European **Rev**iew for **Med**ical and **Pharmacol**ogical **Sci**ences | 2022; 26: 1170-1177

The effect of skeletal muscle area and attenuation in patients with sternum fracture due to blunt chest trauma

H.G. YAVAŞ[1], F. UFUK[2], A. AKÇAY[3], G. ÖZTÜRK[4]

[1]Department of Radiology, Kırşehir Education and Research Hospital, Kırşehir, Turkey
[2]Department of Radiology, Pamukkale University, Denizli, Turkey
[3]Zile Public Hospital, Tokat, Turkey
[4]Department of Chest Surgery, Pamukkale University, Denizli, Turkey

Abstract. – OBJECTIVE: This study aims to retrospectively investigate the imaging features of patients with sternum fracture (SF) and concomitant organ injuries. We also aimed to evaluate the potential prognostic effect of skeletal muscle area (TMA) and muscle attenuation (MuA) values.

PATIENTS AND METHODS: Computed tomography (CT) images of patients with SF were re-evaluated by two observers (Observer-1 and 2). Observer-3 has measured TMA and MuA values. Observer-1 has repeated the measurements blindly to the first measurement results to evaluate the inter-observer agreement. The length of hospital stay, death, hemiplegia, or quadriplegia were investigated from the archives. Mann-Whitney U-test or Student's *t*-test was used to investigate the relationship between linear variables. The intraclass correlation coefficient (ICC) score was used to evaluate the interobserver agreement. Logistic regression analysis was used to estimate the relative effect of variables by calculating unadjusted odds ratios (ORs) for categorical outcomes.

RESULTS: Sixty-five patients had SF and 53 patients had SF and concomitant organ injuries. The most common injuries accompanying SF were rib fracture (73.58%) and lung contusion (60.38%). Manubrium fracture was the most common fracture location (52.3%), and 18 patients (27.7%) had displaced SF. Eight patients (15.1%) were discharged with plegia and five (9.4%) died. Hemothorax, displaced SF and decreased MuA were predictors of prolonged hospital stay, and the presence of cardiac contusion, displaced SF, hemothorax, and vertebra body fracture were independent factors for death.

CONCLUSIONS: The presence of a displaced SF and decreased MuA value are important prognostic factors in patients with SF.

Key Words:
Low skeletal body mass, Prognosis, Sternal fracture, Computed tomography.

Introduction

Sternal fractures (SFs) are rarely seen in trauma patients and 3% to 8% of blunt trauma victims[1]. SF is usually associated with high energy trauma and other organ injuries[2,3]. Isolated SF is rare and usually of no clinical significance and is treated conservatively[2]. The presence of accompanying organ injuries in a patient with SF should be carefully investigated on computed tomography (CT) and clinical examination because there is a high probability of other organ injuries.

Sarcopenia means a decrease in skeletal muscle mass (SMM), function, and strength, and it is related to aging, increased catabolism, and cachexia[4]. It has been shown that sarcopenia or decreased SMM are associated with poor prognosis in many populations, including patients with cancer or trauma, patients in intensive care, and patients undergoing various surgical procedures[5-7]. Cross-sectional total skeletal muscle area (TMA) and muscle attenuation (MuA) values at the L3 vertebra level on computed tomography (CT) have been shown to be good indicators of SMM. Decreased cross-sectional TMA and MuA on CT are strongly associated with poor outcomes in the postoperative or trauma period in elderly patients[8,9]. However, to the best of our knowledge, the effect of TMA and MuA values regardless of age in trauma patients is unknown.

Herein, we aimed to retrospectively investigate the imaging features of patients with SF and concomitant organ injuries. We also aimed to evaluate the potential prognostic effect of TMA and MuA values at the L3 vertebra level on CT in patients with SF due to blunt trauma.

Corresponding Author: Hüseyin Gökhan Yavaş, MD; e-mail: huseyingokhanyavas@gmail.com

Patients and Methods

The Institutional Review Board (IRB) approved this retrospective, cross-sectional study (IRB approve number: 60116787-020/78468), and IRB waived the informed consent requirement.

Study Population

Patients admitted to the Emergency Department between January 2010 and June 2019 and underwent a full-body CT scan due to major blunt trauma were retrospectively investigated from the hospital archive. These patients who underwent full-body CT and had the words "sternum fracture" in the official radiology reports were reevaluated. The study did not include patients under 18 years, patients referred to the external center, patients with incomplete CT images, or non-diagnostic CT image quality. Patients with lesions obscure skeletal muscles in the lumbar region (such as mass or hematoma) were excluded from the study.

