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Validation of chest trauma scoring systems in polytrauma: a retrospective study with 1,038 patients in Korea

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Purpose: Appropriate scoring systems can help classify and treat polytrauma patients. This study aimed to validate chest trauma scoring systems in polytrauma patients.

Methods: Data from 1,038 polytrauma patients were analyzed. The primary outcomes were one or more complications: pneumonia, chest complications requiring surgery, and mortality. The Thoracic Trauma Severity Score (TTSS), Chest Trauma Score, Rib Fracture Score, and RibScore were compared using receiver operating characteristic (ROC) analysis in patients with or without head trauma.

Results: In total, 1,038 patients were divided into two groups: those with complications (822 patients, 79.2%) and those with no complications (216 patients, 20.8%). Sex and body mass index did not significantly differ between the groups. However, age was higher in the complications group (64.1±17.5 years vs. 54.9±17.6 years, P<0.001). The proportion of head trauma patients was higher (58.3% vs. 24.6%, P<0.001) and the Glasgow Coma Scale score was worse (median [interquartile range], 12 [6.5–15] vs. 15 [14–15]; P<0.001) in the complications group. The number of rib fractures, the degree of rib fracture displacement, and the severity of pulmonary contusions were also higher in the complications group. In the area under the ROC curve analysis, the TTSS showed the highest predictive value for the entire group (0.731), head trauma group (0.715), and no head trauma group (0.730), while RibScore had the poorest performance (0.643, 0.622, and 0.622, respectively)

Conclusions: Early injury severity detection and grading are crucial for patients with blunt chest trauma. The chest trauma scoring systems introduced to date, including the TTSS, are not acceptable for clinical use, especially in polytrauma patients with traumatic brain injury. Therefore, further revisions and analyses of chest trauma scoring systems are recommended.

Keywords: Blunt chest trauma; Glasgow Coma Scale; Trauma scoring systems; Abbreviated Injury Scale; Traumatic brain injuries

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INTRODUCTION

Background

Chest injuries, which account for 10% to 15% of all trauma cases, are closely associated with adverse outcomes [1–3]. There are ongoing efforts to identify and assess the severity of thoracic trauma early on [1–6]. To date, four chest injury scoring systems have been introduced to quantify the severity of chest injuries. The Thoracic Trauma Severity Score (TTSS), introduced by Pape et al. [3] in 2000, is a scoring system that incorporates both physiological and anatomical parameters. Its predictability has been relatively well demonstrated [7,8]. The Rib Fracture Score (RFS), introduced by Easter [9] in 2001, is a simple prediction model that consists of the number of rib fractures. The Chest Trauma Score (CTS), introduced by Chen et al. [4] in 2014, includes parameters such as age, pulmonary contusion score, the number of rib fractures, and the presence of bilateral rib fractures. Lastly, the RibScore, introduced by Chapman et al. [6] in 2016, is a scoring system based solely on anatomical parameters, including the number of rib fractures, flail chest, and bilateral fractures.

The predictive ability of scoring systems falls short of expectations due to various limitations [10,11]. One limitation is that these scoring systems were originally designed for patients with multiple traumatic injuries. Therefore, specific critical conditions, such as traumatic brain injury (TBI), may affect the accuracy of these scoring systems [3–6,9]. Of the scoring systems for chest trauma, only the TTSS was specifically developed for patients who had an initial Glasgow Coma Scale (GCS) score of >8 [12,13]. In comparison, other scoring systems did not explicitly exclude patients with concurrent TBIs.

Objectives

TBI is a well-known independent risk factor for adverse outcomes in patients with polytrauma [14–16]. Therefore, we evaluated the predictive ability of the aforementioned chest trauma scoring systems in relation to the presence or absence of TBI. Furthermore, since the TTSS is the only one of the four scoring systems developed with the exclusion of severe TBI, we hypothesized that the TTSS might demonstrate reduced predictive accuracy in cases of severe TBI.

METHODS

Ethics statement

The study was approved by the Institutional Review Board of Chungbuk National University Hospital, with a waiver for informed consent (No. 2023-03-225). All methods were performed in compliance with the applicable guidelines and regulations [17].

