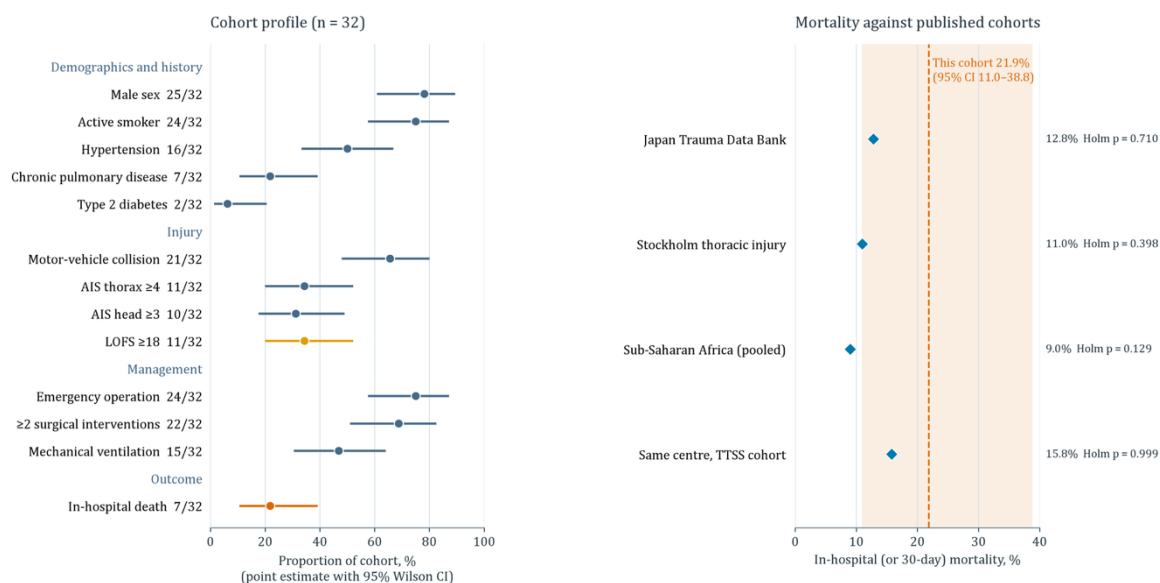


Figure 2. Cohort profile and mortality benchmarks. Left: proportion of the 32 patients with each characteristic (point estimate and 95% Wilson confidence interval). Right: in-hospital mortality of this cohort (dashed line; shaded band, 95% CI 11.0–38.8%) against five published cohorts, with Holm-adjusted exact binomial p values (Table 3). AIS, Abbreviated Injury Scale; LOFS, Lung Organ Failure Score; TTSS, Thoracic Trauma Severity Score.

Survivors and non-survivors

Survivors and non-survivors are compared in Table 4. Non-survivors had a lower GCS on arrival (median 9 vs 14; $p = 0.010$; $r = 0.46$) and a higher lactate (4.8 vs 2.9 mmol/L; $p = 0.002$; $r = 0.55$). They also had a higher ISS (41 vs 25; $p = 0.017$; $r = 0.42$) and received more fluid in the first six hours (4.00 vs 3.00 L; $p = 0.001$; $r = 0.58$). Severe thoracic injury was present in 6 of 7 non-survivors (85.7%) and 5 of 25 survivors (20.0%) (OR 21.0, exact 95% CI 1.94–1157; $p = 0.003$). Mechanical ventilation, a marker

of the clinical course rather than a baseline predictor, was more frequent among non-survivors (85.7% vs 36.0%; Fisher $p = 0.033$); its exact conditional CI for the OR (0.97–520) just includes 1 because the two procedures define the tails differently. Age (51.14 vs 43.28 years; mean difference 7.86, 95% CI –6.32 to 22.04; $p = 0.266$), male sex ($p = 1.000$) and severe head injury (57.1% vs 24.0%; OR 4.00, 95% CI 0.52–35.9; $p = 0.165$) did not differ significantly. Length of stay was shorter among non-survivors (median 4 vs 7 days); this comparison is descriptive only, because death ended the admission.

Table 4. Characteristics of non-survivors and survivors.

Characteristic	Non-survivors (n = 7)	Survivors (n = 25)	Effect size (95% CI)	Test	p
Age, years, mean $\pm$ SD	51.14 $\pm$ 13.28	43.28 $\pm$ 16.89	MD 7.86 (–6.32 to 22.04); g 0.47	t ^a	0.266
Male sex, n (%)	6 (85.7)	19 (76.0)	OR 1.86 (0.16–101)	Fisher ^c	1.000
GCS on arrival, median (IQR width)	9.0 (5.0)	14.0 (4.0)	r 0.46	MW ^b	0.010
Lactate, mmol/L, median (IQR width)	4.8 (1.9)	2.9 (1.8)	r 0.55	MW ^b	0.002
AIS thorax ≥ 4 , n (%)	6 (85.7)	5 (20.0)	OR 21.0 (1.94–1157)	Fisher ^c	0.003
AIS head ≥ 3 , n (%)	4 (57.1)	6 (24.0)	OR 4.00 (0.52–35.9)	Fisher ^c	0.165
ISS, median (IQR width)	41.0 (24.0)	25.0 (14.0)	r 0.42	MW ^b	0.017
Fluid volume, first 6 h, L, median (IQR width)	4.00 (2.00)	3.00 (1.00)	r 0.58	MW ^b	0.001
Mechanical ventilation, n (%)	6 (85.7)	9 (36.0)	OR 9.91 (0.97–520)	Fisher ^c	0.033
Length of stay, days, median (IQR width)	4.00 (15.00)	7.00 (7.00)	r 0.04	MW ^b	0.801
LOFS, points, mean $\pm$ SD	21.00 $\pm$ 5.29	14.16 $\pm$ 3.92	MD 6.84 (3.15–10.53); g 1.58 (0.67–2.48)	t ^a	<0.001
LOFS ≥ 18 , n (%)	6 (85.7)	5 (20.0)	OR 21.0 (1.94–1157)	Fisher ^c	0.003

^aIndependent-samples t test (Student); Welch's test gave $p = 0.218$ for age and $p = 0.013$ for LOFS. ^bMann-Whitney U test; effect size $r = z/\sqrt{N}$ back-calculated from the reported p value. ^cFisher's exact test (two-sided); odds ratio by conditional maximum likelihood with exact confidence interval, which can include 1 when the two-sided Fisher p is <0.05 because the two procedures use different tail definitions. Recomputation from the group summaries reproduced every Fisher p exactly; for age it gave $p = 0.267$ against 0.266 from the patient records, a rounding difference. AIS, Abbreviated Injury Scale; g, Hedges g; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; LOFS, Lung Organ Failure Score; MD, mean difference; MW, Mann-Whitney; OR, odds ratio.

Mean LOFS was 21.00 $\pm$ 5.29 points in non-survivors and 14.16 $\pm$ 3.92 points in survivors (Figure 3). The difference of 6.84 points (95% CI 3.15–10.53) was large (Hedges $g = 1.58$, 95% CI 0.67–2.48; Student $p < 0.001$). It remained significant with Welch's correction for unequal variances ($p = 0.013$). The

point-biserial correlation between LOFS and death was 0.568 (95% CI 0.274–0.765). The rank-based Kendall's τ -b, which depends on how scores are tied, lies between 0.411 and 0.512 across all score distributions compatible with the data.

