Sternal Fractures in Blunt Chest Trauma: Retrospective Analysis of 330 Cases

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ABSTRACT

Objective: To analyse the range of injuries associated with sternal fracture (SF) and their clinical features and outcomes.
Study Design: Observational study.
Place and Duration of Study: Department of Emergency Medicine, Faculty of Medicine, Selcuk University, Konya, Turkey, from July 2010 to July 2020.
Methodology: Sternal fractures were considered in 330 patients with blunt trauma during the study period. They were categorised according to the Johnson and Branfoot classification and the *Arbeitsgemeinschaft fur Osteosynthesefragen* / Orthopaedic Trauma Association classification. Demographic data were collected, including age, gender, mechanism of injury, associated injuries, and the length of hospital stay.
Results: During the 10-year study period, a total of 4024 thoracic trauma patients were admitted to the emergency department. Of these, 330 (8.2%) had a sternal fracture. The median age of the patients was 41 (8-90) years, and 72.7% were male. Isolated sternal fractures occurred in 93 patients (28.2%). An additional thoracic injury was observed in 74 patients (22.4%) included in the study, and an accompanying extrathoracic injury was observed in 34 patients (10.3%). In 129 patients (39.1%), both thoracic and extrathoracic pathologies were detected, in addition to SF. The mortality rate among patients with isolated sternal fracture was 1.1%; the mortality rate among patients with sternal fracture accompanied by additional pathologies was 6.6%.
Conclusion: Sternal fractures are frequently associated with other injuries. Although isolated sternal fracture has a good prognosis, careful evaluation and clinical observation are essential for additional injuries.

Key Words: *Emergency medicine, Sternal fracture, Chest trauma.*

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INTRODUCTION

Sternal fracture (SF) accounts for approximately 3% to 8% of all thoracic trauma admissions.[1] SFs are encountered with increasing frequency in motor vehicle accidents, particularly since the introduction of seat belt legislation.[2] The mechanisms leading to SFs include both direct and indirect chest trauma. Direct trauma is typically caused by deceleration injuries and blunt anterior chest trauma; the majority of other cases are caused by direct impact from the steering wheel, falls, contact sports, pedestrian-vs.-car accidents. Indirect causes include deceleration injuries from motor vehicle accidents, stress fractures, and osteoporotic fractures.[3]

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SFs are commonly associated with other injuries to the heart and lungs; if a person is injured with force enough to fracture the sternum, myocardial and pulmonary contusions are likely. Other associated injuries include damage to blood vessels in the chest, myocardial rupture, head and abdominal injuries, flail chest, and vertebral fractures.[1] The disposition of patients diagnosed with SF depends on several variables, including potentially significant associated injuries, comorbidities, and inadequate pain control.[4,5]

The purpose of this study was to determine the frequency, mechanism of injury, significance, and associated morbidity and mortality among patients diagnosed with SFs.

METHODOLOGY

This study comprised a retrospective review of patients admitted to the Emergency Medicine Department (ED) between July 2010 and July 2020 due to trauma. Radiological investigations included X-ray and chest computed tomography (CT) in all cases. Data were obtained from hospital records; these included gender, age, mechanism of trauma, localisation of SF, associated injuries, electrocardiographic (ECG) and echo-

cardiographic (ECHO) findings, creatine kinase myocardial band (CK-MB) and troponin levels, hospital and intensive care unit length of hospital stay (LOS), and in-hospital mortality. Patients whose SFs developed due to cardiopulmonary resuscitation were not included in the study.

Isolated SF (ISF) was defined as any SF without accompanying thoracic or extrathoracic injuries. There are many systems for classifying SFs according to localisation and degree of displacement,[6] including the Johnson and Branfoot classification and the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classification.[7,8] The Johnson and Branfoot classification system divides SFs into four grades as: Grade I = unicortical; Grade II = bicortical (nondisplaced); Grade III = minimally displaced; and Grade IV = displaced fracture. The AO/OTA classification categorises SFs into three anatomical segments and divides each segment according to the shape of the fracture, defining transverse, oblique, and multifragmentary fractures for the manubrium, corpus, and xiphoid. Both the systems were used for classification.

