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Vertebral fractures and concomitant fractures of the sternum

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Abstract From October 1996 to August 2001, 721 patients with vertebral fractures were admitted to our unit. Ten patients suffered from vertebral fractures and concomitant sternal fractures. The clinical notes and plain film radiographs of these patients were studied. The average age of the patients was 37 (20–69) years. Nine had been involved in road traffic accidents. Three patients had fractures of the cervical spine, six of the upper thoracic spine (T1–T6) and one had a lumbar spine fracture. The extra-thoracic fracture group included two patients with neurological compromise and two patients who were neurologically intact. The entire upper thoracic fracture group suffered neurological compromise, with four patients suffering complete neurological deficit. In addition, four of these patients suffered potentially life-threatening intra-thoracic injuries. The relative severity of the neurological compromise and the attendant injuries in the upper thoracic fracture group offers compelling evidence in support of the "fourth column" theory, as expressed by Berg [Berg EE (1993), The sternal-rib complex. A possible fourth column in thoracic spine fractures. Spine 18(13):1916–1919].

Résumé D'octobre 1996 à août 2001, 721 malades avec une fracture vertébrale ont été admis dans notre unité. Dix malades ont souffert de fractures vertébrales et de fractures sternales concomitantes. Les observations et les radiographies de ces malades ont été étudiés. L'âge moyen était de 37 ans (20–69). Neuf avaient été impliqués dans des accidents de la circulation. Trois malades avaient des fractures de la colonne cervicale, six de la colonne thoracique supérieure (T1–T6) et un avait une fracture de la colonne lombaire. Le groupe des fractures extra thoraciques a inclus deux malades avec atteinte neurologique et deux sans atteinte neurologique. Il y a toujours eu une atteinte neurologique dans le groupe des fractures thoraciques supérieures , avec quatre malades qui souffrent d'un déficit neurologique complet. En plus, quatre de ces malades avaient des blessures intra-thoraciques potentiellement mortelles. La sévérité relative de l'atteinte neurologique et les lésions associées dans le groupe des fractures thoraciques supérieures appuient la "théorie de la 4^{e}-colonne" comme exprimée par Berg (Berg EE (1993). The sternal-rib complex. A possible fourth column in thoracic spine fractures. Spine 18(13):1916–1919).

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Introduction

Assessment of patients with spinal trauma requires awareness of patterns of associated injuries. An important but frequently overlooked combination is that of sternal and spinal fractures. This association of injuries has been well described by Fowler [4] and more recently by Park et al. [10]. It has been traditionally accepted that the sternum is injured only in association with upper thoracic spine (T1–T6) injuries [5].

The inherent stability of the upper thoracic spine is augmented by the sternum and the rib cage, which are considered to be biomechanically part of the spine. The ribs and sternum stiffen the spine against rotatory forces by increasing the moment of inertia [14]. Dorr et al. [3] claim that it is the sternum, the rib cage and the strong costovertebral ligaments that provide stability in the setting of thoracic vertebral fractures and dislocations.

Based on two cases of displaced sternal fractures associated with thoracic spine fractures, Berg [1] postulated that the sternum and ribs represent a "fourth column" of structural support for the thoracic spine. Based on Berg's theory, the sternum plays an important adjunctive stabilizing function in the thoracic region of the axial skeleton and

with the ribs, represents an additional column of stability. This so-called fourth column is present in addition to the traditional three columns of mechanical support for the vertebrae, as described by Denis [2]. Based on this theory, we set out to examine if indeed this fourth column was a genuine entity and if it constituted any significance in terms of neurological compromise and, additionally, in terms of other injuries.

Material and methods

From 1 October 1996 to 31 August 31 2001, 1,013 patients were admitted to the National Spinal Injuries Unit in the Mater Misericordiae Hospital. All patients were prospectively entered into a computerised database at the time of their admission. Of these, 721 (71.9%) presented with fractures of some part of the vertebral column, and 65 (6.7%) were admitted due to fractures of their upper thoracic spine (T1–T6). In total, ten patients suffered fractures of their sternum.

The clinical notes and plain film radiographs of all ten patients with sternal fractures associated with spinal column fractures admitted to our unit were reviewed. The patients were considered in two subgroups according to the level of spinal injury. One group included patients whose vertebral fractures were located in the upper thoracic spine (between T1 and T6 inclusive) and the second those whose vertebral fractures were outside the upper thoracic spine. The level of spinal injury, the presence or absence of underlying neurological symptoms, the presence of associated injuries—especially life-threatening intra-thoracic injuries—and the type of management undergone by each patient were studied.

