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A review of 35 cases of acute injury of the upper thoracic spine associated with paraplegia was done. In 32, a fracture-dislocation was present; in two, there was a dislocation without associated fracture; and in one, neither fracture nor dislocation was identified. A total of 22 cases conformed to a pattern of injury consisting of anterior fracture dislocation with disruption of the intervening facets joints and various vertebral body fractures. Tomography was necessary for characterization of the injuries. There was a 17% incidence of associated second level spinal injuries, usually a hyperextension injury of the cervical spine.

There has been a progressive annual increase in the number of spinal fractures and spinal cord injuries. Most are attributable to an increase in the number of motor vehicle accidents. The distribution of spinal fractures associated with spinal cord injury [1] varies significantly from the general distribution of spinal fractures without cord injury. Fractures without cord injury are distributed with peaks at C1–C2, C4–C7, and T10–L2, with the largest number at the thoracolumbar junction. In contrast, the distribution of those fractures associated with spinal cord injury is highest at C4–C7, a smaller peak at T10–L2, and an appreciable peak in the middorsal spine. If vertebral body compressions associated with osteoporosis are excluded, fractures of the mid and upper dorsal spine in adults are uncommon. However, there is an appreciable incidence of mid and upper dorsal spinal fractures in those individuals who have sustained an associated spinal cord injury [2].

Patterns and specific types of injury are well described for the cervical, thoracolumbar, and lumbar spine [3–9]. Fractures of the mid and upper dorsal spine do not easily fit into the common classifications for either of these areas. We reviewed 35 cases of thoracic spine trauma associated with spinal cord injury involving T1–T8 in hopes of clarifying this problem.

Materials and Methods

The clinical records and radiographs of all patients admitted to the Midwest Spinal Cord Injury Unit of Northwestern Memorial Hospital with an injury of the spinal cord (T1–T8) since January 1974 were reviewed. Only those with an acute injury of dorsal spine, T1–T8, were accepted for study. Those injuries sustained as a result of gunshot wounds were excluded.

The 35 patients (32 male, 3 female) admitted to the study were 15–73 years old (mean age, 32.6; median age, 27). Auto accidents caused 18 injuries, eight patients were in motorcycle accidents, seven were in falls, and two were in industrial accidents.

In three patients, no fracture was identified with tomography. In two of these three, there was a dislocation; the dislocation was anterior in one patient and posterior in the other. In 32 patients, a fracture-dislocation was present. The distribution of injuries is shown in figure 1. The largest number of injuries (eight) occurred at both T4–T5 and T5–T6. Fractures were usually identified in either or both adjacent vertebrae at this level. All were associated with paraplegia. The most common neurologic deficit was a complete motor and complete sensory deficit distal to the level of injury in 30 cases. Complete motor and incomplete sensory deficits occurred in three cases. Incomplete motor and sensory deficits occurred in two. All patients survived. Neurologic improvement was noted in four cases.

Associated skeletal injuries occurred in 17 patients, excluding fractures of associated ribs. Fractures of the radius and clavicle were the most common, each occurring in five patients. Hemothorax occurred in five cases.

Six patients had discontiguous fractures of the spine. Four involved the cervical spine, consisting of two fractures of the neural arch of the atlas and avulsion fractures of the anterior inferior margin of vertebral bodies C2 (one patient) and C3 (one). There were two associated fracture dislocations of the thoracolumbar spine, one involving T12–L1 and the other L1–L2.

Findings

Radiography

Initial radiographs are anteroposterior and lateral projections of the dorsal spine, with the patient supine. Standard lateral projection may be used after the status of injury has been determined.

The findings may not be immediately obvious on the anteroposterior projection. The injury may be manifested by a paraspinous hematoma (fig. 2A; see also figs. 5A, 6A, and 7A) usually asymmetric and more easily identified on the left. This often extends over the apex of the lung in upper dorsal fractures. Lateral displacement of a dorsal fracture dislocation is usually about 2–3 mm and might be easily overlooked. In 12 cases (34.3%) there was no significant lateral displacement of one vertebra relative to the other at the level of the dislocation. The lateral displacement varied from 2 to 10 mm when present.

