# Sternal Fractures due to Blunt Chest Trauma

Shi-Min Yuan

*Department of Cardiothoracic Surgery, The First Hospital of Putian, Teaching Hospital, Fujian Medical University, Putian, Fujian Province, People's Republic of China*

## ABSTRACT

The present article aimed to give an overview of sternal fractures and discuss their management and prognoses. The retrieved pertinent publications of 2011–2021 constituted the materials of the present study. The misdiagnosis rate of X-ray was 5.5% and that of sonography was 6.3% for diagnosing the sternal fractures. There were more patients with complicated than with isolated sternal fractures (98.8% vs. 1.2%, $p<0.001$). Sternal fractures were treated surgically in 59.5%, conservatively in 39.7%, and staged conservatively and surgically in 0.8% of patients. Extremity fractures, brain injury, lung contusion, and intraabdominal/intraperitoneal injuries were the most common associated injuries to sternal fractures. A small number of patients with sternal fractures have fracture-related delayed complications, most of which require surgical treatments with good outcomes. For solitary sternal fractures, short-term pain relief is sufficient. Most complicated sternal fractures require surgical treatment by sternal fixation. Intrathoracic injuries, especially life-threatening cardiopulmonary injuries that are complicated to sternal fractures warrant resuscitation and corresponding active treatment. The causes of patients' death with sternal fractures were usually not related to the sternum fracture itself, but mostly to the associated injuries.

**Key Words:** *Fracture, Sternum, Trauma.*

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## INTRODUCTION

Sternal fractures are most commonly caused by blunt chest trauma and deceleration injury, with a documented incidence of 3–6.8% of motor vehicle accidents. Athletic injuries, falls, and assaults are also frequent causes of sternal fractures.[1] There is a close relation between displaced sternal fractures and lung injury, pericardial effusions, and spinal and rib fractures.[2] Cardiac contusion can be a reason of sudden deaths at an early stage.[3] About 18–62% of sternal fractures are associated with cardiac injury.[2] Therefore, electrocardiography and cardiac enzyme evaluation are necessary for patients suspected of sternal fracture. The most frequently observed intrathoracic injuries in patients with blunt chest trauma are pneumo-, hemo-, or hemopneumothorax with an incidence of 5.1%, 3.1%, and 3.3%, respectively, to which chest tube drainage or thoracotomy can be the first stage of treatment.[3] Some other associated injuries, such as tension pneumothorax, cardiac tamponade and flail chest, require prompt treatment.[3]

*Correspondence to: Dr. Shi-Min Yuan, Department of Cardiothoracic Surgery, The First Hospital of Putian, Teaching Hospital, Fujian Medical University, 389 Longdejing Street, Chengxiang District, Putian, Fujian Province, People's Republic of China*
*E-mail: shiminyuan@126.com*

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A lateral chest X-ray film remains the gold standard for the diagnosis of sternal fractures, while sonography shows an equal or superior sensitivity to chest X-ray in this respect.[2] Axial computed tomography (CT) may miss the diagnosis of sternal fracture and thus it is less sensitive to chest X-ray when there is a transverse sternal fracture.[2]

Although continuously reported, sternal fractures due to blunt chest trauma remained to be clarified in several ways, *e.g.*, the sensitivity of diagnostic means, management strategies of isolated and complicated sternal fractures, surgical indications, and overall prognosis. The diagnosis and management of sternal fractures can sometimes be a challenge. The aim of this study was to review the clinical features, diagnosis, and management strategies of sternal fractures in the published literature.

## METHODOLOGY

Comprehensive retrieval of pertinent literature in PubMed, Google Scholar, and "Baidu" Scholar was done for articles published from 2011 to 2021. The retrieval terms included "blunt chest trauma," "sternal fracture", "manubrium", "manubriosternal joint dislocation" and "xyphoid". The inclusion criteria were clinical prospective / retrospective researches, case series, and case reports of sternal fractures caused by blunt chest trauma. The primary exclusion criteria were publications: with no substantial information of sternal fracture patients (n=19), blunt chest trauma without causing sternal fracture (n=18), stress fracture of the sternum (n=2), rib fractures caused by blunt chest trauma (n=2), no direct chest trauma as a cause of sternal fracture (n=1), traumatic coronary artery dissection (n=1), and sternal nonunion (n=1).