CT Protocols

All CT scans of the full-body were performed using a multi-detector CT scanner (16 detector rows, Brilliance; Philips Healthcare, Best, Netherlands). CT protocol parameters are specified in Table I. The tube voltage and tube current were adjusted to the patient's body weight. The intravenous non-ionic iodinated contrast agent (350 mg/100 ml, iohexol) was used at a 1 ml/kg dose in patients with normal serum creatinine levels and no history of iodinated contrast agent allergy. CT images were obtained without intravenous contrast medium in patients with contraindications for an iodinated contrast agent.

Evaluation of CT Images

Consensus by two observers (Observer 1 and 2) reviewed the patients' full-body CT scans with sternal fractures. The presence of sternal fracture (yes/no), localization of the sternal fracture (manubrium, upper or lower half of sternal body), and the degree of displacement (non-displaced, mildly displaced, or displaced) were investigated. The SF was evaluated as non-displaced if there was no dissociation, mild displaced if ≤ 3 mm dissociation, and displaced if > 3 mm dissociation (Figures 1 and 2).

The presence of rib fracture, pulmonary contusion or laceration, and aortic injury were investigated on chest CT exams. The presence of cardiac contusion was evaluated using CT, laboratory results, and echocardiography findings. Moreover, the presence of pneumothorax, hemothorax, pneumomediastinum, and retrosternal hematoma (if present, the maximum thickness of hematoma was measured in the sagittal plane) were investigated. Moreover, the presence of solid abdominal organ or intestinal injuries was evaluated according to the American Association for Surgery of Trauma-Injury Scoring Scale[10,11]. If the patient's cranial and cervical CT is also available, the presence of fractures (in the neurocranium or viscerocranium), intracranial hemorrhage (subdural, epidural, subarachnoid hemorrhage), vertebral fracture (body fracture or posterior elements fracture), and spinal cord injury were investigated on CT exams (Table II).

Quantitative Muscle Area and Attenuation Measurements

Before quantitative tissue evaluation, all CT images were utterly anonymized. Quantitative TMA and MuA values were measured at the lower part of the third lumbar vertebra (L3) on the axial CT images using a freely accessible DICOM viewer (Osirix v11.0; Pixmeo SARL, Bernex, Switzerland) by a trained and board-certified radiologist (Observer 3) who blinded to the clinical information and body CT findings. Hounsfield unit (HU) thresholds for skeletal muscle (-29 to +150 HU) were determined, and the TMA, as described in previous studies[12,13]. Besides, the mean MuA values were noted in HU according to TMA measurements (Figure 3). Observer-1 has measured the TMA and MuA values blindly to the

Table I. The imaging parameters of the full-body CT scan.

	mA	kV	Matrix	Rotation Time	Slice of Thickness
Head CT	188	120	512x512	0.75 s	1.5 mm
Cervical Vertebra CT	131	120	512x512	0.75 s	1.5 mm
Chest CT	119	120	512x512	0.75 s	1.5 mm
Abdominal CT	119	120	512x512	0.75 s	1.5 mm

mA; milliampere, kV; kilovoltage, CT; computed tomography.

Table II. Full-body CT Scan Indications According to Injury Severity Score[11,12].

Trauma patients with one of the following parameters at hospital arrival
• Respiratory rate ≥30/min or ≤10/min • Pulse ≥120/min • systolic blood pressure ≤100 mmHg • Estimated exterior blood loss ≥500 ml • Glasgow Coma Score ≤13 • Abnormal pupillary reaction
OR Patients with a clinical suspicion of one of the following diagnoses • Fractures from at least two long bones • Flail chest, open chest or multiple rib fractures • Severe abdominal injury • Pelvic fracture • Unstable vertebral fractures/spinal cord compression
OR Patients with one of the following injury mechanisms • Fall from a height (>3 meters/>10 feet) • Ejection from a vehicle • Death of occupant in same vehicle • Severely injured patient in same vehicle • Wedged or trapped chest/abdomen

first measurement results using the same method to evaluate the inter-observer agreement.

Clinical Assessment

The length of hospital stay, death within the hospitalization period, presence of dependency (hemiplegia, quadriplegia) during or after discharge were retrospectively investigated from the clinical archives.

