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ORIGINAL ARTICLE

Can a standardized blunt thoracic trauma score lead to lower length of stay and reduced intensive care unit admission for older patients?

¿Puede un puntaje estandarizado de traumatismo torácico contuso reducir la duración de la estancia hospitalaria y los ingresos a la unidad de cuidados intensivos en pacientes mayores?

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Abstract

Objective: *We implemented and evaluated a novel score called the blunt thoracic trauma score (BTTS) for the triage of chest wall injury (CWI) patients to optimize utilization of the intensive care unit (ICU).* **Method:** *Patients who sustained rib fractures after a traumatic injury (2014-2020) were identified in our trauma registry. Demographics and clinical characteristics were summarized by cohorts pre- and post-BTTS implementation in 2017 and BTTS > 6 versus BTTS < 6 using median or frequency. Wilcoxon rank-sum test was used to compare continuous variables, and χ^2 or Fisher's exact test for categorical variables. Logistic/negative binomial regression models were used to find predictors for ICU admission and length of stay (LOS).* **Results:** *Six hundred thirty-three patients were included; 407 pre-BTTS/226 post-BTTS. Pre-BTTS: higher median ISS ($p < 0.001$), more rib fractures ($p < 0.001$). Post-BTTS: older ($p < 0.001$), more comorbidities (coronary artery disease [$p = 0.028$], hyperlipidemia [$p = 0.004$], pulmonary disease [$p = 0.038$]). Post-BTTS cohort had lower rates of ICU admission ($p = 0.008$), shorter ICU-LOS ($p < 0.001$), and Hospital-LOS ($p < 0.001$). Post-BTTS cohort was associated with shorter Hospital-LOS after adjusting for other factors ($p = 0.004$).* **Conclusions:** *Implementation of a novel BTTS for triage of CWI was associated with decreased ICU admission rates and shorter ICU-LOS and Hospital-LOS. The decreased Hospital-LOS persisted even after controlling for other factors.*

Keywords: *Chest wall injury. Blunt. Admission. Critical care. Thoracic trauma. Triage.*

Resumen

Objetivo: *Implementamos una nueva escala, denominada Blunt Thoracic Trauma Score (BTTS), para la clasificación de pacientes con lesiones de la pared torácica con el fin de optimizar la utilización de la unidad de cuidados intensivos (UCI).* **Método:** *Identificamos pacientes con fracturas costales después de una lesión traumática (2014-2020). Las características demográficas y clínicas se resumieron por cohortes antes y después de la implementación de BTTS en 2017, y BTTS > 6 frente a BTTS ≤ 6. Se utilizó la prueba de suma de rangos de Wilcoxon para comparar las variables continuas y las pruebas de χ^2 o exacta de Fisher para las variables categóricas. Se utilizaron modelos de regresión logística/binomial negativa para*

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encontrar predictores de ingreso en la UCI y de la duración de la estancia. **Resultados:** *Se incluyeron 633 pacientes: 407 pre-BTTS y 226 post-BTTS. Grupo pre-BTTS: mayor Injury Severity Score (p < 0.001), más fracturas costales (p < 0.001). Grupo post-BTTS: edad avanzada (p < 0.001), más comorbilidad (enfermedad arterial coronaria [p = 0.028], hiperlipidemia [p = 0.004], enfermedad pulmonar [p = 0.038]). El grupo post-BTTS tuvo tasas más bajas de ingreso en la UCI (p = 0.008), y duración de la estancia en la UCI (p < 0.001) y duración de la estancia hospitalaria (p < 0.001) más cortas. El grupo post-BTTS se asoció con una duración de la estancia hospitalaria más corta después de ajustar por otros factores (p = 0.004).* **Conclusiones:** *La implementación del nuevo BTTS para la clasificación de lesiones de la pared torácica se asoció con menores tasas de ingreso a la UCI y con estancias en la UCI y hospitalarias más cortas. La disminución de la duración de la estancia hospitalaria persistió incluso después de controlar otros factores.*

Palabras clave: *Lesión contusa de pared torácica. Admisión. Cuidados intensivos. Traumatismo torácico. Triaje.*

Introduction

Chest wall injury (CWI) continues to be a major source of morbidity and mortality in trauma for the older patient. Patients often require admission to the intensive care unit (ICU) for monitoring and management of respiratory status. However, admission of all or most CWI patients to a higher level of care is neither practical nor a good use of resources.

Prior studies have sought to determine prognostic factors for morbidity, such as more ventilator days and mortality, in patients with CWI[1,2]. One of the early proponents of a standardized scoring system for chest trauma was Pape et al.[3] who highlighted the limitations of predicting outcomes in chest trauma patients based on radiographic evidence of chest wall injuries, abbreviated injury score (AIS) and injury severity score (ISS), and proposed a scoring system which included physiologic parameters and demographics such as admission PaO_2/FiO_2 ratio and patient age. They concluded that a more comprehensive scoring system was superior in predicting CWI patient outcome compared to AIS and ISS.

