sciendo Acta Marisiensis - Seria Medica 2023;69(4):266-274 DOI: 10.2478/amma-2023-0046

RESEARCH ARTICLE

The outcome in critically ill patients admitted for thoracic trauma – A single center analysis over one year

Oana Elena Branea[1], Konrád Ottó Kiss[2*], Mihai Pui[2], Vlad Dimitrie Cehan[2], Oana Frandes[2], Anca Gabriela Vlad[2], Ioan Alexandru Branea[3], Andrei Cristian Fulop[4], Monica Chis[5], Alexandra Elena Lazar[1]

1. Department of Anesthesia and Intensive Care, George Emil Palade University of Medicine, Pharmacy, Science, and Technology of Targu Mures, Romania
2. Clinic of Anesthesia and Intensive Care, Emergency Clinical County Hospital of Targu Mures, Romania
3. Emergency Medicine Department, Emergency Clinical County Hospital of Targu Mures, Romania
4. Clinic of Radiology, Emergency Clinical County Hospital of Targu Mures, Romania
5. Rheumatology Department, George Emil Palade University of Medicine, Pharmacy, Science, and Technology of Targu Mures, Romania

Objective: The main objective of the current study was to examine the outcome of critically ill patients in relation to clinical and thoracic injuries. The secondary objectives were to assess the role of CT in the evaluation of the diaphragm and to provide an analysis of prognostic abilities with respect to diaphragm changes. **Methods**: This single-center retrospective observational cohort study was conducted in the ICU of Târgu Mureș County Emergency Clinical Hospital, Romania. This study identified 52 critically ill blunted or penetrating chest trauma patients admitted to the ICU from 01 January 2021 to 31 December 2021. CT scan was used to identify thorax injuries and diaphragm thickness. The outcome of all patients was analyzed. **Results**: Most of the patients experienced traffic accidents (44.23%) or falls (26.93%). The predominant characteristics associated with chest trauma were rib fractures (92.30%), lung contusions (63.50%), and pneumothorax (53.80%). The most common injury seen in the study was rib fractures, accounting for 92.30% of cases. This was followed by lung contusions, which were present in 63.50% of patients, and pneumothorax, which occurred in 53.80% of cases. It was examined ROC AUC for thickness of the right and the left diaphragm and severity scores. When assessing the thickness of the diaphragm in deceased and survivors, no statistically significant differences were found. **Conclusion**: Although no significant differences were found regarding the prognosis between the survivors and the deceased, diaphragm thickness might potentially serve as a predictor for the severity of the injury.

Keywords: thoracic trauma, critically ill, intensive care unit, outcome, computed tomography

Received 19 October 2023 / Accepted 20 November 2023

Introduction

Currently, there is a lack of a comprehensive database in Romania that specifically focuses on patients with chest trauma, resulting in challenges in collecting precise and reliable details relating to thoracic trauma. The topic of trauma continues to be recognized as a major global health challenge and stands as a significant concern within public health, needing greater consideration within the healthcare system [1]. Trauma ranks as the fourth most prevalent cause of mortality in the United States and notably emerges as the primary cause of death within the demographic of children, adolescents, and young adults [1,2]. Thoracic trauma ranks prominently among the primary causes of mortality, second to head injury, in cases of polytrauma [3,4]. The variability of thoracic trauma prognosis is influenced by the interplay of numerous socio-demographic and anatomical variables [4]. Despite the availability of simple surgical procedures for managing life-threatening injuries such as tension pneumothorax, and the possibility of major interventions for some cases, the documented fatality rate in thoracic trauma remains between 15 to 25% [4,5,6].

Of itself, chest injury is a strong predictor of pulmonary decline and repercussions [7,8]. The impact appears to be most pronounced in the elderly who have higher rates of ventilator use, acute respiratory distress syndrome and pneumonia when compared to younger groups [7-9]. Moreover, admission to the intensive care unit (ICU) is necessary for over 80% of patients diagnosed with flail chest, while close to 60% of these patients will need mechanical ventilation (MV), and around 20% of these patients will have tracheostomy [7,10]. Nevertheless, accurately diagnosing traumatic injuries by clinical methods might provide challenges, particularly in life-threatening rescue scenarios [11]. The use of prompt total-body computed tomography (CT) scanning in emergency protocols has emerged as a significant advancement in trauma treatment during recent decades. This development has played a crucial role in facilitating the identification of potentially fatal injuries in a consistent manner [11,12]. Blunt and open thoracic trauma encompasses a range of injuries that can be classified into various categories based on their impact on anatomical structures. These classifications consist of injuries to the pleural space, the lungs, the airways, the oesophagus, the heart, the aorta, the diaphragm, and the chest wall [13].

Although, portable chest radiography is often used as the primary imaging technique during the first evaluation of polytrauma patients in emergency settings, the efficacy of CT in the diagnosis of chest injuries has been widely demonstrated in medical literature, being accepted as the gold standard investigation [14]. However, there is a limited amount of information currently available about its role in diaphragm assessment. The main objective of the

* Correspondence to: Konrád Ottó Kiss
E-mail: kiss.konrad.o@gmail.com

current study was to examine the outcome of critically ill patients in relation to clinical and thoracic injuries. The secondary objectives were to assess the role of CT in the evaluation of the diaphragm and to provide an analysis of the performance and prognostic abilities with respect to diaphragm changes.

