

Comparative Performance of Revised Trauma Score, Injury Severity Score and Penetrating Abdominal Trauma Index for Predicting Mortality Following Penetrating Abdominal Trauma: A Prospective Cohort Study

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Comparative Performance of Revised Trauma Score, Injury Severity Score and Penetrating Abdominal Trauma Index for Predicting Mortality Following Penetrating Abdominal Trauma: A Prospective Cohort Study

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Abstract:

Background:

Penetrating abdominal trauma (PAT) is associated with significant morbidity and mortality, particularly in resource-constrained trauma settings like. In developing countries. Several trauma scoring systems are used to predict outcomes; however, comparative data from South Asia remain limited. This study evaluated the predictive performance of RTS, ISS, and PATI for mortality and morbidity in patients with penetrating abdominal trauma and explored the association between body mass index (BMI) and clinical outcomes.

Methods:

It was a prospective observational study conducted over 18 months at a tertiary trauma center in New Delhi, India. After Institutional ethical clearance obtained 73 adult patients with penetrating abdominal trauma were included. Data required for study collected with a standard Performa. Trauma scores calculated. The primary outcome was 30-day mortality. Secondary outcomes included postoperative complications, ICU admission, and hospital length of stay. Predictive performance was assessed using receiver operating characteristic (ROC) curve analysis.

Results:

The cohort had a median age of 25 years, and 91.8% were male. Overall mortality was 6.8%, while postoperative complications occurred in 50.7% of patients. RTS demonstrated the highest predictive accuracy for mortality (AUROC 0.982; 95% CI 0.951–1.00; $p < 0.001$), followed by ISS (AUROC 0.863; $p = 0.007$) and PATI (AUROC 0.771; $p = 0.043$). At optimal cut-offs (7.55), RTS achieved 100% sensitivity and 90% specificity. Higher ISS and PATI scores were significantly associated with ICU admission, while increasing PATI scores correlated with greater complication severity and mortality. Lower RTS values were associated with adverse outcomes including ICU admission, ARDS, renal failure, surgical site infection, and mortality. BMI showed no significant association with mortality, complications, ICU admission, or hospital stay.

Conclusion:

RTS demonstrated superior performance for predicting mortality in penetrating abdominal trauma and may be the most useful triage tool in resource-limited settings. ISS and PATI provided valuable information regarding injury severity and postoperative morbidity. PATI served well to predict post-operative complications in our study. BMI was not a significant predictor of outcomes in this cohort. Larger multicenter studies are required to validate these findings.

Keywords: Penetrating abdominal trauma; Revised Trauma Score; Injury Severity Score; Penetrating Abdominal Trauma Index; Mortality; Trauma outcomes.

Introduction:

Traumatic injuries contribute significantly to global mortality and disability rates. The younger, productive cohort are disproportionately affected. At 16% of the global disease burden, trauma is the second highest contributor to this (1). About 9-12% of emergency trauma presentations are due to Penetrating Abdominal Trauma (PAT)(2).

Abdominal trauma is the third most common injury in polytrauma, with one-quarter requiring operative intervention. Multi-visceral involvement with unpredictable foreign body trajectory makes management challenging (3). Organ damage, post-operative complications and mortality are higher in PAT compared to blunt trauma (4). Mortality can be reduced by 58% with appropriate assessment and management (5). This highlights the need for a reliable tool for assessment and to aid in decision making.

Penetrating Abdominal Trauma Index (PATI) by Moore et al., in 1981, assesses organ-specific injury severity and estimates the risk of postoperative complications(6). The Revised Trauma Score [RTS] uses physiological parameters based on the Glasgow Coma Scale with systolic blood pressure and respiratory rate(7). The Injury Severity Score [ISS] derived from the Abbreviated Injury Scale uses site of injury – used for overall trauma assessment(8).

The Indian health care system and population differ from their western counterparts in terms of injury patterns, pre-hospital emergency care and resource availability. PATI has not been adequately evaluated for reliability in the trauma setting in India and not many studies from South Asia have directly compared RTS, ISS, and PATI within the same patient population. Validating and comparing of the trauma scores in the Indian context is relevant for the above reason.

This study aims to compare and identify the best scoring system to predict morbidity and mortality in an Indian tertiary healthcare setting, which can be applied to any resource constrained environment.

Obesity is a major global public health concern. Body Mass Index (BMI) and its association to non-communicable diseases and trauma patients in western population have been extensively studied. BMI and the association with penetrating abdominal trauma outcomes are inadequately explored in literature for Asian population. In acute trauma, high BMI can adversely affect physiological response and post-operative complications, apart from making operative intervention technically challenging(9).

In this study, we have analyzed the association of BMI and trauma outcomes, along with trauma scores for Indian population, for better insight.

Objectives:

Primary Objective:

- To compare the predictive accuracy of PATI, RTS, and ISS in determining morbidity and mortality among

patients with penetrating abdominal trauma.

Secondary Objectives

1. To evaluate the association between BMI and clinical outcomes (morbidity and mortality) in patients with penetrating abdominal trauma.
2. To assess the relationship between trauma scores (PATI, RTS, ISS) and:
 - 0 Length of hospital stay
 - 0 ICU admission and duration
 - 0 Postoperative complications (graded using Clavien–Dindo classification, if applicable)
3. To determine optimal cut-off values of PATI, RTS, and ISS for predicting adverse outcomes in our study population using ROC curve analysis.
4. To assess the feasibility and clinical applicability of PATI in routine practice within a tertiary care Indian trauma center.

Materials and Methods

Study Design and Setting

This was a **prospective observational study** conducted in the Department of General Surgery, University College of Medical Sciences and Guru Teg Bahadur (GTB) Hospital (tertiary trauma centre), New Delhi, India over a period of 18 months. A formal sample size calculation was performed before recruitment. Consecutive patients presenting with penetrating abdominal trauma during study period were screened for eligibility over an 18-month period. The study was approved by the Institutional Ethics Committee of the University College of Medical Sciences (registration and final submission number: 801/802A) prior to commencement of the study, and written informed consent was obtained from all participants.