Thoracic trauma scores combining anatomical and physiologic parameters like the trauma thoracic score (TTS) have been used for severity assessment and prediction of outcomes in trauma patients with concomitant blunt chest trauma[4]. More recently-developed scoring systems such as the RibScore have evaluated whether rib fracture injury patterns may predict outcomes[5]. The RibScore study determined that patients with increased number of rib fractures, flail chest, and bilateral rib fractures had increased rates of respiratory failure and pneumonia[5].

Investigations on scoring systems have also incorporated pulmonary function on admission. The sequential clinical assessment of respiratory function (SCARF) score incorporates vital capacity (VC), respiratory rate, pain, and cough, and found that patients with higher scores had longer ICU length of stay (LOS), and increased rates of pneumonia[6].

While these scores were used to predict CWI outcomes, they are not utilitarian for resource allocation of ICU admission. We adapted prior scores and our anecdotal clinical experience of CWI criteria that seem to predict outcomes, to create a comprehensive, novel standardized triage score at our institution – we named this score the blunt thoracic trauma score (BTTS; Table 1). We implemented the score January 01, 2017 to triage CWI, using a BTTS score of 6 or greater to define resource allocation of ICU admission. The BTTS includes components of demographics, number of rib fractures, indices of physiologic derangement (including a marker for post-injury shock state), and measures of pulmonary mechanics such as negative inspiratory force (NIF) and VC.

The aim of the current study was to evaluate BTTS as a standardized score for the triage of patients with CWI. Our primary objective was to determine whether implementation of BTTS led to decreased ICU admissions and shorter ICU and hospital LOS. A secondary objective was to determine whether our pre-determined cutoff score of 6 or greater was the appropriate number to determine ICU need. We hypothesized that use of BTS would lead to fewer ICU admissions and shorter ICU and hospital LOS, and that our cutoff score of 6 or greater accurately predicted patients who ultimately required ICU admission.

Method

Study design

After obtaining Institutional Review Board approval, we retrospectively analyzed prospectively-accrued data from our trauma registry for patients suffering

Table 1. Blunt thoracic trauma score

Blunt thoracic admission score				
	0	1	2	3
Age	< 55	55-64	65-84	≥ 85
Smoking history	None	1 PPD smoker	1.5-2 PPD smoker	> 2 PPD smoker and/or home oxygen
Rib fractures identified by chest X-ray or CT scan	None	1-3 rib fractures	≥ 4 unilateral rib fractures OR > 5 total rib fractures	> 3 bilateral rib fractures or flail chest
Pulmonary contusion identified by chest X-ray	None	< 1 Lobe	> 1 Lobe	Bilateral lobe involvement
Base deficit	≤ –2	–2 to –4	–5 to –8	< –8
Vital capacity	≥15 cc/kg	10-15 cc/kg	5-10 cc/kg	< 5 cc/kg
NIF	≤ –40	–39 to –20	–19 to –10	< –10
Pain scale	0	1-4	5-6	7-10
Cough and mobility	Strong cough, independently mobile, out of bed with no assistance	Weak cough, mobile but difficult alone	Throat clearing, needs assistance to move	No cough, pain with little movement

NIF: negative inspiratory force; NIF: negative inspiratory force; CT: computed tomography; PPD: packs per day; OR: odds ratio.

CWI from 2014 to 2020. From January 01, 2014-December 31, 2016 (pre-BTTS), CWI patients were admitted to the ICU based on the trauma surgeon's clinical judgment and without a standardized scoring system. In the post-BTTS period, defined as January 01, 2018-December 31, 2020, CWI patients were admitted to the ICU based on pre-determined cutoff of the BTS (T 6 triaged to ICU). The use of the BTTS score was initiated as a pilot study January 01, 2017, and the use of BTS and was not established as a formal protocol until September 2017 of that year. As such, data from 2017 were excluded from our analysis. Of note, there was no significant change in our practice and management of patients with blunt thoracic trauma during the COVID-19 pandemic.

Inclusion and exclusion criteria

All patients who sustained rib fractures after blunt traumatic injury were identified in the NYULH-LI trauma registry based on year-appropriate International Statistical Classification of Diseases and Related Health Problems coding for that year for rib fractures. For the purpose of our study, CWI is defined as injury to the chest wall and/or thoracic viscera from a blunt mechanism. Exclusion criteria included age < 18 years old, patients meeting criteria for intubation, or death on arrival to the trauma bay. Patients from calendar year 2017 were also excluded as discussed above. In the pre-BTTS period, patients were excluded due to incomplete information in the electronic medical record; and in the post-BTTS period, patients were excluded if they did not have a documented BTTS (Fig. 1). Exclusion rate from pre-BTTS period was 27%, and from the post-BTTS period was 69%.