Statistical Analysis

In the statistical analyses, IBM SPSS ver. 21.0 (IBM Corp., Armonk, NY, USA) and MedCalc (MedCalc Software Ltd, Ostend, Belgium) statistical software were used. Continuous variables were shown as mean and standard deviation (SD) or median and interquartile ranges (IQR) in normal and abnormally distributed data. Categorical variables were shown as percentages. Mann-Whitney U-test or Student's *t*-test was used to investigate the relationship between TMA, MuA values, localization of the sternal fracture, and degree of displacement of the sternal fracture concomitant injuries. The intraclass correlation coefficient (ICC) score was used to evaluate the interobserver agreement. An ICC score < 0.4 was accepted as poor agreement, 0.4-0.75 as moderate, 0.75-0.9 as good agreement, and > 0.9 as excellent agreement. Spearman correlation coefficients (r) and linear regression analyses were used to evaluate the correlation between continuous variables. Correlation coefficients between 0.2 and 0.4 were considered weak correlations, between 0.4 and 0.6 as a medium, between 0.6 and 0.8 as strong, and > 0.8 as an excellent correlation. Univariate analysis was used to estimate the relative effect of variables (length of hospital stay, plegia, and death), and odds ratios (ORs) were calculated for categorical outcomes.

Results

A total of 2957 patients underwent a full-body CT scan for major blunt trauma between January 2010 and June 2019. Sixty-five of these patients (2.2%) had the terms "sternal fracture" in their official radiology reports, and two observers re-evaluated CT images of those patients. These 65 patients were confirmed to have a sternal fracture on re-evaluation. The most common mechanism of injury was motor vehicle collisions (n = 54, 83.1%), six patients (9.2%) had SF due to falling from the height, and four patients (6.2%) had a crushing injury, and a patient (1.6%) had an assault by a blunt object. Isolated sternal fractures were detected in 18.46% (n = 12) of the patients, and 53 patients (34 male; mean age, 50.7 ± 18.1 years; range, 19-85 years) had SF and concomitant injuries (Figure 4). The most common injuries accompanying sternum fractures in 53 patients were rib fracture (n=39, 73.58%) and lung contusion (n=32, 60.38%). The other concomitant injuries are shown in Table III.

Fifty-three of the 65 patients (81.54%) had a measurable retrosternal hematoma, and the mean

Table III. Concomitant injuries in patients with sternal fracture (SF)[11,12].

	Total Population (n = 53)	Male (n = 34) n (%)	Female (n = 19) n (%)
Retrosternal Hematoma	42 (79.25)	30 (88.24)	12 (63.16)
Lung Contusion	32 (60.38)	23 (67.65)	9 (47.37)
Lung Laceration	7 (13.21)	6 (17.65)	1 (5.26)
Pleural Effusion (<20 HU)	6 (11.32)	4 (11.76)	2 (10.53)
Pericardial Effusion (<20 HU)	3 (5.66)	1 (2.94)	2 (10.53)
Rib Fracture	39 (73.58)	27 (79.41)	12 (63.16)
Single	13 (24.53)	9 (26.47)	4 (21.06)
Multiple	26 (49.06)	18 (52.94)	8 (42.11)
Pneumothorax	22 (41.5)	17 (50)	5 (26.32)
Cardiac Contusion	4 (7.55)	4 (11.76)	0
Pneumomediastinum	9 (16.98)	7 (20.59)	2 (10.53)
Hemothorax	18 (33.96)	14 (41.18)	4 (21.06)
Vertebral Fracture*	26 (49.06)	18 (52.94)	8 (42.11)
Stable	16 (30.19)	12 (35.29)	5 (26.32)
Unstable	10 (18.87)	6 (17.65)	3 (15.79)
Scapula Fracture	9 (16.98)	6 (17.65)	3 (15.79)
Clavicula Fracture	16 (30.19)	12 (35.29)	4 (21.06)
Renal Injury[2]	4 (7.55)	4 (11.76)	0
Mild	3 (5.66)	3 (8.82)	
Severe	1 (1.89)	1 (2.94)	
Bowel Injury	1 (1.89)	1 (2.94)	0
Liver Injury[2]	2 (3.77)	1 (2.94)	1 (5.26)
Mild	1 (1.89)	0	1 (5.26)
Severe	1 (1.89)	1 (2.94)	0
Spleen Injury**	9 (16.98)	6 (17.65)	3 (15.79)
Mild	5 (9.43)	3 (8.82)	2 (10.53)
Severe	4 (3.77)	3 (8.82)	1 (5.26)
Neurologic Disability	8 (15.09)	6 (17.65)	2 (10.53)
1 (5.26)			
1 (5.26)			
Quadriplegia	3 (5.66)	2 (5.88)	
Paraplegia	5 (9.43)	4 (11.76)	
Pelvic Fracture	4 (11.76)	2 (5.88)	2 (10.53)
Fracture in Head CT	13 (24.53)	9 (26.47)	4 (21.06)
Neurocranium	4 (7.55)	3 (8.82)	1 (5.26)
Viscerocranium	9 (16.98)	6 (17.65)	3 (15.79)
Intracranial Hemorrhage***	8 (15.09)	6 (17.65	2 (10.53)
Extraparenchymal	6 (11.32)	4 (11.76)	4 (11.76)
Intraparenchymal	2 (3.77)	1 (2.94)	1 (5.26)