As a result, a total of 77 articles were included and 44 articles were excluded with 118,422 patients included. However, in 21 of the 77 recruited articles, 87,670 cases of sternal fractures were reported with only patient population other than other information of the patients available, and these 21 articles were therefore excluded. Finally, 56 articles with 30,752 patients with sternal fractures were enrolled in this study.

IBM SPSS statistics version 22 software was used for the statistical analysis. The measurement data were expressed as mean ± standard deviation and median (range) while categorical data were given as numbers and percentages. The categorical variables were compared by Chi-square or Fisher exact test with continuity correction. A value of $p<0.05$ was considered statistically significant.

## RESULTS

There were 28 (50%) case reports,[5,6,12,16-19,23-26,29-32,38,39,41,42,50-56,58] 5 (8.9%) small case series,[8,13,27,28,48] 2 (3.6%) prospective,[21,57] and 21 (37.5%) retrospective studies.[4,7,9-11,14,15,20,22,33-36,40,43-47,49,59] Patients aged 48.8 ± 19.6 (range, 6-92; median, 52) years (n=73). Gender was reported for 4,206 patients: 2,802 (66.6%) were males and 1,404 (33.4%) were females ($p<0.001$).

The mechanisms of blunt chest trauma were described for 26,043 patients. Road traffic accident was the most common, and falling from height was the more common mechanism (Table I). In all, 74 symptoms were reported for 51 patients, with chest pain being the most common symptom accounting for 59.5% (44/74). Other symptoms included chest wall swelling (14.9%, 11/74) and palpable deformity and motion of the fracture (14.9%, 11/74), *etc*. The diagnostic means for sternal fracture was reported for 1,134 patients as conventional CT and or three-dimensional CT (n=1,102), chest X-ray (n=198) (one patient had X-ray films examined twice for the diagnosis of sternal fracture[41]), sonography (n=32), magnetic resonance imaging (n=2) and by autopsy (n=2). The sternal fracture was misdiagnosed in 12 patients by 13 examinations: By X-ray films in 11 (11/199, 5.5%) patients,[18,32,41,57,58] and by sonography in 2 (2/32, 6.3%) patients.[6,32] In one patient, the diagnosis was missed by both X-ray film and sonography.[32] The false negative rate of CT was 0%.

The isolated sternal fracture was noted in 360 (360/30,752, 1.2%) patients, [4,7,9-11,14,16,18,21-24,26, 28, 29,32,36-39,41,43,48,54,56,58,59] while the remaining 30,392 (98.8%) patients had complicated sternal fractures ($p<0.001$). The displacement of sternal fractures was described for 350 patients; 196 (56%) were displaced,[5,8-10,13-15,19,24-26,28,29,31,32,41,42,48,51,53,54] and 154 (44%) were nondisplaced ($p=0.833$).[8,11,14-16,18,27,37,39,48,50,55,58]

Sternal fracture locations were reported for 499 patients: sternal body in 408 (81.8%),[5,8,9,11,12,14,16-20,24-29,32,35,37,39,41,44,46-48,52-55,57,58] manubrium in 60 (12.0%),[20,31,44,47] manubriosternal joint dislocation in 23 (4.6%),[9,13,28,42,48,50] manubrium and body in 7 (1.4%),[13,14,35,51] and xyphoid process in 1 (0.2%).[20]

The associated injuries were reported for 3,790 patients. Extremity fractures (69.3%), brain injury (61.4%), lung contusion (46.0%), and intraabdominal/intraperitoneal injuries (44.7%) were the frequent common injuries.

Four patients were not treated. Two did not consult a doctor after trauma, thus without receiving any treatment,[16,23] One died in accident,[17] and one died due to cardiac arrest despite attempted resuscitation.[52] Treatments of choice were described for 484 patients; surgical fixation (288/484, 59.5%), conservative treatment (with pain relief or by observation) (192/484, 40.0%), and both conservative treatment and surgical fixation (4/484, 0.8%). In the surgical patients, a sternal fracture fixation with plate with / without screw was applied in 93 (46.5%) cases of simple and 107 (53.5%) cases of complex sternal structures ($p=0.162$), and a sternal fracture fixation with wire was used in 13 (54.2%) cases of simple and 11 (45.8%) complex sternal structures ($p=0.564$).

In patients with nondisplaced sternal fractures, 3 (33.3%) patients were treated surgically and 6 (66.7%) were treated conservatively. In patients with displaced sternal fractures, 26 (29.9%) were treated surgically and 61 (68.5%) were treated conservatively. No significant difference was found in the prevalence of surgical management requirements between the 2 groups ($p>0.999$).