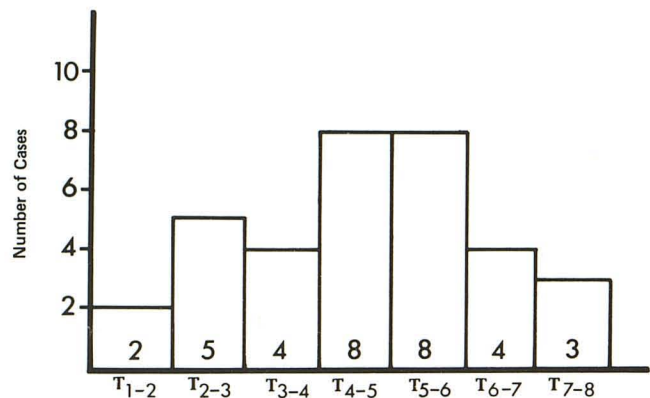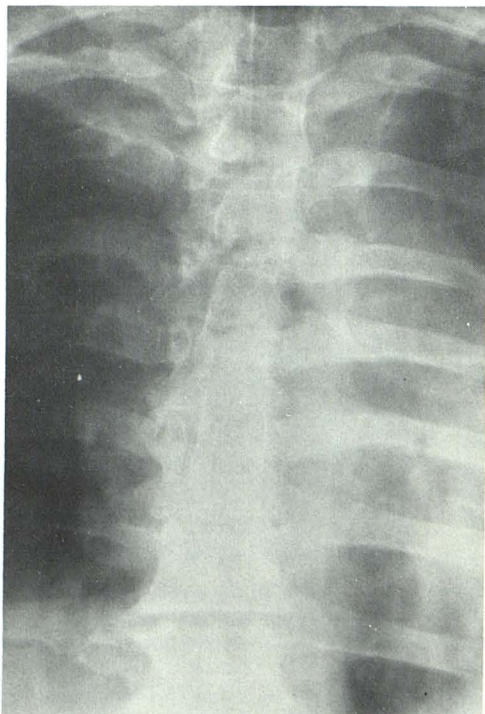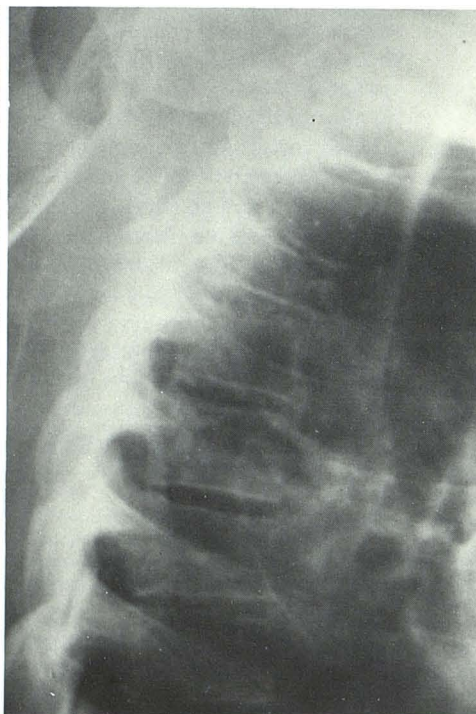The findings on the lateral view are often difficult to

Fig. 1—Level of dislocation in 34 of 35 cases. One case had no identifiable fracture or dislocation. Peak incidence is in middorsal spine.