* Vertebral fractures were evaluated according to TLICS score, and four and above were considered unstable fractures.
** Liver, spleen, and kidney injuries were evaluated according to the AAST score. Grades 1 and 2 were considered mild; grades 3, 4, and 5 were considered severe.
*** One male and one female patient had both extraparenchymal and intraparenchymal bleeding.

hematoma thickness was 10 ± 6.5 mm. Manubrium fracture was found in 34 patients (52.3%), the upper half of corpus fracture was found in 13 patients (20%), and the lower half of corpus in 18 patients (27.7%). Eighteen patients (27.7%) had displaced SF, 11 patients (16.9%) had minimally displaced SF, and 36 patients (55.4%) had non-displaced SF (Figures 1 and 2).

The median length of hospital stay was five days (IQR, 3 – 20.5 days), and there was no significant difference between female and male sexes in terms of length of hospital stay (p = 0.248, 15.5 ± 18.4 *vs.* 23.3 ± 35.7 days, respectively). Eight of the 53 patients (15.1%) were discharged with hemiplegia (n = 5, 9.4%) or quadriplegia (n = 3, 5.7%). Five of the 53 patients (9.4%) died during the hospital stay. Three of them died on the first day, one on the 48th day, and one on the 54th day of admission. The remaining 40 patients (75.5%) were discharged without any complications.

TMA values were significantly higher in males than in females (p = 0.048; 153.8 ± 45.6 mm^2 *vs.*

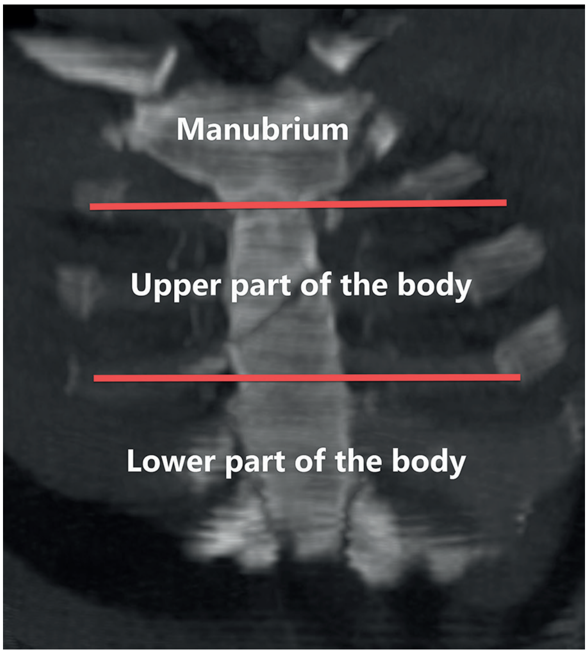

Figure 1. Coronal reformatted chest CT image shows the sternum parts; manubrium, the upper or lower half of the sternal body.

135 ± 35.9 mm^2, respectively). No significant difference was observed between males and females for MuA values ($p = 0.782$; 53.5 ± 2.4 HU, 53.3 ± 2.2 HU, respectively). There was significant correlation with TMA and MuA values ($p = 0.0001$, r = 0.641), and TMA, MuA values showed significant negative correlation with age (r = -0.822, r = -0.860, $p = 0.0001$ for both). There was excellent agreement between Observer-3 and Observer-1 for measurements of TMA with ICC of 0.943 (95% CI, 0.926-0.962) and MuA with ICC of 0.951 (95% CI, 0.930-0.963) (Figure 5).

TMA and MuA values were significantly lower in patients with retrosternal hematoma, pneumomediastinum, pneumothorax, and rib fractures than those without ($p \leq 0.04$). There was no significant relationship between TMA and MuA values and other concomitant injuries. There was no relationship between the localization of the sternal fracture and hospital stay duration, plegia development, or death ($p > 0.05$). The presence of a displacement of more than 3 mm in the sternal fracture was significantly associated with a hospital stay, plegia, and death ($p = 0.012$, r = 0.343 for hospital stay; $p = 0.033$, r = 0.293 for plegia; $p = 0.003$, r = 0.407).