Results

The average age of the study cohort was 37±18 (range 20–69) years. There were six male and four female patients. Of the those, nine were involved in road traffic accidents (RTA), and one fell from a height. Based on the level of injury to the spinal column, we identified two subgroups (Table 1).

Sternal fractures associated with upper thoracic vertebral fractures

There were six patients: three men and three women. Their average age was 34±19 (range 20–69) years. All were involved in road traffic accidents. Five suffered undisplaced fractures of their sternum, of which two were fractures of the manubrium. The final patient suffered a comminuted fracture of his sternum.

Four patients had complete neurological deficits (Frankel grade A), and two had incomplete deficits (Frankel grades B and C). Neither of these patients went on to exhibit any improvements to change their Frankel grades. All required surgical management and underwent posterior decompression and stabilisation.

Four patients exhibited mediastinal shadow widening on the initial chest radiograph. All underwent aortograms that ruled out any acute aortic injury, and the radiographical changes were considered to be due to a paravertebral haematoma. Five patients also sustained multiple fractured ribs in addition to their sternal fracture.

Four patients also suffered from potentially life-threatening intra-thoracic injuries. One patient sustained a blunt cardiac injury (BCI) diagnosed by acute ECG changes, elevated cardiac enzyme values and by trans-thoracic

Table 1 Details of ten patients with combined sternal fractures and spinal column fractures

Case no.	Age	Gender	Cause	Spinal injury level	Sternal fracture	Neurology	Associated injuries	Management
1	21	F	RTA	Cervical	Undisplaced	No	Fract. R and L radius	Conservative
2	35	M	RTA	Upper Thoracic Cervical	Undisplaced	Complete	Fract. ribs, multiple bilateral haemothorax lung contusion	Surgical
3	32	M	RTA	Cervical	Undisplaced	No	Fract. R clavicle	Conservative
4	67	M	RTA	Cervical	Undisplaced manubrium	Central cord syndrome	Fract. R and L clavicle	Conservative
5	44	M	Fall	Lumbar	Undisplaced	Incomplete	No	Surgical
6	38	M	RTA	Upper thoracic	Undisplaced	Incomplete	Fract. ribs, multiple bilateral haemothorax pulmonary contusion	Surgical
7	20	F	RTA	Upper thoracic	Undisplaced manubrium	Incomplete	No	Surgical
8	69	F	RTA	Upper thoracic	Comminuted	Complete	Fract. ribs, multiple blunt cardiac injury	Surgical
9	22	F	RTA	Upper thoracic	Undisplaced manubrium	Complete	Fract. ribs, multiple bilateral haemothorax pulmonary contusion	Surgical
10	20	M	RTA	Upper thoracic	Undisplaced	Complete	Fract. ribs, multiple bilateral haemothorax pulmonay contusion	Surgical

F female, *M* male, *RTA* road traffic accident, *Fract.* fracture, *R* right, *L* left

echocardiography. The patient was conservatively managed and her injury resolved.

Three patients suffered pulmonary contusions demonstrated on both plain chest films and computerised tomography (CT) scans of the thorax. All three resolved with conservative management including prophylactic antibiotics, but in one case, a period of mechanical ventilation was required.

Sternal fractures associated with extra-thoracic vertebral fractures

Four patients suffered sternal fractures in association with fractures of the spinal column outside the upper thoracic spine. The average age of this group was 41±20 (range 21–67) years. Three of these patients were men and one was a woman. Three patients had been involved in RTAs, and one had fallen from a height.

Three presented with cervical spine fractures, all of which were associated with undisplaced sternal fractures. The final patient suffered a burst fracture of the L1 vertebra following a fall from a height of approximately 45 feet. Two of the patients with cervical fractures had no neurological compromise. The remaining patient suffered a central cord syndrome that later fully resolved. The patient with the burst lumbar fracture suffered incomplete neurological compromise, Frankel grade C, that improved to a Frankel grade D after intensive rehabilitation. All cervical spine fractures were treated conservatively with cervical orthoses. The patient with the lumbar burst fracture underwent posterior decompression and stabilisation. Two of the patients with cervical spine fractures also suffered fractures of their clavicle. The third patient with a cervical spine fracture also had bilateral distal radial fractures. The patient with the lumbar fracture suffered no other injuries.

Discussion

The incidence of sternal fractures associated with spinal injury is uncertain. Gopalakrishnan and El Masri [5] reported 12 patients with this association of fractures. Eight of the patients had their spinal injury in the upper thoracic spine while a further two had fractures in the lower thoracic region. A further one patient was injured at the lumbar level and one at the cervicothoracic junction. Jones at al. [8] studied eight patients with sternal fractures associated with spinal injuries and found that four of these had thoracic spine fractures. None of these patients sustained any intrathoracic injuries. In addition, isolated cases of sternal fractures associated with spinal fractures outside the upper thoracic region have been reported [5, 6, 8, 11].