A **B**

Fig. 2.—49-year-old man with T4–T5 fracture-dislocation from auto accident. **A,** Anteroposterior view. Some narrowing of T4 without significant lateral offset. Paraspinous hematoma extends over left apex. **B,** Lateral view. Fracture-dislocation of vertebral bodies; posterior elements not seen. Frequently, even vertebral bodies are not clearly seen on lateral plain film, particularly in high thoracic fractures.

visualize because of the overlying shoulders and upper arms. A modification of the "swimmer's" projection (fig. 2B) was found helpful in visualization of the otherwise obscured upper dorsal vertebral bodies. This requires that one arm be fully extended above the head and the other held perpendicular to the body. Even this affords only a limited view of the posterior elements.

The important diagnostic findings are those of vertebral body compression and malalignment. The degree of anterior displacement at the level of the dislocation varied from 2 to 35 mm, the average being 8 mm. In this series the upper vertebral body was anteriorly dislocated upon the lower vertebral body in 31 of 35 cases. In three cases, the upper vertebral body was posteriorly dislocated. One patient had no dislocation.

Tomography

Tomography is indispensable in the clarification of the morphologic abnormalities associated with a fracture dislocation of the upper dorsal spine. However, the anteroposterior projection often does not add significant information beyond that of the plain film. The status of the injury of the vertebral bodies may be clarified, but important information regarding the posterior elements is difficult to appreciate. While fractures of the lamina are well visualized, fractures of the facets are often difficult to see and it is very hard to appreciate the degree of dislocation in this projection. Lateral projection tomography is essential. The status and relations of the posterior elements are clarified, and the exact morphology of the vertebral body injuries is revealed. The position of the vertebral bodies, posterior elements, and fracture fragments relative to the spinal canal and the degree of narrowing or compromise of the spinal canal are demonstrated.

Judicious patient handling is mandatory. The patient must be transferred carefully by at least three people from the stretcher or Stryker frame to the tomographic table. All life support systems and traction can be maintained during the examination. Continuous traction can be provided by attaching a pulley to the end of the radiographic table [9], thus suspending the traction weights over the end of the table during the examination. The patient can then be carefully rolled onto his side and secured by pressure bands and foam rubber bolsters.

Tomography was performed in 27 patients at 4–5 mm intervals from the lamina to the anterior part of the vertebral bodies in the anteroposterior projection and at 4–5 mm intervals from one lateral edge of the vertebral body to the other in the lateral projection. In 24, both anteroposterior and lateral projections were obtained, while three patients were examined in only the lateral projection. In our opinion, the anteroposterior projection was of limited value. This opinion is shared by others [6].

Because of the cross-sectional display, CT offers a unique opportunity to evaluate the injured spine. The relation of any fracture fragment to the spinal canal can be determined [10] and otherwise obscure fractures of the posterior elements may be revealed. However, while CT affords an exceptional
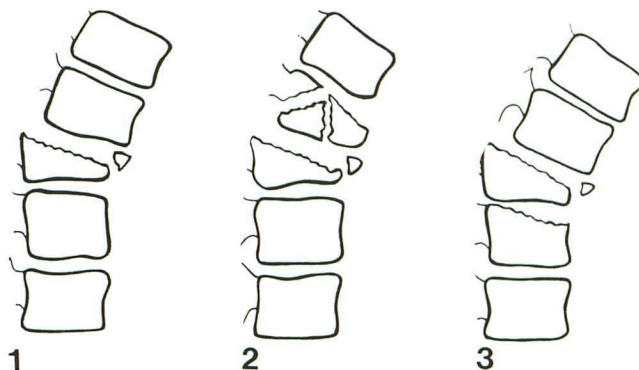