In the univariate analyses, cardiac contusion ($p = 0.013$, odds ratio [OR]; 3.6 [95% CI, 2.1 to 17.3]), hemothorax ($p = 0.04$, OR; 4.13 [95% CI, 0.92 to 53.4]), and vertebra corpus fracture ($p = 0.042$, OR; 10.1 [95% CI, 0.91 to 52.1]) were significantly associated with death. When a hospitalization length of 10 days or longer is considered a "prolonged hospital stay", hemothorax ($p = 0.008$, OR; 15.8 [95% CI, 2 to 125.4]), displaced sternal fracture ($p = 0.015$, OR; 4.1 [95% CI, 1.3 to 12.7]), and incrementally decreasing MuA values ($p = 0.038$, OR; 1.36 [95% CI, 0.9 to 2.1]) were significantly associated with prolonged hospital stay. There was no significant relationship between other factors and death or prolonged hospital stay.

Discussion

The present study showed that hemothorax and decreased MuA lead to prolongation of hospital stay in patients with SF. The presence of cardiac contusion, hemothorax, and vertebra body fracture were independent factors for death. The presence of a displacement of more than 3 mm in the sternal fracture was significantly associated with a prolonged hospital stay, plegia, and death. Besides, patients with SF and concomitant retrosternal hematoma, pneumomediastinum, pneumothorax, or rib fractures had lower TMA and MuA values than those without.

In the literature, the incidence of sternal fracture has been reported to be about 3% to 8% of blunt trauma patients[1]. In line with the literature, we found the incidence of SF as 2.2% in blunt trauma patients. Besides, traffic accidents are the most common type of injury that causes trauma to SF, and similar to the literature, we found that in 54 patients (83.1%), the cause of SF was traffic accidents[14,15]. It has been shown that the most common accompanying injury of SF was rib fracture[14,15]. Similar to the literature, we found that most patients with SFs had concomitant injuries (81.54%), and the most frequent concomitant injury was rib fractures (73.58%). Von Garrel et al[14] reported that SF's most common location is the body of the sternum. However, Scheyerer et al[15] reported the most common SF location as the manubrium of the sternum. In the present study, we found that the most common SF location was the manubrium of the sternum (52.3%). Besides, we found that displaced sternal fractures are significantly correlated with a prolonged hospital stay, plegia, and death. These findings suggest that displaced fractures are associated with more severe trauma and concomitant injuries. Therefore, we