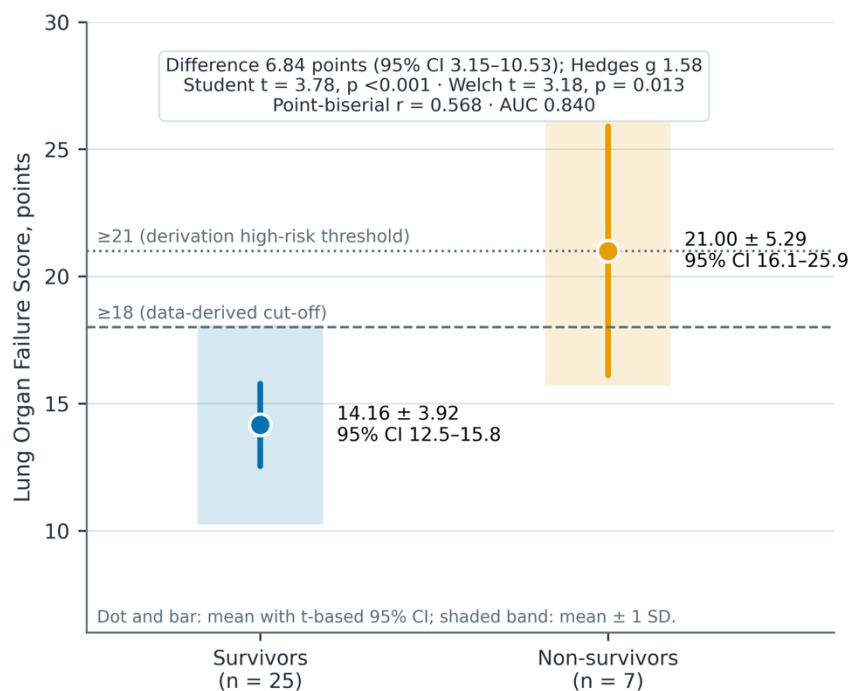
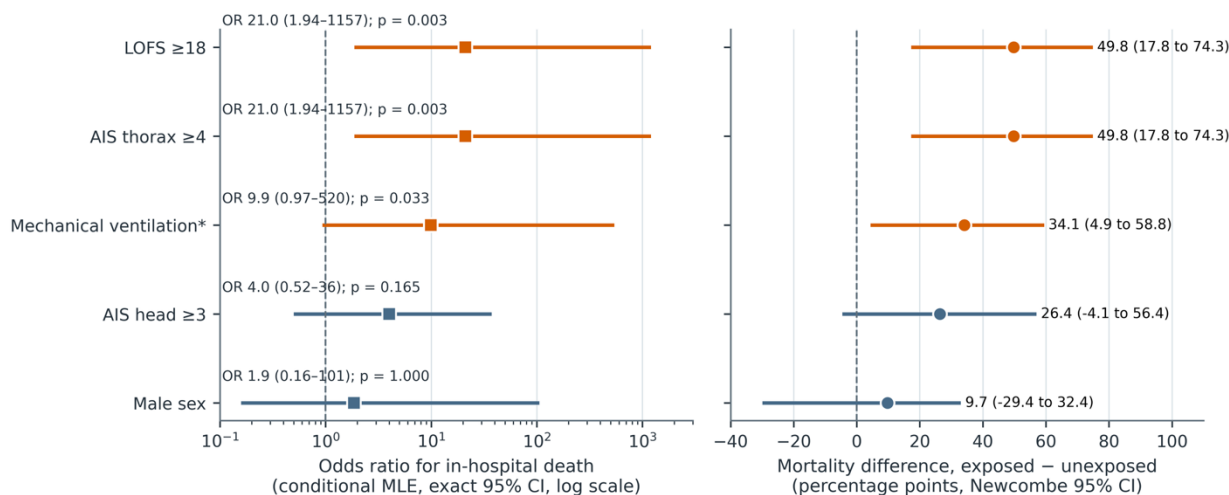


Figure 3. Lung Organ Failure Score in survivors ($n = 25$) and non-survivors ($n = 7$). Dots and bars show the mean with its t-based 95% confidence interval; shaded bands show mean ± 1 standard deviation. Dashed and dotted lines mark the data-derived cut-off (≥ 18) and the high-risk threshold of the derivation study (≥ 21). Values are the reported group summaries; individual scores were not available for this analysis.

Figure 4 summarizes the observed associations of the five binary characteristics with death. LOFS ≥ 18 identified 6 of 7 non-survivors and 5 of 25 survivors, giving a mortality of 54.5% (6/11) above the threshold and 4.8% (1/21) below it. The risk

difference was 49.8 percentage points (95% CI 17.8–74.3) and the OR 21.0 (exact 95% CI 1.94–1157; Fisher $p = 0.003$). This 2 $\times$ 2 table is identical to that of severe thoracic injury.



Red: Fisher exact $p < 0.05$. LOFS ≥ 18 and AIS thorax ≥ 4 have identical 2 $\times$ 2 tables (6/5/1/20). *Mechanical ventilation occurred after admission and is a marker of the clinical course, not a baseline predictor. LOFS, Lung Organ Failure Score; AIS, Abbreviated Injury Scale.

Figure 4. Observed associations of five binary characteristics with in-hospital death. Left: odds ratio (conditional maximum likelihood) with exact 95% confidence interval on a log scale; the upper limits for LOFS ≥ 18 and AIS thorax ≥ 4 extend beyond the axis (1157). Right: absolute mortality difference between exposed and unexposed patients with Newcombe 95% confidence interval. Red: Fisher exact $p < 0.05$. Mechanical ventilation is a post-admission marker.

Discrimination and classification

Classification accuracy is given in Table 5. At ≥ 18 , LOFS had a sensitivity of 85.7% (95% CI 48.7–97.4) and a specificity of 80.0% (60.9–91.1). Its PPV was 54.5% (28.0–78.7) and its NPV 95.2% (77.3–99.2), with likelihood ratios of 4.29 (1.85–9.93) for a positive and 0.18 (0.03–1.11) for a negative result. The

diagnostic odds ratio was 24.0 (2.33–247) and accuracy 81.3%. AIS thorax ≥ 4 alone produced exactly the same values. Mechanical ventilation had the same sensitivity but lower specificity (64.0%), severe head injury discriminated poorly (sensitivity 57.1%, specificity 76.0%) and male sex not at all (specificity 24.0%).

Table 5. Classification accuracy of LOFS ≥ 18 and single binary markers for in-hospital death.

Marker	Sensitivity, %	Specificity, %	PPV, %	NPV, %	LR+	LR-	DOR	Youden J	Accuracy, %
LOFS ≥ 18	85.7 (48.7–97.4)	80.0 (60.9–91.1)	54.5 (28.0–78.7)	95.2 (77.3–99.2)	4.29 (1.85–9.93)	0.18 (0.03–1.11)	24.0 (2.33–247)	0.66	81.3
AIS thorax ≥ 4	85.7 (48.7–97.4)	80.0 (60.9–91.1)	54.5 (28.0–78.7)	95.2 (77.3–99.2)	4.29 (1.85–9.93)	0.18 (0.03–1.11)	24.0 (2.33–247)	0.66	81.3
Mechanical ventilation ^a	85.7 (48.7–97.4)	64.0 (44.5–79.8)	40.0 (19.8–64.3)	94.1 (73.0–99.0)	2.38 (1.30–4.36)	0.22 (0.04–1.40)	10.7 (1.10–103)	0.50	68.8
AIS head ≥ 3	57.1 (25.0–84.2)	76.0 (56.6–88.5)	40.0 (16.8–68.7)	86.4 (66.7–95.3)	2.38 (0.92–6.14)	0.56 (0.23–1.36)	4.22 (0.73–24.4)	0.33	71.9
Male sex	85.7 (48.7–97.4)	24.0 (11.5–43.4)	24.0 (11.5–43.4)	85.7 (48.7–97.4)	1.13 (0.78–1.64)	0.60 (0.09–4.16)	1.89 (0.19–19.0)	0.10	37.5

Estimates with 95% Wilson confidence intervals (log-method intervals for likelihood ratios and the diagnostic odds ratio). Prevalence of death 21.9%; post-test probability 54.5% after LOFS ≥ 18 and 4.8% after LOFS < 18 .^a Post-admission marker of the clinical course, shown for comparison only. DOR, diagnostic odds ratio; LR, likelihood ratio; NPV/PPV, negative/positive predictive value.