Study design and data source

This retrospective single-center study was conducted at a level I trauma center in Korea (Chungbuk National University Hospital, Cheongju, Korea). We recorded the data of all patients with blunt chest trauma from the time of admission, which included their Injury Severity Score (ISS) [18], Abbreviated Injury Scale (AIS) [19], and GCS. We also prospectively recorded any developments in the patients' conditions, such as flail chest or pneumonia, during their initial hospital stay. The patterns of rib fracture and the extent of pulmonary contusion were determined once, based on the initial chest computed tomography (CT) scan. At our trauma center, CT scans from the head to the pelvis are routinely performed for all patients. If indicated, CT scans of the extremities are also conducted. Utilizing the collected data, we calculated the TTSS, RFS, CTS, and RibScore for all patients with blunt chest trauma, as previously mentioned.

Study population, inclusion criteria, and exclusion criteria

This study enrolled consecutive patients with chest trauma who were hospitalized at our trauma center from January 2019 to January 2023. Fig. 1 illustrates the inclusion and exclusion criteria. Initially, only patients with blunt chest trauma were considered for inclusion. The exclusion criteria were as follows: (1) patients who did not survive beyond 24 hours; (2) patients in whom the extent of pulmonary contusion could not be determined, such as those with a completely collapsed lung due to tension pneumo-

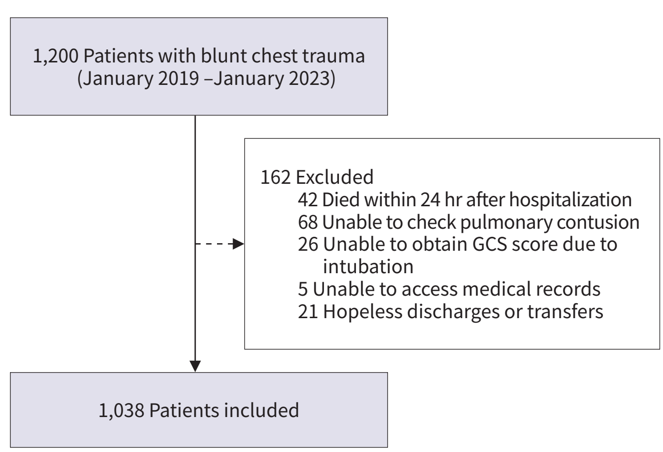

Fig. 1. Study flowchart of patients with blunt chest trauma. GCS, Glasgow Coma Scale.

thorax or those with a single lung state from a previous pneumonectomy; (3) patients lacking GCS records because they were intubated; (4) patients who were discharged or transferred within 24 hours of admission; and (5) patients with missing essential medical records.

Definitions of parameters

Number of rib fractures by the degree of displacement

All parameters were determined based on the initial chest CT and laboratory findings. The number of ribs was determined and categorized based on the extent of fracture displacement as follows: grade 0, no rib fractures (rib fractures); grade 1, rib fractures with less than 50% rib width displacement on axial CT; grade 2, greater than 50% but less than 100% displacement; grade 3, 100% or more displacement [10]. In cases where a single rib was fractured into multiple segments, only the fractures at the two most severely damaged locations were recorded and assessed.

Rib fracture location

The rib fracture location was divided into three parts using the anterior and posterior axillary lines [20]. However, the upper first and second ribs and the lower 11th–12th ribs do not conform to these anatomical landmarks. Moreover, these four ribs are considered to be of relatively minor importance for respiratory function [21–23]. Therefore, they were excluded from the definitions and calculations used in this study to analyze the rib fracture patterns.

Degree of pulmonary contusion

The degree of pulmonary contusion was assessed using the Blunt Pulmonary Contusion 18 (BPC 18) score [24,25]. This scoring system divides each lung field into upper, middle, and lower thirds. Each third is assigned a score ranging from 0 to 3, reflecting the density of the affected lung tissue. The maximum possible score is 18, indicative of severe bilateral damage encompassing the upper, middle, and lower regions of the lungs.