We report an incidence of 1.4% of sternal fractures associated with vertebral fractures. When we analyse our two subgroups, there were four cases with an attendant sternal fracture in 656 extra-thoracic vertebral fractures, giving an incidence of 0.6%. This compares to an incidence of 6/65 (9.2%) within the upper thoracic spine group.

The application of huge forces is required to produce a fracture of the sternum in association with a vertebral column injury. The mechanism of spinal injury is complex, combining several movements either simultaneously or in sequence. It is likely that the fractures to the spine represent the end result of either sequential or simultaneous flexion, axial compression, rotation and forward-shearing forces [5].

Fowler [4] felt that the ribs played the primary role in transmitting the force from the spine to the sternum. He described sternal injuries as being either direct or indirect. Direct violence from a force applied to the front of the chest usually displaces the lower fragment of the sternum posteriorly. Injury from indirect violence is usually due to flexion compression or flexion rotation of the upper thorax on the lower thorax. We encountered nine undisplaced and one comminuted fracture of the sternum. In the subgroup of sternal fractures associated with upper thoracic fractures, five of the six patients presented with associated multiple rib fractures. In our series, it appears that the mechanism of sternal injuries is indirect, a result of transmission through the rib cage of the forces required to fracture the spinal column at various levels.

That the sternum confers stability to the thoracic spine is attested by case reports in which patients with severe thoracic kyphotic deformities developed collapsed sternal fatigue fractures [7, 8]. Biomechanical studies have neglected to define the role of the sternum and the rib cage in stabilisation of the spine or to quantify the amount of support and stability conferred by the so called fourth column to the thoracic spine. Although the relative importance of the ribs and sternum to spinal stability is unknown, injury to these two structures should be factored into an analysis of spinal stability. It is thus advised that a sternal fracture in conjunction with a thoracic vertebral body fracture represents a flexion distraction injury that can result in an unstable thoracic spinal injury unless proven otherwise.

As sternal dislocation and sternal fracture displacement occur in the sagittal plane, lateral radiographs are the most useful for identifying and determining the degree of injury. A lateral radiograph of the sternum would, therefore, be recommended to screen for suspected sternal injury in patients with spinal injury. Indeed, it would be our recommendation, based on this series, that all patients sustaining fractures of their upper thoracic spine should undergo a lateral plain film of their sternum. The reported concomitant incidence of sternal fractures and upper thoracic spine fractures of 9.2% would underscore this recommendation. Given the magnitude of forces acting on patients in order to produce this unusual combination of fractures, the presence of other accompanying injuries must be sought. We report a significant difference in the incidence and severity of extra-vertebral injuries between the two subgroups in this study.

The four patients in the extra-thoracic group suffered only minor bone injuries (clavicle and radius) in addition to their sternal and vertebral fractures. One of these patients

sustained no additional injuries. This is in stark contrast to the high incidence of potentially life threatening intra-thoracic injuries recorded in the upper thoracic spine group. Three patients were noted to have significant pulmonary contusions, a complication that has been reported as having 35% mortality in the polytrauma setting by Tyburski et al. [13]. Similarly, one patient was diagnosed with having a blunt cardiac injury. This condition can be associated with life-threatening arrhythmias in up to 16% of cases [12].

It has been traditionally accepted that in spinal injuries, the sternum is injured only in association with upper thoracic spinal injuries. Our findings suggest that spinal injury at the lower thoracic, upper lumbar and cervical levels may also be associated with sternal injuries. The relative severity of the neurological compromise, attendant injuries and need for more invasive treatment in the upper thoracic spine subgroup as opposed to the extra-thoracic subgroup offers compelling evidence in support of Berg's fourth column theory [1].

Literature on the treatment of combined sternal and spinal injury has been sparse. Recommendations have included closed reduction of the sternum by hyperextending the thoracic spine [4]. Extension of the spine could be maintained by bracing or bed rest. All our patients with sternal fractures associated to upper thoracic injuries underwent posterior decompression and stabilisation. Open reduction of the sternum and fixation with Kirscner wires or Steinmann pins has also been described [4, 9]. We believe that posterior spinal stabilisation will restore the stability, and support of the spine and will prevent further progression of neurological symptoms.

We feel the loss of the fourth column in upper thoracic spinal fractures is a reliable marker of the magnitude of the forces applied to the patient and as such should be recognised as an independent variable in the assessment and treatment of these patients.

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