Sternal fixation was performed on day 20.8 ± 56.9 after blunt chest trauma (n=13).[5,6,8,11,13,28,31,41,50,51,59] The duration of hospitalisation (after sternal fracture fixation) was 10.5 ± 10.0 (range, 1–41; median, 7) days.[4,5,8,10,11,13-15,19,21,22,26,27,31,35,36,42,51]

Patients were on a follow-up of 11.0 ± 12.0 (range, 2-54; median, 6) months (n=23).[5,6,8,9,13,1621,28,29,41-43,48,49,53,55,58,59] Outcomes were known for 30,341 patients: recovered 26,914 (88.7%), improved 1 (0.0%), complicated 1,126 (3.7%), and died 2,300 (7.6%). The prognoses of patients of 3 treatment groups (484 patients) did not differ between each other (Table II).

## DISCUSSION

The diagnosis of sternal fractures is based on a history of chest trauma and pertinent clinical presentations. Palpable deformity of sternal fracture is helpful for the diagnosis. However, a definite diagnosis relies on medical imaging techniques. A lateral chest radiograph remains the gold standard investigation in diagnosing sternal fractures.[2] Chest X-ray film and sonography are noninvasive diagnostic methods, but there is a certain false negative rate. The present study revealed the false negative rates of these two techniques which were 5.5% and 6.3%, respectively. CT is a more sensitive diagnostic technique except for a horizontal sternal fracture. The appliance of three-dimensional reconstructive CT in the sternal fracture can improve the detection rate of sternal fracture diagnosis. As sternal fractures are associated with blunt cardiac injury, electrocardiography and cardiac monitoring as well as cardiac enzyme detection are necessary for patients with sternal fractures.[2]

**Table I: The mechanisms of blunt chest trauma of 26,043 patients.**

| Mechanism | n (%) |
|---|---|
| Road traffic accident | 23,620 (90.7) |
| Motor vehicle accident [6, 7, 10, 13, 14, 17–20, 23, 24, 27, 28, 32–36, 38, 40, 42–44, 47, 49, 53–55, 58, 59] | 20,464 (86.6) |
| Motorcycle [14, 34, 36, 47] | 1,925 (8.1) |
| Bicycle [30, 34, 40] | 373 (1.6) |
| Sled crash [47] | 1 (0.0) |
| Pedestrian-struck [7, 34] | 820 (3.4) |
| Road traffic accident, unspecified [21] | 37 (0.2) |
| Fall [7, 8, 13, 14, 21, 25, 29, 33–36, 40, 41, 44, 47–50, 56] | 2,334 (9.0) |
| Assault [7, 8, 33, 39] | 64 (0.3) |
| Heavy object strike [12, 26, 27, 59] | 11 (0.0) |
| Gymnastic exercises | 4 (0.0) |
| Broad jump [48] | 1 (25) |
| Elbowed [16] | 1 (25) |
| Gymnastic exercises, unspecified [37] | 1 (25) |
| Surfing accident [28] | 1 (25) |
| Others | 10 (0.0) |
| Animal bumps [14] | 5 (50) |
| Burying [47] | 1 (10) |
| Soil bank collapse [31] | 1 (10) |
| Industrial accident [5] | 1 (10) |
| Cardiopulmonary resuscitation [52] | 1 (10) |
| Sustaining blunt trauma [51] | 1 (10) |

**Table II: Prognoses of 484 patients of 3 treatment groups.**

| Treatment | Recovered | Complicated | Died |
|---|---|---|---|
| Surgical | 285 (99.0) | 3 (1.0) | 0 (0) |
| Conservative | 183 (95.3) | 4 (2.1) | 5 (2.6) |
| Conservative and surgical | 3 (75) | 1 (25) | 0 (0) |
| p value | >0.999 | >0.999 | >0.999 |

Patients with isolated sternal fractures are at low risk of significant cardiac, pulmonary or mediastinal complications and do not need extensive investigations or routine admission.[60] Most isolated sternal fractures, however, will heal spontaneously over the average course of 10 weeks.[1] Routine hospital admission and extensive investigation are not necessary for patients with isolated sternal fractures.[2] Adequate analgesia is the mainstay of treatment for isolated sternal fractures.[2]