Segmental fractures and flail segment

A segmental rib fracture was diagnosed when a rib sustained two or more fractures at different locations. In this study, we adopted the term "flail segment" in place of "flail chest" [11]. A flail segment was defined as a series of three or more consecutive segmental rib fractures, as verified by the initial chest CT scan. A flail segment composed of multiple bilateral rib fractures on the anterior sections of each hemithorax, with or without an accompanying sternal fracture, was classified as a bilateral anterior–anterior flail segment. If the fracture lines within a flail segment were not linear, the flail segment was categorized as indistinguishable. This study identified seven types of flail segments: type 1, bilateral anterior–anterior; type 2, ipsilateral anterior–anterior; type 3, ipsilateral anterior–lateral; type 4, ipsilateral anterior–posterior; type 5, ipsilateral lateral–lateral; type 6, ipsilateral lateral–posterior; and type 7, indistinguishable.

The primary outcome was defined as the occurrence of one or more of the following events: (1) pneumonia; (2) pulmonary complications necessitating surgical intervention, including empyema, injury to the descending aorta from rib fractures, or thoracotomy for delayed tension hemothorax; and (3) death occurring more than 24 hours after admission.

Statistical analysis

All statistical analyses were conducted using R ver. 4.1.2 (R Foundation for Statistical Computing). The "pROC," "tidyverse," and "moonBook" packages were utilized for data analysis and visualization. Additionally, we employed a receiver operating characteristic (ROC) curve to validate the predictability of previous chest trauma scoring systems and calculated the area under the ROC curve (AUROC).

RESULTS

Univariate analysis of patient characteristics

Table 1 presents the baseline characteristics and outcomes of the study population. A total of 1,038 patients with blunt chest trauma were included in the study. These patients were divided into two groups based on whether they experienced complications. Of these, 822 patients (79.2%) had no adverse outcomes, while 216 patients (20.8%) experienced one or more complications.

Sex and body mass index were not significantly different between the groups. However, the patients in the complications group were, on average, older (64.1 ± 17.5 years vs. 54.9 ± 17.6 years, $P < 0.001$). The complications group also had significantly longer hospital stays (median [interquartile range, IQR], 32 days [14.6–62.5 days] vs. 13 days [6.0–26.0 days]), intensive care unit stays (median [IQR], 12,735 minutes [3,777.5–30,287.5 minutes] vs. 1,000 minutes [0–3,860 minutes]), and durations of mechanical ventilator support (median [IQR], 5,202 minutes [0–14,692.5 minutes] vs. 0 minutes [0–0 minutes]), with $P < 0.001$ for each comparison.

In the complications group, the proportion of head trauma patients was higher (58.3% vs. 24.6%, $P < 0.001$). The complications group also showed a worse GCS score (median [IQR], 12 [6.5–

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Table 1. Classification of patients based on the presence or absence of complications

