

Intercostal Muscle Density as a Prognostic Imaging Marker in Isolated Blunt Thoracic Trauma

 Kadir Baturhan Çiflik¹

¹ Department of Thoracic Surgery, Kırıkkale Yüksek İhtisas Hospital, Kırıkkale, Türkiye

*Correspondence: Kadir Baturhan Çiflik; baturhanciflik@gmail.com

Cite as: Çiflik KB. Intercostal Muscle Density as a Prognostic Imaging Marker in Isolated Blunt Thoracic Trauma. J Cukurova Anesth Surg. 2026;9(3):1095-1108. doi: 10.36516/jocass.1991163

Received: 10.07.2026, Accepted: 23.09.2026, Published: 30.09.2026, CC BY-NC 4.0

Abstract

Aim: To investigate the value of intercostal muscle density measured at the primary trauma site in predicting subsequent thoracic injuries, unexpected injuries, and poor clinical outcomes in patients with isolated blunt thoracic trauma, and to evaluate the relationship between muscle density and trauma characteristics, treatment modalities, and the follow-up process. **Methods:** This single-center, retrospectively designed study included 124 patients. The primary trauma site was determined by combined assessment of patient history, physical examination, and thoracic computed tomography (CT) findings. The density of the intercostal muscles corresponding to this site was measured and averaged. **Results:** Hounsfield unit (HU) values were significantly higher in patients with subsequent injury (n=14, 11.3%), unexpected injury (n=12, 9.7%), and poor outcome (n=30, 24.2%) (p=0.001, p=0.005, and p<0.001, respectively). HU value significantly predicted subsequent injuries (AUC=0.773, cutoff=56.0 HU, p=0.001), unexpected injuries (AUC=0.754, cutoff=56.0 HU, p=0.004), and poor outcome (AUC=0.746, cutoff=54.95 HU, p<0.001). On multivariate analysis, intercostal muscle density (OR=1.041, p<0.001) and number of rib fractures (OR=1.885, p<0.001) were identified as independent predictors of poor outcome. Age and sex were not significantly associated with poor outcome (p=0.767 and p=0.920, respectively). **Conclusions:** Intercostal muscle density measured at the primary trauma site, which can be obtained from routine thoracic CT without additional cost, may represent a potential, complementary imaging parameter that could help predict and may provide a complementary contribution to existing risk assessment methods.

Keywords: Thoracic Injuries; Intercostal Muscles; Tomography, X-Ray Computed

1. Introduction

Blunt thoracic trauma accounts for the large majority of thoracic injuries. It ranges from simple chest wall injuries to life-threatening conditions such as hemothorax, pneumothorax, and pulmonary contusion¹⁻³. In some patients without evident pathology on initial evaluation, new thoracic injuries may emerge during follow-up, or the clinical severity of existing injuries may increase^{1,3-5}.

Numerous clinical parameters, including age, trauma mechanism, number of rib fractures, associated intrathoracic injuries, and various trauma scores, are currently used

to predict the severity and prognosis of thoracic trauma^{6,7}. However, most of these variables reflect the anatomical damage that occurs after trauma and do not directly assess the patient's biological response to trauma or the structural characteristics of the chest wall⁸. Furthermore, the fact that subsequent injuries can develop in some patients who initially appear to be at low risk suggests that current risk assessment methods are not sufficient on their own^{4,9}.

Muscle density obtained from computed tomography (CT) images has increasingly attracted attention in recent years as an objective imaging biomarker reflecting the structural integrity and quality of skeletal muscle^{10,11}. Particularly in abdominal and oncologic surgery, low muscle density has been shown to be associated with sarcopenia, increased complication rates, and poor prognosis^{12,13}. However, a limited number of studies in trauma patients have assessed muscle characteristics by focusing on general muscle groups and examined their relationship with trauma^{14,15}. To date, no study has evaluated the relationship between intercostal muscle density at the trauma site and clinical outcomes in patients with thoracic trauma. The potential role of the imaging characteristics of the intercostal muscle at the trauma site in predicting subsequent thoracic injuries or poor clinical outcomes remains unknown.

The primary aim of this study is to investigate the value of intercostal muscle density measured at the primary trauma site in predicting subsequent thoracic injuries and poor clinical outcomes in patients with isolated blunt thoracic trauma. The secondary aim of the study is to evaluate the relationship between intercostal muscle density and trauma characteristics, the treatment methods applied, and the patient follow-up process.

2. Materials and Methods

This study was designed as a single-center, retrospective study and was approved by the local ethics committee (Decision No: 2026.03.22). Patients aged 18 years and older who were evaluated for isolated blunt thoracic trauma between October 2024 and March 2026, and who had complete clinical follow-up, radiological, and treatment data, were included in the study (n=124). Patients with penetrating thoracic trauma, concomitant extrathoracic injury, age under 18 years, unavailable thoracic CT images, or incomplete clinical follow-up and treatment data were excluded from the study.

Patients' demographic data, physical examination findings at presentation, thoracic CT images, diagnostic process data, treatment methods applied, intensive care unit admission, length of intensive care unit stay, length of hospital stay, and mortality data were retrospectively obtained from the hospital information management system. All data were recorded after patient identification information was anonymized.

