Fractures of the upper transthoracic cage

We have reviewed our experience in managing 11 patients who sustained an indirect sternal fracture in combination with an upper thoracic spinal injury between 2003 and 2006. These fractures have previously been described as ‘associated’ fractures, but since the upper thorax is an anatomical entity composed of the upper thoracic spine, ribs and sternum joined together, we feel that the term ‘fractures of the upper transthoracic cage’ is a better description. These injuries are a challenge because they are unusual and easily overlooked. They require a systematic clinical and radiological examination to identify both lesions. This high-energy trauma gives severe devastating concomitant injuries and CT with contrast and reconstruction is essential after resuscitation to confirm the presence of all the lesions. The injury level occurs principally at T4-T5 and at the manubriosternal joint. These unstable fractures need early posterior stabilisation and fusion or, if treated conservatively, a very close follow-up.

When indirect fractures of the sternum are combined with an injury to the upper thoracic spine they are usually described as an ‘associated’ fracture.\(^1,4\) However, the upper thoracic cage is an anatomical entity including the thoracic spinal levels T1-T7, the ribs and the sternum since they are directly joined together.\(^5\) For this reason, these injuries should be described as fractures of the upper transthoracic cage. We have reviewed a series of patients with this uncommon injury and have analysed the level of injury, associated fractures, other concomitant injuries and treatment.

**Patients and Methods**

Between August 2003 and December 2006, 11 patients were admitted to our unit with fractures of the upper transthoracic cage (Fig. 1). There were six women and five men with a mean age of 38.6 years (22 to 56; Table I). Eight were injured in car accidents; seven were wearing a seat belt. One was involved in a motor cycle accident, one fell from a ladder directly on to the apex of the skull and the remaining patient was knocked over by a wave causing his head to strike the beach. Four of the patients who had been wearing a seat belt in a car accident had a complete neurological deficit (Frankel grade A\(^6\)), and seven remained neurologically intact. After resuscitation all patients underwent CT with contrast and three-dimensional reconstruction. The CT scan included the entire spine and thoracic region for all patients, with inclusion of the head and abdomen when an injury to these areas was suspected. Nine patients had a fracture at either T4 or T5, and five at T3, one with a double-level fracture at T3 and T8 associated with a double-level fracture of the sternum (Fig. 2). In six patients A2\(^7\) compression or A3 burst fractures were found involving one or two vertebrae (seven A.2.3, one A.3.2, one unknown overlooked) with a mean kyphotic deformity of 23\(^\circ\) (14\(^\circ\) to 30\(^\circ\)) in the vertebral body and of 38\(^\circ\) (32\(^\circ\) to 50\(^\circ\)) in the thoracic spine. One A1-wedge compression at T3 and T5 produced a kyphosis of the vertebral body of 10\(^\circ\) representing a kyphosis of the thoracic spine of 22\(^\circ\). In all, four patients had fracture-dislocations involving from one to four vertebrae with a mean kyphosis of 36\(^\circ\) (34\(^\circ\) to 40\(^\circ\)).

In nine patients sternal injuries were located at the manubriosternal joint of which five were fracture-dislocations, three a fracture-subluxation and one a subluxation. Only three fractures of the sternal body with minimal displacement were found. One patient had a double fracture located at the manubriosternal joint and the sternal body. In all cases of dislocation the proximal manubrial fragment tended to displace posteriorly (Fig. 3). In the sternal fractures, which were difficult to classify, CT reformating with coronal and sagittal images was used to confirm the diagnosis.
All patients sustained concomitant fractures, six had hyperextension injuries of the cervical spine below C5, involving laminae and spinous processes of two or more vertebrae. Three patients had clavicular fractures.

Severe associated injuries were sustained in nine patients. All of those with bilateral pulmonary contusions (nine), multiple rib fractures (nine) and bilateral haemothorax (five) or haemopneumothorax (four) required intubation and resuscitation. Head injuries resulting in a loss of consciousness or coma occurred in eight patients, and five had lacerations of the scalp. Widening of the mediastinum was observed on a CT scan in three patients without any signs of aortic injury on aortography. The motorcyclist had a tracheolaryngeal perforation with neck swelling, surgical emphysema and dyspnoea, without an injury to the cervical spine. One young woman presented with traumatic amputation of an arm.

