Impaction fracture of the lumbar vertebrae with dural tear

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The authors describe a lumbar spine fracture that is characterized on anteroposterior x-ray views by separation of the pedicular shadows. It is almost invariably associated with posterior interlaminar herniation of the cauda equina through a dorsal dural split, and anterolateral entrapment or amputation of the nerve root. The fracture is unstable and requires internal fixation and fusion at the time of neurolysis. Fractures meeting these criteria should be explored as soon as the patient's condition permits. Myelography is usually unnecessary and may be contraindicated in some cases. The postulated mechanism of injury is hyperextension with vertical impaction and rupture of the ring made up of the lamina, pedicle, and vertebral body. The ring is fractured in several places in a manner similar to that seen in "Jefferson fracture" of C-1. The special anatomical relationships of the thoracolumbar junction and the plane of the lumbar facets are also discussed.

Key Words: lumbar spine fracture · dural rupture · cauda equina compression · nerve root compression · paraplegia · spinal fusion · Harrington rods · thoracolumbar junction

Injury to the lumbar spine is common and highly variable. The injury can range in severity from a muscle or ligament strain to fracture-dislocation with permanent paraplegia. Fractures of the lumbar spine with neurological deficit present a special problem. Treatment of the skeletal and the neurological disorders remains controversial, in part because the potential instability has not been clearly described and the threat to neural structures has not been fully recognized. Treatment is aimed to achieve three goals: 1) preservation and protection of neurological function; 2) stabilization of the fractured spine, internally or externally; and 3) ultimate bone stabilization of the spine with or without bone grafts.

This paper describes one particular type of fracture, occurring at the T12-L1 junction and the upper L-3 or L-4 vertebrae, that is characterized on anteroposterior (AP) radiographs by separation of the pedicular shadows. A series of 19 such cases is presented. This fracture is unstable and is usually accompanied by a dorsal dural tear with posterior interlaminar herniation of the cauda equina, and entrapment or amputation of nerve roots.

Summary of Cases

Presenting Features

We are reporting 19 cases of this particular fracture (Table 1), which was associated with dural rent and herniation of the cauda equina in 18 of them. The pathognomonic finding in such cases is the separation of the pedicular shadows seen on the AP radiograph (Fig. 1). There is also comminution of the body, and some misalignment may be present. Occasionally, a

<table>
<thead>
<tr>
<th>Fractured Vertebrae</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-12</td>
<td>1</td>
</tr>
<tr>
<td>L-1</td>
<td>8</td>
</tr>
<tr>
<td>L-2</td>
<td>5</td>
</tr>
<tr>
<td>L-3</td>
<td>3</td>
</tr>
<tr>
<td>L-4</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 1
Fracture site in 19 patients with lumbar impaction fractures
TABLE 2
Etiology of injury in 19 cases of lumbar impaction fractures

<table>
<thead>
<tr>
<th>Etiology</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>motor-vehicle accident</td>
<td>11</td>
</tr>
<tr>
<td>fall</td>
<td>4</td>
</tr>
<tr>
<td>aircraft crash</td>
<td>2</td>
</tr>
<tr>
<td>crush</td>
<td>2</td>
</tr>
</tbody>
</table>

TABLE 3
Associated injuries in 19 patients with lumbar impaction fractures

<table>
<thead>
<tr>
<th>Associated Injuries</th>
<th>No. of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>rib fractures</td>
<td>10</td>
</tr>
<tr>
<td>pneumothorax</td>
<td>6</td>
</tr>
<tr>
<td>pelvic fracture</td>
<td>5</td>
</tr>
<tr>
<td>abdominal contusion</td>
<td>6</td>
</tr>
<tr>
<td>depressed skull fracture</td>
<td>1</td>
</tr>
<tr>
<td>basilar skull fracture</td>
<td>3</td>
</tr>
<tr>
<td>fractured humerus</td>
<td>4</td>
</tr>
<tr>
<td>cerebral contusion</td>
<td>4</td>
</tr>
<tr>
<td>brachial plexus injury</td>
<td>1</td>
</tr>
<tr>
<td>cervical spine fracture</td>
<td>1</td>
</tr>
<tr>
<td>3rd degree burns</td>
<td>1</td>
</tr>
<tr>
<td>ruptured spleen</td>
<td>3</td>
</tr>
<tr>
<td>ruptured liver</td>
<td>2</td>
</tr>
<tr>
<td>fractured ulna &amp; radius</td>
<td>1</td>
</tr>
</tbody>
</table>

FIG. 1. The pathognomonic finding is separation of the pedicular shadows, as indicated by the arrows. Communion of the vertebral body and bone misalignment may also be present.