This study was conducted and reported in accordance with Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement., with additional consideration of TRIPOD principles for reporting predictive performance. This study was designed to evaluate both discrimination and clinical applicability of three commonly used trauma scoring systems in a resource-constrained trauma setting.

Participants

Adult patients aged 18–60 years with confirmed penetrating abdominal trauma admissions to general surgery department were eligible for inclusion. Patients who declined consent or were brought dead to the emergency department were excluded.

A total of 284 patients with penetrating abdominal trauma were assessed, of whom 73 fulfilled the inclusion criteria and were enrolled in the final analysis.

Data Collection and Scoring

Standardized data collection forms and predefined outcome measures were used to reduce information bias. Consecutive recruitment was employed to minimize selection bias. All patients were managed according to **Advanced Trauma Life Support (ATLS)** protocols. Trauma severity was assessed using the Revised Trauma Score (RTS), Injury Severity Score (ISS), and Penetrating Abdominal Trauma Index (PATI), and organ injuries were graded using the AAST classification..

BMI was included as an exploratory variable because obesity has been associated with adverse outcomes following traumatic injury in previous studies, although evidence in penetrating abdominal trauma remains limited.

The primary endpoint was all-cause 30-day mortality. Secondary endpoints included postoperative complications, Clavien–Dindo complication grade, ICU admission, duration of ICU stay, and hospital length of stay. Patients were followed for 30 days after injury through inpatient review or telephone follow-up.

Statistical analysis:

As no directly comparable study was available, we based our estimate on previous trauma literature reporting up to a 58% reduction in mortality with improved trauma assessment and management(10). Assuming an expected proportion of 58%, an absolute precision of 20% on either side, and a 5% level of significance, the minimum required sample size was calculated to be 70 patients. The final cohort included 73 patients, thereby meeting the required sample size.

Data was analyzed using SPSS. Continuous normally distributed variables were expressed as mean $\pm$ standard deviation (SD), whereas non-normally distributed variables were reported as median with interquartile range (IQR). Categorical variables were summarized as frequencies and percentages.

Comparisons between groups were performed using Student's t-test, Mann–Whitney U test, Chi-square test, Fisher's exact test, or Kruskal–Wallis test where appropriate. Receiver operating characteristic (ROC) analysis was performed to evaluate the discriminative ability of RTS, ISS, and PATI for mortality prediction. Areas under the ROC curve (AUROC) with 95% confidence intervals were calculated and were compared using DeLong's test. Optimal cutoff values were determined using the Youden Index. Sensitivity, specificity, positive predictive value, negative predictive value, likelihood ratios, and diagnostic accuracy were calculated for each scoring system. A p-value <0.05 was considered statistically significant.

No variables included in the final analysis had missing data requiring imputation.

Results:

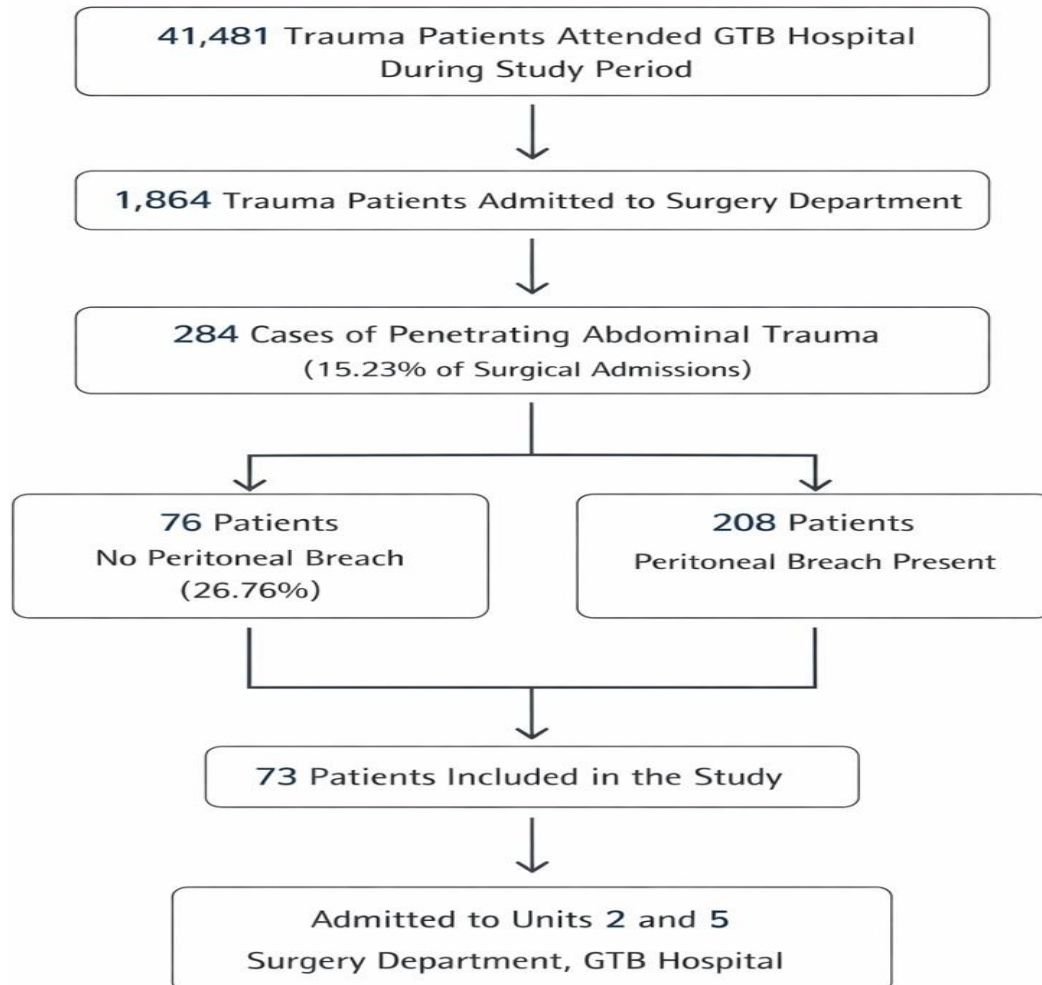
During the study period, a total of 41,481 trauma patients attended the General surgery emergency department of Guru Teg Bahadur Hospital. Among them, 1,864 trauma patients required admission under the Department of General Surgery (**4.49%** trauma admissions rate to General surgery dept).