To standardize the assessment, if the trauma was detected within 24 hours of occurrence it was classified as "day 1"; if detected between 24-48 hours, as "day 2"; if detected between 48-72 hours, as "day 3"; and if detected after 72 hours, as "subsequent days."

Although various approaches to dividing the thorax into different regions have been reported in studies on thoracic trauma, there is not yet a single standardized classification system for this purpose^{16,17}. In this study, the regional division was based on the anatomical areas that patients described in their own words as the location of pain or trauma during physical examination. Each hemithorax was divided into four regions, for a total of eight regions (right upper anterior, right lower anterior, right upper posterior, right lower posterior, left upper anterior, left lower anterior, left upper posterior, left lower posterior). For these regions, the boundaries on thoracic CT were determined as the fifth rib for the upper and lower regions and the midaxillary line for the anterior and posterior regions. The "primary trauma site" was determined by a thoracic surgeon based on the patient's history, tenderness and ecchymosis over the chest wall, and thoracic CT findings.

Intercostal muscle density was assessed on noncontrast thoracic CT images (axial plane, 0.5-1 mm slice thickness, soft tissue window [WW 400, WL 40]) corresponding to the primary trauma site. Measurements were performed using the Picture Archiving and Communication System (PACS). To minimize the influence of surrounding bony structures, pleural tissue, and subcutaneous fat, circular or oval regions of interest (ROI) with a standard diameter of 3-6 mm were used in all patients. At least one and at most three separate measurement points were obtained from each intercostal muscle within the primary trauma site on the CT slices, and the mean of the resulting Hounsfield unit (HU) values was recorded as the patient's intercostal muscle density. All HU measurements were performed by a single thoracic surgeon to ensure methodological consistency.

Patients were hospitalized if they had injuries such as three or more rib fractures, hemothorax, pneumothorax, pneumomediastinum, contusion, or sternal fracture, and if the trauma was detected on day 1 or day 2. Otherwise, patients were discharged from the emergency department. If surgical procedures such as tube thoracostomy were not performed and no clinical or radiological deterioration occurred during follow-up, patients were discharged after 48 hours of hospitalization. In other cases, and in patients admitted to the intensive care unit, the length of hospital stay was longer. In these patients, the decision to discharge was made once clinical and radiological improvement was observed.

Injuries in patients who were discharged after hospitalization, or who presented to the hospital after day 1 or day 2 following trauma were defined as "subsequent injury." Injuries in patients who were discharged from the emergency department and later required hospital admission were defined as "unexpected injury." Poor clinical outcome was defined as present in any patient who had intensive care unit admission, underwent tube thoracostomy, underwent emergency thoracotomy, had a subsequent injury, had an unexpected injury, or experienced mortality. This composite outcome was constructed to capture any deviation from an uncomplicated clinical course, ranging from the need for additional intervention to mortality. However, we acknowledge that the individual components of this composite outcome differ substantially in terms of clinical severity.

2.1. Statistical Analysis

Data were analyzed using IBM SPSS Statistics Standard Concurrent User V 27 (IBM Corp., Armonk, New York, USA). Descriptive statistics were presented as mean $\pm$ standard deviation for normally distributed data, and as median (M), interquartile range (IQR), minimum (min), and maximum (max) for non-normally distributed data. Normality of distribution of numerical variables was assessed using the Shapiro-Wilk test. Homogeneity of variances was assessed using Levene's test. When analyzing the relationship between numerical variables, the Spearman correlation test was used if any variable was non-normally distributed. For comparisons of numerical variables between two categorical groups, the independent samples t-test was used for normally distributed data, and the Mann-Whitney U test was used for non-normally distributed data. For comparisons of numerical variables among more than two categorical groups, one-way analysis of variance was used for normally distributed data. The Chi-square test based on the exact method was used for comparisons between categorical variables. When the Chi-square test result was significant, subgroup analyses were performed using the Bonferroni-corrected two-proportion z-test. The performance of intercostal muscle density in predicting subsequent injuries, unexpected injuries, and poor clinical outcomes was evaluated using Receiver Operating Characteristic (ROC) curve analysis. In the ROC analysis, the area under the curve (AUC), 95% confidence interval (95% CI), sensitivity (Sen), and specificity (Spe) values were calculated. Optimal cutoff values were determined using the Youden index. Multivariate binary logistic regression analysis was performed to identify

independent risk factors associated with poor clinical outcome. Variables considered clinically significant or found significant in univariate analyses were included in the model. HU was included because it was the primary variable of interest. The number of rib fractures was included because it was significant in the univariate analysis and is a well-established prognostic factor in the literature. Age and sex were also included in the model because, although they were not significant in the univariate analysis, they are widely recognized as classical prognostic and potential confounding variables in the trauma literature. Results were presented as odds ratio (OR) and 95% CI. Model fit was assessed using the Hosmer-Lemeshow goodness-of-fit test. A p-value <0.05 was considered statistically significant in all comparisons.

3. Results

3.1. General Information about the Patients

The study included a total of 124 patients, 60 (48.4%) female and 64 (51.6%) male. The mean age of the patients was 53.6 ± 17.0 years. The most common cause of blunt thoracic trauma was traffic accident (n=54, 43.5%). The most frequently detected thoracic injury was superficial chest wall injury (n=57, 36.3%). Subsequent injury was present in 14 patients (11.3%), with pneumothorax being the most common finding in this group (n=8, 57.1%). The number of patients with unexpected injury was 12 (9.7%). Mortality occurred in a total of two patients (1.6%). One of these patients died during hospitalization, and the other died within the first 30 days after discharge. The cause of death in the patient who died during hospitalization was renal failure secondary to comorbid conditions, while the cause of death in the patient who died after discharge was pulmonary thromboembolism (Table 1).