For unstable or significantly displaced sternal fractures, especially those with severe combined injuries, patients should be hospitalised, operative fixation may be necessary. The indications for sternal fractures were unstable anterior chest wall, fracture displacement, nonunion and sustained chest pain unresponsive to analgesia management.[11,43,59] Safranek *et al*. reported that among 293 patients with sternal fractures,[61] 16 (5.5%) were treated surgically and the remaining 277 (94.5%) patients were treated conservatively. Of the surgical group patients, 11 (68.8%, 11/16) were operated on with sternal or thoracic fixation, while 5 (31.2%) were for sternum fracture-related cardiovascular surgery. Moreover, the surgical group had more patients with comminuted fractures, rib fractures, concomitant abdominal injuries, and elevated serum troponin-T and myoglobin than the conservative group patients.

Most displaced fractures have been treated with open reduction and internal fixation with titanium plates and screws. Byun *et al*. reported that, in patients with severe displaced sternal fractures, a titanium plate with screws was more stable than a figure-of-8 wiring.[7] Sternal fixation with a titanium plate and screws could be also applied for the treatment of chronic sternal nonunion by facilitating a rapid bone union.[7,8]

Blunt chest trauma is usually caused by motor vehicle accidents, falling from the height, blunt instrument injury, and physical assault. Blunt chest trauma may cause thoracic, intrathoracic, and spinal injuries. Hills *et al*. illustrated that sternal fractures in motor vehicle occupants had no significant association with intrathoracic injuries but with thoracic spine fractures.[62]

Sternal fractures may be associated with major injuries to thoracic organs, with potentially fatal sequelae.[2] Pulmonary injuries including pneumothorax, haemothorax, pulmonary contusion, and tracheobronchial injuries, are one of these complications, and often require urgent intervention. Patients with pulmonary injuries may present with dyspnoea or even respiratory distress.[63] In urgent cases, resuscitation, and treatment of associated injuries are mandatory.[2] Dogrul *et al*. proposed that six life-threatening events (airway obstruction, tension pneumothorax, open pneumothorax, massive haemothorax, flail chest, and pericardial tamponade) require immediate investigations and interventions.[63]

In patients with myocardial infarction due to blunt chest trauma, the aetiologies of myocardial infarction included coronary artery dissection, acute plaque rupture, coronary artery thrombosis, cardiac contusion, and coronary artery fistula.[32] Treatment of myocardial infarction due to blunt chest trauma included coronary bypass surgery, percutaneous stenting, aspirational thrombectomy without stenting, or medical management.[32]

The prognosis of patients with isolated sternal fractures is excellent and complete recovery occurs in about 10 weeks.[2] Surgical sternal fixation for sternal fractures due to blunt chest trauma was associated with a significant decrease in absolute pain scores, decreased pain medication agent requirements, and decreased narcotic use.[64] About two-thirds of sternal fractures have associated injuries, with mortality ranging from 25% to 45% in these cases.[1] The overall mortality rate of sternal fractures was 0.7%.[2]

This study identified early and late complications of sternal fractures, even in patients with isolated sternal fractures. The traumatic complications, such as coronary aneurysms and nonunion, *etc*, were prone to occur especially in the elderly with osteoporosis. Thus the treatment resorted to teriparatide in addition to surgical fixation. In this study, the proportion of surgical fixation was about 70%, with good results and good prognosis. Most of the deaths were caused by compound trauma rather than the sternal fracture itself.

A group of authors who worked on the same database of different year ranges may lead to the re-use of, at least in part, patient data. Patient information in many reports was far from complete. The details of patient information in the large sample cohorts are often missing. For example, the treatment and prognosis of isolated and complex sternal fractures are not separately explained. These defects constitute the main drawbacks of this study.

## CONCLUSION

Motor vehicle accidents and falling from height are the two common mechanisms of sternal fractures. This patient cohort included more complicated than isolated sternal fractures. Patients with isolated sternal fractures usually do not need surgical treatment unless they have a severely displaced sternal fracture. Most complicated sternal fractures require surgical treatment by sternal fixation. Patients with sternal fractures associated with cardiopulmonary injuries require resuscitation and urgent interventions.

**COMPETING INTERESTS:**
The author declared no competing interests.

**AUTHOR'S CONTRIBUTIONS:**
SMY: Substantial contribution to the conception and design of the work; and the acquisition, analysis, and interpretation of data for the work; drafting the work and revising it critically for important intellectual content; final approval of the version to be published; agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy and integrity of any part of the work are appropriately investigated and resolved.

