FRACTURES, DISLOCATIONS, AND FRACTURE-DISLOCATIONS
OF THE SPINE*

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I have chosen the subject of injuries to the vertebral column because it is one that has
interested Watson-Jones for many years, and one upon which he has written extensively.
Indeed it was his writings which stimulated me to study vertebral injuries, especially those
associated with paraplegia. I am pleased to be able in this paper to pay tribute to him as a
great surgeon who is also a great personal friend.

Thirty years ago Watson Jones (1931), following the work of Davis (1929), published a
classification of fractures of the spine together with a method of treatment of what were
considered to be pure flexion fractures, whereby the fracture was reduced by hyperextension,
position being maintained by fixation of the spine in plaster in hyperextension for many weeks.
He stated that accurate reduction was almost always possible, that consolidation occurred
without deformity, and that provided exercise in plaster was properly performed the functional
results were excellent.

My experience of the treatment of vertebral fractures did not confirm this. I found that
in a considerable proportion of patients the displacement could not be reduced by
hyperextension, and that even if good position was obtained it could not be maintained by
a plaster jacket in hyperextension. Moreover, the final functional results were far from
satisfactory. Many patients suffered from persistent pain, not so much at the fracture site
as over the whole back.

This opinion was confirmed by Nicoll (1949), who in a classic paper based upon the study
of a large number of fractures of the thoraco-lumbar spine found the results of treatment by
hyperextension to be unsatisfactory, and suggested a new classification of thoraco-lumbar
fractures into stable and unstable types. In stable fractures the intraspinous ligaments
remained intact, whereas in the unstable types these ligaments were ruptured. He stated that
in stable fractures reduction and immobilisation were unnecessary—indeed if the spine was
left free and exercises were carried out from within a week or two of the time of injury the
results were much better than those after plaster fixation. Unstable fractures and fracture-
dislocations, however, required plaster fixation but not reduction. The best results were
obtained when the affected vertebral bodies fused spontaneously in the deformed position.
His investigation was confined to thoraco-lumbar fractures.

At this time I had begun to be interested in traumatic paraplegia, particularly at the
thoraco-lumbar level, and in order to investigate the exact nature of the damage to the spinal
cord, the nerve roots and the vertebral column, I explored a number of fracture-dislocations
with paraplegia, and was struck by the fact that almost invariably the posterior ligaments
were completely ruptured. This observation led to a long investigation into vertebral injuries.
As a result of clinical, radiological, post-mortem and operative investigations on a large number
of injured spines, a classification has now been evolved which forms, in my opinion, a rational
basis for treatment. This classification is an elaboration of Nicoll's original classification into
stable and unstable injuries extended to the whole spine.

ANATOMY

With the exception of the first two cervical and the sacral vertebrae all the vertebrae
articulate together in the same way—by the intervertebral disc and by the postero-lateral


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joints. The synarthroses between the vertebral bodies rely for their stability upon the immensely strong annulus fibrosus. The diarthrodial apophysial joints are stabilised by the capsule, by the intraspinous and supraspinous ligaments and the ligamenta flava. This group of ligaments I call the "posterior ligament complex." It is upon this complex that the stability of the spine largely depends (Fig. 1).

![Diagram of the vertebral articulations with the principal ligaments.](image)

**FIG. 1**
Diagram of the vertebral articulations with the principal ligaments. The intraspinous and supraspinous ligaments, the capsules of the lateral joints and the ligamentum flavum constitute the "posterior ligament complex."

![The articular processes of the cervical, thoracic and lumbar vertebrae.](image)

**FIG. 2**
The articular processes of the cervical, thoracic and lumbar vertebrae.

The shape of the articular processes varies in the different parts of the spine (Fig. 2). In the cervical spine the articular processes are small and flat, those of the upper vertebra pointing downwards and forwards, those of the lower upwards and backwards. In the thoracic spine the processes are also flat, but point almost directly backwards and forwards. In the
lumbar spine they are large and curved and point almost directly inwards and outwards, the upper facets of the lower vertebra embracing the lower facets of the upper vertebra. The joints of the thoracic spine are further stabilised by the rigidity of the thoracic cage.

The spine may be subjected to four types of violence: 1) flexion, 2) flexion and rotation, 3) extension, and 4) compression. The type of fracture, dislocation or fracture-dislocation which results from each of these types of violence will depend upon whether or not the posterior ligament complex is ruptured and, because of the shape of the bones, upon the part of the spine involved.

The posterior ligament complex is seldom if ever ruptured by pure flexion violence; it is always or almost always ruptured when the spine is subjected to forcible rotation or flexion-rotation, and the greater the rotational element the greater the liability to rupture.