Table 1. General information about the patients

	n(%)
Gender	
Female	60(48.4)
Male	64(51.6)
Age, (year) $\bar{x} \pm SD$	53.6 $\pm$ 17.0
Type of trauma	
Animal kick	1(0.8)
Assault	29(23.4)
Fall	40(32.3)
Traffic accident	54(43.5)
Injuries	
Flail chest	3(1.9)
Contusion	4(2.5)
Pneumomediastinum	7(4.5)
Sternal fracture	8(5.1)
Hemothorax	10(6.4)
Pneumothorax	13(8.3)
Rib fracture	55(35)
Superficial chest wall injury	57(36.3)
Injury side	
Bilateral	11(8.9)
Right	52(41.9)
Left	61(49.2)

	n(%)
Primary trauma site	
Left upper-posterior	5(4)
Left upper-anterior	5(4)
Right upper-anterior	13(10.5)
Right upper-posterior	13(10.5)
Left lower-posterior	17(13.7)
Right lower-anterior	31(25)
Left lower-anterior	33(26.6)
Density of the primary trauma sites, (HU) $\chi \pm SD$	56.3 $\pm$ 28.9
Day of injury detection	
Day 1	110 (88.7)
Day 2	2(1.6)
Day 3	5(4)
Subsequent days	7(5.6)
Subsequent injury	
Present	14(11.3)
Absent	110(88.7)
Unexpected injury	
Present	12(9.7)
Absent	112(90.3)
Number of rib fractures, (n) M(IQR, min-max)	0(2,0-11)
Side of rib fracture	
Bilateral	4(7.3)
Right	25(45.4)
Left	26(47.3)
Treatment	
Tube thoracostomy	14(11.3)
Conservative	110(88.7)
ICU admission	
Present	12(9.7)
Absent	112(90.3)
Discharge status	
After hospital admission	37(29.8)
After emergency department evaluation	87(70.2)
Mortality	
Present	2(1.6)
Absent	122(98.4)
Poor outcome	
Present	30(24.2)
Absent	94(75.8)

n: Number of patients, %: percentage of patients, χ : mean, SD: standard deviation, HU: Hounsfield unit, M: Median, IQR: interquartile range, min: minimum, max: maximum, ICU: intensive care unit.

3.2. Analyses Related to HU

HU value was significantly higher in patients with subsequent injury compared with other patients ($p=0.001$). Similarly, HU value was also higher in patients with unexpected

injury ($p=0.005$). HU value was significantly higher in hospitalized patients compared with other patients ($p<0.001$). No significant difference in HU values was found between patients with and without intensive care unit admission ($p=0.534$). Although HU value was lower in patients with mortality, this difference was not statistically significant ($p=0.392$) (Table 2).

HU values differed significantly according to the day on which the injury was detected ($p=0.002$). In post-hoc analyses, HU values were significantly higher in patients whose injury was detected on day 2 compared with those detected on day 1 ($p=0.026$). Similarly, HU values were higher in the group whose injury was detected on subsequent days compared with the day-1 group ($p=0.043$). HU value was significantly higher in patients who underwent tube thoracostomy compared with those who received conservative treatment ($p<0.001$). A significant positive correlation was found between HU value and length of hospital stay ($r=0.323$; $p<0.001$). In contrast, no significant correlation was found between HU value and number of rib fractures ($r=0.081$; $p=0.372$) or length of intensive care unit stay ($r=0.079$; $p=0.384$) (Table 2).

Table 2. Analyses related to HU

	HU	Test value	p	Cohen's d	%95 CI
Subsequent injury					
Present	79.58±22.02	3.313	0.001t	0.94	0.37–1.51
Absent	53.42±28.44				
Unexpected injury					
Present	78.35±23.13	2.848	0.005t	0.87	0.26–1.47
Absent	54.01±28.58				
Hospitalization					
Present	72.32±27.79	4.275	<0.001t	0.84	0.44–1.24
Absent	49.59±26.80				
ICU admission					
Present	61.33±24.33	0.624	0.534t	0.19	-11.95–22.94
Absent	55.84±29.43				
Mortality					
Present	38.90±8.20	-0.860	0.392t	-0.61	-2.01–0.79
Absent	56.66±29.08				
Day of injury detection			0.002f		
Day 1a	52.97±28.17		0.026ab*		
Day 2b	89.04±11.82		0.743ac*		
Day 3c	72.90±2.82	5.094	0.043ad*		
Subsequent daysd	81.67±26.65		0.897bc*		
			0.968bd*		
			0.979cd*		
Primary trauma site					
Left upper-posterior	57.94±25.67				
Left upper-anterior	64.04±33.28				
Right upper-anterior	66.78±29.07	1.149	0.338f		
Right upper-posterior	57.94±25.67				
Left lower-posterior	60.40±25.01				
Right lower-anterior	49.59±30.16				
Left lower-anterior	50.36±28.32				