Methods

Study design

This single-centre retrospective observational cohort study was conducted in the ICU of Târgu Mureș County Emergency Clinical Hospital, Romania. The research methodology was developed in accordance with the STROBE criteria. The research was granted approval by the Institutional Ethics Committee, with reference number 14737/ 21.06.2022, and it was conducted in accordance with the principles outlined in the Declaration of Helsinki. Due to the anonymized nature of the data obtained for this study, the necessity for obtaining informed permission from all participating patients was waived.

Study population and data collection

This study identified all critically ill blunted or penetrating chest trauma patients admitted to the ICU from 01 January 2021 to 31 December 2021. Patients included in the study were adults admitted to the ICU for at least 24 hours and needed any type of oxygen therapy. They had a CT examination during their admission. The exclusion criteria encompassed noncritical patients, critically ill patients without chest trauma, and positive for COVID-19. Additionally, patients under the age of 18 years, those who received critical care support for less than 24 hours, or pregnant women were also excluded. Adequacy screening for diaphragm assessment was conducted on all CT images. Non-diagnostic CT scans (due to incomplete field of view, artefacts, or patient movements) were excluded. Chest CT scan results were analyzed for pneumothorax, hemothorax, flail chest, rib fractures, and lung contusions. Figure 1. displays the flowchart outlining the criteria for the inclusion and exclusion of participants in the research population. Additionally, demographic information, ICU admission status, trauma diagnosis, clinical monitoring of respiratory disease progression (including the need for non-invasive ventilation (NIV) or invasive mechanical ventilation (IMV)), duration of stay in the ICU and hospital, and mortality data were extracted from the electronic medical records (specifically, the Hipocrate3 Concept system). In addition, laboratory results were identified for every individual patient. The set of blood tests included hemoglobin, hematocrit, lactate, base excess, and arterial blood gas analysis.

The study population was stratified according to the trauma severity scores, either to measure anatomical inju-

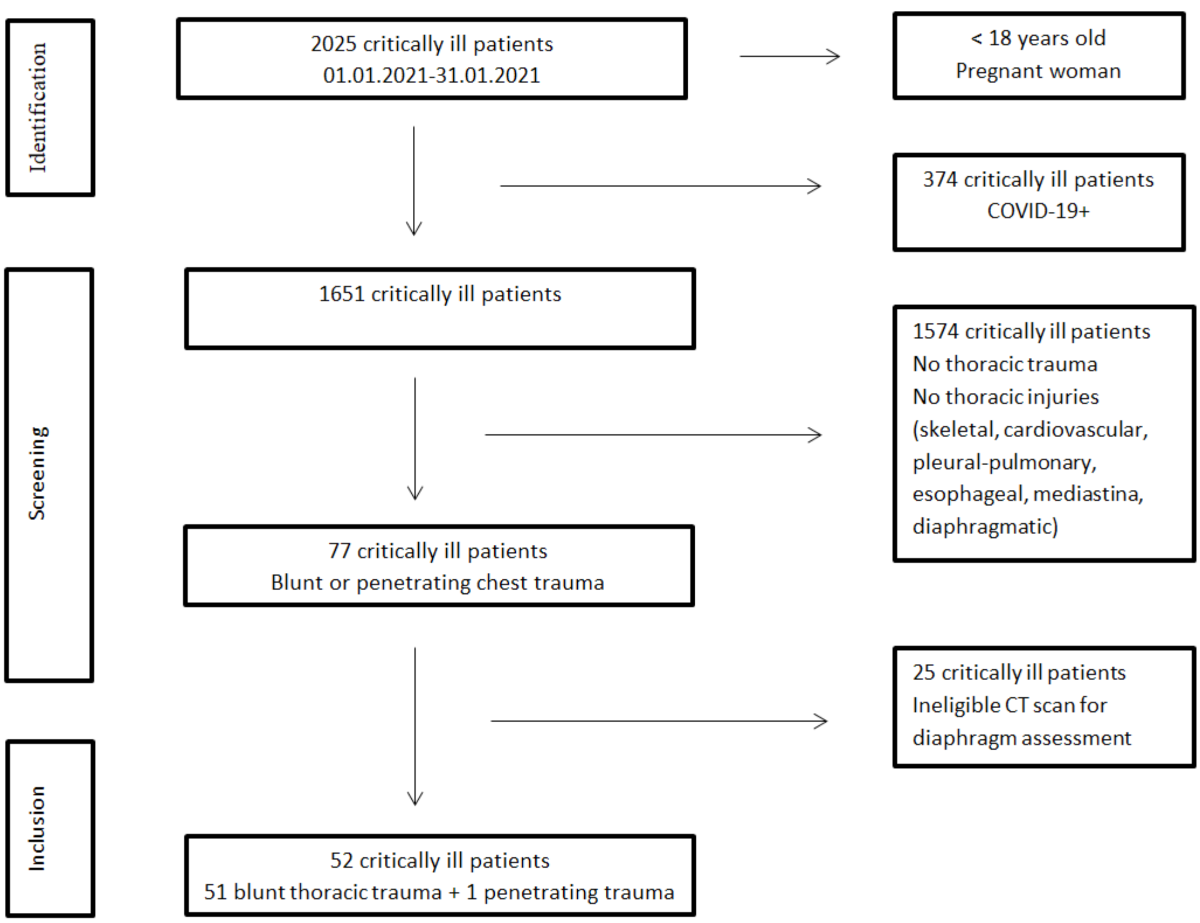

Fig.1. Chest trauma patients' flowchart

ries, for example: Abbreviated Injury Scale (AIS, <3 minor or moderate severity, ≥ 3 severe or critical) [15], Injury Severity Score (ISS, <16 minor or moderate, ≥ 16 severe or very severe) [16]; or to assess the functional implication of trauma, like Revised Trauma Score (RTS, < 4, the topic under consideration for trauma center)[17]. Additionally, the participants were further categorized based on outcome variables, precisely the distinction between survivors and deceased individuals.

