HYPEREXTENSION INJURIES OF THE SPINE

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Little has been written about hyperextension injuries in comparison with other mechanisms of injury to the spine. Probably the explanation for this is that in the cervical spine hyperextension injuries are much more difficult to diagnose radiologically, and in consequence proportionately fewer of these injuries are diagnosed by surgeons and radiologists than are flexion and vertical compression lesions. It is also possible that because of the inherent stability that remains after most hyperextension injuries there has been little to excite controversy between the surgical and conservative schools as to the correct method of early management, or discussion on the relative merits of different surgical approaches to the problem. Extension injuries of the thoracic and lumbar spines appear to be so rare that they fail to excite much comment.

The varying pattern of hyperextension injuries has been studied over the last five years, and it is proposed to correlate the clinical and pathological findings from patients admitted to the Victorian Spinal Injuries Centre at the Austin Hospital between January 1965 and December 1969, and to discuss these in relation to a proposed sub-classification of hyperextension injuries of the spine.

PREVIOUS REPORTS

Cervical spine—Hyperextension injuries of the cervical spine seem to have been thought rare until Taylor and Blackwood (1948) reported a patient who sustained incomplete tetraplegia in the presence of normal radiological appearances of the cervical spine, and postulated that the paralysis was caused by a hyperextension force. They showed that the spinal cord could be damaged by anterior compression by an intervertebral disc, and posterior compression by the ligamentum flavum. Taylor (1951) extended this theory with myelographic studies on cadaveric spines. Before Taylor's work the only recognised cause of cervical lesions from hyperextension were those rare cases in which posterior dislocation was demonstrated.

Another significant contribution came from Schneider, Cherry and Pantek (1954), who described the acute central cervical spinal cord syndrome. They showed that this syndrome commonly followed hyperextension injuries of the cervical spine, with or without radiographic evidence of cervical skeletal injury or displacement. Both Taylor and Schneider et al. stressed the importance of the history of the injury, or of clinical evidence of facial injury in proving the mechanism of these injuries. Schneider et al. described the full range of spinal cord injury in hyperextension injuries, from the transient central cord syndrome (from spinal cord concussion), central cord oedema, central haematomyelias, to complete transverse cord necrosis.

Bedbrook (1966) found that vertical compression injuries and anterior dislocation caused either central cord or anterior cord syndromes, whereas extension injuries caused either anterior or posterior cord syndromes. Barnes (1948) recognised two types of hyperextension injury of the spine: 1) posterior dislocation (one patient, under fifty years of age); and 2) injury to arthritic spines (all more than fifty years of age). Later, Barnes (1961) stated that the prognosis for the spinal cord was worse in hyperextension injuries in patients with ankylosing spondylitis and cervical spondylosis than it was with similar injuries sustained by patients with normal cervical spines. He emphasised that rupture of the anterior longitudinal ligament might be present even though radiographs appeared normal.
Holdsworth (1963) thought that there was momentary dislocation as the anterior ligament ruptured or stretched but that immediate spontaneous reduction occurred. Guttmann (1966) detailed five cases of hyperextension injuries of the cervical spine in patients with ankylosing spondylitis, drawing attention to the gross fracture that occurs through the vertebral column.

Roaf (1960) performed experimental work with fresh cadaveric spines, and his results led to a greater understanding of the mechanism of all spinal injuries. He found that he could not rupture the anterior longitudinal ligament by hyperextension, but could do so easily if rotation was applied with extension. Pure hyperextension caused fracture of the neural arch first.

Forsyth (1964) introduced another group of extension injuries of the cervical spine, which present as forward displacements, and therefore masquerade as flexion injuries. He postulated the continuation of the extension force in an arc, with the continuation of that force acting successively in a backward, downward, and finally forward direction. On the basis of different patterns of bony injury to articular masses and posterior vertebral structures, he subdivided these injuries into two more groups: 1) extension-rotation injuries; and 2) extension-compression injuries, unilateral or bilateral.