	HU	Test value	p	Cohen's d	%95 CI
Type of trauma					
Animal kick	89.10±NA				
Assault	60.14±31.55	1.522	0.212f		
Fall	49.39±21.56				
Traffic accident	58.89±31.68				
Treatment					
Tube thoracostomy	97.63±19.66	-6.562	<0,001t	-1.86	-2.46--1.26
Conservative	51.12±25.54				
Length of hospital stay		0.323	<0.001r		
Number of rib fractures		0.081	0.372r		
Length of ICU stay		0.079	0.384r		

Numerical values are presented as mean ± standard deviation. HU: Hounsfield unit, ICU: intensive care unit, CI: confidence interval, tindependent samples t-test, fANOVA, r Spearman correlation test, *Tukey post-hoc, NA: Not available. The letters a, b, c, and d were used to indicate the p-values from the pairwise comparisons among the parameters.

Intercostal muscle density showed significant discriminative power in predicting subsequent injuries (AUC=0.773; 95% CI: 0.650-0.895; $p=0.001$). For the cutoff value of 56.0 HU determined by ROC analysis, sensitivity was 85.7% and specificity was 65.5% (Figure 1a). It also showed significant discriminative performance in predicting patients with unexpected injury (AUC=0.754; 95% CI: 0.617-0.892; $p=0.004$). For the cutoff value of 56.0 HU determined by ROC analysis, sensitivity was 83.3% and specificity was 64.3% (Figure 1b).

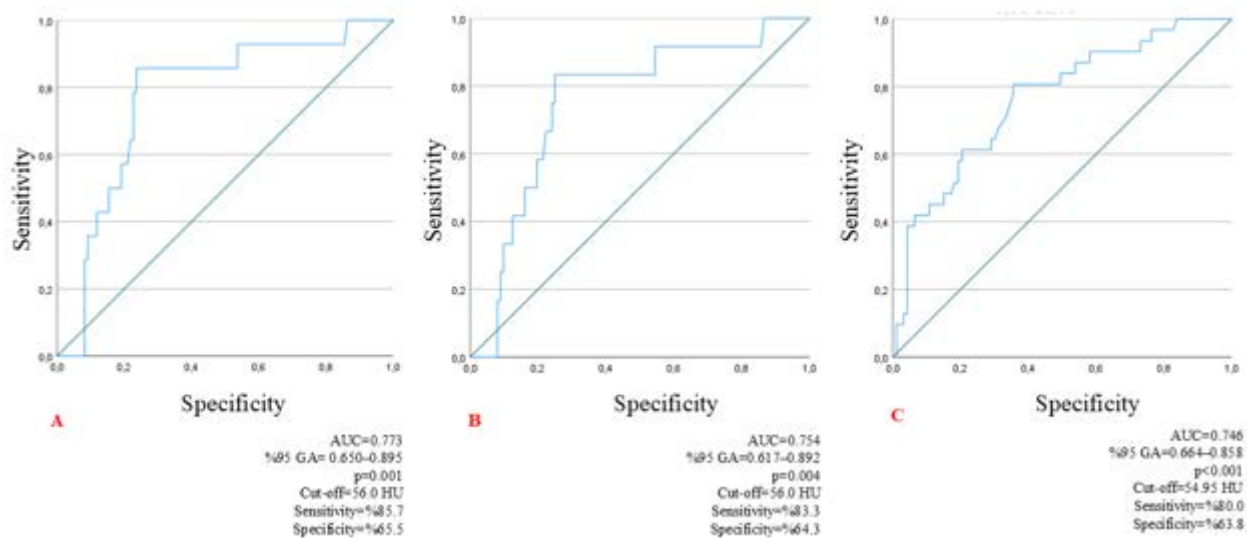


Fig 1. A) Subsequent injury. AUC=0.773; %95 GA: 0.650–0.895; $p=0.001$. The optimal cutoff value was 56.0 HU, yielding a sensitivity of %85.7 and a specificity of %65.5. B) Unexpected injury. AUC=0.754; %95 GA: 0.617–0.892; $p=0.004$. The optimal cutoff value was 56.0 HU, yielding a sensitivity of %83.3 and a specificity of %64.3. C) Poor outcome. AUC=0.746; %95 GA: 0.664–0.858; $p<0.001$. The optimal cut-off value was 54.95 HU, yielding a sensitivity of %80.0 and a specificity of %63.8.

3.3. Analyses Related to Subsequent Injuries

A significant relationship was found between subsequent injury and the day on which the injury was detected; however, no significant pairwise difference was observed in post-hoc analyses ($p<0.001$). A significant relationship was found between trauma mechanism and subsequent injury ($p=0.022$). Post-hoc analyses showed that this

significance originated from a single patient who presented following an animal kick. Since this involved only one patient, this relationship was not considered clinically meaningful, and no causal or associative interpretation should be drawn between animal-kick trauma and subsequent injury risk based on this isolated observation. A significant relationship was found between hospitalization and subsequent injury ($p<0.001$), but no relationship was found with intensive care unit admission ($p=0.625$). A significant relationship was found between treatment method and subsequent injury ($p<0.001$). No significant relationship was found between mortality status and subsequent injury ($p=1.000$) (Table 3).

The number of rib fractures was significantly higher in patients with subsequent injury ($p=0.043$). In addition, length of hospital stay was significantly longer in this group ($p<0.001$). In contrast, no significant difference was found between groups in length of intensive care unit stay ($p=0.601$) (Table 3).