Characteristic	All patients (n=1,038)	Complication		P-value
		Yes (n=216, 20.8%)	No (n=822, 79.2%)	
Sex				0.084
Female	266 (25.6)	45 (20.8)	221 (26.9)	
Male	772 (74.4)	171 (79.2)	601 (73.1)	
Age (yr)	56.8±18.0	64.1±17.5	54.9±17.6	<0.001
Body mass index (kg/m^2)	23.9±3.7	24.0±3.6	23.6±4.0	0.182
Length of stay				
Hospital stay (day)	15 (7.0–32.0)	32 (14.6–62.5)	13 (6.0–26.0)	<0.001
ICU stay (min)	2,077.5 (0–6,135)	12,735 (3,777.5–30,287.5)	1,000 (0–3,860)	<0.001
Mechanical ventilator (min)	0 (0–0)	5,202 (0–14,692.5)	0 (0–0)	<0.001
Glasgow Coma Scale	15 (14–15)	12 (6.5–15)	15 (14–15)	<0.001
PaO_2:FiO_2	310.6±118.9	243.0±109.1	328.3±114.9	<0.001
Lung parenchymal injury				
Pneumothorax	531 (51.2)	126 (58.3)	405 (49.3)	0.022
Hemothorax	513 (49.4)	124 (57.4)	389 (47.3)	0.010
BPC 18 score	1 (0–3)	2 (0–5)	1 (0–2)	<0.001
Rib fracture pattern				
No. of rib fractures	4 (2–6)	5 (4–8.5)	4 (2–6)	<0.001
Fracture grade				
II	0 (0–1)	0 (0–1)	0 (0–1)	0.008
III	0 (0–2)	1 (0–3)	0 (0–1)	<0.001
Segmental rib fracture	0 (0–2)	1 (0–4)	0 (0–1)	<0.001
Bilateral rib fracture	163 (15.7)	60 (27.8)	103 (12.5)	<0.001
Flail chest				
Flail segment	239 (23.0)	80 (37.0)	159 (19.3)	<0.001
Bilateral anterior–anterior	53 (5.1)	24 (11.1)	29 (3.5)	<0.001
Ipsilateral anterior–anterior	4 (0.4)	1 (0.5)	3 (0.4)	1.000
Anterior–lateral	35 (3.4)	20 (9.3)	15 (1.8)	<0.001
Anterior–posterior	14 (1.3)	6 (2.8)	8 (1.0)	0.086
Lateral–lateral	9 (0.9)	4 (1.9)	5 (0.6)	0.180
Lateral–posterior	158 (15.2)	44 (20.4)	114 (13.9)	0.024
Indistinguishable	2 (0.2)	2 (0.9)	0	0.059
Head trauma	328 (31.6)	126 (58.3)	202 (24.6)	<0.001
Whole body injury score				
Abbreviated Injury Scale				
Head	0 (0–2)	2 (0–4)	0 (0–0)	<0.001
Face	0 (0–0)	0 (0–1)	0 (0–0)	<0.001
Chest	3 (3–3)	3 (3–3)	3 (3–3)	<0.001
Abdomen	0 (0–2)	0 (0–2)	0 (0–2)	0.003
Extremities	0.5 (0–2)	2 (0–3)	0 (0–2)	<0.001
External	1 (0–1)	1 (0–1)	1 (0–1)	0.020
Injury Severity Score	17 (10–25)	27 (19–36)	14 (10–22)	<0.001
Chest only injury score				
Thoracic Trauma Severity Score	9 (6–12)	12 (9–15)	8 (6–11)	<0.001
Rib Fracture Score	6 (4–9)	8 (6–14)	5 (3–8)	<0.001
Chest Trauma Score	5 (4–7)	6 (5–8)	5 (4–6)	<0.001
RibScore	0 (0–2)	2 (0–3)	0 (0–2)	<0.001

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Table 1. (Continued)

Characteristic	All patients (n=1,038)	Complication		P-value
		Yes (n=216, 20.8%)	No (n=822, 79.2%)	
Overall complication				
Mortality	45 (4.3)	45 (20.8)	0	<0.001
Pneumonia	162 (15.6)	162 (75.0)	0	<0.001
Surgically treated chest complications	39 (3.8)	39 (18.1)	0	<0.001

Values are presented as number (%), mean±standard deviation, or median (interquartile range).
ICU, intensive care unit; FiO_2, fraction of inspired oxygen ratio; BPC 18, Blunt Pulmonary Contusion 18.

15] vs. 15 [14–15]; P < 0.001).

The parameters reflecting lung parenchymal injuries also significantly differed. The incidence rates of both pneumothorax (58.3% vs. 49.3%) and hemothorax (57.4% vs. 47.3%) were higher in the complications group (P < 0.05), and the BPC 18 score was also higher in the complications group (median [IQR], 2 [0–5] vs. 1 [0–2]; P < 0.001). The PaO_2 to fraction of inspired oxygen ratio (PFR) measured by an initial arterial blood gas analysis was also significantly different (243.0 ± 109.1 vs. 328.3 ± 114.9, P < 0.001).

Table 1 also shows that the rib fracture patterns differed between the two groups. The complications group had more fractured ribs (median [IQR], 5 [4–8.5] vs. 4 [2–6]; P < 0.001). The severity of rib fracture displacement was also higher in the complications group, including the number of segmental rib fractures and grade II and III displacement (all P < 0.05).

In addition, a higher proportion of patients in the complications group had a flail segment (37.0% vs. 19.3%, P = 0.001). Among the subclassified parameters of the types of flail segments, the bilateral anterior–anterior (11.1% vs. 3.5%, P < 0.001), the anterior–lateral (9.3% vs. 1.8%, P < 0.001), and the lateral–posterior (20.4% vs. 13.9%, P = 0.024) types were more frequently observed in the complications group.