FIG. 2. Computerized tomography scan showing a pure hyperextension injury. Scans by kind permission of Edward Reifel, M.D., Seattle, Washington. Left: Fragmentation of the vertebral body and a fracture through the base of both pedicles are visible. The fracture extends through the pedicle on the left and through the left lamina at the base of the spinous process. This is the point of nerve root herniation (arrows). Right: Scan showing a fracture at the base of both pedicles into the body of the vertebra (arrows). Fracture at the base of the spinous process again seen.

A description of the traumatic event may lead the surgeon to suspect this injury. Neurological deficit may be incomplete and sometimes concealed by the presence of multiple serious injuries (Tables 2 and 3). A widened interpedicular distance is an indication for surgery at the earliest possible time, but, obviously, life-threatening injuries must take precedence. In only one case with this radiographic finding was the dura intact at exploration, and this patient had no neurological deficit.

Myelography

Ten patients underwent preoperative myelography (Table 4). Five patients had a complete myelographic block, and in one of these dye was seen leaking from the dural tear. All five of these patients had herniated cauda equina roots, which in four were incarcerated in the laminar fracture. Four patients had incomplete block, and two of these had torn dura and incarcerated nerve roots. One patient with complete block while prone had an incomplete block when turned to the supine position. He had no motor dysfunction on admission to another service, but his condition deter-
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FIG. 3. Demonstration of a laminar spreader between T-12 and L-2. Once the dissection of muscle and ligaments is complete and the spinous processes above and below the lesion are freed, the laminar spreader can be placed and often allows reduction of posterior-element fragments without excessive dissection at the fracture site.

iorated to paraplegia in 12 hours, at which time neurosurgical consultation was obtained. His deficit has remained complete.

Based on this analysis, we have discontinued preoperative myelography when the pedicles are separated. Myelography does not add significant information and requires manipulation of the patient which may lead to further neurological damage. The possibility of a Pantopaque arachnoiditis, particularly if the cerebrospinal fluid (CSF) is bloody at the time of lumbar puncture, is also a consideration. Metrizamide myelography and the body scan may play a significant role in the diagnosis of these fractures, but we have not yet evaluated them. Computerized tomography may also prove to be helpful (Fig. 2).

Operative Technique and Results

It is probable that a slightly flexed position for the patient during surgery is safer than an extended one, but this varies from case to case. Attention to the patient’s description of pain and numbness may help in finding the optimum position for operation, which will usually be prone, but at times the lateral decubitus position may be preferable. We have operated on two patients under local anesthesia because of our uncertainty about the optimum position and our concern about increasing an incomplete and variable deficit.

Sharp dissection under direct vision is essential. The spinous processes of the nearest intact neural arches are identified. Usually the joint capsules binding the adjacent superior and inferior articular facets are intact, and the joint is displaced laterally with the pedicle-body complex of the vertebra below. The facet-pedicle-body fragment may come free in toto as sharp dissection proceeds, aided by minimal use of rongeurs. Cerebrospinal fluid may appear in the wound. Unexpectedly displaced bundles of cauda equina are at risk. The theca and root sleeves are visualized by the use of a laminar spreader* (Fig. 3) and by minimal laminectomy. The laminar spreader between intact spinous processes is an invaluable aid in anterolateral exploration for reduction or removal of displaced fragments of the vertebral body. We con-

TABLE 4

<table>
<thead>
<tr>
<th>Myelographic Findings*</th>
<th>Total Cases</th>
<th>Surgical Findings</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Torn Dura Herniated Roots Amputated Roots</td>
</tr>
<tr>
<td>complete block (CSF bloody in all)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>incomplete block (CSF bloody in 3)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>normal (CSF clear)</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

*CSF = cerebrospinal fluid.