## REFERENCES


1. Bentley TP, Ponnarasu S, Journey JD. Sternal fracture. Book from stat pearls publishing, Treasure Island (FL), 26 Jun 2018. PMID: 29939567.
2. Khoriati AA, Rajakulasingam R, Shah R. Sternal fractures and their management. *J Emerg Trauma Shock* 2013; **6(2)**:113-16. doi: 10.4103/0974-2700.110763.
3. Dongel I, Coskun A, Ozbay S, Bayram M, Atli B. Management of thoracic trauma in emergency service: Analysis of 1139 cases. *Pak J Med Sci* 2013; **29(1)**:58-63. doi: 10.12669/pjms.291.2704.
4. Abd-Elnaim MK, El-Minshawy A, Osman AE, Ahmed MM. Plating versus wiring for fixation of traumatic rib and sternal fractures. *J Egypt Soc Cardio-Thorac Surg* 2017; **25(4)**: 356-61.
5. Apaydin T, Arapi B, Basaran C. Surgical reconstruction of traumatic flail chest with titanium plaques. *Int J Surg Case Rep* 2018; **50**:72-74. doi: 10.1016/j.ijscr.2018.07.033.
6. Brown SR, Fernandez C, Bertellotti R, Asensio JA. Blunt rupture of the thoracic duct after severe thoracic trauma. *Trauma Surg Acute Care Open* 2018; **3(1)**:e000183. doi: 10.1136/tsaco-2018-000183.
7. Byun CS, Park IH, Hwang WJ, Lee Y, Cho HM. Analysis of sternal fixation results according to plate type in sternal fracture. *Korean J Thorac Cardiovasc Surg* 2016; **49(5)**: 361-5. doi: 10.5090/kjtcs.2016.49.5.361.
8. Chou SS, Sena MJ, Wong MS. Use of sterna lock plating system in acute treatment of unstable traumatic sternal fractures. *Ann Thorac Surg* 2011; **91(2)**:597-99. doi: 10.1016/j.athoracsur.2010.07.083.
9. Divisi D, Leonardo GD, Crisci R. Surgical management of traumatic isolated sternal fracture and manubriosternal dislocation. *J Trauma Acute Care Surg* 2013; **75(5)**:824-9. doi: 10.1097/TA.0b013e3182a686a5.
10. Dua A, McMaster J, Desai PJ, Desai SS, Kuy S, Mata M, Cooper J. The association between blunt cardiac injury and isolated sternal fracture. *Cardiol Res Pract* 2014; **2014**: 629687. doi: 10.1155/2014/629687.
11. Ergene G, Tulay CM, Anasiz H. Sternal fixation with nonspecific plate. *Ann Thorac Cardiovasc Surg* 2013; **19(5)**:364-7. doi: 10.5761/atcs.oa.12.01980.
12. Gao E, Li Y, Zhao T, Guo X, He W, Wu W, Zhao Y, Yang Y. Simultaneous surgical treatment of sternum and costal cartilage fractures. *Ann Thorac Surg* 2019; **107(2)**:e119-e120. doi: 10.1016/j.athoracsur.2018.06.044.
13. Gloyer MA, Frei HC, Hotz TK, Käch KP. Osteosynthesis of traumatic manubriosternal dislocations and sternal fractures with a 3.5/4.0 mm fixed-angle plate (LCP). *Arch Orthop Trauma Surg* 2011; **131(9)**:1261-6. doi: 10.1007/s00402-011-1297-2.
14. Guler O, Kozanli F. Is sternum fracture a concerning clinical situation? Is sternum fracture a concerning clinical situa-

tion? *Ann Clin Anal Med* 2021; **12(2)**:195-8.