The continuous score had an AUC of 0.840 (Table 6). Its primary, logit-transformed 95% CI was 0.553–0.957; the software output gave 0.685–0.995 and the Hanley–McNeil method 0.646–1.000. Across the admissible score distributions, the DeLong standard error ranged from 0.069 to 0.132, a range that contains the standard error implied by the software interval (0.079). Accuracy at thresholds other than ≥ 18 was not reported, but it is bounded by the reported statistics (Figure 5);

these bounds are not observed values. At the derivation threshold of ≥ 21 , sensitivity could lie anywhere between 28.6% and 85.7% with a specificity of 80.0–100%. At ≥ 16 , sensitivity was 85.7–100% and specificity 40.0–80.0%; at ≥ 24 , sensitivity was 14.3–57.1% and specificity 92.0–100%. This variation between neighboring thresholds indicates how optimistic a threshold chosen in the same 32 patients is likely to be.

Table 6. Discrimination of the continuous LOFS and accuracy at alternative thresholds.

Quantity	Value or attainable range	Comment
AUC (Mann–Whitney U = 147 of 175 pairs)	0.840	Reproduced from the group comparison
95% CI, software (SPSS non-parametric)	0.685–0.995	Implied standard error 0.079
95% CI, Hanley–McNeil (Wald)	0.646–1.000	Standard error 0.099; conservative
95% CI, logit-transformed (Hanley–McNeil standard error)	0.553–0.957	Range-respecting; primary interval
DeLong standard error, admissible range	0.069–0.132	672 admissible score distributions; contains the software value
Point-biserial correlation r (95% CI)	0.568 (0.274–0.765)	p = 0.0007
Kendall τ -b, admissible range	0.411–0.512	p 0.002–0.007
Threshold ≥ 16	Sensitivity 85.7–100.0%; specificity 40.0–80.0%	Bounded
Threshold ≥ 18 (Youden-optimal in these data)	Sensitivity 85.7%; specificity 80.0%	Observed; exploratory (derived in-sample)
Threshold ≥ 21 (derivation high-risk threshold)	Sensitivity 28.6–85.7%; specificity 80.0–100.0%	Bounded
Threshold ≥ 24	Sensitivity 14.3–57.1%; specificity 92.0–100.0%	Bounded

Bounded values are the minimum and maximum over every integer LOFS distribution consistent with all reported statistics (group sums 147 and 354, sums of squares 3255 and 5382, U = 147, six non-survivors and five survivors ≥ 18 , Youden index maximal at ≥ 18); 48 of 50 candidate non-survivor distributions were compatible. These configurations bound unreported quantities only; none is presented as observed data. AUC, area under the receiver operating characteristic curve.

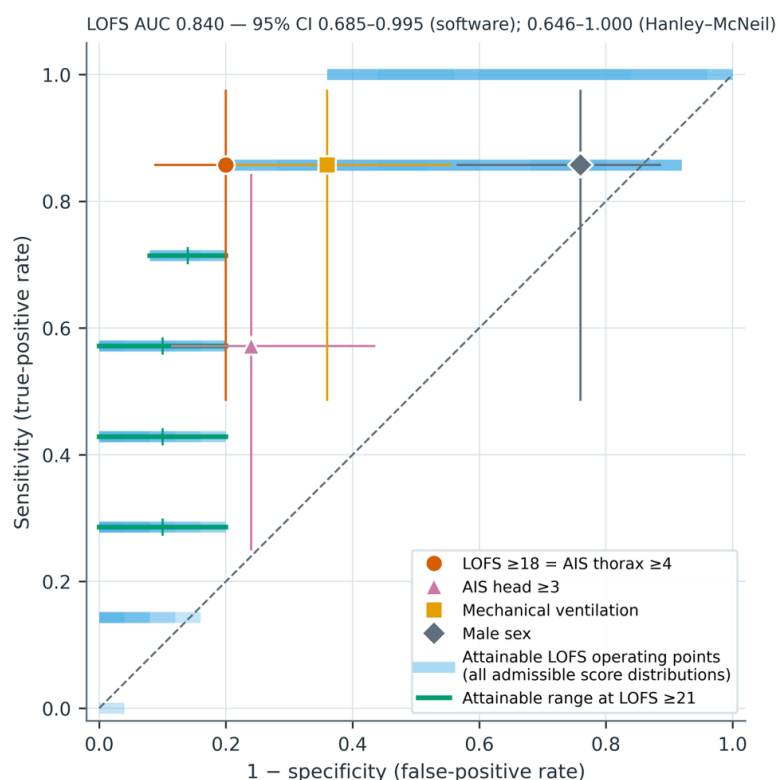


Figure 5. Receiver operating characteristic space for in-hospital death. Shaded segments are every operating point of LOFS attainable across the integer score distributions consistent with all reported statistics; green segments are the attainable range at the derivation threshold (≥ 21). Markers show the observed operating points of the binary characteristics with 95% Wilson confidence intervals for sensitivity and false-positive rate; LOFS ≥ 18 and AIS thorax ≥ 4 coincide. The diagonal marks chance discrimination.

Figure 6 places these values in context. Treated as binary tests, AIS thorax ≥ 4 and LOFS ≥ 18 had an AUC of 0.829, mechanical ventilation 0.749 and severe head injury 0.666. The AUCs implied by the reported Mann-Whitney p values for single admission markers were at most 0.912 for six-hour fluid volume, 0.887 for lactate, 0.823 for GCS and 0.799 for ISS.

Published mortality AUCs for the retained Figure 6 comparators ranged from 0.727 to 0.920. Applied at other prevalences of death and assuming the same sensitivity and specificity (Figure 7), LOFS ≥ 18 would have a PPV of 19.7% and an NPV of 99.0% at an illustrative mortality prevalence of 5.4%, and 38.6% and 97.4% at the 12.8% of the Japan Trauma Data Bank.