Of the admitted patients, 284 were diagnosed with penetrating abdominal trauma, accounting for **15.24%** of trauma admissions to the General surgical department.

Among these 284 patients, 76 (26.76%) did not demonstrate peritoneal breach. Absence of peritoneal violation was confirmed through radiological evaluation, local wound exploration, or exploratory laparotomy where indicated. After applying inclusion and exclusion criteria, a total of **73** patients with confirmed penetrating abdominal trauma were enrolled in the study and formed the final study cohort for analysis. The study selection process and final cohort inclusion are illustrated in Figure 1

The study selection process and final cohort inclusion are illustrated in Figure 1

Fig, 1 Flow diagram of patient selection for the study. During the study period, 41,481 trauma patients attended GTB Hospital, of whom 1,864 were admitted under the Department of Surgery. A total of 284 patients (15.23%) had penetrating abdominal trauma; 76 patients had no peritoneal breach and 208 had confirmed peritoneal violation. Of these, 73 patients meeting inclusion criteria were included in the final analysis and were admitted to U nits 2 and 5, Department of Surgery, GTB Hospital



Baseline characteristics:

Detailed cohort characters have been previously published in a journal and are summarized here for context(11). The cohort in this study included 73 adults; median age was 25 (IQR 14) and 91.8% were male. 87.67% under 40 years of age. Assault/violence was the most common cause (84.9%). Stab injuries and gunshot wounds comprised most mechanisms, with a smaller “other” category (e.g., bull horn injury, fall on sharp object). Low-velocity injuries were observed in 56.2% (n = 41).

The most frequently injured structure was small bowel: 19/73 and AAST grading revealed a predominance of moderate-to-severe (Grade ≥ 3) injuries. Most common injury site: abdomen proper.

Median time to hospital presentation was 70 minutes, and mean time to surgery was 5.6 hours (range 30 minutes–31 hours). Surgical intervention was required in 71% of gunshot wounds and 61% of low-velocity injuries.

Clinical Outcomes:

Overall survival was 93.2%, with a mortality rate of 6.8% (n = 5). One death occurred in the emergency department, and the majority occurred within the first 6 hours of presentation.

Postoperative complications were observed in 50.7% (n = 37) of patients, with most classified as Clavien–Dindo Grade II (44.7%). The mean hospital length of stay was 9.75 ± 9.16 days (median 7 days; range 1–40 days).

A total of 13 patients (17.8%) required ICU care.

Clinical outcomes and healthcare resource utilization are summarized in Table 1.

Table 1: Summary of clinical outcomes & resource utilization (n=73)

Outcome	n (%)
Alive	68 (93.2%)
Alive with complications	37 (50.7%)
Mortality	5 (6.8%)
Duration of ICU stay (resource utilization)	
<1 day	7 (9.6%)
1 -7 days	5 (6.8%)
>7 days	1 (1.4%)
Hospital stays (Days)	1-40 days (Mean-9.75 days)
Hospital Stay	
<1 day	5 (6.8%)
1 day -1 week	42 (57.5%)
1-3 weeks	13 (17.8%)
>3 weeks	8 (11%)

Table I Summary of clinical outcomes in patients with penetrating abdominal trauma. Values are presented as number (percentage) unless otherwise specified.

The timing and distribution of mortality events are shown in Table 2.

Table 2: Mortality details (n=5)

Mortality Details	n (%)
Died in ED	1 (20.0)
Died within 6 hours	4 (80.0)
Total	5 (100.0)

Table II Timing of mortality among patients with penetrating abdominal trauma.

Postoperative complications classified according to the Clavien–Dindo grading system are shown in Table 3.

Table 3: Post op complications classified based on Clavien-Dindo Classification (n=38)

Clavien-Dindo Classification	n (%)
Grade I	4 (10.5)
Grade II	17 (44.7)
Grade IIIa	5 (13.2)
Grade IIIb	3 (7.9)
Grade IVa	4 (10.5)
Grade IVb	1 (2.6)
Grade V	4 (10.5)
Total	38 (100.0)

Table III Distribution of postoperative complications according to the Clavien–Dindo classification

Parameters significantly associated with outcomes $P < 0.05$

Pneumonia occurred in 9/73 patients (12.3%). Among the variables analyzed, only the interval between injury and hospital presentation was significantly associated with pneumonia. Patients who developed pneumonia had a shorter mean interval to presentation compared to those without pneumonia (49.9 ± 22.3 vs 206.1 ± 327.3 minutes; $p = 0.031$). Acute respiratory distress syndrome (ARDS) occurred in 1/73 patients (1.4%). Among the variables analyzed, only mode of injury was significantly associated with ARDS ($p = 0.014$). The single ARDS case occurred in a patient with a combined stab and gunshot injury, whereas no cases were observed in isolated stab or gunshot injuries. Mortality analysis demonstrated that injury-to-intervention time was the only variable significantly associated with death ($p < 0.05$), with longer delays linked to increased mortality. The mode of injury was significantly associated with duration of ICU stay ($p < 0.05$), with more complex injury patterns associated with prolonged ICU requirement. Prehospital care was significantly associated with hospital length of stay ($p < 0.05$).

Variables demonstrating statistically significant associations with clinical outcomes are summarized in Table 4.

Table 4: Parameters significantly associated with outcomes $P < 0.05$

Complications	Associated factors $P < 0.05$	Interpretation
Pneumonia	Interval between injury and hospital presentation	Early presentation linked to higher pneumonia*
ARDS	Mode of injury	Complex mechanisms ↑ risk
Mortality	Injury-to-intervention time	Increased delay ↑ mortality
ICU stay	Mode of injury (more complex injuries)	Complex injuries ↑ ICU need
Hospital stay length	Prehospital care	Associated with Length of stay

Table IV Factors significantly associated with clinical outcomes in patients with penetrating abdominal trauma. Only variables with statistically significant associations ($p < 0.05$) are presented

BMI distribution:

The distribution of patients across BMI categories is shown in Table 5

Table 5: Distribution of study participants according to body mass index (BMI) categories (n = 73). BMI was categorized using Asian-specific cutoffs. Values are presented as frequency (percentage).