The head, face, abdomen, extremities, and external AIS scores were higher in the complications group (P < 0.001). The scores for the ISS and all four chest trauma scoring systems were also higher in the complications group (P < 0.001).

Analyses according to the presence of head injury

We compared the scoring systems between patients with and without traumatic head injury (Table 2). Patients were classified into the head injury group when they had a head AIS > 0 and into the non-head injury group when their head AIS was 0. Among 1,038 patients, 328 (31.6%) had a head injury and 710 (68.4%) did not.

There were no statistically significant differences in sex and age between the two groups. However, the group with head injuries had significantly longer hospital stays, durations of intensive care unit admission, and periods of mechanical ventilator support (all P < 0.001). The GCS (median [IQR], 14 [9–15] vs. 15 [15–15]; P < 0.001) and initial PFR (279.1 ± 117.6 vs. 325.1 ± 116.7, P < 0.001) were also lower in the head injury group. The head injury group also showed higher BPC 18 scores (median [IQR], 1 [0–5] vs. 1 [0–2]; P < 0.001). However, no significant differences were found in the proportion of patients with pneumothorax and hemothorax.

No significant difference in the number of rib fractures was observed between the head injury group and the no head injury group. However, the head injury group had a higher incidence of segmental rib fractures (median [IQR], 0 [0–3] vs. 0 [0–2]; P = 0.017), flail segments (89 [27.1%] vs. 150 [21.1%], P = 0.040), and bilateral rib fractures (77 [23.5%] vs. 86 [12.1%], P < 0.001).

Notably, all chest trauma scoring systems (TTSS, RFS, CTS, and RibScore) showed higher (more severe) scores in the head injury group, even though they did not include a head injury parameter (TTSS: 10 [IQR, 7–13] vs. 9 [IQR, 6–11], P < 0.001; RFS: 6 [IQR, 4–10] vs. 5 [IQR, 4–9], P = 0.002; CTS: 6 [IQR, 4–8] vs. 5 [IQR, 4–6], P < 0.001; RibScore: 1 [IQR, 0–3] vs. 0 [IQR, 0–2], P < 0.001).

The AUROCs of the scoring systems

Fig. 2 shows the results of AUROC analyses. In the AUROC analysis for the entire patient population, the TTSS (0.731), CTS (0.711), RFS (0.680), and RibScore (0.643) demonstrated insufficient predictive accuracy. The order of TTSS, CTS, RFS, and RibScore was the same in both the head injury group and the no head injury group. Table 3 summarizes the AUROC, cutoff value, sensitivity, specificity, and positive and negative likelihood ratios for all scores.

DISCUSSION

We aimed to investigate whether scoring systems developed to

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Table 2. Classification of patients based on the presence or absence of head trauma