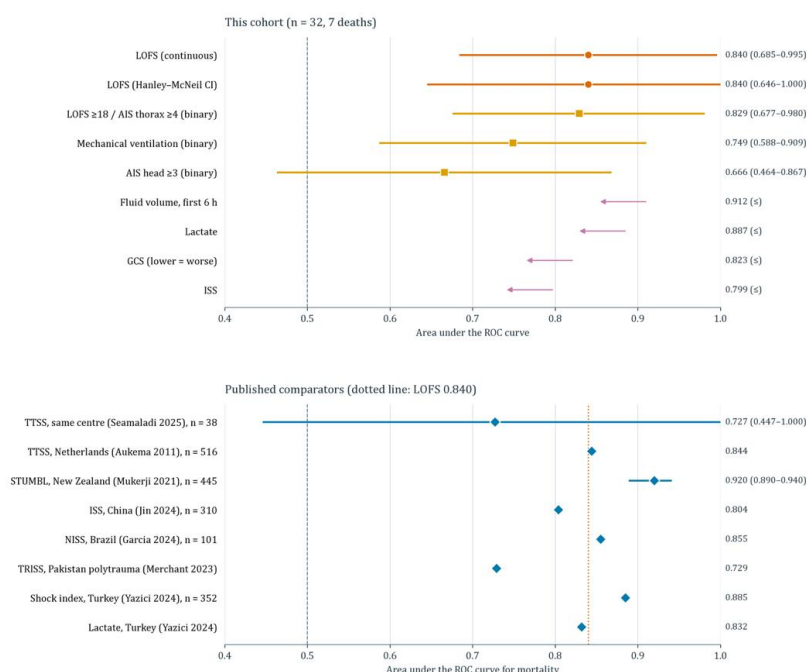


Figure 6. Discrimination of LOFS in context. Upper: area under the ROC curve (AUC) for LOFS with the software and Hanley-McNeil confidence intervals, for binary markers [$AUC = [sensitivity + specificity]/2$] and, as upper bounds, for single admission markers whose AUC was back-calculated from the reported Mann-Whitney p values. Lower: mortality AUCs reported by published studies of other scores, with confidence intervals where reported; the dotted line marks the LOFS AUC of 0.840.

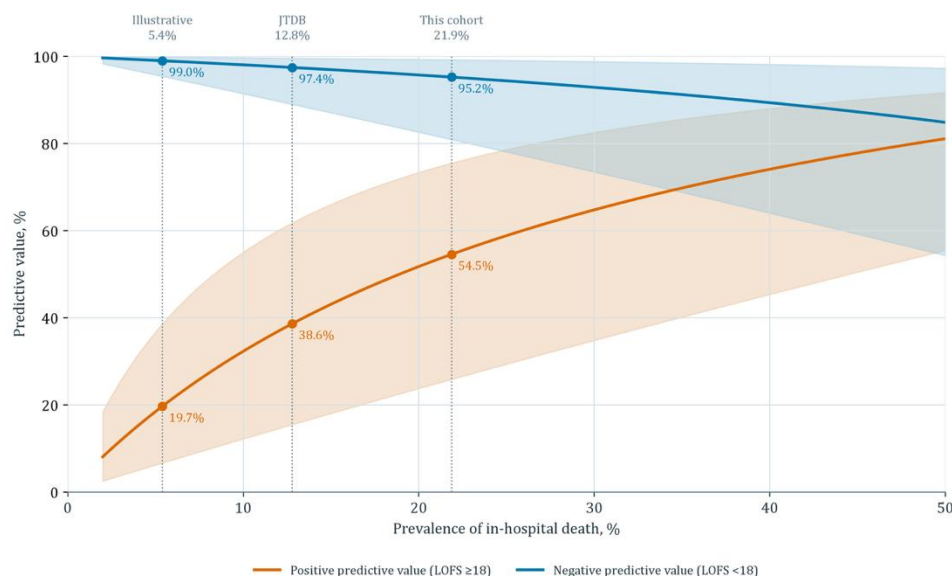


Figure 7. Positive and negative predictive values of LOFS ≥ 18 across the prevalence of in-hospital death, obtained by applying the observed sensitivity (85.7%) and specificity (80.0%) through Bayes' theorem. Bands combine the Wilson 95% limits of sensitivity and specificity. Vertical lines mark an illustrative mortality prevalence (5.4%), the Japan Trauma Data Bank (12.8%) and this cohort (21.9%).

Sensitivity analysis over admissible datasets

Seven characteristics were reported only as cohort totals (Table 7). For each of them, the attainable OR range spanned 1 (Figure 8). For example, the OR for emergency operation ranged from 0.004 to 7.29 across its eight admissible tables, and for chronic pulmonary disease from 0.16 to 765. Some admissible tables

reached significance in either direction, but such tables accounted for at most 4.7% of patient-level arrangements. The data therefore cannot identify any association of smoking, hypertension, diabetes, chronic pulmonary disease, mechanism of injury, emergency operation or multiple operations with death.

Table 7. Bounds analysis for characteristics reported only as cohort totals (sensitivity analysis over all margin-consistent tables)

Characteristic	n exposed	Admissible tables	OR range	Fisher p range	Tables with p < 0.05	Arrangements with p < 0.05, %	Conclusion
Active smoker	24	8	0.004–7.29	<0.001–1.000	4/8	4.7	Not identifiable
Hypertension	16	8	0.04–26.1	0.007–1.000	2/8	0.7	Not identifiable
Type 2 diabetes mellitus	2	3	0.63–23.2	0.042–1.000	1/3	4.2	Not identifiable
Chronic pulmonary disease	7	8	0.16–765	<0.001–1.000	4/8	2.6	Not identifiable
Motor-vehicle collision	21	8	0.01–11.9	<0.001–1.000	3/8	3.2	Not identifiable
Emergency operation	24	8	0.004–7.29	<0.001–1.000	4/8	4.7	Not identifiable
≥ 2 surgical interventions	22	8	0.01–10.2	<0.001–1.000	3/8	1.9	Not identifiable

Each admissible table has the reported number of exposed patients, 7 deaths and 25 survivors. Odds ratios use the Haldane–Anscombe correction when a cell is zero.

'Arrangements' weights each table by its hypergeometric probability, i.e. the share of patient-level labelings that produce it. OR, odds ratio.

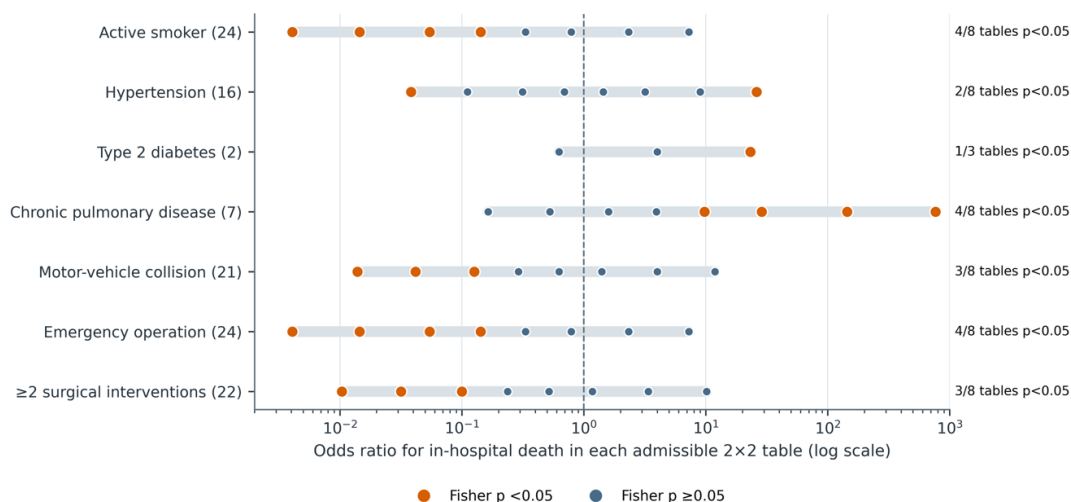


Figure 8. Bounds analysis for characteristics reported only as cohort totals. Each dot is the odds ratio for in-hospital death in one 2×2 table consistent with the reported number of exposed patients (in brackets), 7 deaths and 25 survivors; red dots are tables with Fisher $p < 0.05$. Every range spans 1, so none of these associations can be identified from the reported data (sensitivity analysis over the space of datasets consistent with the observed marginals).