BMI	Categories	n (%)
<18.5 Kg/m ²	Underweight	2 (2.7)
18.5-22.9 Kg/m ²	Normal	20 (27.4)
23.0-24.9 Kg/m ²	Overweight (At risk)	17 (23.3)
25.0-29.9 Kg/m ²	Obesity Class 1	24 (32.9)
30.0-34.9 Kg/m ²	Obesity Class 2	8 (11.0)
35.0-39.9 Kg/m ²	Obesity Class 3	2 (2.7)
Total		73 (100.0)

The association between BMI and clinical outcomes is presented in Table 6

Table 6: Association between body mass index (BMI) and clinical outcomes in patients with penetrating abdominal trauma (n = 73). BMI is presented as mean $\pm$ standard deviation for each outcome category. Comparisons between groups were performed using the Mann–Whitney U test or Student’s t-test for two groups and the Kruskal–Wallis test for multiple groups, as appropriate. No statistically significant associations were observed ($p > 0.05$ for all comparisons).

Parameters	BMI (Kg/m2)	p-value
Complications: Pneumonia		0.603 ¹
Present	25.37 $\pm$ 2.87	
Absent	25.04 $\pm$ 4.38	
Complications: ARDS		0.521 ¹
Present	23.10 $\pm$ 0	
Absent	25.11 $\pm$ 4.23	
Complications: Pyothorax		1.000 ¹
Present	24.90 $\pm$ 0	
Absent	25.08 $\pm$ 4.23	
Complications: Renal Failure		0.521 ¹
Present	23.10 $\pm$ 0	
Absent	25.11 $\pm$ 4.23	
Complications: Surgical Site Infection		0.212 ²
Present	26.09 $\pm$ 4.67	
Absent	24.64 $\pm$ 3.96	
Complications: Pancreatic Fistula		0.905 ¹
Present	25.60 $\pm$ 0	
Absent	25.07 $\pm$ 4.23	
Complications: Vesico-Enteric Fistula		0.094 ¹
Present	20.15 $\pm$ 4.17	
Absent	25.22 $\pm$ 4.15	
Complications: Intra/Post-Operative Mortality		0.290 ³
Absent	25.05 $\pm$ 4.24	
On table	23.05 $\pm$ 5.16	
Present	28.05 $\pm$ 0.64	
Complications: Re-Surgery		0.512 ¹
Present	23.78 $\pm$ 3.52	
Absent	25.17 $\pm$ 4.26	
Complications: ICU care		0.159 ¹
Present	26.25 $\pm$ 3.64	
Absent	24.82 $\pm$ 4.30	

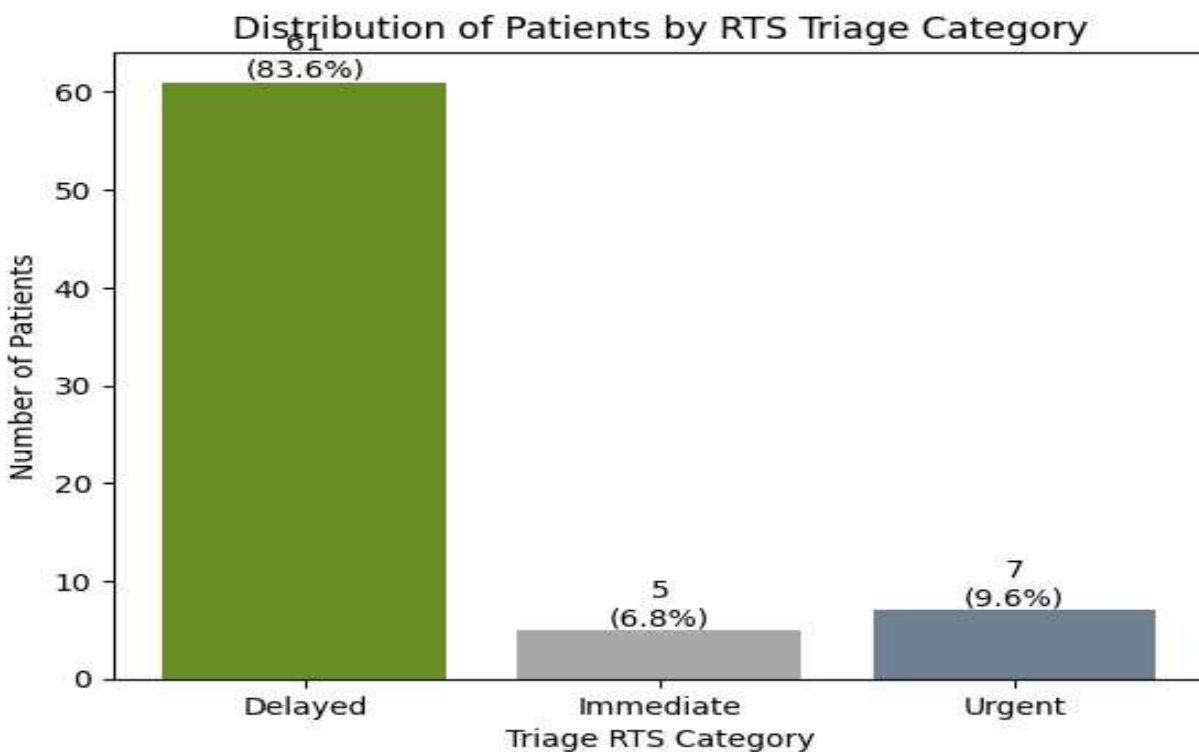
Parameters	BMI (Kg/m2)	p-value
Complications: Diaphragm Repair Failure		0.168 ¹
Present	19.60 ± 0	
Absent	25.15 ± 4.18	
Complications: Bowel Anastomosis/Repair Leak		0.335 ¹
Present	22.55 ± 1.77	
Absent	25.15 ± 4.24	
Clavien-Dindo Classification		0.844 ³
Grade 1	26.35 ± 2.89	
Grade 2	25.61 ± 5.09	
Grade 3a	24.98 ± 3.60	
Grade 3b	23.57 ± 2.16	
Grade 4a	26.23 ± 4.94	
Grade 4b	23.10 ± 0	
Grade 5	25.55 ± 4.17	

***Significant at $p < 0.05$, 1: Mann-Whitney U Test, 2: t-test, 3: Kruskal Wallis Test

In this cohort, BMI did not show a clear monotonic association with mortality or ICU admission, but inference is limited by small event counts and wide uncertainty.