Fig. 3.—Classification of upper dorsal spine fracture-dislocation. Pattern 1 (basic pattern): anterior fracture dislocation with compression of vertebral body below dislocation with small fragment anteriorly; pattern 2 (basic plus crush): additional comminuted fracture of anteriorly dislocated vertebral body; pattern 3 (basic plus compression): additional compression fractures of one or more vertebral bodies below dislocation.
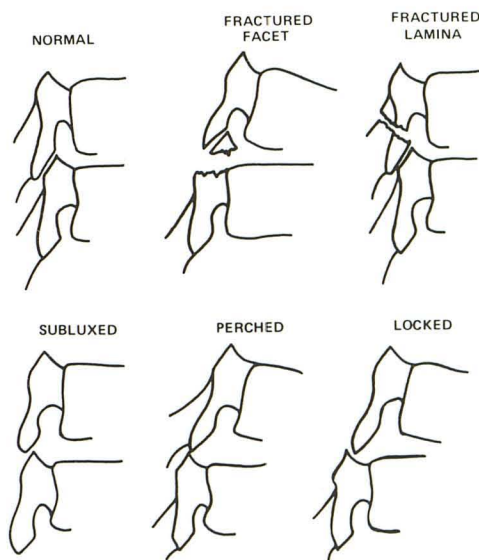

Fig. 4.—Various types of disruptions of apophyseal joints.

view of any given vertebra, the important relation between adjacent vertebrae is better demonstrated and more easily appreciated by standard tomography or routine plain radiographs of the spine. In the future, CT may play a greater role with improvements in sagittal and coronal computer reconstruction. In one of our cases, CT was performed to exclude the presence of a bone fragment within the spinal canal. None had been demonstrated by polytomography and none was seen on CT.