Multivariable bounds are presented in Table 8 and Figure 9. Adjusted for severe head injury, LOFS ≥ 18 had an adjusted OR of 12.3–64.4 and was significant in all 12 admissible tables, whereas the adjusted OR for severe head injury ranged from 0.16 to 14.6. Adjusted for sex, LOFS ≥ 18 had an adjusted OR of 14.4–143 and was again significant in every table. Adjusted for severe thoracic injury, the two characteristics could not be separated. Their adjusted ORs ranged from 4.46 to 41.1 and were significant in 45.5% of the 11 estimable tables, depending

entirely on how far the two classifications overlap. With severe thoracic and severe head injury in the same model, the adjusted OR for LOFS ≥ 18 remained above 1 in all 1020 estimable tables (1.77–872) and was significant in 49.5% of them. For the secondary outcome, between 5 and 11 patients could have had both LOFS ≥ 18 and mechanical ventilation. The resulting OR range of 0.92–89.4 leaves the association of LOFS with ventilation, the outcome closest to its design target, unidentified.

Table 8. Multivariable bounds: Firth-penalized adjusted odds ratios for in-hospital death across every admissible joint table

Model	Predictor	Estima- ble tables	Adjusted OR range	Weighted median (2.5th–97.5th percentile)	Tables with p <0.05, %	Conclusion
LOFS ≥ 18 + AIS head ≥ 3	LOFS ≥ 18	12	12.3–64.4	14.1 (12.3–40.6)	100.0	Direction robust
LOFS ≥ 18 + AIS head ≥ 3	AIS head ≥ 3	12	0.16–14.6	2.87 (1.14–14.6)	8.3	Not identifiable
LOFS ≥ 18 + male sex	LOFS ≥ 18	12	14.4–143	14.8 (14.4–34.3)	100.0	Direction robust
LOFS ≥ 18 + male sex	Male sex	12	0.15–40.3	1.42 (0.15–5.16)	25.0	Not identifiable
LOFS ≥ 18 + AIS thorax ≥ 4	LOFS ≥ 18 (AIS thorax ≥ 4 identical)	11	4.46–41.1	13.9 (6.45–41.1)	45.5	Direction robust
LOFS ≥ 18 + AIS thorax ≥ 4 + AIS head ≥ 3	LOFS ≥ 18 (AIS thorax ≥ 4 identical)	1020	1.77–872	12.3 (4.75–82.9)	49.5	Direction robust
LOFS ≥ 18 + AIS thorax ≥ 4 + AIS head ≥ 3	AIS head ≥ 3	1020	0.003–146	3.57 (0.46–25.7)	3.7	Not identifiable
Secondary outcome: mechanical ventilation	LOFS ≥ 18 (unadjusted)	12	0.92–89.4	—	41.7	Not identifiable

Admissible joint tables reproduce the observed variable-by-death tables (LOFS ≥ 18 6/7 vs 5/25; AIS thorax ≥ 4 6/7 vs 5/25; AIS head ≥ 3 4/7 vs 6/25; male 6/7 vs 19/25). Enumeration was exhaustive (12 tables for two-predictor models, 1032 for the three-predictor model); tables in which LOFS ≥ 18 and AIS thorax ≥ 4 coincide perfectly are not estimable (1 and 12). LOFS ≥ 18 and AIS thorax ≥ 4 have identical margins, so their bounds are identical. P values from penalized-likelihood-ratio tests; weights are numbers of patient-level arrangements, which assume exchangeability within outcome strata. The secondary-outcome row gives unadjusted odds ratios over the 12 tables consistent with the death-stratified counts. AIS, Abbreviated Injury Scale; LOFS, Lung Organ Failure Score; OR, odds ratio.

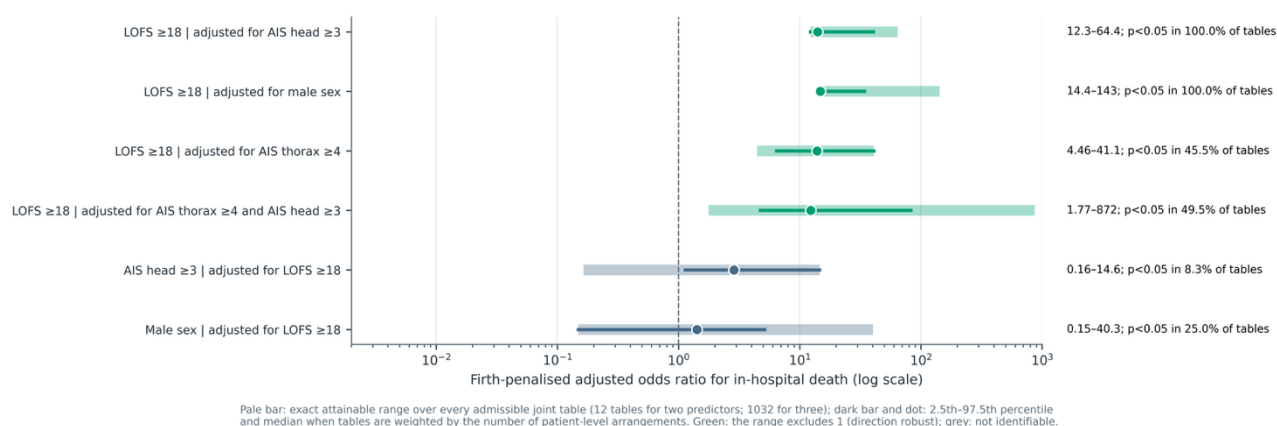


Figure 9. Multivariable bounds: Firth-penalized adjusted odds ratios for in-hospital death across every joint table consistent with the observed variable-by-death tables. Pale bars: exact attainable range (12 tables for two-predictor models; 1032 for the three-predictor model); dark bars and dots: 2.5th–97.5th percentiles and median when each table is weighted by its number of patient-level arrangements. Green ranges exclude 1 (direction robust); grey ranges are not identifiable.

Precision

With seven deaths, the 95% CI for sensitivity was 48.7 percentage points wide and the Hanley–McNeil half-width of the AUC interval was ± 0.194 (Figure 10). Narrowing the AUC interval to ± 0.05 at the observed mortality would require 103 deaths, or about 471 patients.

Excluding patients who died before full evaluation could bias these estimates in either direction (Table 9). If one to five such

deaths had been included and all had scored below 18, sensitivity would fall from 85.7% to between 75.0% and 50.0%, the NPV from 95.2% to between 90.9% and 76.9%, and mortality would rise to between 24.2% and 32.4%. If all had scored 18 or more, sensitivity would rise to between 87.5% and 91.7% and the PPV to between 58.3% and 68.8%. The negative predictive value is therefore the estimate most vulnerable to the exclusion of early deaths.