Trauma score summaries:

1) Triage RTS:

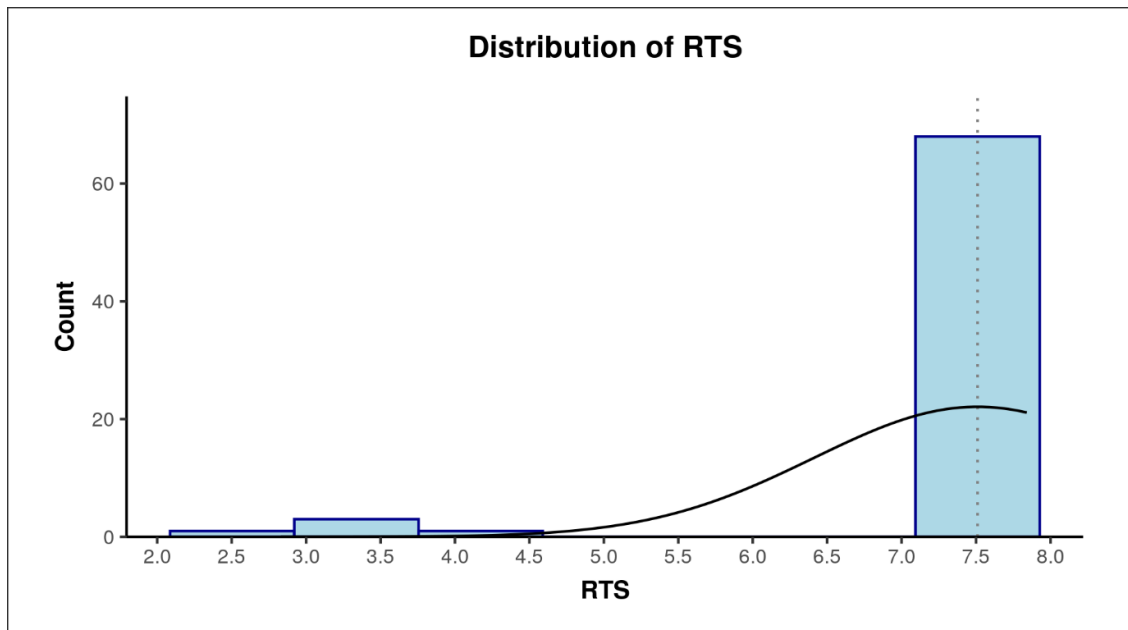


Distribution of patients according to RTS triage categories is shown in Figure 2.

Fig 2: Distribution of patients according to triage category based on Revised Trauma Score (RTS). Most patients were categorized as delayed (83.6%), followed by urgent (9.6%) and immediate (6.8%).

2) RTS Distribution

The Revised Trauma Score (RTS) was not normally distributed (**Shapiro–Wilk test, $p < 0.001$**). The mean RTS was 7.51 ± 1.10 , while the median (IQR) was **7.84 (0.00)**, indicating clustering of values at the upper range. RTS values ranged from **2.83 to 7.84**

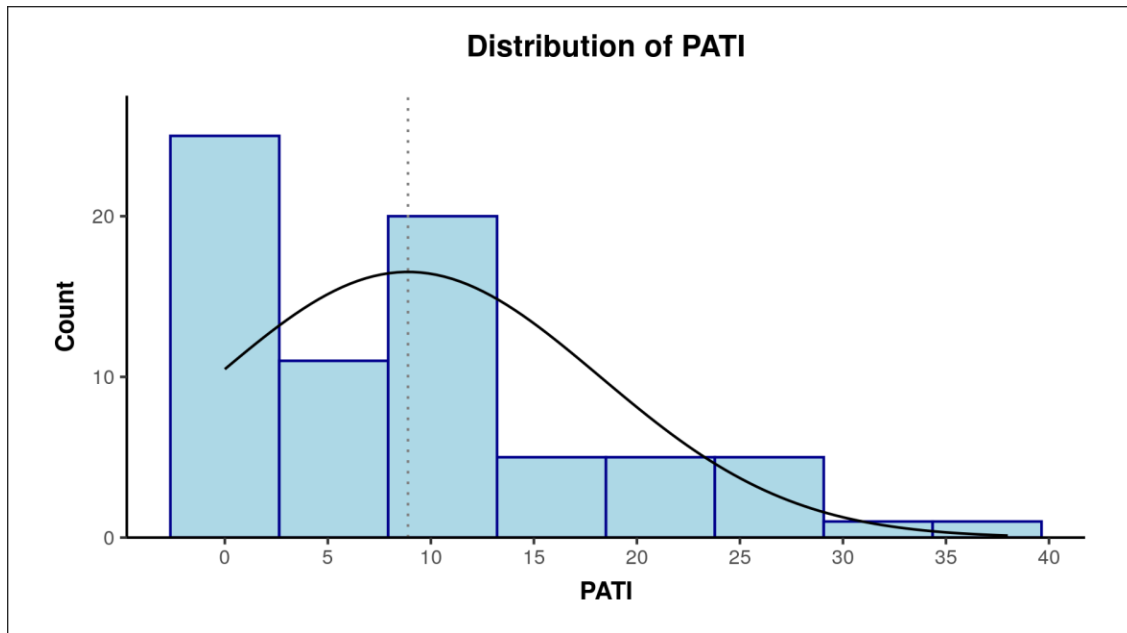


The distribution of RTS values is illustrated in Figure 3.

Fig 3: Distribution of Revised Trauma Score (RTS) among study participants (n = 73). RTS values were skewed towards higher scores, with a median of 7.84 and a narrow interquartile range, reflecting predominance of physiologically stable patients at presentation

3) PATI Distribution

The Penetrating Abdominal Trauma Index (PATI) was not normally distributed (Shapiro–Wilk test, $p < 0.001$). The mean PATI was 8.89 ± 9.31 , while the median (IQR) was 8 (0–12). PATI values ranged from 0 to 38, indicating a wide variability in injury severity across the cohort.