If the posterior ligament complex remains intact then the violence is expended upon the vertebral body and a wedge compression fracture results (Fig. 3). This type of fracture results from pure flexion and is most common in the thoracic and lumbar spines, for in the thoracic spine stability is increased by the rib cage and in the lumbar spine the ligament complex is extremely strong. The resulting wedge compression fracture is stable, for the fragments of the body are firmly impacted and the articular processes and the posterior ligaments are intact. Further displacement will not occur unless the spine is subjected to greater violence than that which caused the fracture.

With flexion-rotation violence the posterior ligaments rupture, the posterior tie is lost, and if the amount of flexion is sufficient to disengage the articular processes, then pure dislocation results (Fig. 4). The vertebral body cannot be compressed because there is no
fulcrum for the lever. Pure dislocation is common in the cervical spine, for the amount of flexion necessary to disengage the articular processes is slight. It occurs but rarely in the lumbar spine, where the amount of flexion necessary to disengage the large articular processes is great. It never occurs in the thoracic spine because of the supporting rib cage. Pure dislocations are unstable.

Rotation or flexion-rotation in the lumbar spine results in a fracture-dislocation, for the flexion is not sufficient to disengage the articular processes (Fig. 5). The posterior ligaments rupture, one or other or both the articular processes fracture and the upper vertebra swings upon the lower, carrying with it the disc and a wedged slice of the upper border of the lower vertebral body. This is the classical rotational fracture-dislocation of the thoraco-lumbar and lumbar spine, which is so constantly associated with paraplegia. This fracture-dislocation is clearly very unstable. It corresponds to Nicoll’s fracture-dislocation and lateral wedge fracture.

Extension violence produces the reverse of flexion injury. In pure extension the ligaments usually remain intact and the posterior part of the vertebra, that is the lamina and pedicles, fractures. This is a rare injury, because more frequently the anterior common ligament ruptures and an extension dislocation occurs. This is common in the cervical region as a result of “whiplash” injuries, but extremely rare in the lumbar spine. These injuries are stable in flexion (Fig. 6).

The fourth type of violence is a compression force—that is, a force transmitted directly along the line of the vertebral bodies. This can only occur in those parts of the spine that can be held straight, the lumbar and cervical spines. With the neck slightly flexed the cervical spine is straight and violence applied to the vertex of the skull will be transmitted along the line of the vertebral bodies (Fig. 7). This force ruptures one of the end plates and the disc is forced into the body of the vertebra, which bursts (Fig. 8). All the ligaments remain intact.
and the spine is stable. This is the compression "burst" fracture and corresponds to the comminuted wedge fracture of Nicoll and Watson-Jones. It is often associated with tetraplegia in the cervical region, the cord being damaged by the posterior fragments of the exploding body. This type of violence also produces the characteristic "burst" fracture of the atlas.

The mechanism of production of the burst fracture as well as the tearing of the posterior ligament complex by rotational violence has recently been confirmed by the ingenious experimental work of Roaf (1960).

Thus the basic classification of stable and unstable fractures which Nicoll applied to the thoraco-lumbar spine can be extended to cover the whole spine and elaborated in order to describe more accurately the exact type of injury.

**DIAGNOSIS**

Early diagnosis of the type of injury is of crucial importance because treatment and prognosis depend upon an accurate assessment of the damage to the spine.

Diagnosis is easy if it is appreciated firstly that stability after injury depends upon whether or not the posterior ligament complex remains intact, and secondly that each type of fracture and fracture-dislocation has a characteristic radiographic appearance.

Clinical examination is of great importance. Inspection of the back will often give a clue to the exact type of violence which has caused the injury. For example, abrasions and contusions over one scapula show that the force has connected at that spot, producing flexion and rotation at the thoraco-lumbar level (Fig. 9); or an abrasion on the vertex would suggest vertical compression force to the cervical spine. Palpation of the back is of great value. Rupture of the
supraspinous and intraspinous ligaments can readily be detected. This physical sign is perhaps the best indication of instability of the spine, and together with careful examination of good antero-posterior and lateral radiographs which include the spinous processes will usually enable the injury to be placed in the appropriate category.

Radiographs of the wedge fracture show a compression of the anterior part of the body with minimal separation of the spinous processes (Fig. 10). Often more than one vertebra is involved and the end plates are usually intact.

With compression or "burst" fractures the vertebral body is shattered and fragments are displaced outwards from the centre: again the spinous processes are not separated (Figs. 11 and 12).

With flexion-rotation force and rupture of the ligament complex there is separation of the spinous processes and, if the articular processes disengage, the pure dislocation is obvious (Figs. 13 and 14).

If there is more rotation than flexion and the articular processes fail to disengage then a rotational fracture-dislocation results. Separation and lateral displacement of the spinous processes, together with fracture of one or both articular processes, can be seen in the antero-posterior view and the characteristic slice wedge of the upper part of the body of the lower vertebra can be seen in both views (Fig. 15). It is this slice wedge of the body which can lead to confusion, for it can easily be mistaken in the lateral view for a wedge compression with comminution. The wedge fracture is never extensively comminuted.

