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Sternal fracture in the age of pan-scan§

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ABSTRACT

Study objective: Widespread chest CT use in trauma evaluation may increase the diagnosis of minor sternal fracture (SF), making former teaching about SF obsolete. We sought to determine: (1) the frequency with which SF patients are diagnosed by CXR versus chest CT under current imaging protocols, (2) the frequency of surgical procedures related to SF diagnosis, (3) SF patient mortality and hospital length of stay comparing patients with isolated sternal fracture (ISF) and sternal fracture with other thoracic injury (SFOTI), and (4) the frequency and yield of cardiac contusion (CC) workups in SF patients.

Methods: We analyzed charts and data of all SF patients enrolled from January 2009 to May 2013 in the NEXUS Chest and NEXUS Chest CT studies, two multi-centre observational cohorts of blunt trauma patients who received chest imaging for trauma evaluation.

Results: Of the 14,553 patients in the NEXUS Chest and Chest CT cohorts, 292 (2.0%) were diagnosed with SF, and 94% of SF were visible on chest CT only. Only one patient (0.4%) had a surgical procedure related to SF diagnosis. Cardiac contusion was diagnosed in 7 (2.4%) of SF patients. SF patient mortality was low (3.8%) and not significantly different than the mortality of patients without SF (3.1%) [mean difference 0.7%; 95% confidence interval (CI) _1.0 to 3.5%]. Only 2 SF patient deaths (0.7%) were attributed to a cardiac cause. SFOTI patients had longer hospital stays but similar mortality to patients with ISF (mean difference 0.8%; 95% CI -4.7% to 12.0).

Conclusions: Most SF are seen on CT only and the vast majority are clinically insignificant with no change in treatment and low associated mortality. Workup for CC in SF patients is a low-yield practice. SF diagnostic and management guidelines should be updated to reflect modern CT-driven trauma evaluation protocols.

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Introduction

The standard teaching that sternal fracture (SF) is best diagnosed by lateral chest X-ray (CXR) and that it represents a major, clinically significant injury with high associated morbidity and mortality is based on literature performed in the last millennium before the explosion in use of computed tomography (CT) for blunt trauma patient evaluation [1,2]. When SF is diagnosed, authorities advocate for monitoring with special consideration and workup for cardiac contusion (CC) [3,4].

Widely available, rapid CT has transformed diagnostic trauma evaluation with many centres adopting routine head-to-pelvis CT (pan-scan) for victims of major trauma [5–8]. Computed tomography has replaced X-ray as the imaging modality of choice for evaluation of patients with trauma. Many studies have demonstrated that cervical spine CT diagnoses many more injuries than plain cervical spine radiographs, and recent literature suggests that chest CT similarly detects many more thoracic injuries, such as rib fractures and pulmonary contusions, than plain CXR. Given that sternal fracture is not readily seen on the single anterior-posterior view radiographs primarily used in trauma patients and the upsurge in chest CT use with much greater sensitivity for injury, it is likely that more sternal fractures – especially minor ones – are now being diagnosed [7–13]. Traditional teachings regarding diagnosis and management may therefore no longer apply with these minor SF diagnoses.

Considering recent changes in trauma diagnostic imaging, the objectives of this study were to determine: (1) the frequency with which SF patients are diagnosed by CXR versus chest CT by current imaging protocols (SF diagnoses missed by CXR), (2) the frequency of surgical procedures related to SF diagnosis, (3) the mortality and hospital length of stay (LOS) of patients diagnosed with SF, comparing patients with isolated sternal fracture (ISF) and sternal fracture with other thoracic injury (SFOTI), and (4) the frequency and yield of CC workups in patients diagnosed with SF. We postulated that a significant proportion of SF would be missed by CXR but diagnosed by CT, that SF associated morbidity and mortality would be low, and that the former recommendations regarding intensive monitoring and workup for CC would no longer be appropriate.