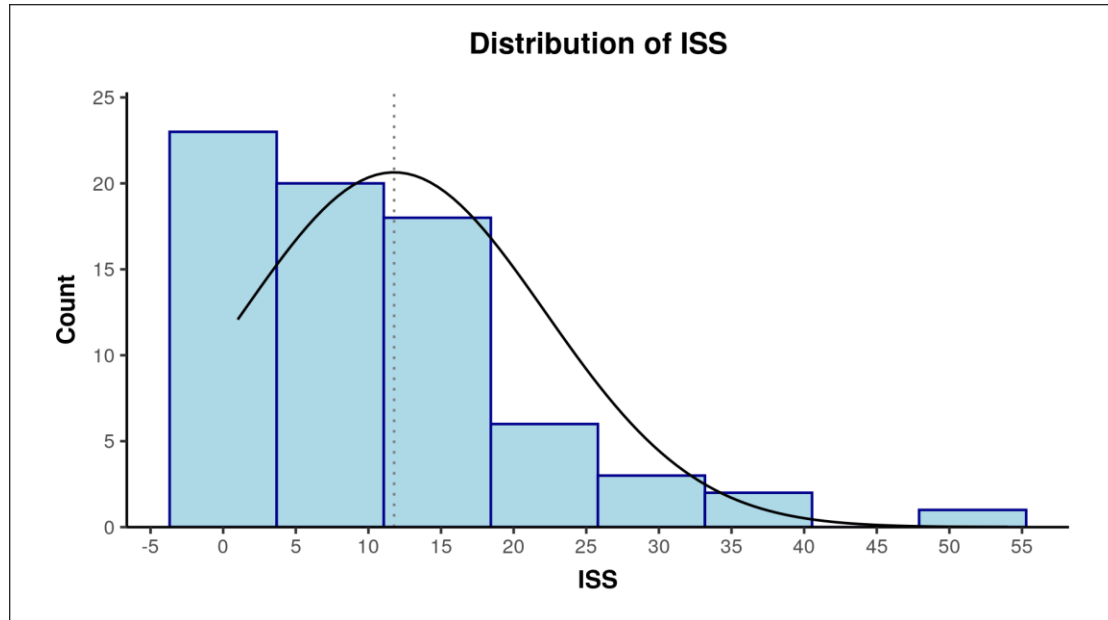


The distribution of PATI scores is shown in Figure 4.

Fig 4: Distribution of Penetrating Abdominal Trauma Index (PATI) among study participants (n = 73). The distribution was right-skewed, with most patients demonstrating lower PATI scores and a smaller proportion exhibiting higher injury severity.

4) ISS Distribution

The Injury Severity Score (ISS) was not normally distributed (Shapiro–Wilk test, $p < 0.001$). The mean ISS was 11.77 ± 10.40 , while the median (IQR) was 9 (2–16). ISS values ranged from 1 to 54, demonstrating considerable variability in injury severity across the cohort.



The distribution of ISS scores is presented in Figure 5.

Fig 5: Distribution of Injury Severity Score (ISS) among study participants (n = 73). The distribution was right-skewed, with most patients having lower ISS values and a smaller proportion exhibiting higher injury severity.

Comparison of Trauma Scores for Predicting Mortality

All three trauma scores—RTS, ISS, and PATI—demonstrated significant ability to predict mortality.

Receiver operating characteristic (ROC) analysis showed that RTS had the highest discriminative performance with an AUROC of 0.982 (95% CI 0.951–1.00; $p < 0.001$), followed by ISS with an AUROC of 0.863 (95% CI 0.652–1.00; $p = 0.007$), and PATI with an AUROC of 0.771 (95% CI 0.459–1.00; $p = 0.043$).

At optimal cutoffs, RTS demonstrated 100% sensitivity and 90% specificity, while ISS showed the highest specificity (91.2%), and PATI demonstrated fair performance with sensitivity of 80% and specificity of 88.2%. Negative predictive values were consistently high across all scores ($\geq 98\%$), whereas positive predictive values were modest.

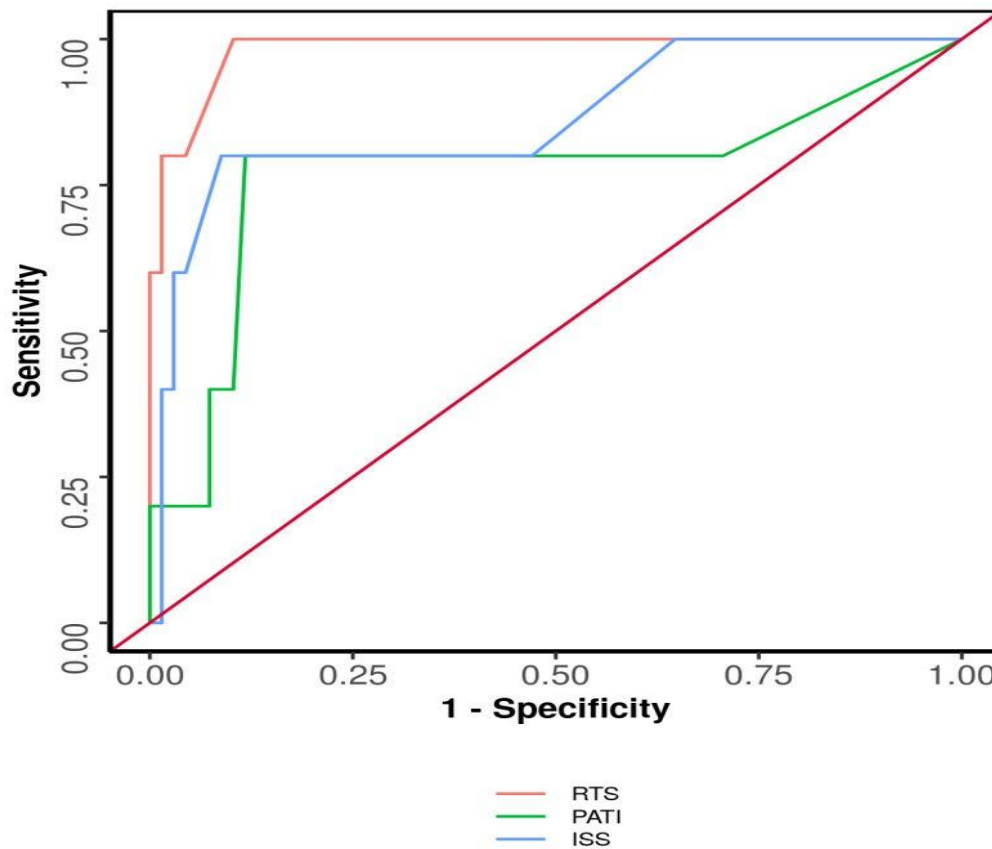
Overall diagnostic accuracy was highest for RTS (90%) and ISS (90%), compared to PATI (87.7%). Likelihood ratio analysis demonstrated strong rule-in value for ISS (LR+ 9.07) and PATI (LR+ 6.80), while RTS showed excellent rule-out capability.