Data analysis was performed using SPSS (Windows, Version 22.0, SPSS Inc., Chicago, IL). The data distributions were examined for normality using the Kolmogorov–Smirnov test; for non-normally distributed variables, the descriptive statistics are expressed as median (minimum–maximum). Continuous variables were evaluated with the Kruskal–Wallis test for more than two groups, and the Mann–Whitney U-test for two groups. Frequency and percentage measurements were made using frequencies, descriptives and crosstabs features of SPSS. Categorical variables were evaluated using the χ^2 test (Chi-square test). The threshold for statistical significance was set as $p \leq .05$.

RESULTS

A total of 4024 patients were admitted to our clinic with chest trauma during the study period. Of these, 330 patients (8.2%) were diagnosed with SF, including 93 (28.2%) diagnosed with ISF and 237 (71.8%) diagnosed with SF with associated injury. Among this cohort, 240 (72.7%) patients were male. The median age of the patients diagnosed with SF was 41 (range: 8–90) years (Table I). The most common mechanism of injury was motor vehicle collision, accounting for 74.2% (n = 245) of cases (Table I).

Among patients with ISF, 17 of 93 patients were discharged from the ED after treatment, and the remaining 76 patients were hospitalised. While the median LOS for patients with ISF was 4 (range: 1–20) days, the median LOS was 6 (range: 1–36) days for patients with SF with associated injury (p = .001, Table II).

All SF cases were categorised according to both the Johnson and Branfoot classification system and the AO/OTA classification system. According to Johnson and Branfoot classification, 176 patients (53.4%) had Grade II fractures. According to AO/OTA classification, 208 (63%) fractures were at the corpus level, and 216 patients (65.5%) had oblique fractures. CK-MB and troponin values of the patients were compared according to trauma type, associated injury, outcome, and classification systems (Table III).

Among the 330 patients included in this study, 304 patients were discharged from the ED or after hospitalisation, 10 were referred to other institutions, and 16 died during in-hospital follow-up.

In all admissions with SF, concomitant injuries were diagnosed (Table IV). An additional thoracic injury was observed in 74 patients (22.4%) included in the study, and an accompanying extrathoracic injury was observed in 34 patients (10.3%). In 129 patients (39.1%), both thoracic and extrathoracic pathologies were detected, in addition to SF.

According to the Johnson and Branfoot classification, the heart rate and ISS values associated with Grade III fractures were significantly higher than those associated with other fracture grades (Table III). While the ISS values of the manubrium fractures are higher in terms of the anatomical segment of the fracture and the patients have a worse prognosis, the ISS values of the xiphoid fractures were lower and the patients had a better prognosis (p = 0.03, Table III). The Medium age of the patients who expired was ordered (medium age 70.5 *vs*. 39 years, p = 0.001, and with lower medium GCS (12.5 *vs*. 15, p = 0.001). Those with associated injury had a significantly higher mortality than those with isolated fracture (15 *vs*. 01, p = 0.030).

DISCUSSION

In this study, patients diagnosed with SF in the ED were analysed in terms of their clinical characteristics, follow-up, and treatment results. The study population was identified by retrospectively reviewing the trauma registry at a Level 3 trauma center to identify all patients with SFs over a 10-years period.

SFs are primarily transverse corpus sterni fractures; manubrial and xiphoid fractures occur less frequently.[2,6,9–11] The three most common causes of fracture were motor vehicle collisions, falls, and violent assaults. This study identified frequent SFs (74.2%, n = 245/330) among patients who experienced blunt trauma injury secondary to motor vehicle collisions.