Cornish (1968) thought that many fractures of the axis in which there was a fracture in a coronal plane passing through the posterior part of each lateral mass were caused by an extension-vertex compression force. This distinctive fracture caused some forward displacement of the body of the axis on the body of the third cervical vertebra. The presence of an avulsion fracture from the antero-inferior lip of the body of the axis was sometimes supporting evidence of the extension mechanism in these injuries.

Cheshire (1969) in a detailed classification of cervical spine injuries recognised four patterns of extension-rotation injury: 1) extension-disruption of normal spines and spines affected by cervical spondylitis; 2) extension-disruption of a spine affected by ankylosing spondylitis; 3) extension injury of a spine affected by cervical spondylitis, but no bony injury or ligamentous disruption; and 4) complete instability in apparent extension injuries. The last group, that is complete instability due to rupture of all anterior and posterior ligamentous structures, has probably been foreshadowed by Whitley and Forsyth (1960). They included four sub-groups of extension injury in their classification of cervical spine injuries, one of which they called "combined flexion and extension".

Thoraco-lumbar spine—Schneider et al. (1954) cited a case of Perardi’s in which a hyperextension injury produced a central haematomyelia at the fourth thoracic level. Guttmann (1963) showed a radiograph of a severe extension-disruption of the twelfth thoracic vertebra on the first lumbar, and in 1966 reported seven cases of extension injury in ankylosing spondylitis, two of which occurred in the thoraco-lumbar region of the spine.

Most other writers, if they mention them at all, refer to extension injuries of the thoracic and lumbar spines, in passing, as rare. Bedbrook (1969) had seen only one such case in a personal experience of 200 fractures and dislocations of the spine.

MATERIAL

In the five years between January 1965 and December 1969, 332 patients were admitted to the Spinal Injuries Centre for Victoria at the Austin Hospital with spinal cord injuries: there were 178 injuries of the cervical region and 154 of the thoraco-lumbar region.

Of the cervical lesions, classified according to Holdsworth (1963), there were fifty-one (29 per cent) extension injuries. The average age of these patients was forty-eight years (range nineteen to seventy-two) compared with an average age of thirty-one years (range nine to sixty-seven) for all other cervical lesions (Table I).

Of 154 patients admitted with thoraco-lumbar injuries only four (2.5 per cent) had extension injuries, all of the thoracic spine. Their average age was fifty-four years (range forty-six to sixty-two).
PATTERNS OF HYPEREXTENSION INJURY OF THE CERVICAL SPINE

It is proposed to discuss the different patterns of hyperextension injury of the cervical spine under the following headings: 1) posterior dislocation; 2) extension disruption without dislocation; 3) extension disruption of a spine affected by ankylosing spondylitis; 4) complete ligamentous rupture in apparent extension injuries; 5) hyperextension injuries masquerading as flexion injuries, a) in the lower cervical spine, and b) in the upper cervical spine.

Posterior dislocation—Although this is the classical form of hyperextension injury it was seen in only one patient in this series. It occurred in a twenty-four-year-old man who presented with complete tetraplegia below the fourth cervical segment after a motor car accident. A lacerated forehead and fractures of the mandible and maxilla suggested the possibility of an extension mechanism, and radiographs showed posterior dislocation of the fourth cervical vertebra on the fifth. The patient died after ten days despite intensive respiratory management, but in that time he had regained some motor and sensory function in the fifth cervical segment. Complete transection of the spinal cord was observed at necropsy (Fig. 1).

Extension-disruption without dislocation—In this group are included all those hyperextension (extension-rotation) injuries of the cervical spine in which rupture or stretching of the anterior longitudinal ligament occurs, but there is little or no displacement of the vertebrae. This is the group described by Taylor and Blackwood (1948) and by Schneider et al. (1954) in which the spinal cord is compressed between the ligamentum flavum posteriorly and the intervertebral disc (and posterior osteophytes) anteriorly. Slight posterior subluxation of the upper vertebra at the site of injury may occur, but by no means invariably. Attempts to subdivide this group into those with cervical spondylosis and those with normal cervical spines on radiological grounds is often difficult, because only the more severely degenerated spines show obvious radiographic changes.