Myelography in three patients demonstrated an intramedullary process presumed to be hematomyelia. Two were associated with a block of the spinal canal. At our institution myelograms are thought to be of limited value in the evaluation of spinal injury. The principal indications are a spinal cord injury in the absence of radiographic abnormalities and
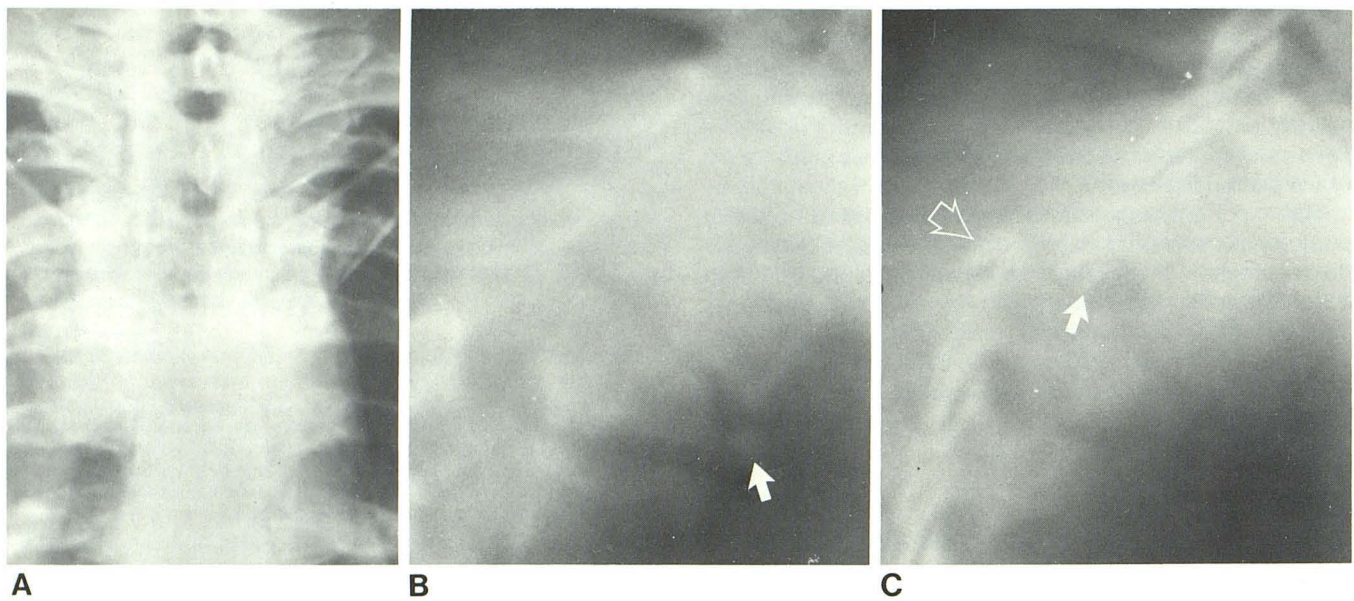
Fig. 5.—19-year-old man with pattern 1; T2–T3 fracture-dislocation sustained in fall. **A**, Anteroposterior view. Some angulation of spine at T2–T3 as well as paraspinous hematoma. **B**, Midline tomogram. Anterior dislocation of T2 with associated compression of T3. Triangular fracture fragment anteriorly (*arrow*). **C**, Tomogram to left of midline. Fracture of superior facet of T3 (*closed arrow*) and small avulsion fracture of inferior facet of T2 (*open arrow*).
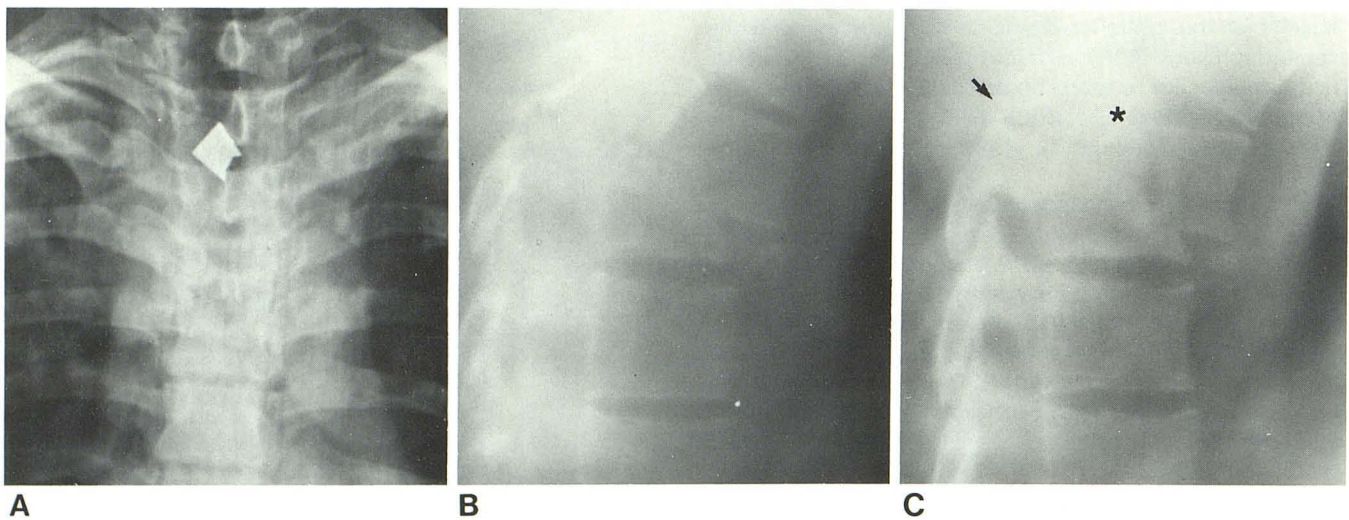

Fig. 6.—24-year-old man with pattern 2, T4–T5 fracture-dislocation from auto accident. **A**, Anteroposterior view. Indistinct T4–T5 interspace and paraspinous hematoma. **B**, Midline tomogram. T4 and T5 fractures with T4 dislocated anteriorly in relation to T5. **C**, Lateral tomogram to left of midline. Locked facets (*arrow*). Large posterior fracture fragment (asterisk) of T4 vertebral body includes pedicle.

the progression of neurologic findings after initial stabilization.

Pattern of Injury

The radiographs were reviewed with the aim of recognizing any pattern or patterns of injury. Such a pattern or patterns might provide insight into the mechanism of injury, furnish a useful clinical shorthand to designate such injuries, and might prove to have either therapeutic or prognostic implications.