Score development and implementation

The BTTS was developed and implemented in 2017 to triage patients admitted with CWI to the ICU. The score includes age, smoking history, number of rib fractures, the presence or absence of pulmonary contusion identified on imaging, base deficit, VC, NIF, pain scale, and cough/mobility (Table 1). The BTTS was generated from previous published research demonstrating factors that predict worse outcomes for patients with rib fractures such as TTS, RibScore, and SCARF[2-6]. From TTS and RibScore, we included age, number of rib fractures, and rib fracture pattern (e.g. presence of flail chest), and pulmonary contusions. From SCARF, we included pain, cough strength, and VC. Smoking history, base deficit, and NIF were included after several discussions amongst senior faculty. The integer values were allocated based on surgical attending experience. The lowest score for a

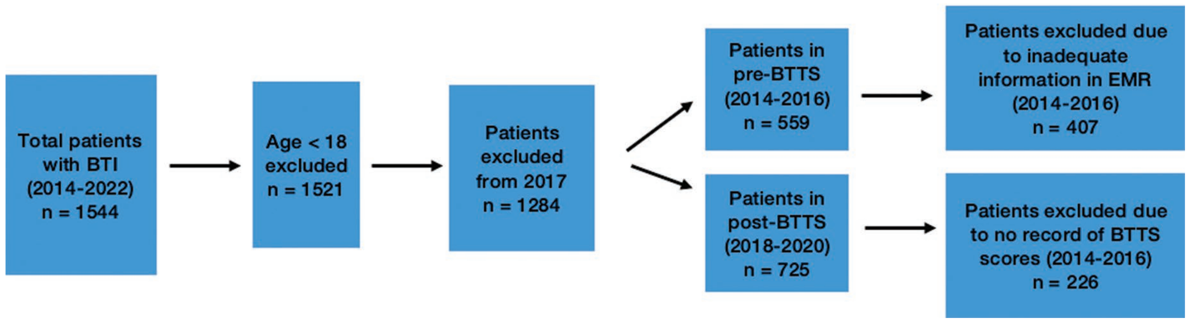

Figure 1. *Flowchart.*

patient is one with the highest score possible of 27. A cutoff score of 7 or greater was chosen to include a majority of higher values among the eight categories in the score. As part of the BTTS implementation, all patients with rib fractures were reviewed at table rounds to confirm that the BTTS had been used to guide triage to the appropriate location.

Patients with BTTS of 7 or higher were admitted to the ICU for respiratory monitoring such as measurement of NIF and VC every 4 h, careful pain control, and strict pulmonary hygiene, while patients with a BTTS of 6 or lower were admitted to the regular floor if they had no other indications for admission to the ICU (e.g. traumatic brain injury requiring neurologic monitoring). The ICU attending ultimately decides which patients are admitted to the ICU, but with standardized practice, patients meeting BTTS criteria for ICU were universally accepted. Patients admitted to the ICU received multimodal pain management with an assortment of acetaminophen, gabapentin, methocarbamol, ketorolac, and opiates as needed. Their NIF and VC were monitored every four to 6 h by nursing and respiratory therapy, and physiotherapy was performed. Typical regular floor care consisted of use of the incentive spirometry, daily ambulation out of bed, and multimodal pain control. BTTS was completed before admission by the admitting trauma team, which included physician assistants, residents, and attendings.

We do not have high-dependency or stepdown units at our institution. Patients requiring invasive analgesia, non-invasive mechanical ventilation, and high-flow nasal oxygen do not require an ICU for admission at our hospital.

Definition of variables

For the BTTS, age is defined as the patient's reported age in years at the time of presentation, and smoking history is based on packs per day. Rib fractures and pulmonary contusions were identified on chest X-ray and/or computed tomography of the chest by the radiologist. Pulmonary contusions were considered more clinically significant if visible on chest X-ray or were multilobular and/or bilateral. Base deficit was obtained from an arterial blood gas. VC and NIF values were obtained by respiratory therapists, using incentive spirometry and a NIF meter. Pain scale and cough/mobility were qualified by the admitting team.

Data collection

Data for analysis were extracted from the Trauma Registry and from the Electronic Health Record (EHR) and entered retrospectively into RedCap. Trauma Registry records were reviewed to obtain information on demographics, comorbidities, mechanisms of injury, severity of injury, and outcomes (e.g. admission to ICU vs. admission to regular floor). Additional relevant information, such as vital signs on presentation, ICU LOS, and disposition, was retrieved from the EHR. For patients sustaining a CWI from 2018-2020, BTTS reports were reviewed in the EHR and recorded.

Statistical analysis

Demographics and clinical characteristics were summarized by pre-versus post-BTTS and BTTS > 6 versus BTTS Tsu cohorts using median (interquartile range) or frequency (percentage) as appropriate. Continuous variables were assessed for normality using formal statistical tests and visual plots such as histograms and Q-Q plots. In general, the Wilcoxon rank-sum test was used to compare continuous variables, and the χ^2 or Fisher's exact test was used for categorical variables. Logistic regression models were used to find predictors for ICU admission. The model fit was

Table 2. Demographics and clinical characteristics between 2014 and 2016 (Pre-BTTS) and 2018-2020 (Post-BTTS) periods