3.4. Analyses Related to Unexpected Injuries

A statistically significant relationship was found between the day on which the injury was detected and unexpected injury status ($p<0.001$). No significant relationship was found between the primary trauma site and unexpected injury ($p=0.776$). A significant relationship was found between trauma mechanism and unexpected injury, but no significant pairwise difference was observed in post-hoc analyses ($p=0.015$). A relationship was found between treatment method and unexpected injury ($p<0.001$). No significant relationship was found between intensive care unit admission ($p=0.327$) or mortality status ($p=0.815$) and unexpected injury (Table 3).

The number of rib fractures was significantly higher in patients with unexpected injury compared with those without ($p=0.024$). Length of hospital stay was significantly longer in the group with unexpected injury ($p<0.001$). No significant difference was found between the two groups in length of intensive care unit stay ($p=0.448$) (Table 3).

Table 3A. Analyses related to subsequent injuries

	Subsequent injury		Test value	p
	Present n(%)	Absent n(%)		
Day of injury detection				
Day 1	1(0.9)	109(99.1)	106.119	<0.001 χ^2
Day 2	4(80)	1(20)		
Day 3	2(100)	0(0)		
Subsequent days	7(100)	0(0)		
Primary trauma site				
Left upper-posterior	0(0)	5(100)	6.235	0.513 χ^2
Left upper-anterior	2(40)	3(60)		
Right upper-anterior	2(15.4)	11(84.6)		
Right upper-posterior	2(15.4)	11(84.6)		
Left lower-posterior	2(11.8)	15(88.2)		
Right lower-anterior	3(9.7)	28(90.3)		
Left lower-anterior	2(6.1)	31(93.9)		
Type of trauma				
Animal kick	1(100)	0(0)	9.679	0.022 χ^2
Assault	5(17.2)	24(82.8)		
Fall	3(7.5)	37(92.5)		
Traffic accident	5(9.3)	49(90.7)		
Hospitalization				
Present	11(29.7)	26(70.3)		<0.001f
Absent	3(3.4)	84(96.6)		

	Subsequent injury		Test value	p
	Present n(%)	Absent n(%)		
ICU admission				
Present	2(16.7)	10(83.3)		0.625f
Absent	12(10.7)	100(89.3)		
Treatment				
Conservative	6(5.5)	104(94.5)		<0.001f
Tube thoracostomy	8(57.1)	6(42.9)		
Mortality				
Present	0(0)	2(100)		1.000f
Absent	14(11.5)	108(88.5)		
Rib fracture				
M (IQR, min-max)	2 (4, 0-6)	0 (2, 0-11)	540.5	0.043u
Length of ICU stay				
M (IQR, min-max)	0 (0, 0-4)	0 (0, 0-12)	736.0	0.601u
Length of hospital stay				
M (IQR, min-max)	7 (9.2, 0-15)	0(0, 0-18)	409.5	<0.001u

n: Number of patients, %: percentage of patients, χ : mean, SD: standard deviation, M: Median, IQR: interquartile range, min: minimum, max: maximum, ICU: intensive care unit, χ^2 Ki-kare testi, f Fisher's Exact Test, u Mann-Whitney U Test,

Table 3B. Analyses related to unexpected injuries

	Unexpected injury		Test value	p
	Present n(%)	Absent n(%)		
Day of injury detection				
Day 1	1(0.9)	109(99.1)	87.985	<0.001 χ^2
Day 2	4((80)	1(20)		
Day 3	1(50)	1(50)		
Subsequent days	6(85.7)	1(14.3)		
Primary trauma site				
Left upper-posterior	0(0)	5(100)	4.037	0.776 χ^2
Left upper-anterior	1(20)	4(80)		
Right upper-anterior	2(15.4)	11(84.6)		
Right upper-posterior	2(15.4)	11(84.6)		
Left lower-posterior	2(11.8)	15(88.2)		
Right lower-anterior	3(9.7)	28(90.3)		
Left lower-anterior	1(3.2)	32(97)		
Type of trauma				
Animal kick	1(100)	0(0)	10.431	0.015
Assault	4(13.8)	25(86.2)		
Fall	3(7.5)	37(92.5)		
Traffic accident	4(7.4)	50(92.6)		
Hospitalization				
Present	10(27)	27(73)	0.001 f	
Absent	2(2.3)	85(97.7)		
ICU admission				
Present	2(16.7)	10(83.3)	0.327 f	
Absent	10(8.9)	102(91.1)		
Treatment				
Conservative	5(4.5)	105(95.5)	< 0.001 f	
Tube thoracostomy	7(50)	7(50)		

	Unexpected injury		Test value	p
	Present n(%)	Absent n(%)		
Mortality				
Present	0(0)	2(100)		0.815 f
Absent	12(9.8)	110(90.2)		
Rib fracture				
M (IQR, min-max)	1.5(1.7, 0-2)	0(2, 0-11)	433.0	0.024 u
Length of ICU stay				
M (IQR, min-max)	0(0, 0-4)	0(0,0-12)	626.0	0.448 u
Length of hospital stay				
M (IQR, min-max)	7(9.7.3-15)	0(0,0-18)	341.5	< 0.001 u

n: Number of patients, %: percentage of patients, χ : mean, SD: standard deviation, M: Median, IQR: interquartile range, min: minimum, max: maximum, ICU: intensive care unit, χ^2 Ki-kare testi, f Fisher's Exact Test, u Mann-Whitney U Test,