TABLE 1

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Cervical</th>
<th>Thoraco-lumbar</th>
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<td></td>
<td>332</td>
<td>178</td>
<td>154</td>
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<td>Extension injuries</td>
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<td>Other</td>
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<td>Extension injuries</td>
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<td>4 (2.5%)</td>
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<tr>
<td>Other</td>
<td>150</td>
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</table>
ILLUSTRATIVE CASE REPORTS

Case 1—A sixty-nine-year-old man was admitted three hours after a motor car accident with complete tetraplegia below the fifth cervical segment. Bruises and lacerations of the forehead and a left periorbital haematoma suggested an extension mechanism. Radiographs showed a severely spondylotic spine with posterior subluxation of the fourth cervical vertebra on the fifth, and a fracture through an anterior osteophyte on the fifth cervical vertebra. He died on the twelfth day after injury. There had been return of only a little sensibility, in the legs.

Examination of the spine at necropsy (Fig. 2) showed the classical central haematomyelopathy described by Schneider, suggesting that he probably would have made an incomplete neurological recovery in the pattern of the central cord syndrome had he survived. Rupture of the anterior longitudinal ligament and of the intervertebral disc between the fourth and fifth cervical vertebrae was also seen.

Case 2—A fifty-nine-year-old man was riding a horse in a jumping event when the horse shied as it approached a hurdle and struck him in the face with its head. He became immediately tetraplegic and fell from the horse. On admission three hours later he had an abrasion across the bridge of the nose and incomplete tetraplegia below the sixth cervical segment, showing the acute central cervical cord syndrome of Schneider. Radiographs showed moderate degenerative changes, with old compression fractures of the bodies of fifth and sixth vertebrae (from a fall in 1931). There was a widening of the disc space anteriorly between the sixth and seventh vertebrae, and a flake fracture from the anterolateral lip of the body of the seventh cervical vertebra (Fig. 3). The deformity was corrected by flexion of the neck (Fig. 4); so it was considered that he had suffered an extension injury of the spine, causing rupture of the anterior longitudinal ligament between the sixth and seventh cervical vertebrae.

The neck was immobilised in flexion in a collar. During the succeeding few days there was slight neurological deterioration, presumably due to oedema, but thereafter progressive neurological improvement occurred until the patient regained normal bladder and bowel function, and normal power in the left leg. The right leg improved in power also, but not to the same extent, and both hands improved, but not to normal power. There was overlying spasticity in all four limbs, particularly in the right leg and the hands. He was able to walk quite well, but remained significantly handicapped in hand function.

It is probable that the spinal cord in Case 2 suffered similar changes to those seen in the specimen in Case 1: that is, central haematomyelia and rupture of the anterior longitudinal ligament and intervertebral disc opposite this level. Of the fifty-one extension injuries under review twenty-three could be considered to have an area of central cord necrosis and haemorrhage of varying extent, because the permanent neurological changes were those of acute central cervical spinal cord syndrome. Not all had definite radiological evidence of cervical spondylosis, but some radiological evidence of anterior longitudinal ligament damage could be found in all but two patients.

Three patients with similar radiological appearances to those described presented with complete tetraplegia, which remained complete in two, and would have remained complete in a third (Fig. 5) if the patient had survived. This case illustrates that greater spinal cord damage may occur if the degenerative changes—or the degree of injury—are greater than as in the two cases described above.

At the opposite extreme are those patients who suffered a transient paralysis of the acute central cervical spinal cord syndrome, but who made a full neurological recovery after a period varying from forty-eight hours to two weeks after injury. Ten such patients were seen, four of
Case 2.  