Great care must be taken to recognise this fracture-dislocation. The displacement seen in the radiographs is often minimal, for the fracture is so unstable that the spine falls into alignment when the patient is laid supine, or when the pelvis is held in line with the shoulders, and conversely, it may completely redislocate with torsion. Injudicious handling can easily damage the cord or nerve roots. Almost all paraplegia in the lumbar and thoraco-lumbar regions is associated with this fracture-dislocation.
Figure 11—"Burst" fracture of two lumbar vertebrae. The typical shattering of the vertebral body is well illustrated. The spinous processes are not separated. Figure 12—"Burst" fracture of a cervical vertebra.

Figure 13—Dislocation of the cervical spine. Figure 14—Dislocation of the lumbar spine. In both cases the posterior ligament complex is ruptured. Note the separation of the spinous processes.
FIG. 15
Rotational fracture-dislocation of the twelfth thoracic vertebra upon the first lumbar. Note the "slice" fracture of the vertebral body and the displacement of the spinous processes.

FIG. 16
Figure 16—Extension dislocation in ankylosing spondylitis. The deformity has remained.

FIG. 17
Figure 17—Extension dislocation. The lower anterior margin of the body of the second cervical vertebra has been avulsed. This is an unusually large fragment.
Extension dislocations can be difficult to recognise. They are common in the cervical region. The dislocation usually becomes reduced spontaneously and the reduction is stable in flexion. The only radiographic abnormality is often a small avulsion fracture of the front edge of the vertebral body indicating a rupture of the anterior common ligament. This small avulsion fracture can be recognised with good quality radiographs including oblique views (Figs. 16 and 17).

To recapitulate: fractures, dislocations and fracture-dislocations of the whole spine can be divided into stable and unstable types. The diagnosis of each type of fracture by clinical examination and by radiography is simple.

Figs. 18 and 19
Figure 18—"Burst" fracture of the third lumbar vertebra. Figure 19—Fusion between the bodies of the second, third and fourth lumbar vertebrae after immobilisation for four months.

TREATMENT

The classification of fractures is only of real value if the separation into distinct types is of value in treatment. In this respect the importance of distinguishing between stable and unstable fractures of the spine cannot be over-emphasised. In addition to this, however, treatment depends upon a number of additional factors.

The object of treatment of any fracture, dislocation or fracture-dislocation of the spine is to restore a painless, powerful, mobile back. Nicoll has shown that this objective is best achieved by obtaining stability at the affected segments rather than by the restoration of anatomical position, and most surgeons with experience of vertebral fractures will agree with this.

When the posterior ligament complex has been ruptured, healing such as to restore the original strength does not occur. For example, it is common knowledge that after accurate reduction and prolonged immobilisation of dislocations of the cervical spine late redisplacement often occurs. Thus after unstable injuries to the vertebral column permanent restoration of stability cannot be achieved by healing of the ligaments alone.
When the vertebral body is fractured and the intervertebral disc destroyed, healing of the fracture almost always results in fusion of the fractured body to that of the adjacent vertebra, and this is even more certain if the articular processes have also been broken. The result of this spontaneous inter-body fusion is the restoration of complete stability to the injured segment of the spine, and is independent of healing of the ligaments. It does not usually occur, however, if the vertebra is not fractured. If these facts are remembered rational treatment of each type of vertebral injury becomes clear.

**STABLE INJURIES**

**Wedge compression fracture**—The simple wedge fracture, often occurring in more than one vertebra in the same patient, does not require reduction or immobilisation. All that is necessary is rest in bed for two to three weeks, followed by active exercises for six to eight weeks. The fracture unites with some deformity, but this seldom causes any disability, for since the posterior ligament complex is intact the spine is stable. The patients are usually able to return to all but the most arduous forms of physical work, and even this is often possible. Nicoll found that over 80 per cent of his patients were able to return to hard manual work underground in the coal pits.

**Compression burst fractures**—Although the ligaments remain intact and the spine is therefore stable, the body of the vertebra is comminuted, and since the bone fragments are not impacted any movement causes considerable pain. It is therefore necessary to immobilise the spine by a plaster applied in the neutral position. Reduction of deformity is not important. Since the body of the vertebra is fractured and the disc disrupted, healing can confidently be expected to lead not only to consolidation of the fracture but to fusion of the affected vertebra with the vertebra above, with resulting complete stability of the spine (Figs. 18 and 19).

In both the cervical and lumbar spines a plaster is therefore applied with the spine in the neutral position, and retained until union and fusion have occurred—usually a matter of three to four months.