3.5. Analyses Related to Poor Outcome

Intercostal muscle density was significantly higher in patients with poor outcome compared with those without poor outcome (75.06±27.35 HU vs. 50.40±26.93 HU; $t=-4.350$; $p<0.001$). The mean difference was 24.66 HU (95% CI: 13.44-35.88), with a large effect size (Cohen's $d=0.912$). Intercostal muscle density showed significant discriminative performance in predicting poor outcome (AUC=0.746; 95% CI: 0.664-0.858; $p<0.001$). For the cut-off value of 54.95 HU determined by ROC analysis, sensitivity was 80.0% and specificity was 63.8% (Figure 1c). Multivariate logistic regression showed that intercostal muscle density was independently associated with poor outcome (OR=1.041; 95% CI: 1.020-1.062; $p<0.001$). Number of rib fractures was also identified as an independent predictor of poor outcome (OR=1.885; 95% CI: 1.407-2.527; $p<0.001$). No significant relationship was found between age and sex and poor outcome ($p=0.767$ and $p=0.920$, respectively) (Table 4).

Table 4. Analyses related to poor outcome

Variable	B	SE	OR(Exp(B))	%95 CI	p
HU	0.040	0.010	1.041	1.020–1.062	<0.001
Age	-0.005	0.016	0.995	0.964–1.028	0.767
Gender (Female vs Male)	0.056	0.559	1.058	0.354–3.166	0.920
Number of rib fractures	0.634	0.149	1.885	1.407–2.527	<0.001

OR (odds ratio) values represent Exp(B) from multivariate logistic regression analysis. B: regression coefficient, SE: standard error, CI: confidence interval, HU: Hounsfield unit.

4. Discussion

This study demonstrated that intercostal muscle density measured at the primary trauma site was significantly associated with subsequent injuries, unexpected injuries, and poor clinical outcome in patients with isolated blunt thoracic trauma. In addition to these three outcomes, HU values were also significantly higher in patients who underwent tube thoracostomy and in those who developed poor clinical outcome. The observation of significant discriminative performance around similar cutoff values (56.0 and 54.95

HU) for three distinct but clinically related outcomes suggests that our findings represent a consistent indicator of clinical severity rather than a coincidental result. According to conventional AUC interpretation criteria, the values obtained for subsequent injury (AUC=0.773), unexpected injury (AUC=0.754), and poor outcome (AUC=0.746) correspond to moderate discriminatory performance rather than excellent diagnostic accuracy. Furthermore, in multivariate logistic regression analysis, intercostal muscle density and number of rib fractures emerged as independent predictors of poor clinical outcome. We believe these results indicate that intercostal muscle density may have a practical cutoff value that could be used for clinical decision support during initial evaluation. However, given the moderate discriminatory performance and the retrospective, single-center design of our study, the proposed cutoff values require external validation in independent, prospective cohorts before they can be recommended for routine clinical decision-making.

The relationship between muscle density and clinical outcome has previously been examined in the literature in oncologic and abdominal surgery populations, in the context of myosteatosis, a chronic process. These studies have shown that low muscle density (increased intramuscular fat infiltration) is associated with sarcopenia, decreased functional capacity, and poor prognosis^{18,19}. In acute trauma, however, an increase in this parameter has been reported to reflect a different pathophysiology. It has been suggested that this rise on CT may be an acute imaging finding reflecting the severity of soft tissue damage in the affected region, related to intramuscular hemorrhage, edema, and inflammatory cell infiltration^{20,21}. Consistent with this, HU values in our study differed according to the day on which the injury was detected. The finding that HU values were higher in injuries detected on day 2 and thereafter compared with those detected on day 1 suggests that the increase in density may be related to edema and hemorrhagic changes that develop over time.

The positive correlation found between HU value and length of hospital stay, in contrast to the lack of significant correlation with rib fracture count and length of intensive care unit stay, is noteworthy. This finding suggests that intercostal muscle density is not merely a reflection of structural damage, but rather carries additional prognostic information independent of this variable. Furthermore, in multivariate analysis, both variables were found to be independently associated with poor outcome. Given that number of rib fractures is a well-established and commonly used parameter for predicting outcome in thoracic trauma^{7,22,23}, this finding supports the consistency of our cohort with the existing literature and suggests that intercostal muscle density may provide a complementary contribution to existing risk assessment tools.

The lack of a significant association between age and sex and poor outcome in our study does not fully align with studies in the thoracic trauma literature that have particularly associated advanced age with poor prognosis^{24,25}. This may be attributable to our limited sample size, the relatively narrow age range of our study population, or the possibility that part of the age-related risk was accounted for by the inclusion of intercostal muscle density and number of rib fractures in the model. Similarly, the very small number of patients with mortality in our study (n=2) is a major limitation, and any apparent relationship — or lack thereof — between HU and mortality in this cohort should not be generalized or considered statistically conclusive; this finding requires confirmation in larger cohorts with a sufficient number of mortality events.