Characteristic	All patients (n=1,038)	Head trauma		P-value
		Yes (n=328, 31.6%)	No (n=710, 68.4%)	
Sex				0.696
Female	266 (25.6)	81 (24.7)	185 (26.1)	
Male	772 (74.4)	247 (75.3)	525 (73.9)	
Age (yr)	56.8±18.0	57.8±18.7	56.4±17.6	0.231
Body mass index (kg/m^2)	23.9±3.7	23.3±3.5	24.2±3.8	<0.001
Length of stay				
Hospital stay (day)	15.0 (7.0–32.0)	22.6 (10.1–48.1)	11.9 (6.0–26.0)	<0.001
ICU stay (min)	2,077.5 (0–6,135.0)	5,472.5 (2,170.5–17,760)	0 (0–3,710)	<0.001
Mechanical ventilator (min)	0 (0–0)	0 (0–7,142)	0 (0–0)	<0.001
Glasgow Coma Scale	15 (14–15)	14 (9–15)	15 (15–15)	<0.001
PaO_2:FiO_2	310.6±118.9	279.1±117.6	325.1±116.7	<0.001
Lung parenchymal injury				
Pneumothorax	531 (51.2)	167 (50.9)	364 (51.3)	0.969
Hemothorax	513 (49.4)	158 (48.2)	355 (50.0)	0.630
BPC 18 score	1 (0–3)	1 (0–5)	1 (0–2)	<0.001
Rib fracture pattern				
No. of rib fractures	4 (2–6)	5 (2–7)	4 (2–6)	0.101
Fracture grade				
II	0 (0–1)	0 (0–1)	0 (0–1)	0.659
III	0 (0–2)	0 (0–2)	0 (0–2)	0.639
Segmental rib fracture	0 (0–2)	0 (0–3)	0 (0–2)	0.017
Bilateral rib fracture	163 (15.7)	77 (23.5)	86 (12.1)	<0.001
Flail chest				
Flail segment	239 (23.0)	89 (27.1)	150 (21.1)	0.040
Bilateral anterior–anterior	53 (5.1)	16 (4.9)	37 (5.2)	0.940
Ipsilateral anterior–anterior	4 (0.4)	0	4 (0.6)	0.410
Anterior–lateral	35 (3.4)	12 (3.7)	23 (3.2)	0.871
Anterior–posterior	14 (1.3)	7 (2.1)	7 (1.0)	0.230
Lateral–lateral	9 (0.9)	4 (1.2)	5 (0.7)	0.637
Lateral–posterior	158 (15.2)	57 (17.4)	101 (14.2)	0.222
Indistinguishable	2 (0.2)	2 (0.6)	0	0.186
Whole body injury score				
Abbreviated Injury Scale				
Head	0 (0–2)	3 (2–4)	0 (0–0)	<0.001
Face	0 (0–0)	0 (0–1)	0 (0–0)	<0.001
Chest	3 (3–3)	3 (3–3)	3 (3–3)	0.755
Abdomen	0 (0–2)	0 (0–2)	0 (0–2)	0.366
Extremities	0.5 (0–2)	2 (0–3)	0 (0–2)	<0.001
External	1 (0–1)	1 (0–1)	0 (0–1)	<0.001
Injury Severity Score	17 (10–25)	24 (17–34)	14 (9–19)	<0.001
Chest only injury score				
Thoracic Trauma Severity Score	9 (6–12)	10 (7–13)	9 (6–11)	<0.001
Rib Fracture Score	6 (4–9)	6 (4–10)	5 (4–9)	0.002
Chest Trauma Score	5 (4–7)	6 (4–8)	5 (4–6)	<0.001
RibScore	0 (0–2)	1 (0–3)	0 (0–2)	<0.001

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Table 2. (Continued)

Characteristic	All patients (n=1,038)	Head trauma		P-value
		Yes (n=328, 31.6%)	No (n=710, 68.4%)	
Overall complication	216 (20.8)	126 (38.4)	90 (12.7)	<0.001
Mortality	45 (4.3)	38 (11.6)	7 (1.0)	<0.001
Pneumonia	162 (15.6)	91 (27.7)	71 (10.0)	<0.001
Surgically treated chest complications	39 (3.8)	15 (4.6)	24 (3.4)	0.445

Values are presented as number (%), mean±standard deviation, or median (interquartile range).
ICU, intensive care unit; FiO_2, fraction of inspired oxygen ratio; BPC 18, Blunt Pulmonary Contusion 18.