It was found that a basic pattern of injury (fig. 3) was present in 22 cases. It consisted of a fracture dislocation involving two contiguous vertebrae with the superior verte-
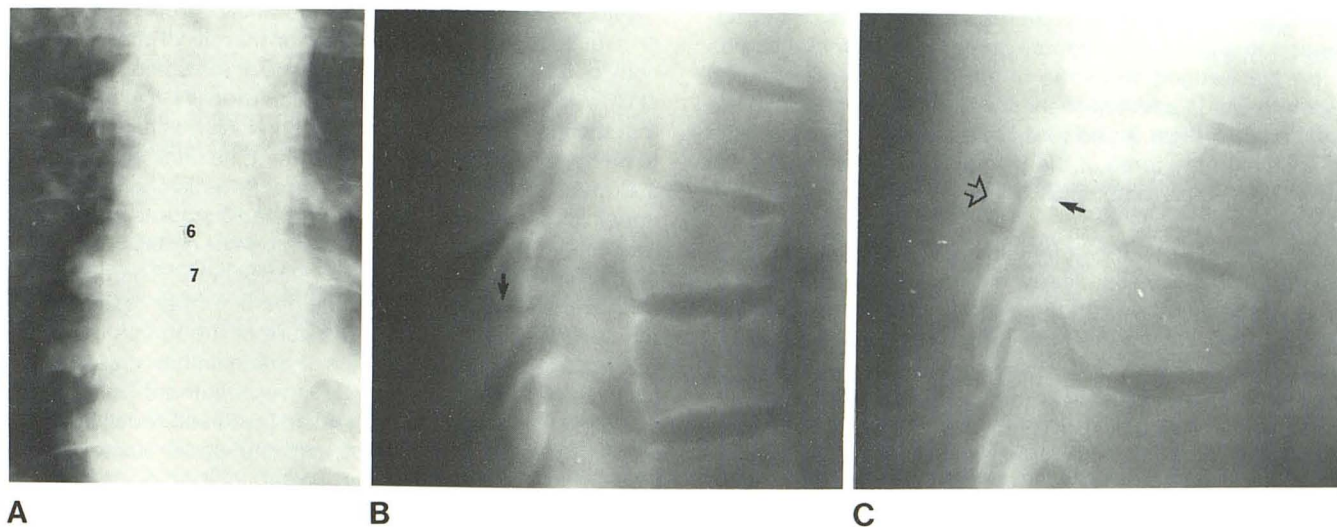
A   B   C

Fig. 7.—23-year-old man with pattern 3, T6–T7 fracture-dislocation from motorcycle accident. **A,** Anteroposterior view. T6 offset slightly to right in relation to T7. Paraspinous hematoma. **B,** Midline tomogram. Fracture-dislocation at T6–T7 with additional compression fracture of T8. Transverse fracture of the lamina of T7 (*arrow*). **C,** Lateral tomogram left of midline. Perching of facets (*closed arrow*). Associated avulsion fracture of inferior facet of T6 (*open arrow*).

Fig. 8.—**A,** 26-year-old man involved in motorcycle accident. Lateral tomogram. Inferior facet of T6 distracted posteriorly and superiorly in relation to superior facet of T7. No associated fracture. Despite absence of fracture, patient was completely paraplegic at T6 level. **B,** 62-year-old woman with T5–T6 fracture-dislocation from auto accident. T5 vertebral body fractured and dislocated posteriorly in relation to T6.