On physical examination, SFs can easily be diagnosed by the detection of sternum tenderness, swelling, crepitation, and deformity. SF can be confirmed by examination of lateral or oblique radiographs of the sternum. CT can be used as a screening tool for SF and associated complications. SFs are visible on axial or sagittal reconstructed CT scans.[12,13] SFs can occur either alone or with other associated injuries. The mortality rate due to ISF is extremely low, at 0.7%. Death and morbidity in SF cases are related almost entirely to associated injuries, such as aortic disruption, cardiac contusion, and pulmonary contusion, or to unrelated injuries to the abdomen or head sustained during the accident. Up to two-thirds of SFs have accompanying injuries, and the related mortality rate ranges from 25% to 45%.[3,14] In this study, hemorrhagic shock, intracranial bleeding, and spinal injuries were the main causes of death.

Table I: Baseline characteristics of the study population and mechanisms of injury.

Characteristic[a]	ISF	SF with associated injury	Total	p ≤
No. of patients (N,%)	93 (28.2)	237 (71.8)	330 (100)	---
Age (years)	39 (8-84)	43 (12-90)	41 (8-90)	NS[b]
Male gender N, %	63 (19.1)	177 (53.6)	240 (72.7)	NS[c]
Mechanism of injury (N,%)				
Falls	23 (7.0)	36 (10.9)	59 (17.9)	
<2 meters	15 (4.6)	7 (2.1)	22 (6.7)	
≥2, <5 meters	8 (2.4)	19 (5.8)	27 (8.2)	0.007[c]
≥5, <10 meters	0 (0)	6 (1.8)	6 (1.8)	
≥10 meters	0 (0)	4 (1.2)	4 (1.2)	
Motor vehicle collisions	58 (17.6)	187 (56.6)	245 (74.2)	
Violent assaults	12 (3.6)	14 (4.3)	26 (7.9)	

SF: Sternal fracture; ISF: Isolated sternal fracture. [a] Data reported as number (%) or median (min-max). [b] Mann-Whitney U-test was used for p value. NS, not significant (p > .05). [c] χ^2 test was used for p values. NS, not significant (p > .05).

Table II: LOS and GCS data with regard to presence of associated injuries.

Characteristic[a]	ISF	SF with associated injury	Total	p ≤[b]
GCS	15 (15-15)	15 (3-15)	15 (3-15)	.001[b]
LOS	4 (1-20)	6 (1-36)	6 (1-36)	.001[b]
LOS until death	20 (20-20)	5 (0-25)	8.5 (0-25)	NS[b]
Hospitalisation	76 (25.5)	222 (74.5)	298 (100)	
Discharged within the first 3 days[d]	30 (39.5)	37 (16.7)	67 (22.5)	
Hospitalized for 4 to 9 days[d]	41 (53.9)	121 (54.5)	162 (54.4)	.001[c]
Stayed in the hospital ≥ 10 days[d]	5 (6.6)	64 (28.8)	69 (23.1)	

GCS: Glasgow coma scale; LOS: Length of hospital stay; SF: Sternal fracture; ISF: Isolated sternal fracture; [a] Data reported as number (%) or median (min-max). [b] Mann–Whitney U-test was used for p values. NS: Not significant (p > .05). [c] χ^2 test was used for p values. [d] Percentages indicate values within associated injury groups.

Table III: Laboratory results and clinical findings with regard to the sternal fracture type, mechanism of injury and outcome.