This is the first study to evaluate intercostal muscle density directly at the primary trauma site, as opposed to general skeletal muscle groups, in patients with isolated blunt thoracic trauma, and to examine its prognostic relevance across these three clinical endpoints. The strengths of our study include the standardized determination of the trauma site through combined assessment of the patient's own history, physical examination

findings, and CT images; the use of a standardized ROI protocol for measurements; and the evaluation of multiple clinical outcomes with multivariate analyses.

However, our study also has several important limitations. First, the study was designed as single-center and retrospective, and the sample size is limited, particularly for mortality ($n=2$) and some subgroups; this reduces the statistical power of some analyses. Second, the classification system used to divide the thorax into eight regions is based on an approach that has not yet been standardized in the literature. Third, intercostal muscle density measurements were performed using a manual ROI method by a single observer. Neither interobserver nor intraobserver reliability was assessed in this study, and the measurement method itself is not based on a standardized approach in the literature. This raises the possibility of measurement variability that could affect the reproducibility of the reported cutoff values, and future studies should assess inter- and intraobserver agreement using multiple independent observers before these measurements can be adopted as a standardized clinical tool. Fourth, the composite 'poor outcome' endpoint combines clinically heterogeneous events — ranging from tube thoracostomy, a relatively common intervention, to mortality, the most severe possible outcome — within a single category. Although this approach allowed evaluation of any deviation from an uncomplicated course, it may obscure differences in severity among its components, and future studies should consider analyzing these events separately or using a weighted/ordinal severity scale. Fifth, although the primary trauma site was determined using a combination of physical examination and CT findings, patient-reported pain location constituted one of the three criteria used in this assessment, which may introduce an element of subjectivity and recall bias into site determination. Finally, measurements reflect only a single time point at presentation, and it was not possible to assess the temporal course of changes in muscle density. Prospective, multicenter studies with larger sample sizes are needed to validate our findings.

5. Conclusion

In patients with isolated blunt thoracic trauma, intercostal muscle density measured at the primary trauma site may serve as a promising, but not yet validated, imaging parameter that helps predict subsequent injuries, unexpected injuries, and poor clinical outcome, and that can be easily obtained from routine thoracic CT images without additional cost. When evaluated together with number of rib fractures, intercostal muscle density may provide a complementary contribution to current risk stratification approaches and may highlight the need for close clinical and radiological follow-up even in patients who initially appear to be at low risk.

CRedit authorship contribution statement: Kadir Baturhan Çiflik: Writing– review & editing, Writing– original draft, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Conflict of interest: KBC reports no conflict of interest and no financial disclosure was declared by the author.

AI Disclosure Statement: During the preparation of this manuscript, the authors used Claude Sonnet 5 for the purpose of English language editing. Also www.tureng.com was used as a dictionary during the English language editing. The authors reviewed and take full responsibility for all content in the manuscript.

Ethics committee approval: The study was conducted at Kırıkkale Yüksek İhtisas Hospital in Türkiye. The Ethics Committee of Kırıkkale University approved the study protocol under decision

number 2026.03.22. The study has been conducted in accordance with the World Medical Association Declaration of Helsinki.

Patient consent for publication: Due to the retrospective nature of the study, written informed consent was not obtained from the patients.

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Funding: The author received no financial support for the research and/or authorship of this article.