A   B
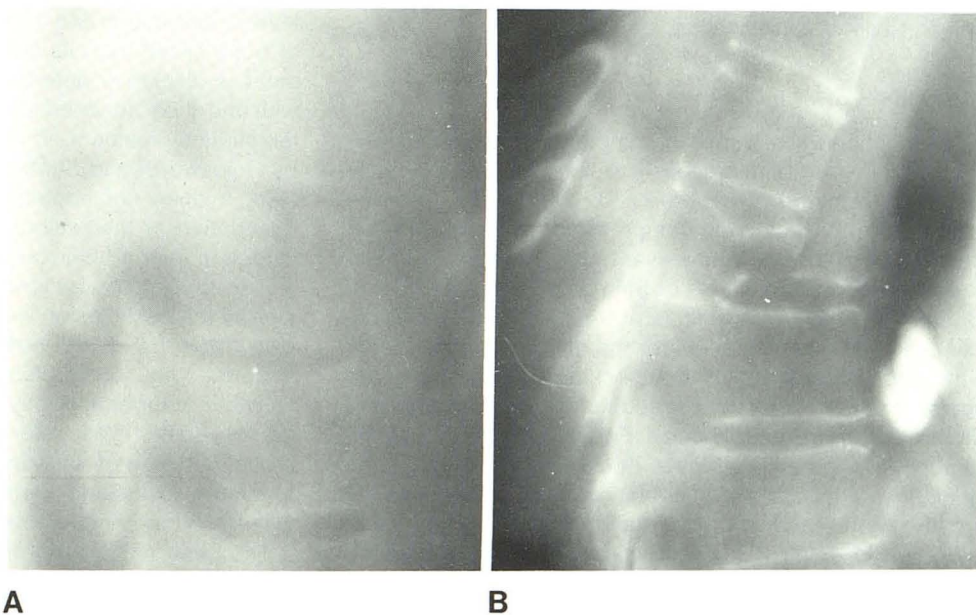
bra dislocated anteriorly. There was a wedged compression fracture of the inferior vertebra with a small triangular fragment displaced anteriorly and the facet joints between the involved vertebrae were disrupted. The disruption of the facet joints consisted most commonly of a horizontal fracture through the base of the superior facet of the vertebra below or a fracture through the lamina (fig. 4) of the vertebra above the level of the dislocation.

Subluxation of the facet joints and locking or perching of the facets were less common (fig. 4). Locking of facets is a displacement of the inferior facet of the vertebra above anterior to the superior facet of the vertebra below the level

of dislocation. Perching of facets is an upward and anterior displacement of the inferior facet of the vertebra above such that it comes to rest on top of the superior facet of the vertebra below the dislocation. This basic pattern, pattern 1, was found in nine patients (figs. 3 and 5).

In nine other patients, there was a comminuted compression fracture of the anteriorly dislocated vertebral body in addition to the basic pattern of injury described above (fig. 3). Usually there was a large fragment of the superior posterior aspect of the vertebral body to which the pedicle remained attached (fig. 6). This "basic plus crush" pattern is pattern 2.

In four other patients, compression fractures of the superior end plate of one or more contiguous vertebral bodies below the wedged vertebrae at the level of the dislocation were present in addition to those fractures described in the basic pattern (figs. 3 and 7). In this pattern there may also be additional fractures of the posterior elements below the dislocation. This "basic plus compression" pattern is pattern 3.

In seven patients, the deformities were well visualized on tomography and were clearly different in character from those described above. In three, no fracture was identified. Two of these had a minimal dislocation of 2–3 mm. In one, the superior vertebra was dislocated anteriorly and in the other, posteriorly (fig. 8A). In the third, there was neither dislocation nor fracture. In two other patients, there was posterior dislocation of the vertebral column above a grossly comminuted vertebral body (fig. 8B), and in two others, lateral dislocation in association with gross comminution of a vertebral body. In each of these there were a variety of fractures of the posterior elements.

The injury could not be classified in the remaining six patients, primarily because only plain films had been obtained. Tomography had not been performed and the morphology of the lesion was not thought to be sufficiently defined to allow classification.