Methods

We conducted a secondary analysis of data collected during the NEXUS Chest (January 2009 to December 2012) and NEXUS Chest CT (August 2011 to May 2013) studies – two prospective, multicenter observational cohorts of blunt trauma patients that were conducted at 10 urban US Level 1 trauma centres. Inclusion criteria for both studies was as follows: (1) patients aged 14 years and above, (2) blunt trauma occurring within 24 h of emergency department (ED) presentation, and (3) receiving chest imaging (CXR or chest CT) in the ED as part of a trauma evaluation [14,15]. During these studies, we left all imaging decisions as to whether or not to perform CXR and chest CT up to providers without any input. Due to study personnel limitations, we enrolled patients between the hours of 7 AM and 11 PM daily.

We used interpretations of chest imaging by board-certified radiologists, who were blinded to patient enrollment, to determine the diagnosis of sternal fracture and other thoracic injuries. We defined sternal fracture with other thoracic injury (SFOTI) as SF with one or more of the following: two or more rib fractures, pulmonary contusion, pneumothorax, haemothorax, pneumomediastinum, diaphragmatic rupture, aortic or great vessel injury, scapula fracture, thoracic spine fracture, mediastinal or pericardial haematoma, tracheobronchial injury, and esophageal injury. All other patients were classified as ISF.

We reviewed charts of SF patients using standard chart review techniques described by Gilbert et al. [16]. We defined CC in two ways: (1) diagnosis of CC documented in patient records, and (2) at least two of the following three elements during CC workup within the first 48 h after ED presentation: any acute ECG abnormality, elevation of troponin >0.04 mg/L, and any acute abnormalities on echocardiogram.

We obtained institutional board approval at all study sites. In order to test chart abstraction consistency, two abstractors independently reviewed 10% of SF patient charts, and we calculated a kappa statistic for agreement. We analyzed our data using STATA v12 (College Station, TX).

Results

Of the 14,553 patients enrolled into our study, 292 were diagnosed with sternal fracture (2.0%). In the 275 patients (94% of SF patients) who had both CXR and chest CT, 257 (93.4%) patients had SF seen on CT only.

Of the 86.2% of SF subjects who were admitted, the median LOS was 4 days and their hospital survival rate was 95.8%. See Table 1 for comparisons of characteristics between patients with SF and the other enrolled blunt trauma population who did not have SF. Overall mortality in patients with SF was 3.8% and not significantly different than the 3.1% mortality seen in patients without SF (mean difference 0.7%; 95% confidence interval _1.0 to 3.5%).

Of SF patients, 99 (33.9%) had mediastinal haematoma, but none of them had evacuation procedures for the haematoma. Of the 79 (26.9%) patients with displaced SF, only one had surgical reduction and fixation; this patient's SF was seen on CXR. Overall, only one patient (less than 0.4% of patients) underwent a surgical procedure directly related to their SF diagnosis.

Most SF patients had SFOTI (81.4%). Compared to ISF patients, SFOTI patients were more often admitted (92.8% vs. 58.1%; $p < 0.01$), more commonly had mediastinal haematoma (50.4% vs. 14.5%; $p < 0.001$), and had longer mean LOS (4 days vs. 11.8 days; $p = 0.001$). However, hospital mortality was similar in both groups (SFOTI = 3.8% and ISF = 3.1%: mean difference 0.8%; 95% CI _4.7% to 12.0%).

The most common concomitant thoracic injuries were two or more rib fractures, mediastinal haematoma, pulmonary contusion, and pneumothorax. Table 2 lists the associated injuries of all

SF patients in this patient population. Non-thoracic traumatic injury was present in 35.2% of SFOTI cases. See Table 3 for other ISF and SFOTI patient characteristics.

Of the eleven SF patients who died, eight (72.7%) were male, the median age was 68 years (IQR 87-46), and motor vehicle accident was the most common mechanism of injury (63.6%). Only two patients had cardiac related deaths (one from heart failure, and the other from an acute myocardial infarction that occurred on the third hospital day following negative troponin and EKG results on admission). The primary causes of death in the other nine patients were traumatic brain injury (TBI) in four patients, abdominal/ pelvic haemorrhage in two patients, and septic shock, respiratory arrest and renal failure in one patient each.