In nine patients operative treatment to stabilise the thoracic spine was undertaken through a posterior approach. The patients were positioned prone in the reverse Trendelenburg position with the anterior sternal pad placed on the epigastric area on the prominences of the lower ribs to avoid any compression on the sternal fracture and to leave its proximal part free from constraint for reduction. The head was placed in a Mayfield headrest (Maquet, Rastatt, Germany), without traction to protect the cervical spine. Posterior spinal stabilisation was secured proximally by pediculotransverse claws and by pedicular hooks in the T1, T2 and T3 areas when the pedicles were too narrow to accommodate pedicular screws. At least one double-level polyaxial pedicular screw was placed below the lesion. The Passmed (Medicrea, La Rochelle, France) pediculotransverse polyaxial claws comprise a main pedicle hook and an opposing transverse counterhook which are connected by a threaded rod and locked by a nut. They constitute a self-stabilising polyaxial anchor (Medicrea), which is as stable as a pedicle screw (Fig. 4). In all cases, passive reduction of the sternal fracture was noted once thoracic spinal fixation had been achieved (Fig. 2). In one patient with severe overlapping displacement with transection of the spinal cord, a posterior total vertebrectomy was performed to obtain the reduction without exerting traction on the fractures of the cervical spine and on the fragile pedicles of the first thoracic vertebra. The space created around the vertebral body by the anterior traumatic dissection allowed an approach to be made in order to carry out its extraction as an en bloc resection, following which an easy reduction of both spinal components was performed (Fig. 3). Of the two patients not treated surgically, the first sustained a T3-T5 wedge-compression injury and was treated with an orthosis and followed for three months until the fractures had healed. The second was not treated surgically since both burst fractures were at T3 and T4 and the fracture-dislocation of the manubriosternal joint had been undetected during initial admission to the intensive-care unit for a pneumohaemothorax.

Results

The nine patients who underwent internal fixation all obtained fusion without late kyphotic deformity. The fractures healed with a mean kyphotic angulation of the thoracic spine of 23° (14° to 42°); the mean correction achieved was...
### Table I. Details of the 11 patients