Figure 3—Lateral radiograph of cervical spine (see text).  

Figure 4—Lateral radiograph of cervical spine with the neck flexed.  

Figure 5—Sagittal section of a cervical spine showing complete transverse spinal cord necrosis in a patient who suffered an extension injury to a markedly spondylotic spine. Note the upward and downward extension of the cord necrosis, in a central distribution, from the area of greatest damage opposite the fourth-fifth intervertebral disc level, where the disc and anterior ligament have ruptured.  

Figure 6—Sagittal section of a cervical spine showing rupture of anterior longitudinal ligament and intervertebral disc between fourth and fifth cervical vertebrae, but no macroscopic evidence of spinal cord injury.
whom had convincing radiological changes of cervical spondylosis, but in only one was no
damage to the anterior longitudinal ligament demonstrated. Figure 6 shows the spinal cord
of one patient, who died from a pulmonary embolus two weeks after injury, having made a
full neurological recovery from a central cervical spinal cord syndrome. Although the spinal
cord was undamaged macroscopically there were slight changes to be seen microscopically.
According to Schneider et al. (1954) there is a central cord oedema and recovery occurs as
it subsides.

Thirty-six of the fifty-one patients with extension injuries of the cervical spine fell into
the category of “Extension-disruption without dislocation”. With the exception of three young
men aged twenty to twenty-six years with normal cervical spines, it seems probable that the
rest, with an average age of fifty-six years (range thirty-four to seventy-two years) had
degeneration of the intervertebral discs, and also possibly degenerated anterior ligaments.
It is the author’s opinion that this lesion rarely occurs without degenerative changes existing
in the cervical spine, although radiographs may not demonstrate cervical spondylosis, and
diagnosis depends on an accurate history and general clinical examination, precise neurological
examination and radiographs.

![Figure 7](image1.png)  ![Figure 8](image2.png)

**Fig. 7** Sagittal section of the cervical spine of a man suffering from severe cervical
spondylosis. Note the anterior interbody fusions between the third and fourth, and sixth and
seventh, cervical vertebrae. **Fig. 8**—Lateral radiograph of cervical spine showing a fracture
extending through the intervertebral disc between the fifth and sixth cervical vertebrae of a
spine severely affected by ankylosing spondylitis.

It is a compression of the spinal cord that causes the damage, and that this is more likely
to occur in the older age group with a spinal canal narrowed by a thickened and felted
ligamentum flavum and posteriorly protruding osteophytes and intervertebral discs is shown
in Figures 2, 5 and 6. Figure 7 shows the narrow canal in a patient who had had anterior
decompressions and fusions at two levels for severe cervical spondylosis causing incomplete
tetraplegia.

**Extension-disruption in ankylosing spondylitis**—According to Guttmann (1966) disruption
through a vertebral column affected by ankylosing spondylitis only occurs with a hyperextension
force and never with flexion. There were four such patients in this series, aged from thirty to sixty
years, two with complete tetraplegia and two with incomplete tetraplegia; all four had a fracture line extending horizontally at the level of an intervertebral disc (Fig. 8).

Of the two incomplete tetraplegic patients one had a central cord syndrome and the other a Brown-Sequard syndrome.

ILLUSTRATIVE CASE HISTORY

Case 3—The patient with the central cord syndrome had an interesting onset of paralysis. After a road accident he felt pain in the neck, but did not develop any neurological signs immediately. An hour later at another hospital he was placed supine for radiography, after which he felt numbness; weakness gradually developing in his arms and legs. Because of this history and the radiographs which showed a fracture line extending through an ankylosed spine at the level of the sixth cervical intervertebral disc, the patient was sat up with the neck flexed slightly; shortly afterwards he began to get some return of motor and sensory function in his legs. He was transferred to the Spinal Injuries Centre eight hours after the accident, when he had a classical central cord syndrome with slight weakness and spasticity in both legs, complete paralysis of the intrinsic muscles of both hands and marked weakness of finger flexors, finger extensors and triceps, particularly on the right side. He improved with conservative management and when last seen had only residual weakness in the intrinsic muscles of both hands and very slight weakness of the right finger extensors and triceps.