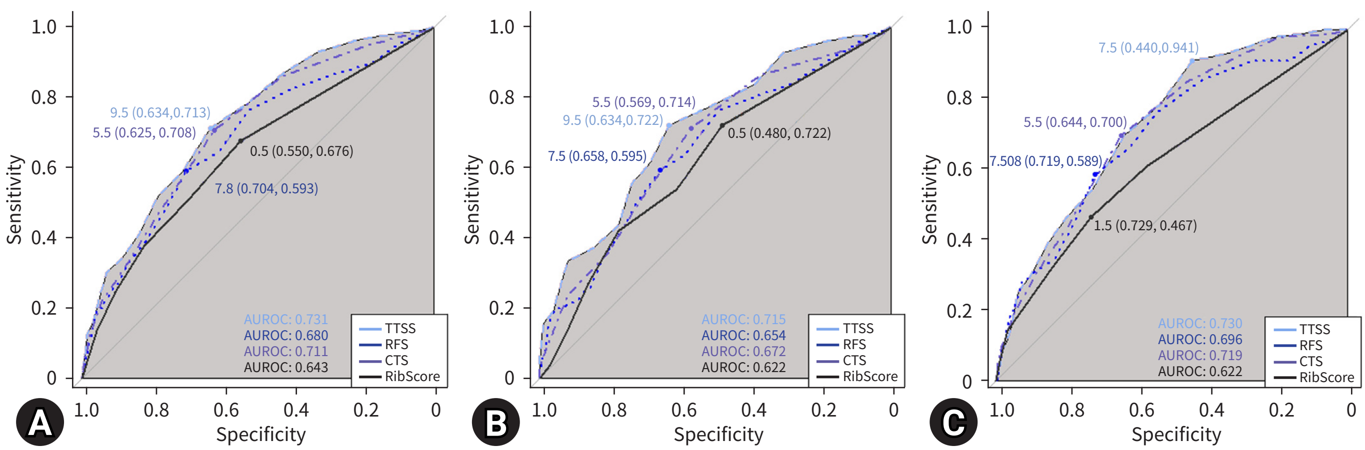

Fig. 2. Area under the receiver operating characteristic curve (AUROC) analysis for overall complications. (A) All patients. (B) Patients with head trauma. (C) Patients without head trauma. TTSS, Trauma Severity Score; RFS, Rib Fracture Score; CTS, Chest Trauma Score.

Table 3. Diagnostic accuracy of TTSS, RFS, CTS, and RibScore for the prediction of overall complications

Group	AUROC	Best cutoff value	Sensitivity	Specificity	Positive likelihood ratio	Negative likelihood ratio
All patients						
TTSS	0.731	9.5	0.713	0.366	1.125	0.784
RFS	0.680	7.5	0.593	0.296	0.841	1.378
CTS	0.711	5.5	0.708	0.375	1.133	0.778
RibScore	0.643	0.5	0.676	0.450	1.229	0.720
Head trauma						
TTSS	0.715	9.5	0.722	0.633	1.140	0.758
RFS	0.654	7.5	0.595	0.342	0.904	1.185
CTS	0.672	5.5	0.714	0.431	1.255	0.663
RibScore	0.622	0.5	0.722	0.520	1.504	0.534
No head trauma						
TTSS	0.730	7.5	0.911	0.560	2.069	0.159
RFS	0.696	7.5	0.589	0.281	0.819	1.465
CTS	0.719	5.5	0.700	0.356	1.088	0.842
RibScore	0.622	1.5	0.467	0.271	0.640	1.968

TTSS, Thoracic Trauma Severity Score; RFS, Rib Fracture Score; CTS, Chest Trauma Score; AUROC, area under the receiver operating characteristic curve.

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assess the severity of chest injuries could also predict polytrauma patients with accompanying head trauma. Because TBI is a major cause of death in approximately half of the patients with polytrauma [26], we hypothesized that for patients with head trauma, scoring systems like RibScore, which was developed with patient populations including severe head trauma, would have better predictive ability than those like TTSS, which was developed excluding patients with severe head trauma. However, this study showed results similar to the author's previous study conducted on patients with isolated blunt chest trauma [10]. In isolated blunt chest trauma patients, the AUROCs for TTSS and RibScore were 0.723 and 0.582, respectively. In this study, they were 0.731 and 0.643, respectively. A notable point is that even though TTSS was developed excluding patients with severe head trauma, it still showed the highest predictive ability for patients with head trauma (GCS median [IQR], 14 [9–15]). We believe this is due to the characteristics of the parameters that TTSS contains.

The TTSS is the most comprehensive scoring system among the four chest scoring systems we compared. It considers age, pulmonary contusion, rib fracture, and respiratory status, as indicated by the PFR. In contrast, RibScore only includes parameters related to rib fracture patterns [10]. Our study found that the complications group presented with a more severe rib fracture pattern. When conducting a multiple linear regression analysis for complications, factors such as age, ISS, GCS, the presence of an anterior–lateral flail segment, and initial PFR were identified as significant risk factors in both the entire cohort and the subgroup without head injuries. This finding implies that the chest trauma scoring systems evaluated in this study may have been developed with certain important risk factors overlooked or with the inclusion of less relevant risk factors, which could account for their relatively lower predictive power [11]. Moreover, the relatively acceptable predictive ability of the TTSS is likely due to its incorporation of physiological parameters, including PFR and age.