CT diaphragm analysis

Patients with CT scans were included in the study group to examine musculoskeletal characteristics. The CT pictures were acquired with 64-slice CT scanners operating at a voltage of 120 kilovolts (kV) and an automated milliampere (mA) setting. The patients were in a supine position. The inspiratory breath-hold command was exclusively employed in patients not under sedation. A slice thickness of 1 mm and a normal b31f kernel were used to reconstruct axial pictures. Hospital Picture Archiving and Communicating System (PACS) were used to obtain the images, and data analysis was conducted using the RadiAnt DICOM Viewer.

Images evaluation

The images were assessed by a radiologist (+ 2 years of experience). The radiologist was not aware of the patient's evolution and outcome. The abdominal window of the CT scans was used for evaluation (window center-center, 60 HU; window width, 400 HU), and the magnification was freely adjustable. The measurement of diaphragmatic thickness was performed at the level of the celiac truncus, with a plane that intersects the anterior border of the vertebral body. This methodology aligns with prior studies documented in the literature [18]. The visual evaluation is displayed in Figure 2.

Data processing and statistical analysis

The data were systematically grouped within Excel spreadsheets and subjected to statistical analysis. The statistical analysis was conducted using SPSS software, specifically version 27. (SPSS Inc. Chicago, IL, USA). Continuous data are presented as medians (minimum-maximum) or means (±standard deviation), and categorical data as proportions. The Kolmogorov–Smirnov test was used to assess the normal distribution of continuous numerical variables. The statistical differences among groups were evaluated with the Chi-square test using Yates' correction or Fisher's exact test, when appropriate, for categorical variables. The Mann-Whitney U test was used for non-Gaussian variables, and the Student's t-test was used for the Gaussian continuous variables. The receiver operating characteristics (ROC) curve analysis was performed for biomarkers and combinations. Cut-off values for diaphragm thickness and severity scores were developed to assess patients' outcomes, utilizing Youden's Index. The study presented the values of the area under the curve (AUC), along with their corresponding 95% confidence intervals (CI), and compared them using Hanley and McNeil's approach. For correlations, Pearson's coefficients were used. A p-value of less than 0.05 was considered statistically significant.

Results

The study included a cohort of 52 critically ill patients diagnosed with thoracic trauma, of which 51 had blunt trauma. Most of the patients experienced traffic accidents (n=23; 44.23%) or falls (n=14; 26.93%). The predominant characteristics associated with chest trauma were rib fractures (92.30%), lung contusions (63.50%), and pneumothorax (53.80%). All patients underwent treatment according to the advanced trauma life support guidelines. The most frequent thoracic procedures performed were the insertion of a pleural drainage tube

Fig. 2. An illustrative image demonstrating the evaluation of the right and left diaphragm axial thickness by the use of CT scan imaging

(55.76%) and the stabilization of a flail chest (9.61%). Demographics and patients admission characteristics are described in Table I.

Patients with severe or critical trauma scores were classified as having AIS≥ 3 points (n=31), ISS≥ 16 points (n=29) and RTS< 4 points (n=18). Over 80% were male, with a mean age of 57.38±18.9 years. The results indicated no statistically significant differences in hemodynamic measurements between the minor and severe trauma groups, with mean values of 117.5±19.1 mmHg for systolic blood pressure and 94.7±23.1 beats per minute for heart rate. On patients' admission to the ICU, the hemoglobin (10.33±1.86 g/dl) and hematocrit (28.1±6.88%) levels indicated anemia, but no statistically significant difference was observed for these results. The median values of metabolites ranged from 1 to 6 mmol/l for lactate (AIS, p=0.56; ISS, p=0.60; RTS, p=0.49) and -14 to 4 for base excess (AIS, p=0.35; ISS, p=0.19; RTS, p=0.31), respectively, demonstrating no statistically significant difference.

Arterial blood gas levels were obtained for all patients upon admission to the ICU, exposed in Table II. The study revealed that acidosis, with a pH value of 7.30±0.70 compared to a pH value of 7.36±0.05, was seen to be statistically significant among patients who required treatment at a trauma center (with a Revised Trauma Score of less than 4 points), with a p-value of 0.005. Normal values of PaO_2, $PaCO_2$, HCO_3 and SaO_2>95% were determined in all patients, regardless of whether they experienced spontaneous breathing or were mechanically ventilated. To evaluate pulmonary function and oxygenation multiple variables were examined: Horrowitz index (P/F), A-a gradient, A/a ratio and RI (respiratory index). The results showed no statistically significant differences between the groups, except for the A-a values. Patients with RTS scores