15. Heidelberg L, Uhlich R, Bosarge P, Kerby J, Hu P. The depth of sternal fracture displacement is not associated with blunt cardiac injury. *J Surg Res* 2019; **235**:322-8. doi: 10.1016/j.jss.2018.08.051.
16. Ichimura H, Ozawa Y, Sato T, Matsuzaki K, Yoshii Y, Shiotani S. Sternal osteomyelitis and abscess caused by elbowing during a basketball game. *Case Rep Med* 2012; **2012**: 298187. doi: 10.1155/2012/298187.
17. Janardhanan J, Tarvadi PV, Manipady S, Shetty M, Somashekar C. Traumatic displacement of stomach - a case report. *J Forensic Leg Med* 2014; **21**:53-5. doi: 10.1016/j.jflm.2013.10.007.
18. Kapisiz NS, Ozpolat B, F Kapisiz, Yücel E. Sternal fracture due to airbag injury: Case report. *Turk J Trauma Emerg Surg* 2010; **16(2)**:181.
19. Kara H, AvciA, Akinci M , Degirmenci S, Bayir A, Ak A. Blunt chest trauma as a cause of acute myocardial infarction. *Acta Clin Belg* 2014; **69(5)**:367-70. doi: 10.1179/ 2295 333714Y.0000000047.
20. Kim EY, Yang HJ, Sung YM, Hwang KH, Kim JH, Kim HS. Sternal fracture in the emergency department: Diagnostic value of multi detector CT with sagittal and coronal reconstruction images. *Eur J Radiol* 2012; **81(5)**:e708-11. doi: 10.1016/j.ejrad.2011.05.029.
21. Kouritas VK, Zisis C, Vahlas K, Roussakis AG, Bellenis I. Isolated sternal fractures treated on an outpatient basis. *Am J Emerg Med* 2013; **31(1)**:227-30. doi: 10.1016/j.ajem.2012.05.027.
22. Krinner S, Grupp S, Oppel P, Langenbach A, Hennig FF, Schulz-Drost S. Do low profile implants provide reliable stability in fixing the sternal fractures as a "fourth vertebral column" in sternovertebral injuries? *J Thorac Dis* 2017; **9(4)**:1054-64. doi: 10.21037/jtd.2017.03.37.
23. Kurihara I, Kashiura M, Moriya T, Sugawara H. Sternal osteomyelitis and infective endocarditis after old trivial chest trauma in untreated diabetes mellitus: A case report. *J Gen Fam Med* 2020; **21(5)**:188-90. doi: 10.1002/jgf2.347.
24. Lahham S, Patane J, Lane N. Ultrasound of sternal fracture. West J Emerg Med 2015;16(7):1057–1058. doi: 10.5811/westjem.2015.9.28645.
25. Lee WJ, Lin HY. Severe chest pain after blunt chest trauma. *Emerg Med J* 2011; **28(5)**:451-2. doi: 10.1136/emj.2009.090621.
26. Liang HM, Chen QL, Zhang EY, Hu J. Sternal fractures and delayed cardiac tamponade due to a severe blunt chest trauma. *Am J Emerg Med* 2016; **34(4)**:758.e1-3. doi: 10.1016/j.ajem.2015.07.075.
27. Ma DS, Ryu JW, Noh D. Direct cardiac rupture associated with sternal fracture following blunt trauma: A report of two case. *Trauma Case Rep* 2021; **32**:100430. doi: 10.1016/j.tcr.2021.100430.
28. Madjarov JM, Katz MG, Kane PN, Madzharov S, Robicsek F. Early surgical reconstruction of sternum with longitudinal rigid polymer plating after acute chest trauma. *Ann Thorac Cardiovasc Surg* 2018; **24(6)**:324-7. doi: 10.5761/atcs.cr.17-00156.
29. Marin F. Treatment of chronic nonunion of a sternal fracture with teriparatide. *Ann Thorac Surg* 2021; **111(1)**:e41-2. doi: 10.1016/j.athoracsur.2020.05.026.