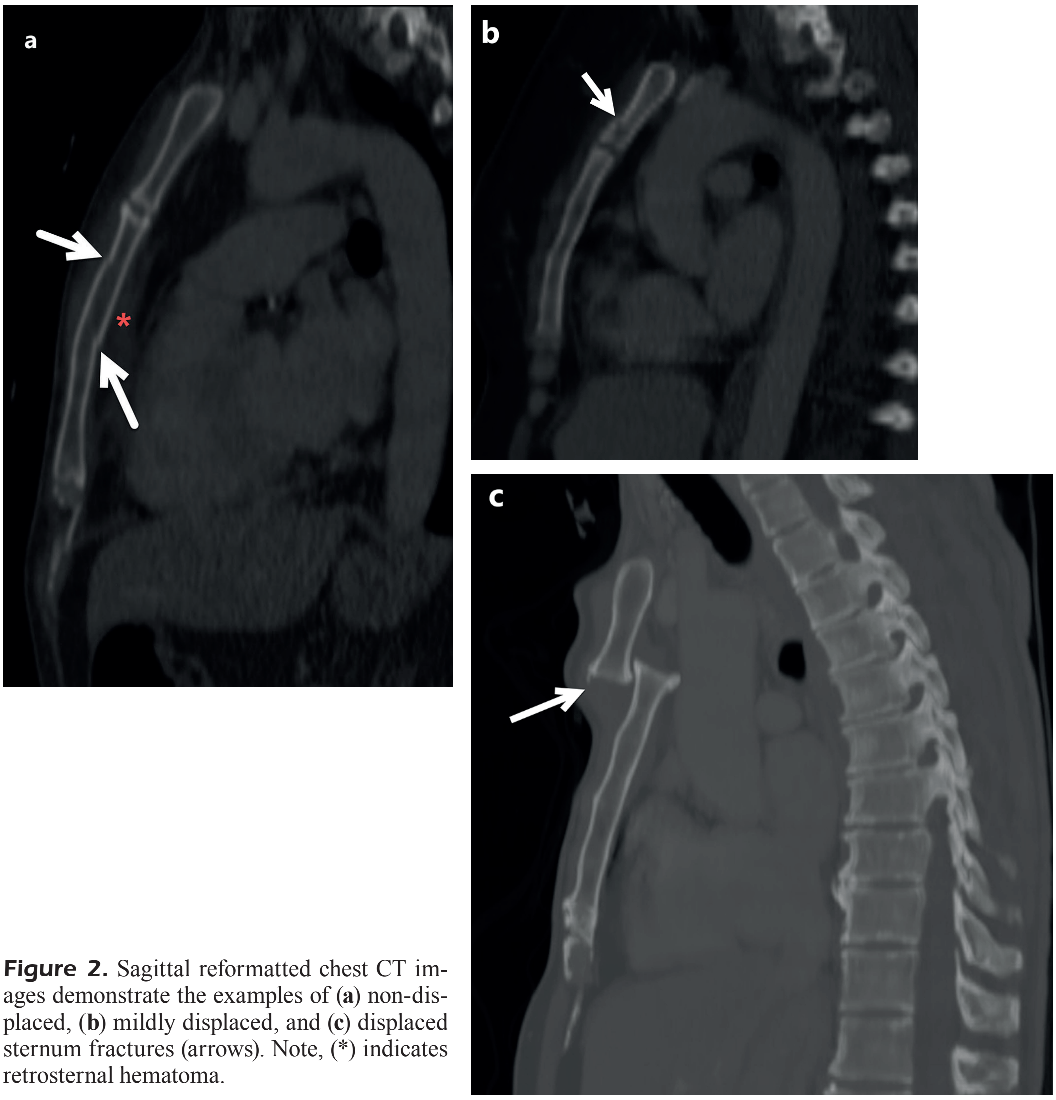

Figure 2. Sagittal reformatted chest CT images demonstrate the examples of (**a**) non-displaced, (**b**) mildly displaced, and (**c**) displaced sternum fractures (arrows). Note, (*) indicates retrosternal hematoma.

recommend that when displaced sternum fractures are detected, CT images should be carefully examined for other injuries, and patients should be followed closely.

Sarcopenia and decreased skeletal muscle mass are associated with poor prognosis and prolonged hospital stays in elderly trauma patients[16-20]. In the present study, trauma patients with sternum fractures did not only comprise of the elderly population, and decreased MuA value was significantly associated with a prolonged hospital stay. Besides, Yoo et al[21] reported that low muscle area values on CT are associated with the increased mortality rate in trauma patients aged 45 years and older. However, our study found no statistically significant relationship between mortality and TMA values. This may be due to the relative-

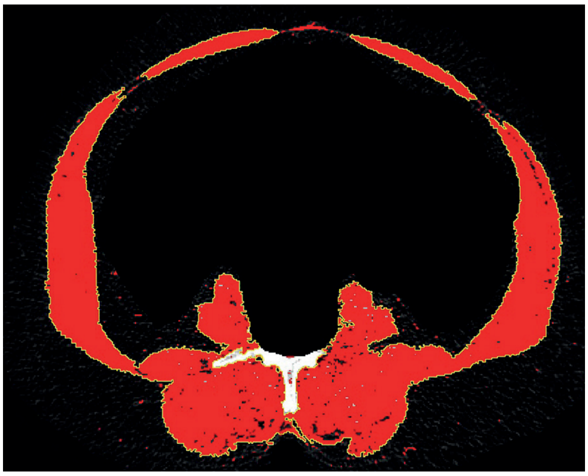

Figure 3. Total muscle area and muscle attenuation value measurement at the L3 vertebra corpus level on axial CT image.

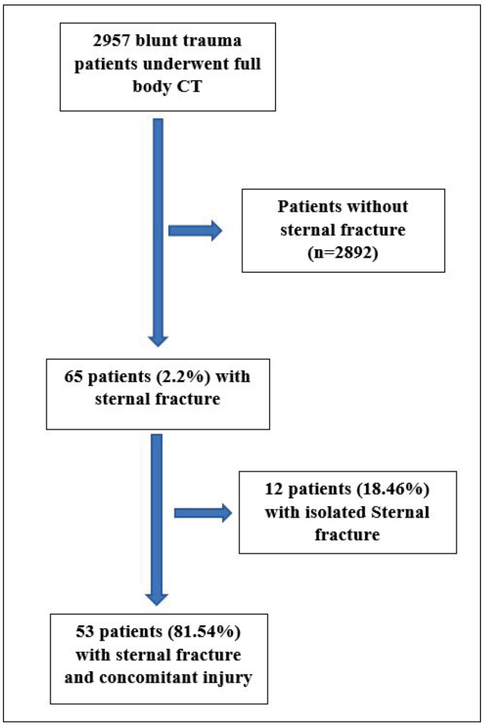

Figure 4. Flowchart showing the study population.

ly small number of cases in our study and the low number of deaths.