Characteristic	N (%)	ISS[a]	*P* ≤[b]	MAP[a]	*P* ≤[b]	HR[a]	*P* ≤[b]	CK-MB[a]	*P* ≤[b]	Troponin[a]	*P* ≤[b]
Mechanism of injury											
Falls	59 (17.9)	9 (4-57)		93 (50-123)		70 (60-130)		6 (1-164)		5 (0-1000)	
Motor vehicle collisions	245 (74.2)	16 (4-75)	.01[b]	93 (37-140)	NS[b]	78 (50-150)	.03[b]	6 (1-146)	NS[b]	4 (0-5520)	NS[b]
Violent assaults	26 (7.9)	8.5 (4-57)		93 (73-110)		70 (70-128)		4 (1-20)		4 (0-11)	
Associated injury											
ISF	93 (28.2)	4 (4-4)	.001[c]	93 (73-123)	.006[c]	70 (70-110)	.001[c]	3 (1-60)	.001[c]	3 (0-530)	.001[c]
SF with associated injury	237 (71.8)	20 (4-75)		93 (37-140)		80 (50-150)		8 (1-164)		5 (0-5520)	
Johnson and Branfoot classification											
Grade 1	70 (21.2)	9 (4-75)		93 (60-140)		70 (66-128)		4 (1-41)		3 (0-279)	
Grade 2	176 (53.4)	13 (4-75)	.001[b]	93 (50-140)	NS[b]	76 (50-145)	.001[b]	6 (1-164)	.05[b]	4 (0-5520)	.001[b]
Grade 3	77 (23.3)	20 (4-66)		92 (37-133)		82 (70-150)		6 (1-98)		7 (0-1002)	
Grade 4	7 (2.1)	16 (8-29)		90 (60-100)		77 (60-116)		15 (3-67)		11 (10-19)	
AO/OTA- anatomical segments											
Corpus	208 (63)	12.5 (4-75)		93 (37-140)		74.5 (50-145)		5 (1-164)		4 (0-1956)	
Manubrium	112 (34)	17 (4-75)	.03[b]	93 (50-140)	NS[b]	80 (60-150)	.01[b]	6 (1-146)	NS[b]	4 (0-5520)	NS[b]
Xiphoid	10 (3)	9 (4-38)		93 (77-110)		70 (70-76)		3 (3-128)		4 (0-5)	
AO/OTA- shape of the fracture											
Oblique	216 (65.5)	13 (4-75)		93 (37-140)		78 (50-145)		5 (1-146)		4 (0-5520)	
Transverse	101 (30.6)	13 (4-75)	NS[b]	93 (50-123)	NS[b]	74 (60-150)	NS[b]	7 (1-164)	NS[b]	8 (0-1956)	.004[b]
Multifragmentary	13 (3.9)	20 (8-34)		93 (67-113)		70 (70-100)		4 (2-17)		3 (0-8)	
Outcome											
Discharged	304 (92.1)	12.5 (4-66)		93 (37-133)		74 (10-150)		5 (1-98)		4 (0-1956)	
Referred to another center	10 (3)	29 (4-41)	.001[b]	93 (70-107)	.05[b]	75 (70-125)	.002[b]	22 (4-37)	.001[b]	4 (0-19)	.05[b]
Died	16 (4.9)	52 (9-75)		83.5 (50-140)		93 (70-140)		29 (6-164)		34 (0-5520)	

ISS: Injury severity score; MAP: Mean arterial pressure; HR: Heart rate; CK-MB: Creatine kinase myocardial band; SF: Sternal fracture; ISF: Isolated sternal fracture; AO/OTA: Arbeitsgemeinschaft fur osteosynthesefragen / Orthopaedic trauma association classification system. [a]Data reported as median (min-max). [b]Kruskal–Wallis test was used for p values. NS: Not significant (p > .05). [c]Mann–Whitney U-test was used for p values.

In one study, examining localisation-related SF injuries, an average ISS of 20.5 was reported.[1] Another study investigating the incidence of SFs over a 10-years period reported a mean ISS > 16, whereas an older study reported an ISS ≤13.[9,15] In this study, the median ISS value among patients diagnosed with SF was 13. The predominant fracture location was the corpus sterni. The median ISS value was highest among those with fractures in the manubrium sterni.