Category	2014-2016 n = 407 (%)	2018-2020 n = 226 (%)	Overall n = 633 (%)	p[1]	Missing n
Demographics					
Age (years)	77.0 (61.0-86.0)	80.0 (70.0-88.0)	78.0 (64.0-87.0)	< 0.001	0
Female gender	184 (45.2)	130 (57.5)	314 (49.6)	0.003	0
Vitals					
Systolic blood pressure	142.0 (123.0-163.0)	143.0 (122.0-162.0)	142.0 (123.0-163.0)	0.624	10
Diastolic blood Pressure	79.0 (70.0-89.0)	77.0 (67.0-90.0)	78.0 (68.0-89.0)	0.272	10
Mean arterial pressure	100.0 (90.0-111.0)	100.0 (87.0-112.0)	100.0 (88.5-112.0)	0.649	21
Heart rate on presentation	82.0 (71.0-95.0)	80.5 (69.0-94.0)	82.0 (70.0-94.0)	0.177	82
SpO_2 on presentation (%)	97.0 (95.0-98.0)	97.0 (95.0-98.0)	97.0 (95.0-98.0)	0.866	17
PaO_2 on initial presentation	84.0 (72.0-101.0)	87.0 (75.0-110.0)	85.0 (73.0-106.0)	0.2	286
Injury severity					
Injury severity score	11.0 (9.0-17.0)	9.0 (4.0-13.0)	10.0 (8.0-14.0)	< 0.001	15
Glasgow coma scale on presentation	15.0 (15.0-15.0)	15.0 (15.0-15.0)	15.0 (15.0-15.0)	0.638	11
Comorbidities	3.0 (2.0-5.0)	3.0 (2.0-5.0)	3.0 (2.0-5.0)	0.06	95
NO. of comorbidities	4.0 (2.0-5.0)	3.0 (2.0-3.0)	3.0 (2.0-5.0)	< 0.001	10
Number of rib fractures	135 (36.0)	73 (33.0)	208 (34.9)	0.463	37
Ever smoked tobacco?	23 (5.8)	20 (9.0)	43 (6.9)	0.133	12
COPD	244 (61.5)	103 (67.3)	347 (63.1)	0.202	83
Hypertension	133 (33.5)	72 (46.8)	205 (37.2)	0.004	82
Hyperlipidemia	66 (16.6)	38 (24.8)	104 (18.9)	0.028	83
Coronary artery disease	37 (9.3)	18 (11.7)	55 (10.0)	0.406	82
Congestive heart failure	21 (5.3)	15 (9.7)	36 (6.5)	0.058	82
Chronic kidney disease	26 (6.5)	6 (3.9)	32 (5.8)	0.239	83
Asthma	16 (4.0)	13 (8.4)	29 (5.3)	0.038	82
Other pulmonary disease	49 (12.3)	6 (3.9)	55 (10.0)	0.003	82
Dementia	74 (18.4)	25 (11.2)	99 (15.8)	0.018	8
Pneumothorax	44 (10.9)	13 (5.8)	57 (9.1)	0.034	7
Hemothorax	78 (19.3)	12 (5.4)	90 (14.4)	< 0.001	6
Pulmonary contusion on initial imaging	66 (16.4)	30 (13.4)	96 (15.3)	0.314	7
Thoracic spine injury					

Continuous data are presented as median (interquartile range), and categorical as frequency (percentage).
[1]p values are from the Wilcoxon rank-sum test for continuous variables and $\chi 2$ or Fisher's exact test for categorical variables.
BTTS: blunt thoracic trauma score; COPD: chronic obstructive pulmonary disease.

assessed using Hosmer and Lemeshow goodness-of-fit test, Akaike information criteria, and c-statistic. LOS was not normally distributed; so, negative binomial regression models were used to analyze this variable. All analyses were performed using statistical analysis system 9.4, and a p < 0.05 was considered statistically significant.

Results

Demographics and comorbidities

A total of 633 patients (407 pre-BTTS, 226 post-BTTS) met criteria for analysis. The post-BTTS cohort was older than the pre-BTTS cohort (median age 80 vs. 77 years old; p < 0.001) and was more likely to be female (57.5% vs. 45.2%; p = 0.003). Patients in the pre-BTTS cohort had a higher median ISS (11 vs. 9; p < 0.001), a higher number of fractured ribs (4 vs. 3; p < 0.001), and higher rates of pneumothorax (18.4% vs. 11.2%; p = 0.018), hemothorax (10.9% vs. 5.8%; p = 0.034), and pulmonary contusion (19.3% vs. 5.4%; p < 0.001), compared to the post-BTTS cohort. However, the pre-BTTS cohort had fewer comorbidities with lower rates of coronary artery disease (16.6% vs. 24.8%; p = 0.028), hyperlipidemia (33.5% vs. 46.8%; p = 0.004), and other pulmonary disease (not asthma or chronic obstructive pulmonary disease [COPD]) (4% vs. 8.4%; p = 0.038). The pre-BTTS cohort, although younger, had a higher rate of dementia (12.3% vs. 3.9%; p = 0.003) when compared to the post-BTTS cohort (Table 2).

Outcome comparisons pre- and post-BTTS implementation

Compared to the pre-BTTS cohort, the post-BTTS cohort had lower rates of ICU admission (42.5% vs. 53.6%; p = 0.008), shorter median ICU LOS (2 vs. 3 days; p < 0.001), shorter median hospital LOS (3 vs.