There were some limitations of our study. Our study's most important limitations were the relatively low number of patients and the study's retrospective nature. However, it is challenging to reach many patients with SF since sternum fractures are rarely seen, even in patients with significant trauma. Another limitation of our study was patients' inclusion with the words "sternum fracture" only in official radiology reports. Therefore, our study may not include patients with a sternal fracture but not specified in the official radiology report. Finally, there are many factors in the prognosis of patients with polytrauma. According to the American Association for Surgery of Trauma-Injury Scoring Scale, we evaluated the injuries only.

Conclusions

The skeletal MuA value is an important prognostic factor in patients with SF. The presence of a displacement of more than 3 mm in the sternal fracture

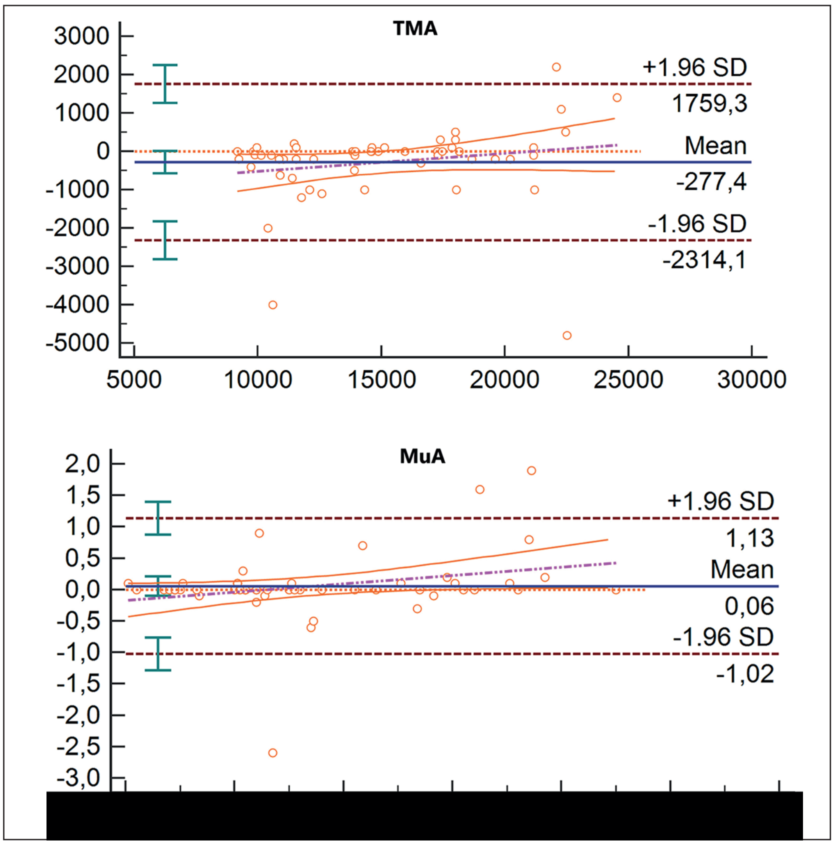

Figure 5. Bland-Altman plots show the agreement of the TMA and MuA measurement results between observers.

was significantly associated with a prolonged hospital stay, plegia, and death. Moreover, prospective studies with a larger population are needed.

ORCID ID

Hüseyin Gökhan Yavaş 0000-0003-4220-3482
Furkan Ufuk 0000-0002-8614-5387
Ahmet Akçay 0000-0001-7016-6004
Gökhan Öztürk 0000-0002-9390-4628

