Impact fractures of the sternum were rare before the days of motorised transport. Their incidence has risen almost parallel with the increase in motor traffic (Tables I and II, and Fig. 1).

Despite the rapid increase, the overall incidence of sternal fracture is still low (less than 0.5 per cent) and direct injuries to the manubrium sterni comprise only one in twenty fractures of the sternum. Fractures caused by direct violence are more common than those produced by indirect violence.

CASE REPORT

Case 1—A man aged forty years was admitted to St Peter’s Hospital, Chertsey, after the car that he was driving had been involved in a collision. He was not wearing a safety belt. He had a graze and bruising over the upper sternum, as well as an injury to the left hip. The lower part of the rim of the steering wheel had snapped so that the hub was on the same level as the manubrium and no doubt was responsible for the injury. Radiographs showed a fracture of the manubrium of the sternum (Fig. 2). There was no injury to the ribs or spine. No special treatment was required for the sternal injury. Three weeks later he had no symptoms referable to his chest and could take a deep breath without discomfort.

Fracture of the manubrium caused by indirect violence is extremely rare: of forty-one cases of fracture of the sternum caused by indirect injury reported in the past 120 years only six involved the manubrium. In three of these there was no associated spinal fracture.

Two further cases are now described.
Case 2—A boy of thirteen years was admitted to St Luke’s Hospital, Guildford, suffering from severe muscle spasms. He had grazed his knee while playing rugby two weeks previously. Ten days later, when he was playing soccer, he felt a severe pain in the back. The next day he was unable to open his mouth or dress himself. A diagnosis of tetanus was at once made. The boy had an obvious deformity of the sternum and a thoracic kyphosis (Figs. 3 and 4). Radiographs taken a few days later, when his general condition permitted, showed angulation at the sterno-manubrial joint and wedge fractures of the bodies of the third to the ninth thoracic vertebrae (Fig. 5).

Treatment and progress—Treatment by antitoxin, relaxants and sedatives was at once started, and a respirator was used during respiratory cramps. The boy made a gradual recovery, though for the first three days he had intermittent muscle spasms which caused an increase of the deformities of the back and sternum.

Seventeen days after admission, when recumbent height was 5 feet 4½ inches, skull traction was applied with the patient resting on fracture boards at a 30-degree incline. The vertebral and sternal deformities were gradually reduced. Eight weeks later the traction was discontinued and back extension exercises were started. Seven months after admission the boy was allowed up wearing a spinal brace; a month later he went home. A month after this the standing height was 5 feet 8 inches. He wore the spinal brace for three years. At the age of seventeen years he was 5 feet 11 inches tall, was leading a normal active life and was doing heavy work as a farm labourer.

Case 3—A woman of sixty-five years walked into the out-patient department at the Rowley Bristow Orthopaedic Hospital with the sole complaint that her breastbone stuck out like a shelf.

Six months previously she was half-way down the stairs at her home—a narrow staircase with a handrail on either side—when she stumbled. She saved herself by clutching the handrails
on both sides so as to bring her forward lurch to an abrupt halt. She felt a sudden severe pain in the front of her chest; this persisted and was made worse by deep breathing and coughing. She had no pain elsewhere. She sought no medical advice and during the next four weeks her pain abated, but at the end of this time she noticed the altered shape of her breastbone. The patient pointed out that although she had had a deformed back from childhood there had never been any deformity of the breastbone. Her general health had been and still remained excellent.

There was a striking shelf-like deformity of the upper sternum (Fig. 6): indeed this was so pronounced that she could rest her chin upon it. The sternum was not tender. The chest expansion was one and a half inches. There was a thoracic kyphoscoliosis. Radiographs showed a fracture of the manubrium, united with posterior angulation (Fig. 7). The thoracic kyphoscoliosis was obviously of long standing and there was no evidence of vertebral fractures. She was reassured and advised to accept the deformity, which could easily be masked by a high neckline.

**THE MECHANISM OF STERNAL INJURIES**

Tarnowsky (1905) gave a comprehensive account of sternal fractures and divided the causal factors into direct violence, indirect violence and muscular action in descending order of frequency.

**Direct violence**—This is the most usual cause and the steering wheel is the common injuring agent. Gibson, Carter and Hinshaw (1962) described five fractures of the manubrium in a series of eighty sternal fractures. Three of these patients with a manubrial injury died of associated visceral injury.

**Indirect violence**—The injury is usually produced by a fall on to the head and neck, by the fall of a heavy object on to this area or more rarely by a fall on to the buttocks. The force is a violent one and there is commonly an associated vertebral fracture (Gurlt 1864, Kirkham 1941, Fowler 1957). The sternum is damaged at one of three sites: 1) the sterno-manubrial joint, which dislocates; 2) the upper pieces of the sternum, which fracture; 3) the manubrium, which fractures.

The first to study the mechanism of fracture of the sternum by indirect injury was Maisonneuve (1842). He, and later Lane (1884), thought that the clavicle was the "key" to
this injury. Lane produced sternal fractures in the cadaver by heavy blows over the scapula and on the point of the shoulder. These fractures were, however, vertical or oblique; they are not encountered in practice.

Rivington (1874) believed that impact of the chin against the chest might produce a fracture of the sternum. Tarnowsky (1905) rightly surmised that concomitant injury to the chin should occur and showed that this did not in fact take place. Fowler (1957) tried to produce a fracture in the cadaver by impacting the chin against the sternum. Even after cutting the sterno-manubrial ligaments the degree of flexion of the neck caused it to break before a displacement of the manubrium took place.