Table 3. Pre- and post-BTS implementation comparison of outcomes

Outcomes	Pre-BTS		Post-BTS		p
	n	Median (IQR) (%)	n	Median (IQR) (%)	
ICU length of stay (d)	218	3 (2-6)	96	2 (1-3)	< 0.001
Hospital length of stay (d)	404	5 (3-9)	212	3 (2-6)	< 0.001
ISS	405	11 (9-17)	213	9 (4-13)	< 0.001
Died	399	22 (5.5)	215	7 (3.3%)	0.208
Hospital acquired infection	397	56 (14.1)	216	3 (1.4%)	< 0.001
Admitted to ICU	407	218 (53.6)	226	96 (42.5%)	0.008
Intubation	404	53 (13.1)	145	1 (0.7%)	< 0.001

*Note that although median ISS is the same, the distribution is different look at IQR; the post BTS ISS scores are lower.
IQR: interquartile range; BTS: ISS: injury severity score.

5 days; p < 0.001), fewer hospital-acquired infections (1.4% vs. 14.1%; p < 0.001), and lower rates of intubation (0.7% vs. 13.1%; p < 0.001). There was no statistically significant difference in mortality between the two cohorts. Only pre/post-BTTS implementation period (odds ratio [OR] [95% confidence interval (CI)] = 0.09 [0.01-0.92]; p = 0.042), and ISS (OR [95% CI] = 1.17 [1.11-1.24]; p < 0.0001) were significantly associated with intubation (Table 3).

Factors associated with hospital LOS

The post-BTTS cohort was associated with a shorter hospital LOS. Incidence rate ratio (IRR = 0.79 [0.67-0.93]; p = 0.004). Age (IRR = 1.04 [1.01-1.06]; p = 0.001), ISS (IRR = 1.05 [1.04-1.06]; p < 0.0001), and the presence of other pulmonary disease (IRR = 1.55 [1.17-2.04]; p = 0.002) were associated with a longer hospital LOS.

Factors associated with ICU admission and ICU admission trend

Age (OR = 1.02 [1.01-1.03]; p = 0.01), ISS (OR = 1.17 [1.13-1.22]; p < 0.0001), presence of other pulmonary disease (OR = 2.49 [1.01-6.14]; p = 0.047), and the presence of pulmonary contusion on imaging (OR = 2.65 [1.33-5.28]; p = 0.005), were associated with ICU admission (Table 4). C-statistic [95% CI] for the adjusted model was 0.77 [0.73, 0.81], Hosmer and Lemeshow goodness-of-fit $\chi^2 = 8.9$, p = 0.35. For ICU admissions, there was a downward trend from 55% in 2014, 50.51% in 2015, and 52.53% in 2016. In 2018, there was a marked drop in CWI ICU admissions to 14.29% in 2018; also lower, the CWI ICU admission rate was 43.50% in 2019 and 48.57% in 2020. The p-value for this decreased trend post-BTTS in CWI ICU admission rate is 0.008 (Fig. 2).

Optimal BTTS cutoff

The optimal cutoff for BTTS predicting ICU admission is 7, and this corresponds to a sensitivity of 0.87 and a specificity 0.84 (Fig. 3). Increasing the cutoff to 7 (i.e. BTTS ≤ 7 admitted to the regular floor) may better utilize resources, but this requires further study.

BTTS ≤ 6 versus BTTS > 6

Patients with a BTTS > 6 were older (mean age 81.5 vs. 74.0 years; p < 0.001), had a higher median ISS (9 vs. 8; p = 0.003), longer median hospital LOS (4 vs. 2.5 days; p < 0.001), higher rates of and more extensive smoking history (13.9% vs. 4.1%; p = 0.038), and thoracic spine injuries (19.4% vs. 8.1%; p = 0.047) compared to patients with a BTTS ≤ 6.

Patients with a BTTS > 6 had higher rates of ICU admission (83.3% vs. 12.2%; p < 0.0001) and a longer median hospital LOS (4 vs. 2.5 days; p < 0.001) compared to those with a BTTS ≤ 6 (Table 5) with IRR 1.70 (1.26-2.29); p = 0.001). ISS was associated with a longer hospital LOS (IRR = 1.05 (1.02-1.07); p = 0.001) in the model. Only having a BTS > 6 was independently associated with ICU admission (Table 6).