Ethics Approval

The study was approved by the Ethics Committee (60116787-020/84593), of the Pamukkale University Non-Interventional Clinical Research Ethics Committee on 19.12.2017.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1) Çelik B, Sahin E, Nadir A, Kaptanoglu M. Sternum fractures and effects of associated injuries. Thorac Cardiovasc Surg 2009; 57: 468-471.
2) Harley DP, Mena I. Cardiac and vascular sequelae of sternal fractures. J Trauma 1986; 26: 553-555.
3) Trinca GW, Dooley BJ. The effects of mandatory seat belt wearing on the mortality and pattern of injury of car occupants involved in motor vehicle crashes in Victoria. Med J Aust 1975; 1: 675-678.
4) Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, Martin FC, Michel J-P, Rolland Y, Schneider SM, Topinkova E, Vandewoude M, Zamboni M. Sarcopenia: European consensus on definition and diagnosis. Report of the European Working Group on Sarcopenia in Older People. Age Ageing 2010; 39: 412-423.
5) Moisey LL, Mourtzakis M, Cotton BA, Premji T, Heyland DK, Wade CE, Bulger E, Kozar RA. Skeletal muscle predicts ventilator-free days, ICU-free days, and mortality in elderly ICU patients. Crit Care 2013; 17: R206.
6) Sheetz KH, Waits SA, Terjimanian MN, Sullivan J, Campbell DA, Wang SC, Englesbe MJ. Cost of major surgery in the sarcopenic patient. J Am Coll Surg 2013; 217: 813-818.
7) Joglekar S, Nau PN, Mezhir JJ. The impact of sarcopenia on survival and complications in surgical oncology: a review of the current literature. J Surg Oncol 2015; 112: 503-509.
8) Farhat JS, Velanovich V, Falvo AJ, Horst HM, Swartz A, Patton JH, Rubinfeld IS. Are the frail destined to fail? Frailty index as predictor of surgical morbidity and mortality in the elderly. J Trauma Acute Care Surg 2012; 72: 1526-1531.
9) Makary MA, Segev DL, Pronovost PJ, Syin D, Bandeen-Roche K, Patel P, Takenaga R, Devgan L, Holzmueller CG, Tian J, Fried LP. Frailty as a predictor of surgical outcomes in older patients. J Am Coll Surg 2010; 210: 901-908.
10) Moore EE, Cogbill TH, Jurkovich GJ, Shackford SR, Malangoni MA, Champion HR. Organ injury scaling. J Trauma Inj Infect Crit Care 1995; 38: 323-324.
11) Moore EE, Cogbill TH, Malangoni MA, Jurkovich GJ, Champion HR, Gennarelli TA, McAninch JW, Pachter HL, Shackford SR, Trafton PG. Organ injury scaling, II: Pancreas, duodenum, small bowel, colon, and rectum. J Trauma 1990; 30: 1427-1429.
12) Jones KI, Doleman B, Scott S, Lund JN, Williams JP. Simple psoas cross-sectional area measurement is a quick and easy method to assess sarcopenia and predicts major surgical complications. Color Dis 2015; 17: O20-26.
13) Ufuk F, Herek D. Reference skeletal muscle mass values at L3 vertebrae level based on computed tomography in healthy Turkish adults. Int J Gerontol 2019; 13: 221-225.
14) von Garrel T, Ince A, Junge A, Schnabel M, Bahrs C. The sternal fracture: radiographic analysis of 200 fractures with special reference to concomitant injuries. J Trauma Inj Infect Crit Care 2004; 57: 837-844.
15) Scheyerer MJ, Zimmermann SM, Bouaicha S, Simmen H-P, Wanner GA, Werner CML. Location of sternal fractures as a possible marker for associated injuries. Emerg Med Int 2013; 2013: 1-7.
16) Fairchild B, Webb TP, Xiang Q, Tarima S, Brasel KJ. Sarcopenia and frailty in elderly trauma patients. World J Surg 2015; 39: 373-379.
17) Hwang F, McGreevy CM, Pentakota SR, Verde D, Park JH, Berlin A, Glass NE, Livingston DH, Mosenthal A. Sarcopenia is predictive of functional outcomes in older trauma patients. Cureus 2019; 11: e6154.
18) Leeper CM, Lin E, Hoffman M, Fombona A, Zhou T, Kutcher M, Rosengart M, Watson G, Billiar T, Peitzman A, Zuckerbraun B, Sperry J. Computed tomography abbreviated assessment of sarcopenia following trauma. J Trauma Acute Care Surg 2016; 80: 805-811.
19) Malekpour M, Bridgham K, Jaap K, Erwin R, Widom K, Rapp M, Leonard D, Baro S, Dove J, Hunsinger M, Blansfield J, Shabahang M, Torres D, Wild J. The effect of sarcopenia on outcomes in geriatric blunt Trauma. Am Surg 2017; 83: 1203-1208.
20) Wallace JD, Calvo RY, Lewis PR, Brill JB, Shackford SR, Sise MJ, Sise CB, Bansal V. Sarcopenia as a predictor of mortality in elderly blunt trauma patients. J Trauma Acute Care Surg 2017; 82: 65-72.
21) Yoo T, Lo WD, Evans DC. Computed tomography measured psoas density predicts outcomes in trauma. Surgery 2017; 162: 377-384.