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yrs)</th>
<th>Gender</th>
<th>Cause*</th>
<th>Sternal injury</th>
<th>Spinal injury</th>
<th>Neurology</th>
<th>Associated fracture</th>
<th>Other injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>41</td>
<td>M</td>
<td>MCA</td>
<td>MS joints subluxation</td>
<td>Fracture-dislocation at T3, T4, T5 and T6</td>
<td>Normal</td>
<td>Ribs</td>
<td>Tracheoararyngeal perforation and bilateral haemothorax</td>
</tr>
<tr>
<td>2</td>
<td>28</td>
<td>M</td>
<td>RTA</td>
<td>MS joint fracturesubluxation</td>
<td>Compression fracture A2.3 of T3 and burst fracture A3.2 of T4</td>
<td>Normal</td>
<td>Maxillofacial and skull</td>
<td>Bilateral fracture of the ribs, intracranial haemorrhage and facial nerve palsy</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>F</td>
<td>RTA with SBF</td>
<td>Buckling of body of the sternum</td>
<td>Fracture-dislocation of T4</td>
<td>Complete paraplegia T4</td>
<td>Lamina and spinous processes C5 and C7, Scapula clavicle, acetabulum and ilium</td>
<td>Bilateral haemopneumothorax and severe head injury with coma</td>
</tr>
<tr>
<td>4</td>
<td>56</td>
<td>F</td>
<td>RTA with SBF</td>
<td>Fracture of body of sternum</td>
<td>A1 wedge-compression fracture of T3 and T5</td>
<td>Normal</td>
<td>Ribs</td>
<td>None</td>
</tr>
<tr>
<td>5</td>
<td>49</td>
<td>M</td>
<td>Fall</td>
<td>MS joint fracture subluxation</td>
<td>Compression fracture of A2.3 of T4 and T5</td>
<td>Normal</td>
<td>Laminae and spinous processes C5 and C6</td>
<td>Scalp laceration and bilateral haemothorax, skull, clavicle, radius</td>
</tr>
<tr>
<td>6</td>
<td>27</td>
<td>F</td>
<td>RTA with SBF</td>
<td>MS joint fracture-dislocation and fracture of the body of the sternum</td>
<td>Compression fracture A2.3 of T3 and fracture-dislocation of T8</td>
<td>Complete paraplegia T7</td>
<td>Laminae and spinous processes C5 to C7</td>
<td>Scalp laceration, severe head injury with coma and bilateral haemopneumothorax, traumatic amputation of right arm</td>
</tr>
<tr>
<td>7</td>
<td>26</td>
<td>M</td>
<td>RTA with SBF</td>
<td>Fracture-dislocation of T4 and T5</td>
<td>Complete paraplegia T4</td>
<td>Laminae and spinous processes C5 to T1 and ribs</td>
<td>Severe head injury and bilateral haemothorax</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>40</td>
<td>F</td>
<td>RTA with SBF</td>
<td>Fracture-dislocation of T4 and T5</td>
<td>Complete paraplegia T4</td>
<td>Lamina spinous processes C5 to C7, clavicle and bilateral ribs</td>
<td>Scalp laceration and bilateral haemothorax</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>50</td>
<td>F</td>
<td>RTA with SBF</td>
<td>Burst fracture of T3 and T4</td>
<td>Normal</td>
<td>Ribs</td>
<td>Haemopneumothorax</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>56</td>
<td>M</td>
<td>Fall in the sea</td>
<td>MS joint fracture-dislocation</td>
<td>Compression fracture A2.3 of T3 and T4</td>
<td>Normal</td>
<td>None</td>
<td>Head injury and bilateral haemothorax</td>
</tr>
<tr>
<td>11</td>
<td>30</td>
<td>F</td>
<td>RTA with SBF</td>
<td>MS joint fracture subluxation</td>
<td>Compression fracture A2.3 of T4</td>
<td>Normal</td>
<td>Laminae and spinous processes C6 to T4 and bilateral rib fractures</td>
<td></td>
</tr>
</tbody>
</table>

* MCA, motor-cycle accident; RTA, road-traffic accident involving collisions in cars; SBF, seat-belt fastened
† MS, manubriosternal joint

14° (37° to 23°). Compression and burst fractures healed with a mean of 9° (5° to 16°) kyphotic angulation of the vertebral body with a mean correction of 14° (23° to 9°; Figs 2 and 4). The conservatively-treated A1-wedge-compression fracture lost 2° after healing at three months. We had no complications such as displacement, failures of instrumentation or screw and rod breakages. Sternal fractures consistently showed spontaneous anatomical reduction and healing after spinal fixation. All the patients who suffered a cervical hyperextension fracture were supported in a cervical collar for three months and recovered without complication. The patient treated conservatively by an orthosis recovered after three months and returned to normal activities. However, the patient whose fractures were missed, when reviewed for the first time three years after injury, had a kyphosis of 90° with marked back pain. She has refused any surgical treatment. All patients treated without a neurological deficit had a total recovery and returned to normal activity (except for one whose fractures were missed). None of the four patients with complete neurological lesions recovered.

### Discussion

Fractures of the upper transthoracic cage remain a challenge because they are unusual and are easily missed in patients with multiple trauma. They may have devastating consequences because of the high levels of neurological compromise and severe concomitant injuries. Many patients die before reaching hospital or during attempts at resuscitation. These fractures are also extremely unstable. Failure to recognise them may result in a major kyphotic deformity, as occurred in one of our patients. The rate of spinal fractures involving the upper thoracic region is estimated at 16%, but the incidence of indirect sternal fractures with upper thoracic spinal injury is uncertain and is most likely to be underestimated because of failure to identify them. This injury is unusual and reports in the literature are limited. In 1957, Fowler added five cases to the 16 previously reported from a review of the literature over 50 years. However, it is now accepted that sternal fractures are not only associated with upper thoracic spinal...
fractures, but also with lower thoracic, upper lumbar and cervical injuries. Gopalakrishnan and El Masri described four patients from a series of 12, with spinal fractures outside the upper thoracic region, as was the case with four of eight patients reported by Jones et al and four of ten patients by Vioreanu et al. Our findings suggest that these spinal fractures outside the upper thoracic region and associated with indirect sternal fracture are less severe, because of the low levels of neurological compromise and concomitant injuries. They do not appear to result from the same mechanism of injury as those of the upper transthoracic cage.