### TABLE I

<table>
<thead>
<tr>
<th>Author</th>
<th>Sternal fractures</th>
<th>Total number of fracture cases</th>
<th>Incidence (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gurit (1864)</td>
<td></td>
<td>22</td>
<td>0.09</td>
</tr>
<tr>
<td>Speed (1916)</td>
<td></td>
<td>12</td>
<td>0.10</td>
</tr>
<tr>
<td>Holderman (1928)</td>
<td></td>
<td>62</td>
<td>0.13</td>
</tr>
<tr>
<td>Gibson, Carter and Hinshaw (1962)</td>
<td></td>
<td>80</td>
<td>0.04</td>
</tr>
</tbody>
</table>

### TABLE II

<table>
<thead>
<tr>
<th>Year</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1864</td>
<td>0</td>
</tr>
<tr>
<td>1904</td>
<td>8,400</td>
</tr>
<tr>
<td>1916</td>
<td>141,621</td>
</tr>
<tr>
<td>1928</td>
<td>884,645</td>
</tr>
<tr>
<td>1961</td>
<td>5,978,500</td>
</tr>
</tbody>
</table>

Servier (1889), Tarnowsky (1905), Stuck (1933) and Fowler (1957) are agreed that the ribs play the major role. Fowler correctly says that the manubrium is firmly held to the spine by the strong articulations of the first ribs and that this attachment causes the manubrium to move backwards when the spine is flexed. The other authors agree with the importance of manubrial anchorage but believe the active force to be a forward displacement of the sternum produced by the lower ribs. It seems that there are two possible factors. As the manubrium is forced backwards a sudden rise in pressure within the thorax will thrust the lower sternum forwards and upwards. The site at which the sternal injury occurs will depend upon two variables: the type of manubrio-sternal joint and the type of articulation with the second rib.

Rivington (1874) demonstrated by dissection of cadavera that there were three types of sterno-manubrial joint: synovial, synchondral or synostal. A mobile synovial joint will be the weakest point of the sternum and displacement will occur at this site. If the joint is a synchondrosis or synostosis and the manubrium is firmly anchored by the second rib (in
addition to the first rib) then the upper pieces of the sternum will break. If the manubrio-sternal joint is a firm one and the second rib articulation is mobile, stress will pass through the body of the manubrium, which will break.

An experiment was carried out on two male cadaveras aged sixty-two and sixty-six years. In the younger a fracture through the second piece of the sternum was produced by levering the sternum forwards and upwards through a transabdominal approach. Fracture occurred after a forward angulation of 30 degrees. In the other cadaver the same procedure was adopted after removal of the anterior ends of the first and second ribs. Despite a forward and upward angulation of 75 degrees, no fracture of the sternum took place. At this point, however, the third to seventh ribs fractured at their posterior angles. In both cadaveras the sterno-manubrial joints were synchondroses.

These experiments suggest that the lower ribs play a passive role by virtue of their mobility and that force transmitted directly through them is more likely to fracture them than the sternum. Tarnowsky (1905) suggested that a sudden rise in the intrathoracic pressure may play a part in forward and upward shift of the lower sternum. This must surely be the explanation for the apparently spontaneous fractures of the sternum which occur without associated spine or rib injury. Chaussier (1903) reported two such fractures in women in labour, Dunlap and Ivins (1952) one during a bout of coughing, and Rutledge (1962) one in a patient who was lifting a parcel on to a shelf.

Muscular action—There is no doubt that bone can be broken by muscular action. The mechanism by which this produces fractures of the sternum, however, must be by fracturing the vertebrae or by causing a rise of intrathoracic pressure, so that all the reported cases would fit into the category of "indirect violence." There is, however, the unique tragi-comic case reported by Dubois (1905) in which a clown fractured his sternum whilst doing a backspring. The mechanism here may have been a direct muscular action on the sternum.

Robertson (1955) reported a case of tetanus with injuries almost identical with those in Case 2. The mechanism in both of these, although the result of muscle action, is really that of indirect injury associated with spinal fracture.

TREATMENT OF STERNAL INJURIES

The sternal injury by itself is of no major significance, but associated injuries, particularly those involving thoracic viscera and vessels, are of paramount importance, and are best dealt with in a thoracic unit.

The indications for treatment of the bony injury are pain and an unacceptable degree of deformity.

When the injury is associated with vertebral wedge fractures, extension of the spine will correct angular deformity at the sternal fracture site or at the manubrio-sternal joint.

If the injury is unstable internal fixation with Kirschner wires as advocated by McKim (1943) would be the method of choice (Fowler 1957; Piardi, Sartori and Manganelli 1962).

SUMMARY

1. Three cases of fracture of the manubrium are described.
2. Two of these cases are very unusual in showing fracture of the manubrium caused by indirect violence.
3. The literature is reviewed and methods of treatment are discussed.
4. The mechanism of fracture of the sternum by indirect violence is discussed.

I am most grateful to Mr F. A. Simmonds, Mr A. G. Apley and Mr G. Hadfield for permission to publish a report on their cases, and in particular to Mr Apley for his advice in preparing this paper. I also thank the British Road Federation for providing the information on road traffic.
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Chaussier, F. (1903): Quoted by Tarnowsky (1905).

Dubois, T. E. (1905): Quoted by Tarnowsky (1905).