30. Mayet M, Hardcastle TC, Muckart D. Benign portal venous gas after blunt abdominal trauma. *Injury Extra* 2011; **42(11)**:189-91. doi: 10.1016/j.injury.2011.06.422.
31. Miller D, Akhtar MA, Fergusson J, McVie JL. A novel method of open reduction and internal fixation of a displaced manubrial fracture using distal clavicle locking plates. *Interact Cardiovasc Thorac Surg* 2017; **25(5)**:842-3. doi: 10.1093/icvts/ivx185.
32. Nasser K, Matsuura J, Diep J. Blunt chest trauma causing a displaced sternal fracture and ST-elevation myocardial infarction: A case report. *Clin Pract Cases Emerg Med* 2021; **5(1)**:85-8. doi: 10.5811/cpcem.2020.12.49875.
33. Odell DD, Peleg K, Givon A, Radomislensky I, Makey I, Decamp MM, *et al*. Israeli trauma group. Sternal fracture: Isolated lesion *versus* polytrauma from associated extrasternal injuries--analysis of 1,867 cases. *J Trauma Acute Care Surg* 2013; **75(3)**:448-52. doi: 10.1097/TA.0b013e31829e227e.
34. Oyetunji TA, Jackson HT, Obirieze AC, Moore D, Branche MJ, Greene WR, Cornwell EE 3rd, Siram SM. Associated injuries in traumatic sternal fractures: A review of the National Trauma Data Bank. *Am Surg* 2013; **79(7)**:702-5.
35. Ozsoy IE, Tezcan MA. A rare injury in children: Sternum fractures. *J Coll Physicians Surg Pak* 2019; **29(10)**:993-5. doi: 10.29271/jcpsp.2019.10.993.
36. Perez MR, Rodriguez RM, Baumann BM, Langdorf MI, Anglin D, Bradley RN, *et al*. Sternal fracture in the age of pan-scan. *Injury* 2015; **46(7)**:1324-7. doi: 10.1016/j.injury.2015.03.015.
37. Popiel A, Siwiera W, Białas AJ. The usefulness of ultrasound in the diagnosis of patients after chest trauma - two case reports. *Kardiochir Torakochirurgia Pol* 2015; **12(4)**:372-6. doi: 10.5114/kitp.2015.56793.
38. Racine S, Drake D. BET 3: Bedside ultrasound for the diagnosis of sternal fracture. *Emerg Med J* 2015; **32(12)**: 971-2. doi: 10.1136/emermed-2015-204985.3.
39. Radojevich LA, Pagel PS. Persistent chest pain in a polysubstance abuser: an unusual consequence. *J Cardiothorac Vasc Anesth* 2012; **26(3)**:532-4. doi: 10.1053/j.jvca.2010.11.011.
40. Rosenfeld EH, Lau P, Shah SR, Naik-Mathuria B, Wesson DE, Wakeman DS, *et al*. Sternal fractures in children: An analysis of the National Trauma Data Bank. *J Pediatr Surg* 2019; **54(5)**:980-3. doi: 10.1016/j.jpedsurg.2019.01.031.
41. Saka N, Watanabe Y, Sasaki G, Iida M, Kawano H. Nonunion of the sternum treated with cervical locking plate: A case report. *J Orthop Sci* 2020; **25(6)**:1119-22. doi: 10.1016/j.jos.2018.02.005.
42. Sarkeshik AA, Jamal A, Perry PA. Manubriosternal joint dislocation due to blunt force trauma. *Trauma Case Rep* 2019; **21**:100187. doi: 10.1016/j.tcr.2019.100187.
43. Schulz-Drost S, Mauerer A, Grupp S, Hennig FF, Blanke M. Surgical fixation of sternal fractures: locked plate fixation by low-profile titanium plates--surgical safety through depth limited drilling. *Int Orthop* 2014; **38(1)**:133-9. doi: 10.1007/s00264-013-2127-7.
44. Schulz-Drost S, Oppel P, Grupp P, Taylor D, Krinner S,