Table I. Demographics and patients' ICU admission characteristics

n=52	Total	Chest AIS			ISS			RTS		
		<3 (n=21)	≥3 (n=31)	P	< 16 (n=23)	≥16 (n=29)	P	<4 (n=18)	≥4 (n=34)	P
Demographics										
Age (mean ±SD)	57.38±18.90	55.90±19.60	58.40±18.70	0.64	60.40±18.70	55.0±19.1	0.31	54.70±19.40	63.90±16.20	0.11
Male (%)	80.80	76.20	83.90	0.72	95.70	69.0	0.03	83.80	73.30	0.44
Hemodynamics										
SBP (mmHg)	117.50±19.10	117.50±16.20	117.50±21.10	0.99	119.40±16.90	115.90±20.80	0.51	116.70±19.50	119.30±18.60	0.67
HR (bpm)	94.70±23.10	100.00±30.90	91.20±15.40	0.23	94.20±21.70	95.10±24.50	0.89	86.10±18.10	98.20±24.20	0.06
Laboratory results										
Hb (g/dl)	10.33±1.86	10.19±1.68	10.52±2.13	0.53	10.03±1.86	10.70±1.84	0.20	10.08±1.70	10.93±2.10	0.13
Ht (%)	28.10±6.88	28.40±7.50	27.80±6.50	0.77	29.60±6.80	26.80±6.70	0.15	30.40±7.90	27.10±6.30	0.12
Lac (mmol/l)	2 (1-6)	2 (1-5)	1 (1-6)	0.56	2 (1-6)	1 (1-5)	0.60	2 (1-6)	1 (1-5)	0.49
BE (mmol/l)	-2 (-14-6)	-2 (-14-4)	-2 (-8-6)	0.35	-1 (-14-6)	-2 (-9-4)	0.19	-2 (-14-6)	1 (-8-4)	0.31

AIS= Abbreviated Injury Scale, ISS= Injury Severity Score, RTS= Revised Trauma Score, SBP= systolic blood pressure, HR= heart rate, Hb= hemoglobin, Ht= hematocrit, Lac= lactate, BE= base excess

Table II. Arterial blood gas analysis results on ICU admission

n=52	Total	Chest AIS			ISS			RTS		
		<3 (n=21)	≥3 (n=31)	P	<16 (n=23)	≥16 (n=29)	p	<4 (n=18)	≥4 (n=34)	P
Ph	7.32±0.07	7.30±0.07	7.33±0.07	0.21	7.34±0.08	7.30±0.05	0.05	7.30±0.70	7.36±0.05	0.005
paO_2 (mmHg)	126.90±53.40	133.20±63.10	122.60±46.30	0.49	113.50±46.40	137.50±56.90	0.10	132.90±55.60	111.90±45.80	0.20
$paCO_2$ (mmHg)	42.60±7.70	44.60±8.10	41.30±7.40	0.14	44.10±8.05	41.50±7.40	0.23	44.50±7.90	38.20±5.40	0.007
HCO_3 (mmol/l)	22.30±3.60	21.70±3.70	22.70±3.40	0.34	22.35±3.70	22.34±3.50	0.98	22.35±3.50	22.33±3.70	0.98
SaO_2 (%)	96.60±4.80	95.40±7.20	97.50±1.70	0.13	95.70±6.20	97.40±3.40	0.21	96.50±5.50	97.10±2.70	0.70
P/F	323.50±89.30	324.20±90.60	323.10±89.90	0.96	305.50±90.10	337.80±87.60	0.19	335.00±80.80	295.30±95.10	0.15
A-a	138.50±50.10	145.60±56.90	133.70±46.80	0.41	129.90±64.30	145.30±37.10	0.28	152.50±42.30	103.80±55.10	0.001
A/a	0 (0-2)	1 (0-1)	0 (0-2)	0.54	0 (0-1)	0 (0-2)	0.92	0 (0-1)	1 (0-6)	0.97
RI	1 (0-6)	1 (0-2)	1 (0-6)	0.54	1 (0-2)	1 (0-6)	0.94	0 (0-2)	1 (0-5)	0.50

AIS= Abbreviated Injury Scale, ISS= Injury Severity Score, RTS= Revised Trauma Score, paO_2= the partial pressure of oxygen in the arterial blood, $paCO_2$= the partial pressure of carbon dioxide in arterial blood, HCO_3= bicarbonate, SaO_2= the oxygen saturation of arterial blood, P/F= ratio of arterial oxygen partial pressure to fractional inspired oxygen, A-a= alveolar-arterial gradient, A/a= alveolar-arterial ratio, RI= respiratory index

<4 had an A-a value of 152.50±42.30 mmHg, whereas patients with RTS ≥4 had an A-a value of 103.80±55.10 mmHg.

Pearson correlation coefficient was applied to evaluate the relationship between injury severity scores (AIS, ISS, RTS) and laboratory data (Table III), respectively arterial blood gas values (Table IV). The correlation noticed for all data, either positive or negative, was found to be weak (Pearson Correlation Coefficient <0.5). Furthermore, a limited number of statistically significant results were identified.

A full CT exam was conducted on all patients to detect any potential thoracic injury. The most common injury seen in the study was rib fractures, accounting for 92.30% of cases. This was followed by lung contusions, which were present in 63.50% of patients, and pneumothorax, which occurred in 53.80% of cases. Statistically significant findings indicate that patients presenting high-severity AIS and ISS had a higher prevalence of rib fractures in comparison to those with lower AIS (p=0.022) and lower ISS (p=0.033). In addition, patients with an ISS of 16 or above had a significantly increased risk of hemothorax (48.30%) and lung contusions (75.90%) compared to those with an ISS of less than 16 points (p=0.038 and p=0.047, respectively). The thickness of both the right and the left diaphragm was also evaluated. The findings demonstrated comparable results for both patient groups, with a mean measurement of 7.38±1.98 mm for the right diaphragm and 5.78±1.59 mm for the left diaphragm. All details are exposed in Table V.