Proper diagnosis is hampered by the fact that the upper thoracic region is difficult to examine on standard chest and spinal radiographs and many fractures are missed. CT with contrast and reconstruction is very effective in identifying these lesions and should be performed as soon as the injury is suspected and the general condition of the patient allows. The CT scan should detail both sternal and vertebral fractures on the same sagittal plane.

Pre-operative a) and post-operative b) CT with sagittal reconstruction of a double-level fracture of the upper transthoracic cage located at T3 and T8, with a fracture-dislocation of the manubriosternal joint and a fracture of body of the sternum. There was paraplegia from the T7 level. Thoracic spinal fixation gave spontaneous reduction of the sternal fracture.

a) CT scan and sagittal reconstruction of a fracture of the upper transthoracic cage with fracture-dislocations of T4-T5 and of the manubriosternal joint. b) – Post-operative anteroposterior radiograph and follow-up sagittal CT reconstruction at two years showing good fusion and no loss of correction after compression osteosynthesis at T3-T5.
reconstruction since it is often focused on the spinal injury only, and must include the entire spine to prevent other fractures being overlooked particularly at the lower cervical spine (60% in our series) and at the lumbar level.

In our series, as described also by Gopalakrishnan and El Masri, it appeared that a severe injury with paraplegia was mainly associated with a fracture-dislocation of the manubriosternal joint and a burst or fracture-dislocation at T4. When this combination of injuries occurs with widening of the mediastinum, a CT aortogram may be necessary to investigate whether there is an associated traumatic disruption of the aorta. In patients without injury to the spinal cord our findings, like others, confirmed that there is widening of the mediastinal shadow with a fracture of the upper thoracic spine and this may be considered to be due to a paravertebral haematoma. In the same manner, a possible tracheo-oesophageal perforation may occur in association with hyperextension of the neck and shear-distraction injuries as we found in the motorcyclist with a fracture-dislocation at T3-T6. Other causes of perforation may result from a penetrating injury, deceleration injury and anteroposterior compression of the thoracic cavity. When a tracheo-oesophageal perforation is suspected oesophagography and bronchoscopy are mandatory to confirm the diagnosis.

The upper thoracic cage includes the upper thoracic spine, ribs and sternum which are joined together by costal cartilages and vertebrocostal articulations. The sternum in conjunction with the rib cage restricts movement and adds rigidity and stability to the spine to represent a real fourth column as an essential mechanical support for the thoracic spine. This fourth column supplements the three-column model of spinal stability described by Denis. The literature contains references to spontaneous sternal fatigue fractures in patients with osteoporosis and severe thoracic kyphosis confirming that the sternum has a role in thoracic spinal stability. In the three-column spinal concept instability occurs when two or more columns are injured, but at the upper extent of the thoracic spine injury to one column may cause instability if there is a fracture of the sternum. Minimal fracture-like wedge compressions of the vertebral bodies can result in considerable instability, and if treated conservatively, require close supervision until healed. Burst fractures or fracture-dislocations are by definition unstable and require immediate surgery for posterior stabilisation and fusion. Anterior interbody fusion needs a thoracotomy and incurs too much risk in respect of the high incidence of severe associated intrathoracic injuries. In high overlap displacement cases with transection of the spinal cord, total vertebrectomy by the posterior approach may be the best compromise. It has been found that open reduction of the sternum and fixation by wires or pins is not necessary when posterior spinal reduction and stabilisation are undertaken since the fracture of the sternum reduces spontaneously. This was also our experience.

The upper thoracic cage functions as an anatomical entity, and includes the upper thoracic spine from T1-T7, the ribs and the sternum since they are directly joined together. Accordingly, fractures of the upper transthoracic cage should be considered as a separate entity and should no longer be referred to as associated fractures when an indirect fracture of the sternum is combined with an injury to the upper thoracic spine.
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References