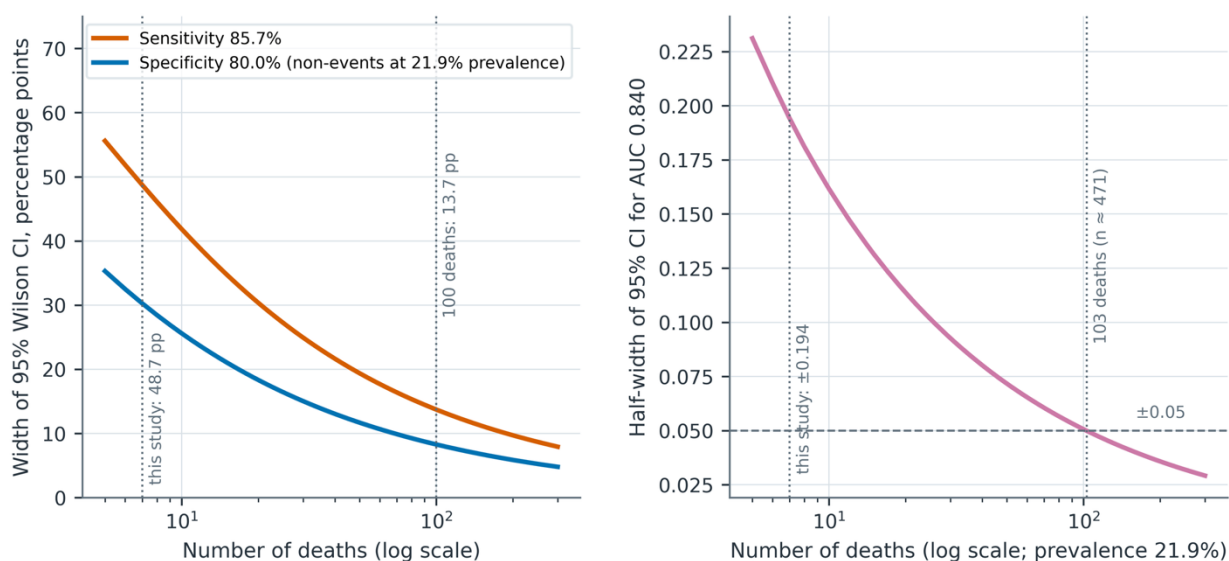
Table 9. Sensitivity of accuracy to excluded early deaths (upper panel) and sample size required for a definitive validation of LOFS for in-hospital death (lower panel)

Excluded early deaths added, n	All scored <18: sensitivity / NPV, %	All scored ≥18: sensitivity / PPV, %	Mortality, %
0	85.7 / 95.2	85.7 / 54.5	21.9
1	75.0 / 90.9	87.5 / 58.3	24.2
2	66.7 / 87.0	88.9 / 61.5	26.5
3	60.0 / 83.3	90.0 / 64.3	28.6
4	54.5 / 80.0	90.9 / 66.7	30.6
5	50.0 / 76.9	91.7 / 68.8	32.4

Table 9B. Sample sizes required for a definitive validation

Objective	Basis	Deaths required	Patients required
AUC 0.84 estimated to ± 0.05 (95% CI)	Hanley-McNeil variance; prevalence 21.9%	103	471
AUC 0.84 estimated to ± 0.075	As above	46	210
Sensitivity 85.7% to ± 10 percentage points	Buderer; normal approximation	48	216
Sensitivity 85.7% to ± 5 percentage points	Buderer; normal approximation	189	861
Lower 95% bound of sensitivity $\geq 75\%$ (rule-out use)	Wilson interval	63	288
Detect AUC 0.84 vs 0.73 (paired, $r = 0.5$), α 0.05, power 80%	Hanley-McNeil paired comparison	54	247
Detect AUC 0.84 vs 0.73 (paired, $r = 0.3$), α 0.05, power 80%	Hanley-McNeil paired comparison	75	343

Upper panel: extreme-case recalculation if 1–5 patients who died before full evaluation had been included (row 0 = observed). Lower panel: calculations assume the AUC (0.840), sensitivity (85.7%), specificity (80.0%) and mortality (21.9%) observed here; the comparator AUC of 0.73 approximates the published same-center TTSS estimate of 0.727¹⁰; r is the correlation between the two scores' AUC estimates in a paired design. Formal criteria for calibration and net benefit⁴³ require additional events once predicted probabilities for death are available. AUC, area under the receiver operating characteristic curve; NPV/PPV, negative/positive predictive value; TTSS, Thoracic Trauma Severity Score.

**Figure 10.** Precision achieved and sample size required. Left: width of the 95% Wilson confidence interval for sensitivity (85.7%) and specificity (80.0%) as the number of care discriminated survivors from non-survivors of blunt thoracic trauma with an AUC of 0.840. The data establish four further points. First, the interval around this estimate (0.553–0.957) is wide enough to include merely modest discrimination. Second, at the data-derived threshold of 18 points the score classified patients exactly as well as severe thoracic injury alone. Third, in every dataset consistent with the observations its association with death was independent of severe head injury and of sex. Fourth, whether it adds information beyond severe thoracic injury cannot be determined from the available data.

4. Discussion

In this first evaluation of LOFS against mortality, conducted at Dr. Mohammad Hoesin General Hospital in Palembang, LOFS calculated from the first hours of care discriminated survivors from non-survivors of blunt thoracic trauma with an AUC of 0.840. The data establish four further points. First, the interval around this estimate (0.553–0.957) is wide enough to include merely modest discrimination. Second, at the data-derived threshold of 18 points the score classified patients exactly as well as severe thoracic injury alone. Third, in every dataset consistent with the observations its association with death was independent of severe head injury and of sex. Fourth, whether it adds information beyond severe thoracic injury cannot be determined from the available data.

Our findings extend the derivation work in a different direction rather than replicate it. Wutzler et al. developed LOFS

to predict severe pulmonary organ failure, which affected 21.3% of their German intensive care cohort, and placed maximal risk at 21 points or more³⁵. Mean LOFS in our non-survivors was 21.0, at that threshold, whereas survivors averaged 14.2, a level at which the derivation model predicts a modest risk of lung failure. The only other study of LOFS in Indonesia used ventilator need as its outcome and found a sensitivity of 85.1% with a specificity of 94.4%³⁸. Our sensitivity for death at ≥ 18 was 85.7%, but our specificity was lower (80.0%), as expected when a score built for pulmonary failure is transported to mortality. In a German emergency-surgery cohort, LOFS averaged 16–17 points, corresponding to an estimated 15% risk of severe pulmonary dysfunction³⁶; our survivors resembled those patients. LOFS still has no external validation for its own outcome²⁶. It has been criticized for ignoring the extent of contusion³⁷, while exploratory extracellular-vesicle research investigates biological signals of organ injury that are not

directly measured by anatomical scores⁴⁶. A mortality AUC of 0.840 is therefore a new and encouraging but preliminary finding.

Against chest-specific scores, LOFS performed in the upper part of the published range, but its interval overlaps all of them. The closest comparator is a TTSS cohort from this hospital over the same period, which reported an AUC of 0.727 with a 95% CI of 0.447–1.000¹⁰. That study may include some of the same patients, so the two estimates cannot be treated as independent, and both intervals are too wide to rank the scores. TTSS was not calculated in the present dataset, so a paired comparison in the same patients was not possible. A Dutch TTSS validation cohort of 516 patients reported a mortality AUC of 0.844²⁷. In 1038 Korean polytrauma patients, TTSS had the highest AUC for complications (0.731) and RibScore the lowest (0.643), and all chest scores deteriorated in the presence of head injury³². STUMBL has the strongest external record: an externally validated original model for complications²⁸, with subsequent AUCs of 0.92 for mortality in New Zealand²⁹, 0.90 for complications in Italy with acceptable calibration⁴⁷ and 0.87 for a composite of death and complications in Canada⁴⁸. Static rib-fracture scores best predicted mortality and ventilator days, whereas a dynamic score best predicted complications⁴⁹. At our own institution, the Chest Trauma Score was associated with length of stay and need for intensive care but not with mortality in 2020³⁹. It was associated with mortality in a larger series⁴⁰ and with ARDS (sensitivity 77.3%, specificity 70.0%)⁴¹.