Pairwise comparison of AUROCs using DeLong's test demonstrated no statistically significant differences between RTS, ISS, and PATI (RTS vs ISS $p = 0.289$; RTS vs PATI $p = 0.197$; ISS vs PATI $p = 0.658$).

The diagnostic performance of RTS, ISS, and PATI for mortality prediction is summarized in Table 7.

Predictor	AUROC	Cutoff value	95% CI	P	Sn	Sp	PPV	NPV	DA
RTS	0.982	7.55	0.951-1	<0.001	100%	90%	42%	100%	90%
PATI	0.771	20	0.459-1	0.043	80%	88%	33%	98%	88%
ISS	0.863	25	0.652-1	0.007	80%	91%	40%	98%	90%

Table 7: Diagnostic performance of Revised Trauma Score (RTS), Injury Severity Score (ISS), and Penetrating Abdominal Trauma Index (PATI) in predicting mortality (n = 73). Performance metrics include area under the receiver operating characteristic curve (AUROC), sensitivity (Sn), specificity (Sp), positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy (DA), with corresponding 95% confidence intervals (CI) and p-values.



Receiver operating characteristic (ROC) curves comparing the predictive performance of RTS, ISS, and PATI are shown in Figure 6.

Fig 6: Receiver operating characteristic (ROC) curves comparing Revised Trauma Score (RTS), Injury Severity Score (ISS), and Penetrating Abdominal Trauma Index (PATI) for prediction of 30-day mortality (n = 73). RTS demonstrated excellent discrimination (AUROC 0.982; 95% CI 0.951–1.00; $p < 0.001$), followed by ISS (AUROC 0.863; 95% CI 0.652–1.00; $p = 0.007$) and PATI (AUROC 0.771; 95% CI 0.459–1.00; $p = 0.043$). The diagonal reference line represents no discriminative ability (AUROC = 0.5).

Trauma scores association with outcomes:

Higher ISS and PATI scores were significantly associated with ICU admission (ISS: 23.54 ± 11.74 vs 9.22 ± 8.17 , $p < 0.001$; PATI: 17.92 ± 10.93 vs 6.93 ± 7.72 , $p = 0.001$). Increasing PATI scores were also associated with greater complication severity as per Clavien–Dindo classification ($p = 0.021$), and with mortality (31.50 ± 9.19 in deaths vs 7.91 ± 8.42 in survivors, $p = 0.014$).

Lower RTS values were significantly associated with adverse outcomes, including ARDS ($p = 0.017$), renal failure ($p = 0.017$), surgical site infection ($p = 0.014$), ICU admission ($p = 0.023$), and mortality ($p < 0.001$). RTS also demonstrated a significant association with increasing Clavien–Dindo grades ($p < 0.001$), with lower scores observed in higher severity grades.

No significant association was observed between PATI and pneumonia ($p = 0.058$), although a trend toward higher values in affected patients was noted.

Associations between trauma scores and postoperative complications, ICU admission, and mortality are presented in Table 8.

Table 8: Association of trauma scores (RTS, ISS, and PATI) with postoperative complications, ICU admission, and mortality in patients with penetrating abdominal trauma (n = 73). Values are presented as mean $\pm$ standard deviation. Comparisons were performed using appropriate statistical tests (Mann–Whitney U test or Student’s t-test for two groups, and Kruskal–Wallis test for multiple groups). Statistically significant associations are indicated ($p < 0.05$).

Outcome	Parameter	Present (Mean $\pm$ SD)	Absent (Mean $\pm$ SD)	p-value
ICU Care	ISS	23.54 $\pm$ 11.74	9.22 $\pm$ 8.17	<0.001
	PATI	17.92 $\pm$ 10.93	6.93 $\pm$ 7.72	0.001
	RTS	7.14 $\pm$ 1.43	7.58 $\pm$ 1.01	0.023
Clavien-Dindo Classification	PATI	Increasing with grade	-	0.021
	RTS	Decreasing with grade	-	<0.001
ARDS	RTS	3.70 $\pm$ 0	7.56 $\pm$ 1.01	0.017
Renal Failure	RTS	3.70 $\pm$ 0	7.56 $\pm$ 1.01	0.017
Surgical site infection	RTS	7.84 $\pm$ 0	7.36 $\pm$ 1.30	0.014
Pneumonia	PATI	13.44 $\pm$ 8.85	8.25 $\pm$ 9.26	0.058
Mortality	PATI	31.50 $\pm$ 9.19	7.91 $\pm$ 8.42	0.014
	RTS	5.88 $\pm$ 2.36	7.68 $\pm$ 0.73	<0.001

Discussion:

This prospective study describes penetrating abdominal trauma in a high-volume Indian tertiary public hospital -mainly concentrating on comparison of three commonly used scoring approaches, BMI effect on outcomes and clinical short-term outcomes (within 30 days of trauma).

The key finding is that RTS demonstrated excellent discrimination for early mortality, outperforming ISS and PATI in this dataset as indicated in table 7 and figure 6. RTS is explicitly designed as a physiologic triage/outcome score based on GCS, SBP, and RR(7), which plausibly explains its strong performance in predicting early death driven by shock, airway compromise, or catastrophic injury physiology. Findings in our studies is consistent with other studies stating RTS is excellent tool for predicting mortality in pre-hospital settings and as well as in hospital settings(12)(13).