Discussion

CWI remains a significant cause of morbidity and mortality after blunt trauma. Patient management

Table 4. Factors associated with ICU admission in full sample

Factors	Unadjusted		Adjusted	
	OR (95% CI)	**p**	**OR (95% CI)**	**p**
2018-2020 versus 2014-2016	0.64 (0.46-0.89)	0.008	1.18 (0.74-1.89)	0.481
Age	1.01 (0.99-1.02)	0.075	1.02 (1.01-1.03)	0.01
Female gender	0.91 (0.67-1.24)	0.55	1.22 (0.79-1.88)	0.369
Injury severity score	1.12 (1.09-1.15)	< 0.0001	1.17 (1.13-1.22)	< 0.0001
Ever smoked tobacco?	1.09 (0.78-1.52)	0.631	0.98 (0.63-1.53)	0.934
COPD	1.62 (0.86-3.04)	0.137	1.82 (0.78-4.27)	0.169
Hypertension	1.26 (0.89-1.78)	0.195	1.04 (0.64-1.71)	0.864
Hyperlipidemia	0.82 (0.58-1.15)	0.249	0.78 (0.5-1.22)	0.275
Coronary artery disease	1.26 (0.82-1.94)	0.29	0.94 (0.54-1.67)	0.843
Congestive heart failure	1.63 (0.92-2.89)	0.093	1.39 (0.68-2.83)	0.366
Chronic kidney disease	1.22 (0.62-2.40)	0.572	1.55 (0.67-3.57)	0.303
Asthma	1.26 (0.61-2.58)	0.534	1.13 (0.5-2.55)	0.775
Other pulmonary disease	1.89 (0.86-4.13)	0.113	2.49 (1.01-6.14)	0.047
Dementia	1.08 (0.62-1.89)	0.787	0.95 (0.47-1.92)	0.878
Pneumothorax	1.95 (1.25-3.03)	0.003	1.09 (0.59-2)	0.782
Hemothorax	2.82 (1.55-5.14)	< 0.001	1.35 (0.61-3.01)	0.462
Pulmonary contusion on initial imaging	2.85 (1.75-4.63)	< 0.0001	2.65 (1.33-5.28)	0.005
Thoracic spine injury	2.97 (1.85-4.79)	< 0.0001	1.69 (0.89-3.18)	0.108

ICU: intensive care unit; CI: confidence interval; OR: odds ratio; COPD: chronic obstructive pulmonary disease.

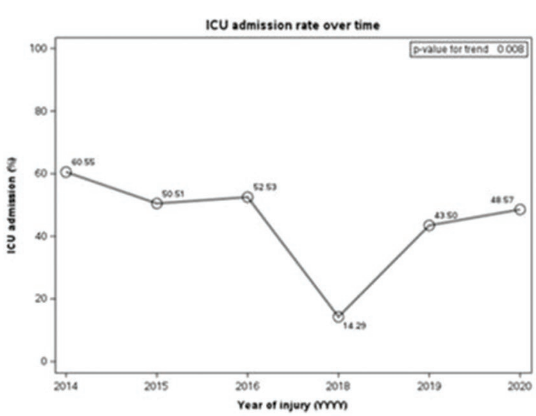

Figure 2. *Intensive care unit admission rate.*

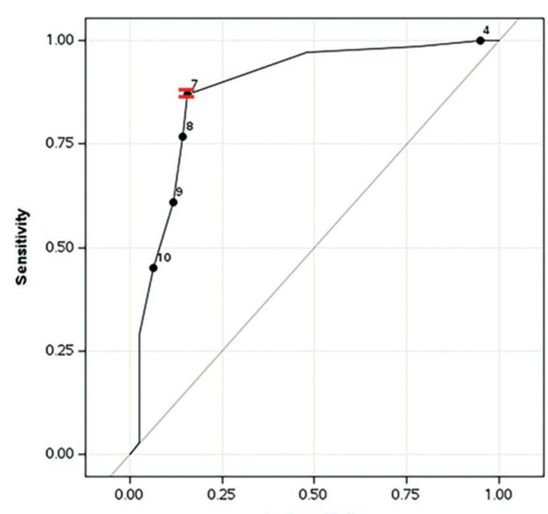

Figure 3. *Receiver operating characteristic curve. The optimal cut-off of blunt thoracic trauma score predicting intensive care unit admission is 7, which corresponds to a sensitivity = 0.87 and specificity = 0.84.*

involves identifying the appropriate level of care with allocation of resources for optimal outcomes. The purpose of our study was to determine if the use of a

Table 5. Descriptive outcomes by group

Outcomes	BTTS > 6		BTTS < 6		p[1]
	n	Frequency (%) or median (IQR)	n	Frequency (%) or median (IQR)	
ICU admission	72	60 (83.3)	74	9 (12.2)	< 0.0001
Mortality	69	2 (2.9)	72	0 (0)	0.238
Intubation	66	1 (1.5)	70	0 (0)	0.485
Hospital-acquired infection	71	2 (2.8)	72	0 (0)	0.245
Hospital length of stay	69	4.0 (3.0-6.0)	70	2.5 (1.0-2.0)	< 0.001
ICU length of stay	60	2 (1.0-2.5)	9	2.0 (1.0-2.0)	0.97

ICU: intensive care unit; IQR: interquartile range; BTTS: blunt thoracic trauma score.