Most subjects (63.4%) underwent at least one of the three CC work-up tests, and seven (7.6%) of these (2.4% of all 292 patients) were diagnosed with CC by treating physicians during their hospital course. None of these seven patients with CC had their SF seen on CXR. When using our two positive workup findings criteria, six (2.2%) of all subjects had CC. Five patients were diagnosed with SF both by treating physicians and by our criteria.

Table 1
Characteristics of sternal fracture vs. non-sternal fracture subjects.

	Sternal fracture *n* = 292	Non-sternal fracture *n* = 14,261
Median age (IQR)	54 (70–37)	45 (61–25)
Gender (% male)	59.7	62.4
Mechanism of injury	MVA (72.7%) Other fall (13.3%) Motorcycle accident (8.3%)	MVA (38.2%) Fall from standing (16.7%) Other fall (15.3%)
Admitted (%)	86.2	52.6
Hospital survival (%)	96.2	96.9

Table 2
Associated injuries of all sternal fracture subjects.

Injury	Number	Percentage
2 or more rib fractures	137	46.9
Mediastinal haematoma	99	33.9
Pulmonary contusion	77	26.3
Pneumothorax	69	23.6
Thoracic spine fracture	38	13.0
Haemothorax	35	11.9
Pneumomediastinum	15	5.1
Scapular fracture	13	4.4
Pericardial haematoma/effusion	9	3.0
Aortic or great vessel injury	4	1.3
Ruptured diaphragm	2	0.6
Tracheal/bronchial injury	0	0.0
Esophageal injury	0	0.0
Other non-thoracic injury	103	35.2

See Table 4 for other details of CC workups. The kappa statistic for inter-abstractor agreement was 1.0 with 100% agreement for the diagnosis of CC on discharge summary.

Focusing on the 257 patients whose SF was diagnosed only by CT, nine patients died, with two patients having cardiac related deaths. The nine non-survivors had a median age of 72 years (IQR: 46–85), and survivors had a median age of 52 years (IQR: 35–63). Of these 257 CT diagnosed SF patients, 228 (88.7%) were admitted with a median LOS of 4 days (IQR: 1–15); none of these admitted patients received surgical intervention for their SF. Seven of these patients (2.7%) were diagnosed with cardiac contusion, including four who experienced dysrhythmia. Five patients (1.9%) exhibited two or more positive workup findings, including two with dysrhythmia. Among SF patients diagnosed only by CT, 13 exhibited dysrhythmia, including four diagnosed with CC and two who exhibited two or more diagnostic findings.

Discussion

Examining a large, multi-trauma centre derived cohort of blunt trauma patients who received chest imaging, we found that that the vast majority of SF were missed on initial CXR and seen only on chest CT. Mortality in SF patients was very low and only two (<1%) patients experienced cardiac related deaths, including one who suffered an acute myocardial infarction three days after an initial negative evaluation for CC. Even though CXR misses most SF, our findings do not necessarily advocate for increased chest CT utilization in blunt trauma—at least not for the purposes of solely identifying SF. Chest CT is much more expensive than CXR and delivers nearly a thousand- fold the effective radiation dose to radiosensitive organs, with quantifiable resultant higher cancer risk [7,17].

SF diagnosis will continue to rise with increasing chest CT use. Most SFs, including the vast majority of those diagnosed only on chest CT are of minimal clinical significance. Less than 2.0% of patients diagnosed only by CT received clinical diagnoses of CC, an none required surgical intervention. Dysrhythmias were seen in a very small minority of patients, and it is unclear whether these dysrhythmias were secondary to acute cardiac injury or reflections of other concomitant problems.

Table 3
Characteristics of patients with isolated sternal fracture (SF) and sternal fracture with other injury (SFOTI).

	ISF (32)	SFOTI (260)
Median age (IQR)	57 (75–42)	54 (69–36)
Gender (% male)	35.1	65.3
MVA mechanism of injury (%)	87.0	71.9
Admitted (%)	58.1	92.8
Hospital survival (%)	98.1	95.3
Surgical procedure for sternal fracture (%)	0	0.4%
Mediastinal haematoma (%)	14.5	50.4
Median hospital LOS in days (IQR)	2 (4–1)	5 (17–2)

Table 4
Cardiac contusion testing among the 184 subjects that received work-up.