This patient illustrates very well the evolution of the central cord injury by compression of the spinal cord when the neck is extended.

Complete ligamentous rupture in apparent extension injuries—There were four patients who appeared to present primarily with an extension injury, but who were shown to have complete antero-posterior ligamentous rupture. Two of the patients initially had incomplete tetraplegia, one of which became complete later and only then was the diagnosis of total instability made. The patients were aged from twenty-six to fifty-eight years. As stated elsewhere it is not possible to be sure whether this clinical entity is caused by extension or by flexion forces, or by both (Burke and Berryman 1971).

ILLUSTRATIVE CASE HISTORY

Case 4—A forty-nine-year-old woman was ejected from a car when it struck a tree. She was admitted to the Spinal Unit seven hours after the accident with a complete tetraplegia below the sixth cervical segment. Other injuries included abrasions to the face and bruising around the right eye, an abrasion of the left vertex, multiple abrasions to both arms and the left leg and a fracture of the shaft of the right femur. Radiographs of the spine showed an extension injury of the fifth cervical vertebra on the sixth with no instability on limited movement (Fig. 9) and also compression fractures of the fifth and sixth thoracic vertebrae. The neck was merely immobilised in a collar. A radiograph the next day showed bilateral forward dislocation of the fifth cervical vertebra on the sixth (Fig. 10). Reduction was achieved and maintained by skull traction. She died suddenly on the eighteenth day after admission, probably from inhalation of vomitus. The only neurological change had been the return of some previously absent motor function to the sixth cervical segment.

Sagittal section of the cervical spine showed a cleavage plane of complete anterior and posterior ligamentous rupture passing through the intervertebral disc between the fifth and sixth cervical vertebrae, with complete destruction of the spinal cord at this level (Fig. 11).

Hyperextension injuries masquerading as flexion injuries. Lower cervical spine—Forsyth (1964) described two different patterns of extension injury which present as flexion injuries of the lower cervical spine; there were two such patients in this series. One was a young man who had had a soft-tissue injury on his forehead and a complete tetraplegia below the sixth cervical segment. He had severe forward dislocation of the sixth cervical vertebra on the seventh (Fig. 12). The rest of the cervical spine was hyperextended although the radiograph was taken supine with the neck in the neutral position. Oblique radiographs showed bilateral fractures of the articular processes of the seventh cervical vertebra, with wide separation of the fragments. The other patient had a similar forward dislocation, of the fourth cervical vertebra on the fifth, with a fracture of the right articular mass of the fifth cervical vertebra. The lesion
Fig. 9—Lateral radiograph of cervical spine showing marked spondylotic changes to the lower spine. Avulsion of an anterior osteophyte from the upper lip of the sixth cervical vertebra suggests a ruptured anterior longitudinal ligament. Figure 10—Lateral radiograph twenty-four hours later showing forward dislocation of the fifth cervical vertebra on the sixth. Figure 11—Sagittal section of cervical spine showing complete rupture of the intervertebral disc and all ligamentous structures between the fifth and sixth cervical vertebrae, with complete transverse cord section at this level.

Fig. 12—Lateral radiograph of a cervical spine showing bilateral forward dislocation of the sixth cervical vertebra on the seventh. Figure 13—Lateral radiograph of a cervical spine showing bilateral fracture of the axis posterior to the articular facets. Note the widening of the intervertebral disc spaces anteriorly between the second and third, third and fourth, and fourth and fifth cervical vertebrae, suggesting multiple anterior ligamentous rupture. Figure 14—Lateral radiograph of a cervical spine showing a compression fracture of the body of the fifth cervical vertebra.

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was complicated only by a partial fifth cervical motor root lesion. At operation all the posterior ligaments between the fourth and fifth cervical vertebrae were intact.