Table 6. Unadjusted and adjusted regression models for ICU admission

Factors	Unadjusted		Adjusted	
	OR (95% CI)	p	OR (95% CI)	p
BTTS > 6 versus BTTS < 6	36.1 (14.2-91.8)	< 0.0001	94.84 (20.01-449.55)	< 0.0001
Age	1.04 (1.01-1.07)	0.002	1.0 (0.94-1.06)	0.87
Female gender	2.43 (1.24-4.78)	0.01	3.25 (0.76-13.86)	0.112
Injury Severity Score	1.09 (1.02-1.17)	0.014	1.03 (0.88-1.2)	0.736
Ever smoked tobacco?	1.08 (0.55-2.13)	0.831	1.26 (0.31-5.1)	0.743
COPD	2.74 (0.80-9.33)	0.108	0.18 (0.02-1.66)	0.131
Hypertension	2.03 (0.99-4.16)	0.053	1.9 (0.39-9.19)	0.425
Hyperlipidemia	1.10 (0.57-2.13)	0.786	0.32 (0.08-1.31)	0.112
Coronary artery disease	1.23 (0.57-2.65)	0.593	2.17 (0.36-13.09)	0.399
Congestive heart failure	3.49 (1.05-11.54)	0.041	1.5 (0.14-16.65)	0.742
Chronic kidney disease	1.13 (0.38-3.42)	0.824	0.52 (0.06-4.32)	0.547
Asthma	1.14 (0.22-5.87)	0.873	6.25 (0.24-166.42)	0.274
Other pulmonary disease	1.63 (0.49-5.41)	0.422	0.73 (0.09-5.8)	0.767
Dementia	0.55 (0.10-3.08)	0.493	0.13 (0.01-2.84)	0.194
Pneumothorax	3.08 (1.03-9.27)	0.045	2.67 (0.42-17.25)	0.301
Hemothorax	14.7 (1.84-116.9)	0.011	9.68 (0.55-169.32)	0.12
Pulmonary contusion on initial imaging	4.3 (0.86-21.47)	0.075	8.16 (0.37-177.9)	0.182
Thoracic spine injury	2.32 (0.87-6.21)	0.093	1.58 (0.19-12.98)	0.669

ICU: intensive care unit; CI: confidence interval; OR: odds ratio; COPD: chronic obstructive pulmonary disease.

standardized BTTS calculated from specific patient data, to include injury severity, demographic characteristics, physiologic derangements, and pulmonary risk factors such as smoking (Table 1), was associated with fewer ICU admissions and shorter ICU and hospital LOS. Before the implementation of BTTS at our institution, decisions on the level of care for CWI patients were at the discretion of the attending surgeon. Although independent clinical judgment remains important, efficient triage of patients is essential.

Our results demonstrate a marked decrease in ICU admission rates for CWI patients in the years after implementation of BTTS. In addition to the reduction in ICU admission rates, the ICU and hospital LOS were shorter in the post-BTTS compared to the pre-BTTS period. Our current practice is to admit any patient with a BTTS of 7 or higher to the ICU after BTI. If the receiver operating characteristic (ROC) curve determined a value of 8 or higher for triage to the ICU had been used, even fewer patients would have been admitted to the ICU, resulting in an even lower ICU admission rate (Fig. 3).

Although injury severity demonstrated by ISS was higher in the pre-BTTS cohort, age and the presence of co-morbidities were higher in the post-BTTS cohort; the post-BTTS cohort was independently associated with a shorter hospital LOS. Although ISS was associated with a longer hospital LOS, so were age and the presence of other (non-asthma, non-COPD) pulmonary diseases, which were more common in the post-BTTS cohort. It is important to note that the pre-BTTS cohort had a higher rate of intubation compared to the post-BTTS cohort (13.1% vs. 0.7%; $p < 0.001$), and this could be due to the higher ISS in the pre-BTTS cohort (Table 3).

Factors found to be independently associated with higher rates of ICU admission were age, ISS, presence of other pulmonary diseases, and the presence of pulmonary contusion on imaging. Patients with a BTTS of 7 or greater were older, more severely injured, had higher rates of COPD, and also had higher rates of thoracic spine injuries. A BTTS of 7 or greater was used as the cutoff for ICU admission, and this is reflected in the ICU admission rate of 83.3% compared to 12.2% in patients with a BTTS of 6 or less. The fact that some patients with a BTTS > 6 were not admitted to the ICU while others with a BTTS of 6 or less were admitted to the ICU may have been due to other issues, such as triaging of resources or physician discretion despite the BTTS protocol.

Since our implementation of BTTS and this analysis of our data, the Rib Injury Guidelines (RIG) were published, providing a tool for triage of CWI patients to the ICU[7]. Compared to RIG, our BTTS provides more nuanced, individualized patient details with score components ranging from 0 to 3[7]. Moreover, BTTS includes base deficit as a marker of shock state that may better inform the physiological derangement of the trauma patient. Although we have yet to perform a head-to-head analysis of BTTS versus RIG, the authors contend that BTTS is most adaptable to our institution's (and similar institutions') populations and more broadly assesses the trauma patient with CWI. A key feature of BTTS, which differentiates it from previous scoring systems[8] is the inclusion of data such as VC and NIF, which are valuable measures of respiratory mechanical function. In addition, the inclusion of base deficit as a reflection of perfusion/shock state may help identify patients with increased risk of physiological deterioration. Several investigators have studied the importance of markers of pulmonary function as risk stratification in CWI patients and stated their association with secondary respiratory complications and outcomes[9,10]. We did not directly apply the RIBS or Battle scores to our patients and so cannot account for how this would compare; however, with the inclusion of functional parameters such as VC and NIF, we believe that important elements are added that allow more effective patient triage.