It was examined ROC AUC for thickness of the right and the left diaphragm and severity scores as shown in Figure 3. A graphical plot illustrated the cut-off values (criterion), sensitivity and specificity as follows: Figure 3A. ROC AUC for the right diaphragm and high AIS values (criterion ≤7.88mm, sensitivity 71.0%, specificity 52.4%) and ROC AUC for the left diaphragm and high AIS values (criterion >4.34mm, sensitivity 83.9%, specificity 33.3%); Figure 3B. ROC AUC for the right diaphragm and high ISS values (criterion ≤7.37mm, sensitivity 58.6%, specificity 60.9%) and ROC AUC for the left diaphragm and high ISS values (criterion >5.92mm, sensitivity 55.2%, specificity 82.6%); Figure 3C. ROC AUC for the right diaphragm and low RTS values (criterion >6.62mm, sensitivity 70.3%, specificity 53.3%) and ROC AUC for the left diaphragm and low RTS values (criterion >5.55mm, sensitivity 56.8%, specificity 80.0%).

When examining the thickness of the diaphragm in deceased and survivors, no statistically significant differences were found, as demonstrated in Table VI. The right diaphragm had a mean thickness of 7.4±2.2mm for deceased individuals and 7.36±1.88mm for survivors, with a p-value of 0.94. Similarly, the left diaphragm had a mean thickness of 5.89±1.73mm for deceased individuals and 5.67±1.48mm for survivors, with a p-value of 0.63.

Table III. Pearson correlation between high severity scores and laboratory results

No. Total (n=52)		Ht (%)	Hb (g/dl)	Lac (mmol/l)	BE (mmol/l)
AIS (points)	Pearson Correlation	0.056	-0.025	-0.151	0.300
	P	0.696	0.860	0.285	0.031
ISS (points)	Pearson Correlation	-0.098	-0.115	-0.095	-0.179
	P	0.488	0.417	0.502	0.205
RTS (points)	Pearson Correlation	0.241	0.237	-0.154	0.169
	P	0.085	0.091	0.276	0.230

AIS= Abbreviated Injury Scale, ISS= Injury Severity Score, RTS= Revised Trauma Score, Ht= hematocrit, Hb= hemoglobin, Lac = lactate, BE= base excess

Table IV. Pearson correlations between high severity scores and arterial blood gas values

No. Total (n=52)		pO_2 (mmHg)	pCO_2 (mmHg)	HCO_3 (mmol/l)	SaO_2 (%)	pO_2/FiO_2	A-a (mmHg)	a/A	RI
AIS (points)	Pearson Correlation	-0.142	-0.150	0.236	0.222	0.038	-0.196	0.002	0.104
	P	0.314	0.290	0.092	0.114	0.791	0.163	0.989	0.462
ISS (points)	Pearson Correlation	0.212	-0.181	-0.106	0.209	0.091	0.195	-0.045	0.282
	p	0.132	0.199	0.456	0.137	0.521	0.166	0.750	0.043
RTS (points)	Pearson Correlation	-0.202	-0.354	0.039	0.044	-0.208	-0.457	-0.018	0.109
	p	0.152	0.010	0.786	0.755	0.140	0.001	0.902	0.440

AIS= Abbreviated Injury Scale, ISS= Injury Severity Score, RTS= Revised Trauma Score, paO_2= the partial pressure of oxygen in the arterial blood, $paCO_2$= the partial pressure of carbon dioxide in arterial blood, HCO_3= bicarbonate, SaO_2= the oxygen saturation of arterial blood, P/F= ratio of arterial oxygen partial pressure to fractional inspired oxygen, A-a= alveolar-arterial gradient, A/a= alveolar-arterial ratio, RI= respiratory index

Table V. Chest CT scan results

n=52	Total	Chest AIS			ISS			RTS		
		<3 (n=21)	≥3 (n=31)	P	<16 (n=23)	≥16 (n=29)	P	<4 (n=18)	≥4 (n=34)	P
Pneumothorax (present)	53.80	47.60	58.10	0.57	60.90	48.30	0.41	62.20	33.30	0.073
Hemothorax (present)	34.60	23.80	41.90	0.24	17.40	48.30	0.038	35.10	33.30	0.90
Flail chest (present)	17.30	0.00	29.00	0.007	13.00	20.70	0.71	13.50	26.70	0.42
Ribs fractures (present)	92.30	81.00	100.00	0.022	82.60	100.00	0.033	89.20	100.00	0.31
Lung contusions (present)	63.50	52.40	71.00	0.24	47.80	75.90	0.047	67.60	53.30	0.36
Right diaphragm thickness (mm)	7.38± 1.98	7.70± 1.80	7.16± 2.09	0.34	7.61± 2.06	7.20± 1.93	0.46	7.49± 1.96	7.10± 2.07	0.52
Left diaphragm thickness (mm)	5.78± 1.59	5.82± 1.84	5.75± 1.42	0.89	5.37± 1.54	6.10± 1.59	0.10	6.03± 1.65	5.17± 1.31	0.07

AIS= Abbreviated Injury Scale, ISS= Injury Severity Score, RTS= Revised Trauma Score