All patients in this study underwent ECG, and in the ECHO examinations performed on admission to the ED and during follow-up, only 8 patients were diagnosed with pericardial effusion. None of the present patients, however, developed cardiac contusion or arrhythmia after trauma. Interestingly, it was found that pericardial effusions occurred most commonly alongside nondisplaced fractures rather than displaced fractures, and no case required further treatment. Therefore, cardiac evaluation should be performed in patients with SF regardless of the fracture type.

Table IV: Thoracic and extrathoracic injuries associated with sternum fracture.

Associated thoracic injuries (202, 61.2%)		Associated extrathoracic injuries (163, 49.4%)	
Patology	**N (%)**	**Patology**	**N (%)**
Rib fractures	138 (41.8)	Traumatic brain injury	50 (15.2)
Isolated rib fracture	31(9.4)	Concussion	4 (1.2)
Serial rib fracture	107 (32.4)	Pneumosefali	3 (0.9)
Thoracic spine injury	42 (12.7)	Brain edema	10 (3)
Lung contusion	110 (33.3)	Intracranial bleeding	30 (9.1)
Scapula fracture	28 (8.5)	Head & facial bone fracture	44 (13.3)
Cardiac contusion	1 (0.3)	Abdominal injury	
Pericardial fluid	8 (2.4)	Liver laceration	15 (4.6)
Pneumothorax	66 (20)	Spleen laceration	9 (2.7)
Pneumomediastinum	5 (1.5)	Kidney laceration	5 (1.5)
Hemothorax	25 (7.5)	Bladder perforation	3 (0.9)
Clavicula frakture	29 (8.8)	Diaphragm injury	1 (0.3)
Mediastinal hematoma	2 (0.6)	Orthopedic Injuries	
Flail chest	5 (1.5)	Upper limb fracture	47 (14.2)
Subcutaneous emphysema	20 (6.1)	Lower limb fracture	37 (11.2)
		Pelvic fracture	34 (10.3)
		Vertebral injury	
		Cervical spine injury	29 (8.8)
		Lumbar spine injury	53 (16.1)

This study shows that the LOS and outcome were determined by the presence of associated injuries. The median LOS among patients discharged after hospitalisation was 6 days, whereas the median LOS among patients who ultimately died was 8.5 days. LOS duration in SF is related to associated traumatic pathologies rather than SF itself. ISF usually shows a benign course and usually heals spontaneously.

The present study has a number of limitations. This study was at a single tertiary hospital; therefore, the results may not be generalisable to the entire population. Multicenter studies may be necessary to confirm and extend the present findings to other clinical situations. The present study was performed as a retrospective study using previous patient records, and the effects of comorbidities or drug treatment protocols on patient outcomes could not be evaluated due to insufficient data.

CONCLUSION

Although SF is rarely encountered in the ED, SFs are most frequently diagnosed in patients who visit the ED for blunt trauma injury secondary to motor vehicle accidents. Low GCS score, advanced age, and associated injuries were found effective in determining high mortality. Other related injuries that often accompany SFs are vital factors that determine mortality, morbidity, and hospitalisation of these patients. Therefore, when evaluating these patients, associated injuries rather than SF should be taken into account.

ETHICAL APPROVAL:

This study was performed in accordance with the ethical standards established by the 1964 Declaration of Helsinki and its later amendments and was approved by the Selcuk University, Faculty of Medicine, Non-drug-using Clinical Research Ethics Committee (Decision No. 2017/297).

PATIENTS' CONSENT:

Because this study was retrospective, the patients' consents were waived.

COMPETING INTEREST:

The authors declared no competing interest.

AUTHORS' CONTRIBUTION:

HK: Designed the study, researched the literature, and drafted the manuscript.
AB: Collected and analysed the data, and drafted the manuscript.
SD: Collected and analysed the data, and edited the manuscript.
HY: Designed the study and edited the manuscript.
MEK: Researched the literature and obtained ethical approval, and edited the manuscript.
AA: Researched the literature and obtained ethical approval, and drafted the manuscript.
All authors approved the final version of the manuscript to be published.

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