In addition, we included cough strength as part of BTTS. A strong cough is needed for airway clearance and forms the physiologic basis for high-frequency chest wall oscillation (HFCWO), an intervention which has been studied in CWI patients as well as other patient populations with favorable results[11-15]. In our population, HFCWO was not incorporated unless there was evidence of lung collapse. Patients are usually treated with incentive spirometry and ambulation where possible (MetaNeb®).

The ICU plays a critical role in the management of appropriately triaged CWI patients, and failed regular floor management has been associated with increased mortality in elderly CWI patients[16]. ICUs represent one of the largest cost centers in hospitals, with mechanical ventilation constituting a significant proportion of that cost[17,18]. Preventing unplanned upgrades to the ICU for respiratory complications requiring intubation and mechanical ventilation, while obviating the need for unnecessary ICU admissions, requires a fine balance. Implementation of the BTTS required no additional personnel, laboratory and diagnostic work-up.

A significant portion of our patients are elderly patients suffering falls. Non-fatal falls cost the US healthcare system $19 billion/year, and a majority of that cost, $12 billion, is from hospitalization[19]. While there was no additional cost in the application of BTTS, the decrease in ICU admission rate and LOS would likely reflect a decrease in cost for the healthcare system overall. Potential BTTS-related cost-savings were not analyzed in this study and warrants further investigation.

A major strength of our study is the prospective nature of the BTTS implementation and Trauma Registry data collection. The majority of research on CWI outcomes is done retrospectively. By incorporating existing research, we were able to create a unique scoring system to apply prospectively. This unique score incorporates patient demographics, injury severity, pain scores, and respiratory function to triage patients to the ICU. Specifically, the inclusion of markers of pulmonary function, such as NIF, VC, and cough strength, makes our score superior in the assessment of patients.

There are significant limitations to our study. This is a single institution with resources that may vary from other centers; the generalizability of our results remains unclear. However, triaging patients based on specific criteria is necessary for optimal management and care. Another limitation is that despite the implementation of BTTS, there were patients who were triaged differently from the BTTS protocol, and not every patient in the post-BTTS period had a documented BTTS score. Furthermore, the exclusion rate in the post-BTTS period (69%) was greater than the exclusion rate in the pre-BTTS period (27%), raising the possibility of bias, including selection bias. In addition, the authors offer that although BTTS captures the severity of the injury, there may be other factors influencing outcome for which it cannot account. A larger prospective multi-institutional study would help identify confounding factors. Further limitations include the difference in our pre- and post-BTTS patient populations. The pre-BTTS patients have a higher ISS, while the post-BTTS patients had more comorbidities. While these differences were accounted for in our multifactorial analysis, there may still be an impact. However, our analysis demonstrates that being in the post-BTTS cohort was independently associated with a shorter hospital LOS. We did not conduct a sample size calculation, and future study would benefit from a sample size calculation to eliminate additional bias.

Adherence to the BTTS protocol will constitute the next phase of our process. Incorporating BTTS as part of our EHR as a “hard stop” would facilitate this, as the current process requires that the BTTS be calculated on printed hardcopy forms.

Surgical stabilization of rib fractures (SSRF) was introduced at our institution towards the end of 2019, but was not formalized until 2020. Patients meeting established criteria that include fracture morphology, chest wall instability, inability to control pain, and/or wean off a ventilator, follow our SSRF protocol. This did not include any specifications for admission to the ICU versus regular floor. It is unlikely that this rib fixation protocol impacted our study in any way.

The ROC analysis demonstrates BTTS of 7 as the ideal cutoff for ICU admission, and that may be a contributing factor to why patients who met criteria but were triaged differently from protocol did well. Based on this ROC analysis, using a score of 8 or more as indication for ICU admission would be most appropriate and may lead to further decrease in ICU admissions (Fig. 3).

Conclusions

The BTTS incorporates patient demographics, injury severity and characteristics, base deficit, and pulmonary function to guide triage of CWI patients appropriately to the ICU. Implementation of a novel BTTS for triage of CWI was associated with decreased ICU admission rates and shorter ICU and hospital LOS at our institution. The decreased hospital LOS persisted even after controlling for other factors. Future research should focus on implementing BTTS in a multi-institutional design and following patients in their hospital course prospectively to determine factors affecting ICU and hospital LOS.

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Conflicts of interest

The authors declare no conflicts of interest.

Ethical considerations

Protection of humans and animals. The authors declare that the procedures followed complied with the ethical standards of the responsible human experimentation committee and adhered to the World Medical Association and the Declaration of Helsinki. The procedures were approved by the Institutional Ethics Committee.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from all patients, and secured approval from the Ethics Committee. SAGER guidelines have been followed as applicable to the nature of the study.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing or creation of the content of this manuscript.

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