ISS demonstrated good discrimination, consistent with its long-standing role as an anatomic severity benchmark(14).ISS also demonstrated comparable predictive ability for mortality (AUROC 0.863 with cutoff value of 25 as shown in table 7), supporting its established role for anatomical score to predict mortality specially in-hospital mortality (some studies showed better than RTS for in-hospital mortality prediction(15). However, ISS require detail injury coding which may not be helpful for immediate triage and emergency assessment(16). It still used to predict outcomes and research purposes.

PATI—while designed for penetrating abdominal trauma risk stratification (6)—showed fair discrimination for mortality (AUROC-0.771 with cutoff value of 20 as shown in table 7) in this cohort; this may reflect that PATI is anatomically focused on abdominal organ risk weighting and may be less sensitive to extra-abdominal physiology-driven early death

mechanisms compared with RTS and also doesn't consider the pre-hospital physiological changes affecting outcomes. Patients who died had significantly higher PATI score than survivors, indicating severe intra-abdominal organ injury is a determinant of outcomes in trauma.

In our study association between trauma scores and secondary outcomes provide insight into their clinical utility. Higher PATI and ISS associated with ICU admissions suggesting both anatomical injury burden and organ specific injury severity contribute towards it. Higher scores of PATI associated with increasing Clavien-dindo classification indicating its value in predicting post op complications. Similar results has been observed in other studies where its strongest predictive value is post op morbidity rather than mortality (17)(18). Conversely lower RTS score associated with adverse trauma outcomes including mortality, ARDS, renal failure, SSI, and ICU admissions as illustrated in table 8. These findings again re-enforce on its ability to capture physiological change and serve as early marker for overall clinical deterioration.

BMI did not show a clear association with mortality, complications, length of stay or ICU stay. BMI didn't clearly affect the outcomes in our study as indicated in table 6. This is consistent with the broader mixed literature: meta-analyses and registry studies variably show higher risk with obesity, no difference, or obesity-paradox patterns depending on trauma type and cohort composition(19)(20)(21)(22). For Asian cohort patients as well over all BMI couldn't predict worse or better outcomes. Cushion effect in western studies is inconsistent with our study as well and other Asian studies. In Asian abdominal-trauma cohorts, higher BMI and unfavorable fat-to-muscle profiles tend to be associated with more severe clinical course rather than protection(23). However the findings in our study may be attributable to small sample size, low mortality rate, and limited patients with severe obesity.

Some additional findings contributing to outcomes are interesting in our study illustrated in table 4. Early presentation was associated with pneumonia is unexpected which is contradictory to trauma principles. Usually, late presentation associated with worse trauma outcomes and mortality(24). This was due to complex and server injuries lead to early transport of patient needing interventions like resuscitation, ICU admissions, Intubation, prolonged stay etc which increased risk of pneumonia in these patients. Therefore, early presentation act as a surrogate marker of injury severity rather than being a direct risk factor. This finding should be interpreted cautiously as this study had only small number of pneumonia cases.

Delays between injury and intervention contributing significantly to mortality as literature also suggest. Association between injury mechanism and ICU admission again re-enforces complex injury pattern leads to healthcare resource utilization. Findings in our study support efforts to improve prehospital systems, trauma triage pathways, and rapid access to definitive surgical care which is ongoing in healthcare system like ours.

Overall mortality of 6.8% (5 patients) seen in our study is comparable to other penetrating abdominal studies as well(25). All deaths occurred in first 6 hours of presentation emphasize of initial physiological derangement rather than post op complications as major determinant of mortality. This finding in our study may explain why RTS is superior in predicting mortality. RTS demonstrated excellent tool for mortality prediction (AUROC 0.982 with cutoff value of 7.55 as shown in table 7), achieving 100% sensitivity and 90% specificity at the optimal threshold. Reinforcing physiological parameters outperform anatomical scores because they directly reflect the patient's immediate response to injury and hemorrhagic shock(26).

Conclusion

In this prospective observational cohort of penetrating abdominal trauma, RTS demonstrated the highest discrimination for mortality, with ISS and PATI showing good-to-fair performance. RTS should be prioritized as a primary triage tool for mortality prediction in trauma patients. BMI did not show a consistent association with mortality or ICU admission in this small cohort. Future work should prioritize larger multi-center validation, incorporate TRISS (and potentially NISS where AIS coding is available), and include calibration and interaction analyses to determine whether BMI modifies predictive performance.

Limitations:

Our study was from single center with relatively small sample size. The cohort had only 5 mortality which limited statistical power and may have contributed to wide confidence interval around AUROC estimates. Our cohort mainly had young males again limits generalizability to other populations. Long term functional outcomes were not assessed. Trauma systems and injury pattern vary widely across regions, and therefore external validation is required before these findings can be

generalized broadly.

Declarations

Clinical trial Number: Not applicable

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No external funding was received for this study.

Conflict of Interest

The authors declare no conflict of interest.

Ethics Approval

The study was registered and approved (registration and final submission number: 801/802A) with the institute (University College of Medical Sciences, Delhi) and the institutional ethics committee. All procedures were conducted in accordance with the 1964 Helsinki Declaration and its later amendments.

Informed Consent

Written informed consent was obtained from all participants prior to enrolment.

Author Contributions

SN: Designed study, made protocol, got ethical approval, Methodology, Data Curation, Investigation, Formal Analysis, Writing – Original Draft, Review and editing, Visualization, Project Administration.

NSU: Supervision, Validation, Writing – Review & Editing.

VN: Data Curation, Literature Review, Writing – Review & Editing.

AMK: Data Analysis, Validation, Writing – Review & Editing.

KK: Investigation, Data Collection, Resources, Writing – Review & Editing.

GND: Validation, Writing – Review & Editing.

LS: Data Collection, Investigation, Writing – Review & Editing.

YK: Supervision, Methodology, Writing – Review & Editing.

VV: Critical Revision of the Manuscript and editing

All authors contributed to the interpretation of data, critically revised the manuscript for important intellectual content, approved the final version for publication, and agree to be accountable for all aspects of the work.

Data Availability

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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