Work-up test	N	Percentage	% abnormal test
Had ECG	164	89.6	24.4
Had troponin	102	55.4	15.9
Had echo	42	22.8	8.8
Had trop and ECG	90	48.9	2.2
Had ECG and echo	33	17.9	0.5
Had trop and echo	25	13.5	0.6

The injury pattern associated with SF is notable in that over 80% of patients are diagnosed with other chest injuries, most commonly rib fractures, mediastinal haematoma, and pulmonary contusion. Beyond monitoring, most SF patients underwent treatments directed at their other thoracic and intra-thoracic injuries (primarily pain control and respiratory support)—therapies that they would have received with or without a SF diagnosis. Only two patients had surgical procedures specifically related to SF diagnosis.

Similarly, we have shown that workup for CC in patients with SF is a low yield practice, regardless of how CC was defined. The traditional teaching about CC and SF may be obsolete –

extensive workups for CC and routine monitoring and admission for all patients with SF is likely unnecessary. Because significant CC is present in such a small minority of patients, and because clinically significant CC is associated with other clinical findings, it is difficult to justify routine screening of patients with SF for CC. A more economically justifiable approach supported by our results is to initiate diagnostic workup only in patients who exhibit findings consistent with CC, such as dysrhythmia or congestive heart failure. Clinicians should nonetheless consider age, comorbidities, other injuries, and relevant drug therapies, such as anticoagulants, in their decisions to monitor and pursue work-up in patients with SF.

Overall, we have demonstrated that increased diagnosis of SF by CT likely produces a phenomenon seen with other clinical scenarios that incorporate high sensitivity diagnostic imaging protocols—the greater detection of injuries that do not change patient manage- ment. These ‘‘clinically insignificant’’ injuries have been well described in the brain and cervical spine trauma literature, in which CT detects many small, non-operative intracranial haemor- rhages and isolated spinous process fractures [18,19]. Widely disparate viewpoints regarding the clinical importance of detecting these minor traumatic injuries exist, and therefore the role of CT in blunt trauma evaluation is evolving [20].

Our findings are consistent with those of other investigators examining the issue of ISF versus SFOTI. Odell et al. found that SFOTI patients have longer hospital courses than ISF patients, and Oyentunji et al. similarly concluded that sternal fracture in the context of poly-trauma is generally a sign of a more difficult hospital course compared to ISF [21,22]. Examining trauma registry data, Yeh et al. found similar low rates of blunt cardiac injury (3.9%) among patients with SF [23].

Limitations

Although we defined SF prospectively by standard criteria, we determined other data elements, especially CC, by retrospective chart review. The clinical criteria for CC diagnosis remain controversial and there may have been variation in how clinicians caring for SF patients at study sites determined this diagnosis. However, when we employed the two positive findings work-up criteria as a means to counter this variation, we found similar low rates of cardiac contusion.

With regard to hospital LOS, it is likely that patients with SFOTI were admitted and monitored for reasons other than the SF itself. Causes of death could similarly be open to interpretation, but the majority of deaths were clearly attributed to TBI and intra-abdominal/pelvic haemorrhage. This study was conducted only at academic, Level 1 trauma centres—the rates of CT use and cardiac contusion testing may differ at dissimilar hospitals. Although further selection bias may have occurred because of the daytime hours of enrollment, we found no differences in patient characteristics presenting during non-enrollment hours [15].

Conclusions

Future teaching and management of SF under current CT-driven imaging protocols for adult victims of blunt trauma should reflect these findings: (1) most SF are missed on plain CXR and only seen on chest CT; (2) most patients with SF have concomitant thoracic injuries; (3) the yield of testing for CC after SF is low; (4) very few patients undergo surgical procedures directly related to SF; and (5) mortality is low with SF and rarely due to cardiac injury. Given these findings and the rise in SF diagnosis with increased CT utilization, an exploration of clinical criteria and guidelines to allow for selective CC workups, cardiac monitoring and hospital admission for SF patients (especially those with ISF) is warranted.

Conflict of interest statement

All authors declare that there are no conflicts of interest.

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