Most trauma centers utilize the ISS for patient classification, and in our study, we also conducted AUROC analyses using the ISS in addition to chest trauma scoring systems (Fig. S1). In these analyses, the AUROCs for the ISS were 0.788 for all patients, 0.780 for patients with TBI, and 0.711 for patients without TBI. It seems reasonable that the ISS, which reflects the extent of injury across the entire body, including the head, showed higher predictive accuracy than chest trauma scoring systems. Additionally, considering that the predictive power of the ISS in patients without TBI did not differ significantly from that of the TTSS, it can be inferred that TBI is the most significant risk factor for the prognosis of blunt chest trauma patients accompanied by TBI. This suggests a need for further research in this area.

To our knowledge, this study is the first to externally validate TTSS, RFS, CTS, and RibScore simultaneously in polytraumatized patients. Furthermore, similar to the results of the previous studies conducted by the authors [10], excluding TTSS, the expected outcomes were not obtained. We believe that a future study involving a larger number of patients is needed.

As previously mentioned, we determined the presence or absence of head injury based on the AIS head score. The AIS is an anatomical scale designed to demonstrate the degree of injury severity and to classify each injury by body region according to its relative severity, including head trauma. The ISS is another anatomical scale calculated by taking the highest AIS severity code in the three most severely injured body regions, squaring each AIS code, and summing the three squared numbers. Niemeyer et al. [14] reported that these anatomical scales might not be suitable for measuring the severity of TBI or for predicting patient outcomes. The authors noted that different types of injuries, such as diffuse axonal injury and epidural hematoma, could receive the same AIS score despite requiring different treatments and having markedly different outcomes. Consequently, they may be assigned the same score on the AIS, yet their clinical management and prognoses vary significantly. For this reason, most trauma centers employ the Revised Trauma Score or the Trauma Injury Severity Score, which combine anatomical and physiological indicators, such as the GCS or systolic blood pressure, to address the shortcomings of purely anatomical scoring systems [27,28]. As shown in this study, the presence or absence of head trauma leads to significant differences in patient outcomes. Therefore, we believe that future research should place greater emphasis on the implications of head trauma.

Limitations

Our study had several limitations. First, its retrospective design may have introduced selection bias. Second, rib fracture patterns are known to vary [29], and additional CT scans might have yielded more accurate results. However, due to concerns about cost and patient safety, we did not perform repeated examinations. Third, there may have been observer bias in the assessment of rib fracture patterns. This issue may require extensive discussion among more researchers, similar to the Delphi consensus exercise that addresses various issues related to rib taxonomy [20]. Additionally, we excluded patients who had not undergone a GCS assessment from this study. While chest trauma scoring systems do not incorporate TBI parameters, our research aimed to evaluate the predictability of these systems in patients with or without TBI, given the close association of the GCS with patient prognosis. Many of these patients were intubated before a GCS evaluation could be conducted due to severe shock or imminent arrest. Consequently, the exclusion of patients with severe injuries for this reason is a limitation of our study. Lastly, we did not perform external validation. Therefore, further research is needed on this topic.

Conclusions

Early detection and grading of injury severity are crucial for providing appropriate management strategies for patients with blunt chest trauma. However, the predictive capabilities of the chest trauma scoring systems introduced to date have not met expectations. We believe that future studies should aim to identify new injury parameters and pursue other avenues to improve the predictive performance of chest trauma scoring systems, particularly for polytraumatized patients with TBI.

ARTICLE INFORMATION

Author contributions

Conceptualization: JS, SYY; Data curation: HK, JS, MSL, SYY, JH; Formal analysis: HK, JS, SYY, JH, JYL; Methodology: JS; Project administration: JS; Visualization: JS, JYL; Writing–original draft: HK, JS; Writing–review & editing: all authors. All authors read and approved the final manuscript.

Conflicts of interest

The authors have no conflicts of interest to declare.

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Data availability

Data analyzed in this study are available from the corresponding author upon reasonable request.

Supplementary materials

Fig. S1. Area under the receiver operating characteristic curve (AUROC) analysis for the Injury Severity Score (ISS).
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