General severity scores and physiology set the bar that LOFS must clear. ISS and NISS reached mortality AUCs of 0.804 and 0.818 in 310 Chinese patients³⁰ and 0.837 and 0.855 in 101 Brazilian patients³¹. In a South Asian cohort, TRISS and ISS performed best in polytrauma (0.729 and 0.722)⁵⁰. In an Indonesian cohort, TRISS correlated only weakly with prognosis⁵¹. Physiology often matches anatomy. Shock index (AUC 0.885) and lactate (0.832) predicted death after isolated thoracic trauma in Turkey³³, and a high shock index separated 8.2% from 0.8% mortality after blunt thoracic trauma in Qatar³⁴. Base deficit outperformed lactate for shock and mortality⁵² and was the strongest predictor of death in older Indonesian major-trauma patients⁵³. In an earlier intensive care cohort, GCS, the PaO₂/FiO₂ ratio and shock independently predicted mortality⁵⁴; a physiology-based nomogram achieved an AUC of 0.854 in a later ICU cohort⁵⁵. In our data, the Mann–Whitney *p* values imply AUCs of up to 0.887 for lactate and 0.912 for fluid volume. These are upper bounds that cannot be compared formally with LOFS, but they caution against assuming that a ten-item score outperforms a single physiological measurement.

The equivalence between LOFS ≥ 18 and AIS thorax ≥ 4 is the most practically important finding. The thoracic item itself

contributes only two or three points. However, severe chest injury travels with a high ISS, emergency operations, repeated operations and large fluid volumes, so a patient with AIS thorax ≥ 4 accumulates points across several domains at once. A cut-off chosen to maximize the Youden index in 32 patients may therefore simply recover the most powerful single variable. If so, the score's complexity buys nothing at this threshold, and a clinician could obtain the same classification from the chest computed tomography report alone. The continuous score may still carry more information (AUC 0.840 against 0.829 for the binary component), and in every admissible dataset LOFS ≥ 18 kept a positive association with death after joint adjustment for thoracic and head injury. Its incremental value, however, depends on how many patients the two classifications share, which was not recorded. Resolving this question requires item-level data and a paired comparison. The score would earn its complexity only if, in such data, the continuous score or a different threshold classified patients better than AIS thorax ≥ 4 alone, for example by identifying deaths among patients without severe thoracic injury.

The pathophysiology summarized in Figure 11 explains why a composite of these domains should track death; these mechanisms frame hypotheses and were not measured in this study. The first hit is direct parenchymal injury. Contusion severity in the TraumaRegister DGU tracked organ failure and sepsis¹⁸; contusion added respiratory failure and intubation risk among rib-fracture patients¹⁹; and contused volume on computed tomography or lung ultrasound predicted pneumonia and ARDS^{20,56}. The second hit is systemic and partly iatrogenic. Crystalloid volume is a modifiable prognostic factor for ARDS²¹ and predicted multiple organ dysfunction and death in a Dutch cohort²². Prehospital crystalloid was associated with higher mortality across Asian systems¹⁶, with a U-shaped relation between prehospital volume and 24-hour mortality in the United States⁵⁷, and trauma guidelines recommend restricted volume replacement until major bleeding is controlled, with different blood-pressure targets when severe TBI is present⁵⁸. The brain–lung axis adds neurogenic and inflammatory injury. ARDS follows TBI in 7.5–19% of patients and worsens survival^{23,24}, concomitant chest injury worsens TBI outcomes²⁵, and chest injury combined with TBI predicts pneumonia and death^{13,14}. In a developing-country flail-chest series, head injury raised the odds of death almost sevenfold⁵⁹. Host reserve completes the picture: age, low GCS, male sex and ISS predict death after rib fractures⁶⁰, age ≥ 65 years doubles mortality in meta-analysis¹², and the risk of early ventilator-associated pneumonia rises with chest AIS, ISS and transfusion⁶¹.

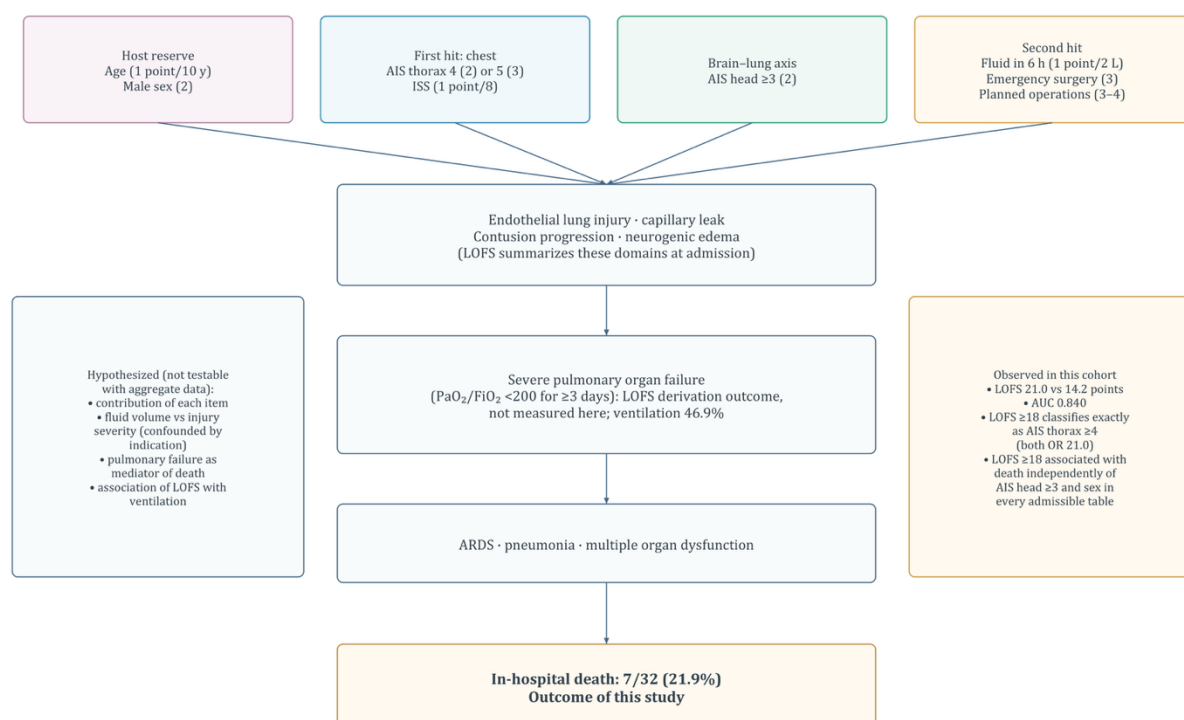


Figure 11. Conceptual framework linking the LOFS domains to pulmonary organ failure and death. Upper boxes show the score's domains and points; the central column shows the hypothesised pathway. The right panel lists what was observed in this cohort and the left panel what cannot be tested with aggregate data. ARDS, acute respiratory distress syndrome; AIS, Abbreviated Injury Scale; ISS, the Injury Severity Score.

Two features of LOFS temper these mechanistic arguments. First, the score contains treatment variables: the fluid volume over six hours and the number of operations reflect clinicians' responses to severity as much as severity itself. The large difference in fluid volume between our groups is therefore confounded by indication and cannot be read as evidence that fluid caused death. Second, the score is not entirely an admission measure, because fluid accumulates over six hours and planned operations may not be known at arrival. Any triage rule based on LOFS should specify when the score is calculated.