**UNSTABLE INJURIES**

**Dislocations**—In dislocations the posterior ligament complex is always ruptured and healing sufficiently strong to restore the full
stability of the spine cannot be depended upon even after months of immobilisation. In all dislocations, therefore, stability must be restored by bone grafting of the affected vertebrae. It is only necessary to fuse the two affected vertebrae.

In the cervical spine reduction of the dislocation is effected by manipulation under anaesthesia, with the additional aid of skull tongs or calipers. After reduction position is maintained for some days by weight traction upon the tongs and then fusion is performed either posteriorly by grafts along the laminae or anteriorly by grafts sunk into the vertebral bodies (Figs. 20 to 22). We now prefer the anterior route because fusion appears to be more certain by this method. The same programme is followed whether there is cord damage or not.

In the rare lumbar dislocations, operative reduction and fusion by bone grafts bolted to the spinous processes and reinforced by small grafts applied to the roughened laminae is carried out at once (Figs. 23 and 24).

**Extension fractures and dislocations**—All these injuries are stable in flexion, and stability can be restored by holding the spine in the neutral position for two to three months. Fusion is unnecessary.

**Rotational fracture-dislocations**—These fracture-dislocations only occur at the thoraco-lumbar junction and in the lumbar spine. The horizontal fracture of the body, the fracture of the articular processes and rupture of all the major ligaments make this fracture the most unstable of all vertebral injuries. It is so unstable that reasonable alignment of the spine can be obtained merely by laying the patient supine. The instability of the spine is so great that the cord and roots are in grave danger of damage—indeed 95 per cent of all paraplegias at the thoraco-lumbar level are associated with this fracture-dislocation.

Because of the fractures of the body and of the articular processes, healing constantly results in fusion of the affected vertebral bodies and complete stability of the spine. In the absence of paraplegia and sensory loss over the sacrum, buttocks and legs, the spine is easily

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**Figure 23**—Dislocation of the lumbar spine. **Figure 24**—After reduction of the dislocation the spine is fused by tibial grafts bolted to the spinous processes.
Rotational fracture-dislocation without paraplegia.

After three months' immobilisation in plaster, fusion is taking place between the adjacent bodies.
restored to satisfactory alignment by laying the patient supine, and satisfactory immobilisation can be secured by nursing the patient in a plaster bed with a turning case. The plaster bed immobilisation should be continued for six weeks, by which time the fracture is sufficiently stable to allow the application of a plaster jacket without risk of damage to the spinal cord or nerve roots. After the jacket has been applied mobilisation and exercise must be insisted upon. The jacket is removed when fusion is firm, usually at twelve to fourteen weeks (Figs. 25 and 26).

When at the original injury the cord or nerve roots or both have been damaged and there is loss of sensation over the sacrum, buttocks and legs, plaster must never be used because it invariably causes serious skin ulceration. Skin ulceration can be prevented only by turning the patient two-hourly day and night. In this region of the spine the paraplegia is mostly due to damage to the nerve roots of the cauda equina, and recovery is always possible; therefore the vertebral fracture must always be accurately reduced in order to free the roots from pressure and firmly fixed to prevent movement at this extremely unstable fracture during the necessary turning. This stability can best be achieved by internal fixation of the unstable spine by plates bolted to the spinous processes (Figs. 27 to 34). The fracture-dislocation is exposed and the spinous processes immediately above and below are gripped by powerful forceps. The

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**Fig. 27**

Flexion-rotation violence. (Reproduced by permission of the *Yorkshire Post*.)

**Fig. 28**

Case 1—The rotational fracture-dislocation of the twelfth thoracic vertebra upon the first lumbar produced by the violence shown in Figure 27. The patient sustained a transection of the cord at the first sacral neurological segment and damage to all the lumbar nerve roots with paraplegia complete from the first lumbar neurological segment. In these circumstances internal fixation is indicated.
displacement is then reduced by manipulation under direct vision. At the same time the damage to the dura and cord can be inspected through the tear in the ligamentum flavum. Plates are laid along each side of the spinous processes and firmly fixed by bolts passed through holes drilled in the processes. Because the fracture-dislocation is the result of rotational violence full stability can be achieved only by fixing at least four spinous processes, two above and two below the fracture-dislocation. The plates firmly fix the spine until spontaneous interbody fusion occurs, usually in three months. It must be emphasised

that this operation is only indicated in unstable fracture-dislocations associated with paraplegia where there is some hope of recovery in cord or root function. The results so far as the spine is concerned are excellent provided the operation is properly performed.

Twenty years ago fractures of the spine were almost entirely the result of accidents occurring in heavy industry, particularly coal mining, and were therefore geographically restricted. Now the incidence is almost equal throughout the country, for whereas spinal
injuries in heavy industry are decreasing, those from road accidents are greatly increasing. We must all be familiar with these serious spinal injuries. This is my excuse for inflicting this dissertation upon you.

REFERENCES