Discussion

The mechanism of injury is complex, combining several movements either simultaneously or in sequence. It is likely that these lesions represent the end result of simultaneous or sequential flexion, axial compression, rotation, and forward shearing forces. In any event, the resultant deformity is grossly unstable because of the complete transection of bone and intervening ligaments at the level of the fracture-dislocation. Flexion accounts for the disruption of the facet joints with resultant subluxation, locking, or perching of the facets. Axial compression accounts for the compression fractures of the vertebral bodies. Forward shear creates the fractures of the superior facets. According to Roaf [11], the ligaments are resistant to injury by compressive or shearing forces but are easily torn by rotational forces. Thus, most authorities [5, 8, 9, 11] believe that rotation plays a significant or predominant role in most fracture-dislocations of the spine. In most of our cases there was little evidence of significant rotation or lateral offset on the initial radiographs. It must be recognized that radiographs depict only the residual dislocation and not the actual degree of dislocation at the time of injury. The gross instability of the injury may allow a spontaneous reduction [6, 9] simply by placing the patient supine with the shoulders in line with the pelvis. Thus, the true severity of the injury is obscured.

The overall incidence of multiple level noncontiguous fractures of the spine in those who have sustained a spinal cord injury is 4.5% [1]. However, the incidence in fractures of the upper dorsal spine [2] is considerably higher, 17.1% in our series. This makes it mandatory to search for the commonly associated fractures of the cervical spine and the thoracolumbar junction. The most common fractures of the cervical spine are fractures of the neural arch of the atlas, or avulsions of the anterior inferior margin of the vertebral body of C2 (fig. 7D) or C3. Fractures of the spinous process at C6 and C7 have also been encountered [1]. It is of interest that the mechanism of injury for these injuries is considered to be hyperextension, suggesting that the neck and cranium are often in extension when a fracture-dislocation of the upper dorsal spine occurs. Associated fractures at the thoracolumbar junction are less common but no less important in their implications for patient management. The presence of these second level spinal injuries is further testimony to the severity and complicated nature of the forces involved.

Fracture-dislocations of the thoracolumbar and lumbar spine have been described by several authors [3, 6, 7, 9] including Holdsworth and Sheffield [4, 5] and Nicoll [8]. The basic lesion we describe of mid and upper dorsal spine fracture dislocations is very similar to that described by these authors. They all have in common a fracture-dislocation of two adjacent vertebrae with anterior dislocation of the vertebral column above this level and disruption of the intervening facet joints, with fracture, subluxation, locking, or perching of facets [6, 8, 12]. This was termed the "slice" fracture by Holdsworth and Sheffield [4, 5] because of the appearance of the wedged compression fracture below the level of dislocation and the characteristic triangular fragment of bone sliced from its superior anterior margin. This fragment is displaced anterior to the wedged vertebra in line with and likely attached to the vertebra above by the anterior longitudinal ligament. The diagram of the injury described by Holdsworth and Sheffield [4, 5] has led to some confusion. It does not appear to precisely reflect either their description or the radiographic examples of the lesion included in their articles on the subject.

Our "basic plus compression" pattern is a simple extension of the basic lesion with minimal to moderate compression fractures of the vertebral bodies below the wedged vertebra. Our "basic plus crush" pattern is not described by other authors and may be unique to the mid and upper dorsal spine. We refer to this as the "basic plus crush"because of the severely comminuted fracture of the anteriorly dislocated vertebral body found in association with the other components of the basic pattern of injury.

The three basic patterns of injury we describe provide a classification of mid and upper thoracic spine injuries not previously depicted. At present, no definite therapeutic or prognostic differences among the three patterns are apparent. However, characterization of the posterior elements in particular is important, since locking of facets requires that the spine be distracted at the time a stabilization procedure is performed. Recognition of noncontiguous fractures also has important therapeutic implications.

It is recognized that CT has the inherent advantages of decreasing the need for patient manipulation, as required for the lateral view in standard tomography, and displays the anatomy in the axial plane that optimizes demonstration of the spinal canal. However, our limited experience with CT is insufficient to recognize and describe the patterns of injury as we have with standard tomography. Very recently, since the completion of this study, a basic pattern fracture

of the dorsal spine was evaluated by both methods. CT clearly demonstrated the displaced fracture of the superior facet into the spinal canal. However, it remains difficult to appreciate the degree of dislocation on CT without the benefit of saggital reconstruction.

ACKNOWLEDGMENT

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