References

1. Dogrul BN, Kiliccalan I, Asci ES, Peker SC. Blunt trauma related chest wall and pulmonary injuries: An overview. *Chin J Traumatol*. 2020;23(3):125-138. doi: 10.1016/j.cjtee.2020.04.003.
2. Oikonomou A, Prassopoulos P. CT imaging of blunt chest trauma. *Insights Imaging*. 2011;2(3):281-295. doi: 10.1007/s13244-011-0072-9.
3. Coccolini F, Cremonini C, Moore EE, Civil I, Balogh Z, Leppaniemi A, et al. Thoracic trauma WSES-AAST guidelines. *World J Emerg Surg*. 2025;20(1):78. doi: 10.1186/s13017-025-00651-1.
4. Misthos P, Kakaris S, Sepsas E, Athanassiadi K, Skottis I. A prospective analysis of occult pneumothorax, delayed pneumothorax and delayed hemothorax after minor blunt thoracic trauma. *Eur J Cardiothorac Surg*. 2004;25(5):859-64. doi: 10.1016/j.ejcts.2004.01.044.
5. Plourde M, Émond M, Lavoie A, Guimont C, Le Sage N, Chauny JM, et al. Cohort study on the prevalence and risk factors for delayed pulmonary complications in adults following minor blunt thoracic trauma. *CJEM*. 2014;16(2):136-43. doi: 10.2310/8000.2013.131043.
6. Pape HC, Remmers D, Rice J, Ebisch M, Krettek C, Tscherne H. Appraisal of early evaluation of blunt chest trauma: development of a standardized scoring system for initial clinical decision making. *J Trauma*. 2000;49(3):496-504. doi: 10.1097/00005373-200009000-00018.
7. Peek J, Ochen Y, Saillant N, Groenwold RHH, Leenen LPH, Uribe-Leitz T, et al. Traumatic rib fractures: a marker of severe injury. A nationwide study using the National Trauma Data Bank. *Trauma Surg Acute Care Open*. 2020;5(1):e000441. doi: 10.1136/tsaco-2020-000441.
8. 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. doi:10.1007/s12055-021-01312-z
9. Ouwerkerk JJJ, Argandkov D, Gerban A, Proaño-Zamudio JA, Dorken-Gallastegi A, Hwabejire JO, et al. Delayed hemothorax readmissions after rib fracture in blunt trauma patients. *J Clin Orthop Trauma*. 2023; 45:102259. doi: 10.1016/j.jcot.2023.102259.
10. Chen X, Gao X, Wang R, Wei Z, Wang J, Wang M, et al. Opportunistic muscle density assay during CT lung cancer screening for low muscle quality evaluation in older adults: a multicenter study. *Aging Clin Exp Res*. 2025;37(1):41. doi:10.1007/s40520-025-02933-9.
11. Chianca V, Albano D, Messina C, Gitto S, Ruffo G, Guarino S, et al. Sarcopenia: imaging assessment and clinical application. *Abdom Radiol (NY)*. 2022;47(9):3205-3216. doi:10.1007/s00261-021-03294-3
12. van Vugt JLA, Coebergh van den Braak RRJ, Lalmahomed ZS, Vrijland WW, Dekker JWT, Zimmerman DDE, et al. Impact of low skeletal muscle mass and density on short and long-term outcome after resection of stage I-III colorectal cancer. *Eur J Surg Oncol*. 2018;44(9):1354-1360. doi: 10.1016/j.ejso.2018.05.029.
13. Guo H, Chen S, Zheng T, Ding P, Yang J, Wu H, et al. Association of low skeletal muscle mass and radiodensity with clinical outcomes in patients undergoing robotic radical gastric cancer surgery: a population-based retrospective cohort study. *BMC Cancer*. 2025;25(1):741. doi: 10.1186/s12885-025-14156-2.
14. Xi F, Tan S, Gao T, Ding W, Sun J, Wei C, et al. Low skeletal muscle mass predicts poor clinical outcomes in patients with abdominal trauma. *Nutrition*. 2021; 89:111229. doi: 10.1016/j.nut.2021.111229.
15. Park J, Oh Y, Kwon S, Lee J, Kim M, Choi D, et al. Impact of CT-Defined Sarcopenia on Clinical Outcomes in Elderly Trauma Patients: A Retrospective Korean Cohort Study. *Healthcare (Basel)*. 2025;13(18):2321. doi:10.3390/healthcare13182321
16. Hefny AF, Kunhivalappil FT, Paul M, Almansoori TM, Zoubeydi T, Abu-Zidan FM. Anatomical locations of air for rapid diagnosis of pneumothorax in blunt trauma patients. *World J Emerg Surg*. 2019; 14:44. doi: 10.1186/s13017-019-0263-0.

17. Li S, Sun D, Wang C, Hu P, Jin F, Huang W. Fracture Mapping in High-Energy Chest Trauma. *Journal of Clinical Medicine*. 2024; 13(20):6127. <https://doi.org/10.3390/jcm13206127>.
18. Chang Y-Y, Cheng B. Prognostic impact of myosteatosi s in patients with colorectal cancer undergoing curative surgery: an updated systematic review and meta-analysis. *Front. Oncol*. 2024; 14:1388001. doi: 10.3389/fonc.2024.1388001.
19. Giudici S, Lanza E, Lofino L, Barison A, Ammirabile A, Mauri G, et al. Sarcopenia and Myosteatosi s as a Predictor of Post-Operative Outcomes in Patients Undergoing Laparotomy for Abdominal Emergencies. *J Clin Med*. 2025;14(18):6639. doi:10.3390/jcm14186639
20. van Ee EPX, Verheul EAH, Dijkink S, Krijnen P, Veldhuis W, Feshtali SS, et al. The correlation of CT-derived muscle density, skeletal muscle index, and visceral adipose tissue with nutritional status in severely injured patients. *Eur J Trauma Emerg Surg*. 2024;50(6):3209-3215. doi: 10.1007/s00068-024-02624-6.
21. Tonolini M, Ippolito S, Patella F, Petullà M, Bianco R. Hemorrhagic complications of anticoagulant therapy: role of multidetector computed tomography and spectrum of imaging findings from head to toe. *Curr Probl Diagn Radiol*. 2012;41(6):233-47. doi: 10.1067/j.cpradiol.2012.05.001.
22. Chien CY, Chen YH, Han ST, Blaney GN, Huang TS, Chen KF. The number of displaced rib fractures is more predictive for complications in chest trauma patients. *Scand J Trauma Resusc Emerg Med*. 2017;25(1):19. doi: 10.1186/s13049-017-0368-y.
23. Söderlund T, Ikonen A, Pyhälä T, Handolin L. Factors associated with in-hospital outcomes in 594 consecutive patients suffering from severe blunt chest trauma. *Scand J Surg*. 2015;104(2):115-20. doi: 10.1177/1457496914543976.
24. Lotfipour S, Kaku SK, Vaca FE, Patel C, Anderson CL, Ahmed SS, et al. Factors associated with complications in older adults with isolated blunt chest trauma. *West J Emerg Med*. 2009;10(2):79-84. PMID: 19561823; PMCID: PMC2691509.
25. Bulger EM, Arneson MA, Mock CN, Jurkovich GJ. Rib fractures in the elderly. *J Trauma*. 2000;48(6):1040-6. doi: 10.1097/00005373-200006000-00007.