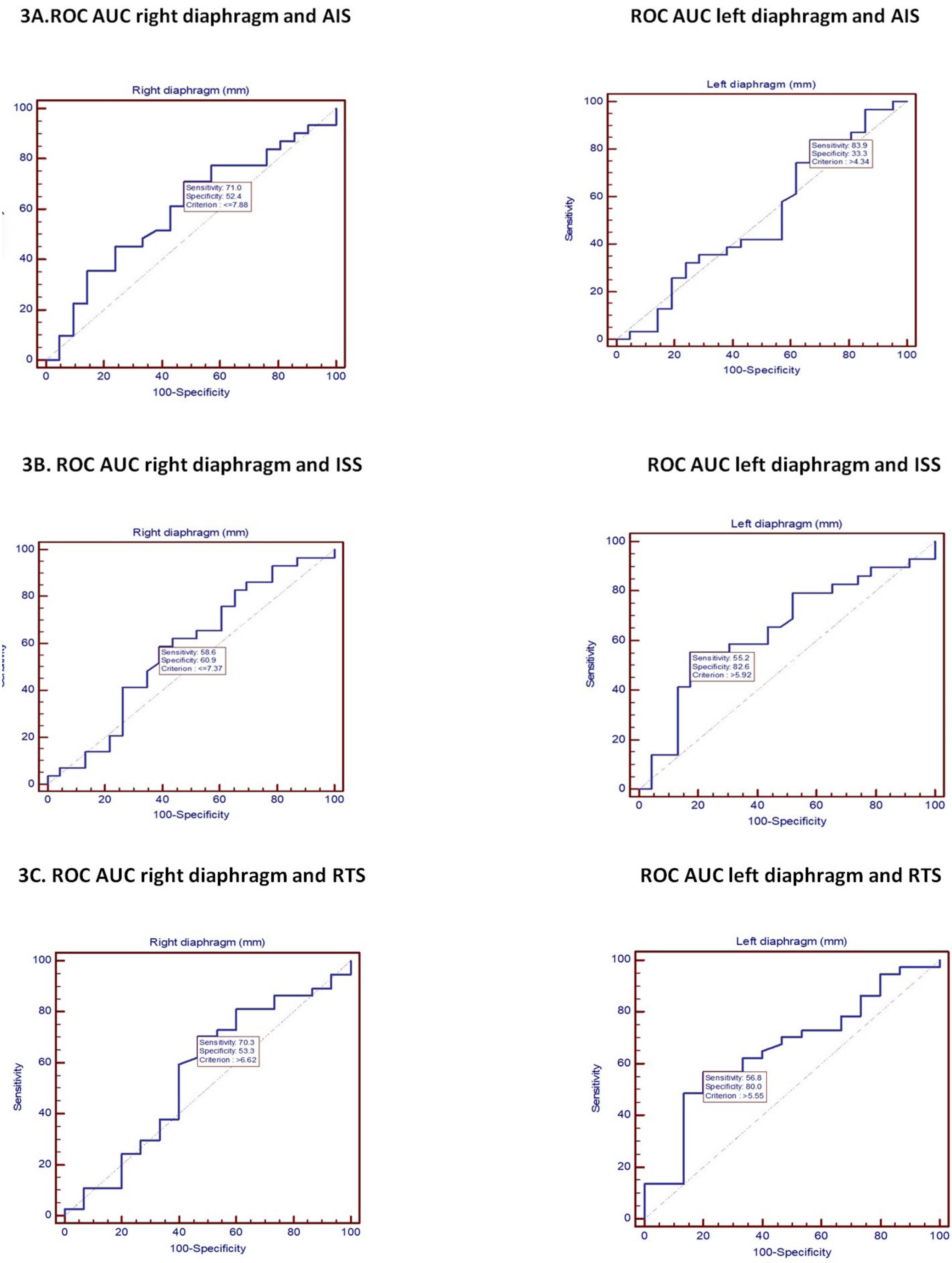

Fig. 3. ROC AUC for right and left diaphragm thickness and severity scores

Table VI. Diaphragm thickness differences in deceased and survivors

Total (n=52)	Mortality (n=26)	Survival (n=26)	P
Right diaphragm thickness (mm)	7.4±2.2	7.36±1.88	0.94
Left diaphragm thickness (mm)	5.89±1.73	5.67±1.48	0.63

AIS= Abbreviated Injury Scale, ISS= Injury Severity Score, RTS= Revised Trauma Score

Furthermore, an analysis was conducted on the outcome of the patients (Table VII.). A mortality rate of 50% was observed. There was no statistically significant difference seen in trauma severity levels (p=0.57 for AIS, p=0.78 for ISS, p=0.22 for RTS) when comparing to the survivors. The incidence rates of pneumothorax, hemothorax, and lung contusions were found to be comparable among the survivors and the deceased (p=0.78 for pneumothorax, p=0.14 for hemothorax, and p=0.77 for lung contusions). When analyzing the length of IMV, it was found that there were no statistically significant differences between the two groups (p=0.98). Although there was no statistically significant difference observed in terms of LOS in the ICU (p=0.48), the deceased patients had a median duration of 7 days (range: 1-35 days), while the survivors had a median duration of 8.5 days (range: 1-50 days). However, a statistically significant difference (p=0.004) was observed among the survivors in terms of LOS in the hospital, with a median duration of 18.5 days (range: 3-52 days), compared to the deceased patients, who had a median duration of 8 days (range: 1-36 days).