It is considered that these patients suffered extension-compression injuries, the forward dislocation being caused by continuation of the force in an arc as described by Forsyth. Upper cervical spine—Four patients presented with fractures of the neural arch of the axis with forward displacement of the body of the axis on the third cervical vertebra. The author agrees with Cornish (1968) that these injuries are probably caused by hyperextension. Figure 13 illustrates this, and it seems that this syndrome is a variant of that described by Forsyth, but it is worth classifying separately because it is a well defined and distinct clinical entity.

All the patients were young men aged nineteen to twenty-nine, all had transient or very incomplete neurological lesions, and all survived.

Fractures of the odontoid, with posterior displacement of the atlas on the axis, are probably caused by hyperextension injuries, but there were none in this series.

According to Roaf (1960) pure hyperflexion causes only a compression fracture of a cervical vertebra, and not dislocation. Figure 14 illustrates such an injury, but in this case the arc of force has continued in the opposite direction to that described by Forsyth and has pushed the body of the fifth cervical vertebra posteriorly into the neural canal. This could give the impression of a posterior dislocation from an extension injury.

HYPEREXTENSION INJURIES
OF THE THORACO-LUMBAR SPINE

Only four patients out of 154 thoraco-lumbar lesions presented with hyperextension injuries, and all were in the thoracic spine. Figure 15 shows the pathological changes in one patient. Massive spinal cord necrosis has occurred above the level of vertebral injury and indicates that the mechanism of this spinal cord injury was traction rather than compression. In two other patients in this group the spinal cord was seen to be transected, at necropsy in one and at laminectomy in the other.

The levels of injury ranged from the third thoracic disc to the tenth thoracic disc. The patients were aged from forty-six to sixty-two years; only one had obvious pre-existing abnormality and this was severe osteoporosis. All four patients had complete and permanent paraplegia.

DISCUSSION

The subdivision of extension injuries of the spine into a number of groups is not merely an academic exercise. The ability to recognise variations in the pattern of these injuries, combined with a knowledge of their varying clinical courses and the expected pathological changes, leads to a more rational approach to treatment. For example, it is important to know that most extension injuries of the cervical spine are stable and should be treated conservatively, particularly because spontaneous neurological recovery—to a greater or lesser extent—may occur in many patients. However, it is equally important to recognise the potentially unstable hyperextension lesions, and before they have become unstable. The
treatment of choice for the latter is still conservative, but knowledge of the different lesions will give a cautious approach; occasionally it will also allow a decision to fuse the spine, as, for example, in a patient with an incomplete tetraplegia because of extension disruption in ankylosing spondylitis, or with a total ligamentous rupture (Cheshire 1969).

The mortality after surgery in aged tetraplegic patients is high, so it is fortunate that most extension injuries which occur in older people are stable lesions with an incomplete neurological lesion. The more unstable injuries are less common and usually are seen in younger people who are usually better able to stand surgical treatment should it be required. There were ten deaths in this series of fifty-one patients, seven of which occurred in elderly tetraplegics who had pre-existing cardiopulmonary disease. This was a low mortality rate, especially in patients with an average age of forty-eight years.

The rarity of extension injuries of the thoraco-lumbar spine has been emphasised by the low incidence in a large series of patients. On the limited experience gained from these patients the prognosis of the spinal cord lesion in these injuries seems to be poor.

SUMMARY

1. The literature on hyperextension injuries of the spine is briefly reviewed.
2. Such injuries in the cervical spine can be subdivided into five groups based on the pathological anatomy, based on the experience of fifty-one patients in the Spinal Injuries Centre for Victoria over the past five years.
3. Extension injuries of the thoraco-lumbar spine are discussed. They are rare and have a poor prognosis.
4. The importance of treatment, based on sound clinical and pathological knowledge is emphasised, particularly in order that stable and unstable lesions may be recognised early and managed correctly.

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