Langenbach A, *et al*. The oblique fracture of the manubrium sterni caused by a seatbelt--a rare injury? Treatment options based on the experiences gained in a level I trauma centre. *Int Orthop* 2016; **40(4)**:791-8. doi: 10.1007/s00264-015-2801-z.

45. Schulz-Drost S, Krinner S, Langenbach A, Oppel P , Lefering R, Taylor D, *et al*. Concomitant sternal fracture in flail chest: An analysis of 21,741 polytrauma patients from the TraumaRegister DGU®. *Thorac Cardiovasc Surg* 2017; **65(7)**: 551-9. doi: 10.1055/s-0037-1598194.
46. Schulz-Drost S, Krinner S, Oppel P, Grupp S, Schulz-Drost M, Hennig FF, *et al*. Fractures of the manubrium sterni: Treatment options and a possible classification of different types of fractures. *J Thorac Dis* 2018; **10(3)**:1394-405. doi: 10.21037/jtd.2018.03.40.
47. Schulz-Drost S, Krinner S, Langenbach A, Merschin D, Grupp S, Hennig FF, *et al*. The operative management of flail chest injuries with concomitant sternal fracture. *Chirurgia (Bucur)* 2017; **112(5)**:573-93. doi: 10.21614/chirurgia.112.5.573.
48. Sesia SB, Prüfer F, Mayr J. Sternal fracture in children: Diagnosis by ultrasonography. *Eur J Pediatr Surg Rep* 2017; **5(1)**:e39-e42. doi: 10.1055/s-0037-1606197.
49. Tahalele P, Puruhito, Prasmono A, Kusbijanto H, Soebroto H, Sembiring YE. Surgical treatment of isolated sternal fracture: Serial of 10 cases. *J Cardiothorac Surg* 2013; **8(Suppl 1)**:42. doi:10.1186/1749-8090-8-S1-P42.
50. Thombare BD, Rane NK, Jain SK. Occult manubriosternal dislocation-role of manubrio-vertebral column. *Indian J Thorac Cardiovasc Surg* 2020; **36(2)**:151-3. doi: 10.1007/s12055-019-00886-z.
51. Wei P, Yan D, Huang J, Dong L, Zhao Y, Rong F, Li J, Tang W, Li J. Anesthetic management of tracheal laceration from traumatic dislocation of the first rib: A case report and literature of the review. *BMC Anesthesiol* 2019; **19(1)**:149. doi: 10.1186/s12871-019-0812-9.
52. Andrew S Williams AS, Castonguay M, Murray SK, Aortic intimal separation resulting from manual cardiopulmonary resuscitation-completing the spectrum of blunt thoracic aortic injury complicating CPR. *Int J Legal Med* 2016; **130(6)**:1581-5. doi: 10.1007/s00414-016-1377-5.
53. Xie ZX, Zhou XT, Zhang DS, Yang Y, Zhang GL, Chen MH, Liang Z. Minimally invasive plate osteosynthesis for the treatment of sternal fracture in the lower chest: A case report. *J Int Med Res* 2019; **47(8)**:4033-8. doi: 10.1177/0300060519865074.
54. Yamamoto N, Sakakibara M, Murakami M, Sakaguchi K. Delayed hemothorax after conservative treatment of sternal fracture. *Gen Med* 2011; **12(2)**:85-8. doi: 10.14442/general.12.85.
55. Yi JW, Kim DH, Heo YM, Jun JB. Bilateral sternoclavicular joint dislocation due to sternal fracture: Is it a dislocation or a separation? *Arch Orthop Trauma Surg* 2016; **136(5)**:605-8. doi: 10.1007/s00402-016-2433-9.
56. Yoshioka D, Izutani H, Ryugo M, Kawachi K, Sawa Y. Asymptomatic giant traumatic right coronary artery pseudoaneurysm caused by sternal fracture. *Ann Thorac Surg* 2011; **92(2)**:e33-5. doi: 10.1016/j.athoracsur.2011.03.046.
57. You JS, Chung YE, Kim D, Park S, Chung SP. Role of sonography in the emergency room to diagnose sternal fractures. *J Clin Ultrasound* 2010; **38(3)**:135-7. doi: 10.1002/jcu.20669.
58. Yuan SM. Isolated sternal fracture. *West Indian Med J* 2016; doi: 10.7727/WIMJ.2016.407.
59. Zhao Y, Yang Y, Gao Z, Wu W, He W, Zhao T. Treatment of traumatic sternal fractures with titanium plate internal fixation: A retrospective study. *J Cardiothorac Surg* 2017; **12(1)**:22. doi: 10.1186/s13019-017-0580-x.
60. Hossain M, Ramavath A, Kulangara J, Andrew JG. Current management of isolated sternal fractures in the UK: time for evidence based practice? A cross-sectional survey and review of literature. *Injury* 2010; **41(5)**:495-8. doi: 10.1016/j.injury.2009.07.072.
61. Safránek J, Spidlen V, Simánek V, Vodicka J, Siroky J, Dolezal J, *et al*. Sternal fractures and their surgical treatment. *Acat Chirur Orthopaed Traumatol Čechosl* 2015; **82**:76-9.
62. Hills MW, Delprado AM, Deane SA. Sternal fractures: Associated injuries and management. *J Trauma* 1993; **35(1)**: 55-60. doi: 10.1097/00005373-199307000-00009.
63. Dogrul BN, Kiliccalan I, Asci ES, Peker SC. Blunt trauma related chest wall and pulmonary injuries: An overview. *Chin J Traumatol* 2020; **23(3)**:125-38. doi: 10.1016/j.cjtee.2020.04.003.
64. Bauman ZM, Yanala U, Waibel BH, Malhotra GK, Cemaj S, Evans CH, *et al*. Sternal fixation for isolated traumatic sternal fractures improves pain and upper extremity range of motion. *Eur J Trauma Emerg Surg* 2022; **48(1)**:225-30. doi: 10.1007/ s00068-020-01568-x.