Discussions

Thoracic trauma is an important trigger to comorbidity in the management of patients with multiple injuries, approximately 50% of those who have multiple trauma also experience secondary chest injury [19]. In the absence of specific local data, the current study aimed to analyze the cohort of patients admitted to a level 3 ICU over a period of one year, focusing particularly on cases with thoracic trauma. Following the initial assessment in the emergency department, patients were admitted to the ICU. All 52 patients were classified according to the severity of their injuries using the AIS, ISS, and RTS scales, as well as the mortality rate.

As presented in Table I., being close to 60 years old (57.38±18.90 years), the majority of those enrolled in our study who suffered primarily from blunt trauma were men (80.80%). While treating trauma patients, it was essential to assess their hemodynamic status in order to rule out hemorrhage. Blood pressure and pulse rate are commonly used to estimate blood loss during the initial evaluation [20]. The results demonstrated no statistically significant difference in these parameters in the two groups of patients. Additionally, as potentially life-threatening injuries could be detected, hemoglobin and hematocrit were examined. The patients were anaemic, as shown by a hemoglobin level of 10.33±1.86 g/dl and a hematocrit of 28.10±6.88%. However, no significant distinctions were seen between the two groups.

A study conducted by Carlino et al., (Respir Physiol Neurobiol., 2020) aimed to assess the usefulness of arterial blood gas analysis parameters in predicting lung damage in cases of acute chest trauma. Their results indicated that individuals with pulmonary impairment had decreased levels of oxygen saturation, arterial partial pressure of oxygen, and P/F ratio [21]. In our study, the assessment of lung function was done by similar etiquette, as presented in Table II. The majority of the parameters had normal values. There were no statistically significant differences seen between the group admitted for mild trauma and the group admitted for severe trauma, except patients classified with RTS <4 points, as needing trauma center for treatment (pH=7.30±0.70 compared to pH=7.36±0.05, p=0.005; $paCO_2$= 44.50±7.90mmHg compared to $paCO_2$= 38.20±5.40mmHg, p=0.007; A-a= 152.50±42.30mmHg compared to A-a=103.80±55.10mmHg, p=0.001). Moreover, weak positive and negative Pearson coefficient correlations were determined for severity injury scores and laboratory results (Table III.), respectively arterial blood gas analysis (Table IV.).

Table VII. Critically ill patients' outcome

Total (n=52)	Mortality (n=26)	Survival (n=26)	p
Severity Scores			
AIS≥3 points	53.8	65.4	0.57
ISS≥16 points	57.7	53.8	0.78
RTS <4 points	80.8	61.5	0.22
Chest CT results			
Pneumothorax	50.0	57.7	0.78
Hemothorax	23.1	46.2	0.14
Flail chest	15.4	19.2	0.74
Ribs fractures	84.6	100.0	0.037
Lung contusions	61.5	65.4	0.77
Prognosis			
IMV (≤96h)	46.2	46.2	0.98
IMV (>96h)	53.8	53.8	0.98
LOS ICU (days) median (min-max)	7 (1-35)	8.5 (1-50)	0.48
LOS HOSPITAL (days) median (min-max)	8 (1-36)	18.5 (3-52)	0.004

AIS= Abbreviated Injury Scale, ISS= Injury Severity Score, RTS= Revised Trauma Score, IMV= invasive mechanical ventilation, LOS ICU= length of stay in intensive care unit; LOS HOSPITAL= length of stay in hospital

According to the study conducted by McGuinness et al. (Injury, 2023), the findings indicated that a significant proportion of trauma patients with thoracic damage (about 79.1%) had rib fractures [22]. In conjunction with these results and regarding the distribution of injuries to various thoracic structures, our data mirror those of TraumaRegister DGU [19], as the majority of patients experienced rib fractures (92.30%, with a statistically significant difference for AIS≥3 points compared to AIS<3 points, p=0.022) and lung injuries (63.50%, lung contusions, with a statistically significant difference for ISS≥16points and ISS<16 points, p=0.007) (Table V.).

In addition to operating as the conventional imaging modality for trauma patients, CT has been established as a valuable tool in evaluating the decrease of diaphragm thickness among mechanically ventilated patients [18, 23, 24]. All patients included in our study were investigated by CT scan in the emergency department. The thickness of the diaphragm was assessed upon the patients' arrival, as presented in Table V., obtaining values of 7.38±1.98mm for the right diaphragm and 5.78±1.59mm for the left diaphragm. In Figure 3., the graphs depicted the cut-off values, sensitivity, and specificity for diaphragm thickness and injury severity scores (in Figure 3A, the ROC AUC is presented for the right diaphragm and high AIS values, with a criterion of ≤7.88mm, and for the left diaphragm and high AIS values, with a criterion of >4.34mm; in Figure 3B., the ROC AUC is displayed for the right diaphragm and high ISS values, with a criterion of ≤7.37mm and for the left diaphragm and high ISS values, with a criterion of >5.92mm; in Figure 3C, the ROC AUC is shown for the right diaphragm and low RTS values, with a criterion of >6.62mm and for the left diaphragm and low RTS values, with a criterion of >5.55mm). No statistically significant differences were identified between survivors and deceased (Table VI.).

Upon analysis, it was shown (Table VII.) that there was no statistically significant difference in terms of injury severity scores, chest CT findings, MV, and length of stay in ICU.

Conclusions

The results of this study represent a complex analysis of critically ill patients admitted to the ICU for thoracic trauma. After implementing the standard care protocol, it was seen that all patients included in the trial had satisfactory hemodynamic and respiratory characteristics. The thoracic CT scan has a purpose that extends beyond the first detection of life-threatening injuries, as it also provides valuable assistance in evaluating the thickness of the diaphragm. Although no significant differences were found regarding the prognosis between the survivors and the deceased, diaphragm thickness might potentially serve as a predictor for the severity of the injury.