This has a practical consequence. A score that partly measures the treatment becomes circular if it is used to allocate that treatment, because aggressive resuscitation raises the score that is supposed to justify it. A triage protocol should therefore fix the time of calculation before the decisions the score is meant to inform, or use a version restricted to items available at arrival and validate that version separately.

If the score is confirmed, a high-risk result could trigger a defined pathway rather than a vague call for 'vigilance'. Serratus anterior plane block improved early pain control and halved opioid use in a randomized trial⁶². Early regional analgesia reduced unplanned intubation in older patients⁶³, although registry data show no mortality benefit⁶⁴. Surgical stabilization of rib fractures is associated with lower mortality in observational data^{65,66}, but randomized trials have not shown shorter intensive care stays^{67,68}. Early non-invasive ventilation or high-flow oxygen did not prevent intubation in hypoxemic chest trauma⁶⁹. In United States registry data from 2007–2009, flail-chest mortality was 16%⁷⁰; this is a historical observational benchmark, not a trial result. The predictive values in Figure 7 show what a positive result would mean elsewhere. At an illustrative mortality prevalence of 5.4%, only one in five patients with LOFS ≥ 18 would die, while 99% of those below the threshold would survive. In this cohort, however, the likelihood ratio for a negative result had a CI reaching 1.11, so a low score cannot yet be used to justify less intensive care.

The NPV of 95.2% is the figure most likely to be quoted and the one that most needs qualification. It rests on 21 patients below the threshold, its likelihood ratio has a CI reaching 1.11, and it would fall to 76.9% if five early deaths with low scores had been included. It would also change with case mix, because the predictive-value curves assume that sensitivity and specificity transfer unchanged to populations with milder injuries, which spectrum effects make unlikely. Under present evidence, no condition can be specified under which a low LOFS would justify de-escalating care. The defensible use is the opposite one: a high score as a prompt for senior review and intensive monitoring, alongside the clinician's own assessment.

The regional context matters for interpretation. Injury burden across the ASEAN states is dominated by road injury¹, and in Indonesia by unhelmeted motorcyclists². Prehospital intervals were not associated with 30-day survival across four Asian countries, although long intervals worsened functional outcome¹⁵. Our mortality of 21.9% exceeds the 15.8% previously reported from Palembang¹⁰. It is also above the 9% pooled across sub-Saharan Africa, where age, head injury, comorbidity and need for intensive care predicted death⁸. A provincial referral center concentrates transferred, severely injured patients, although the proportion of transfers in this cohort was not recorded: the median ISS here was 25, three-quarters of patients underwent an emergency operation and almost half were ventilated. A Saudi series reported a higher share of road-traffic injury and a similar ventilation rate⁴⁵, and flail chest in an Egyptian tertiary center carried a 19.9% mortality⁵⁹. In such settings a score's PPV will be higher and its NPV lower than in unselected emergency-department populations, and any threshold must be recalibrated to the local prevalence.

This study also shows how far a small cohort summarized as aggregates can be pushed without inventing data. Rank correlation is a case in point: with heavily tied integer scores, Kendall's τ -b cannot exceed 0.512 here, so the point-biserial

coefficient of 0.568 must not be reported as a rank correlation. Exhaustive enumeration showed which conclusions survive every possible arrangement of the unrecorded joint data and which do not. In particular, LOFS ≥ 18 is robustly associated with death independently of head injury and sex, whereas its independence from thoracic injury is unidentified. The same reasoning showed that smoking, comorbidities, mechanism and operative management cannot be linked to death from these data in either direction. Firth penalisation reduces small-sample bias but does not repair a small sample⁴⁴. Current guidance requires validation studies sized for precise performance estimates⁴³ and reported in full⁴².

The next step is a prospective multicenter validation across Indonesian referral centers. The lower panel of Table 9 gives the sample sizes such a study would need at the mortality observed here. Estimating the AUC to ± 0.05 requires 103 deaths (about 471 patients), and a sensitivity with a lower 95% bound of at least 75%, the minimum for any rule-out use, requires 63 deaths. A paired comparison able to detect an AUC of 0.84 against 0.73, the value reported for TTSS, requires 54–75 deaths depending on the correlation between the two scores. The protocol should state in advance when LOFS is calculated and which thresholds are tested. Item-level scores, exact AIS grades, physiological values and the number of emergency-department deaths should be recorded. Both outcomes should be assessed: severe pulmonary organ failure, the outcome LOFS was built for, and death. The comparators should be TTSS, STUMBL, ISS and single physiological markers in the same patients, so that differences in AUC can be tested by paired methods. Lung-ultrasound quantification of contusion is feasible in resource-limited settings and could test the main criticism of LOFS^{37,56}.

This study has several strengths. It is the first evaluation of LOFS against mortality and the first in Southeast Asia for any outcome other than ventilator use. Every reported statistic was recomputed from the group summaries. Uncertainty is reported with intervals rather than verbal hedges. The bounds analysis distinguishes conclusions that hold in every dataset consistent with the observations from those the data cannot support, and the cohort is benchmarked against named Indonesian and international comparators.

The limitations are substantial. The study is retrospective and single-center, and with seven deaths every estimate is imprecise; the sensitivity interval is almost 50 percentage points wide. Patient-level cross-classification of the variables was not available. The score's ten item values, exact AIS grades, physiological measurements, comorbidities and operations were reported only as totals or group summaries, so multivariable adjustment is limited to bounds. The threshold of 18 was chosen in the same data and is optimistic. Patients who died before full evaluation were excluded, so the results apply only to patients who survive initial resuscitation; five such deaths scoring below 18 would lower sensitivity to 50.0%. Calibration could not be assessed because LOFS predicts pulmonary failure, not death. Abstractors were not blinded to the outcome, and their agreement was not measured. Ventilation is a crude proxy for pulmonary organ failure, and length of stay is truncated by death.

5. Conclusion

In adults admitted with blunt thoracic trauma to a provincial referral center in Indonesia, the Lung Organ Failure Score discriminated in-hospital death with an AUC of 0.840 (95% CI 0.553–0.957). At 18 points or more, it identified 6 of 7 deaths (sensitivity 85.7%, 95% CI 48.7–97.4) with a specificity of 80.0%, which is exactly the performance of severe thoracic

injury alone. In every dataset consistent with the observations, its association with death was independent of severe head injury and sex, but its contribution beyond severe thoracic injury could not be determined. Until that is resolved, the chest computed tomography report conveys the same triage information as the dichotomized score. LOFS is a promising but unproven mortality tool. It should not yet guide triage, and a low score should not be used to withhold intensive monitoring. A prospective multicenter Indonesian validation with at least 100 deaths, item-level data and paired comparison against TTSS, STUMBL and physiological markers is needed before LOFS enters local trauma pathways.

6. Declarations

Ethics Approval and Consent to Participate

The study was approved by the CMHC Research Center Indonesia ethics committee (approval No. 2024/8426) as a retrospective review of de-identified medical records. The committee waived the requirement for individual informed consent. The study was conducted in accordance with the Declaration of Helsinki.

Consent for Publication

Not applicable. The manuscript contains no individual patient data, images or identifying details.

Availability of Data and Materials

The aggregate data analyzed in this study are reported in full in the tables. Requests for access to the underlying medical-record data should be directed to the corresponding author and are subject to institutional and ethics committee approval.

Artificial Intelligence Use Statement

None declared.

Author Contribution Statement

CUW: conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing – original draft. AHLT: conceptualization, Supervision, Validation, Writing – review & editing. T: Methodology, Formal analysis, Supervision, Writing – review & editing. All authors approved the final version of manuscript.

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Conflict of Interest

The authors declare no conflicts of interest.

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