Authors' contribution

BOE (Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft)
KKO (Data curation, Investigation, Visualization)
PM (Data curation, Investigation, Methodology)
CVD (Data curation, Investigation, Methodology)
FO (Data curation, Investigation, Methodology)
VAG (Data curation, Investigation, Methodology)
BIA (Data curation, Investigation, Methodology)
FAC (Data curation, Investigation, Methodology)
CM (Project administration, Resources, Software Validation, Visualization, Writing – review & editing)
LAE (Supervision, Validation, Visualization, Writing – review & editing)

Conflict of interest

None to declare.

References

1. Nasr A, Tomasich FS, Collaço I, Abreu P, Namias N, Marttos A. The Trauma Golden Hour: A Practical Guide. Springer International Publishing, Cham, 2020, 1-223.
2. Søreide K. Epidemiology of major trauma.Br J Surg. 2009;96(7):697-8.
3. Kanake V, Kale K, Mangam S, Bhalavi V. Thorax trauma severity score in patient with chest trauma: study at tertiary-level hospital. Indian J Thorac Cardiovasc Surg. 2022;38(2):149-156.
4. Bozorgi F, Mirabi A, Chabra A, Mirabi R, Hosseininejad S, Zaheri H. Mechanisms of Traumatic Injuries in Multiple Trauma Patients. Int J Med Invest. 2018;7(2):7-15.
5. Marx J, Walls R, Hockberger R. Rosen's emergency medicine - concepts and clinical practice e-book 9th ed. Elsevier Health Sciences, 2017, 382–391.
6. Peters S, Nicolas V, Heyer CM. Multidetector computed tomography-spectrum of blunt chest wall and lung injuries in polytraumatized patients. Clin Radiol. 2010;65:333–8.
7. Dennis BM, Bellister SA, Guillamondegui OD. Thoracic Trauma. Surg Clin North Am. 2017;97(5):1047-1064.
8. Bulger EM, Arneson MA, Mock CN, Jurkovich GJ. Rib fractures in the elderly. J Trauma. 2000;48(6):1040-6.
9. Bergeron E, Lavoie A, Class D, et al. Elderly trauma patients with rib fractures are at greater risk of death and pneumonia. J Trauma. 2003;54(3):478-85.
10. Dehghan N, de Mestral C, McKee MD, Schemitsch EH, Nathens A. Flail chest injuries: a review of outcomes and treatment practices from the National Trauma Data Bank. J Trauma Acute Care Surg. 2014;76(2):462-8.
11. Struck MF, Kleber C, Ewens S, et al. Chest Tube Placement in Mechanically Ventilated Trauma Patients: Differences between Computed Tomography-Based Indication and Clinical Decision. Journal of Clinical Medicine. 2022;11(14):4043.
12. Huber-Wagner S, Lefering R, Kanz KG, Biberthaler P, Stengel D. The importance of immediate total-body CT scanning. Lancet. 2017;389(10068):502-503.
13. Oikonomou A, Prassopoulos P. CT imaging of blunt chest trauma. Insights Imaging. 2011;2(3):281-295.
14. Choi YU, Kim CW, Lim J, Park IH, Byun CS. Association of Chest Anteroposterior Radiography with Computed Tomography in Patients with Blunt Chest Trauma. Emerg Med Int. 2023;2023:6678211.
15. Anderson K, Schellenberg M, Owattanapanich N, et al. Undertriage of Severely Injured Trauma Patients. Am Surg. 2023;31:31348231177939.
16. Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974;14(3):187-96.
17. Champion HR, Sacco WJ, Copes WS, Gann DS, Gennarelli TA, Flanagan ME. A revision of the Trauma Score. J Trauma. 1989;29(5):623-9.

18. Lee GD, Kim HC, Yoo JW, et al. Computed tomography confirms a reduction in diaphragm thickness in mechanically ventilated patients. J Crit Care. 2016;33:47–50.
19. Bayer J, Lefering R, Reinhardt S, et al. Thoracic trauma severity contributes to differences in intensive care therapy and mortality of severely injured patients: analysis based on the TraumaRegister DGU®. World J Emerg Surg. 2017;12:43.
20. Kuster M, Exadaktylos A, Schnüriger B. Non-invasive hemodynamic monitoring in trauma patients. World J Emerg Surg. 2015;10:11.
21. Carlino MV, Guarino M, Izzo A, et al. Arterial blood gas analysis utility in predicting lung injury in blunt chest trauma. Respir Physiol Neurobiol. 2020;274:103363.
22. McGuinness MJ, Isles S, Xu W, Harmston C. Incidence and outcomes of major trauma patients with thoracic injuries and rib fractures in Aotearoa New Zealand. Injury. 2023;54(9):110787.
23. Branea O, Copotoiu S, Becica D, et al. Assessment of the Diaphragm Thickness Decrease in Critically Ill COVID-19 Patients: Could Computed Tomography Be of Aid Regarding Diaphragm Muscle Mass?. Cureus. 2023;15(10): e47195.
24. Branea OE, Budeanu AR, Budeanu RG, et al. Computed tomography evaluation of diaphragm alterations in 20 critically ill COVID-19 positive patients. Acta Marisiensis - Seria Medica,2022;68(3) 103-107.