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sider it an essential instrument. In none of these cases was herniated disc material encountered.

Herniated cauda equina is replaced and the vertical dural rent repaired. The nerve roots may be entrapped or even amputated by the sharp fragments of the pedicle-body complex. These are decompressed or the torn root sleeve closed with a clip. Watertight closure is achieved. Harrington rods are then placed for immediate stabilization, and appropriate bone grafts are inserted. A suction-drainage apparatus is usually introduced.

The operative findings strikingly demonstrated the vulnerability of the neural structures to further damage at the fracture sites. Of the 19 patients with widening of the interpedicular distance on plain AP x-ray films, 15 had vertical dural lacerations. In 12 patients, the cauda equina herniated through the dural laceration, and in six of them the herniated cauda was caught in the lamina fracture line. In two patients, the cauda equina herniated through a lateral dural laceration, and the roots were incarcerated in the lateral part of the fracture through the pedicle and body. In seven patients, nerve roots were amputated at this point. All the patients in this series underwent neurolysis and lateral process fusion, and 14 of them also had Harrington rods placed for stabilization.

Outcome

Preoperative and late neurological status are compared in Table 5. Prompt postoperative improvement has often been noted, especially in cases with incomplete lesions. The ultimate prognosis is good when compared to fractures with neurological deficit at other levels. Twelve of the 19 patients are ambulatory with mild to moderate weakness. Two of the 19 can walk with support but cannot walk up or down stairs; two are paraplegic. Three patients with L-1 fractures have an atonic bladder and are impotent. Pain has not been a problem except when the spinal cord was involved.

So far, there has been no instance of instability. Rehabilitation has been facilitated by early mobilization, made possible by the internal stabilization. Harrington rods have been removed from several patients for a variety of reasons. There has been no gibbus formation.

Discussion

The literature contains many detailed discussions of fractures of the thoracic, thoracolumbar, and lumbar spine. It has been emphasized that stability depends upon the integrity of either the "anterior column" (vertebral bodies and intervertebral discs) or the "posterior column" (the apophyseal joints). The mechanism of the trauma is sometimes obvious, sometimes obscure. However, the role of the plane of the facets has received insufficient attention. This plane is of crucial importance in determining the
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nature of the fracture as it relates to the mechanism of injury. Three regions can be identified.

First, throughout the thoracic spine to the T11–12 articulation, the plane of the facets is close to the coronal plane of the body (Fig. 4). There is about 10° cephalocaudal deviation from the coronal plane. The costotransverse and costovertebral articulations may stabilize this region to some extent, but the plane of these facets permits flexion, extension, tilt, and rotation. The strong apophyseal joints overlap markedly, and tend to hold in flexion stresses such as trauma, convulsions, and weight-bearing in kyphosis, whereas the weaker vertebral body collapses. The spinal cord is often spared, and the angulated spine is fairly stable, especially in the subacute compression fracture of osteoporosis. Reduction by hyperextension, using the facets as the fulcrum, is an ancient and relatively safe maneuver when the facets are intact. If the facets fracture, that is, if the posterior column of bone is disrupted, immediate and complete paraplegia usually occurs.

The second region, the thoracolumbar junction, presents a different problem. The most common mechanism of injury is hyperflexion, when the thorax is forced forward by direct trauma or by its own inertia, as in falls on the buttocks. After the cervical region, the thoracolumbar junction is the most mobile and vulnerable region of the spinal column. 26 Forty percent of all spinal cord injuries occur at this level. 24 The T12–L1 articulation differs strikingly from that of T11–12 in that the inferior facets lie near the sagittal plane. The T12–L1 articulation is the first and weakest of the sagittal articulations. It permits either compression fracture in flexion or, less often, the impaction fracture, described herein, in which the mechanism of trauma is extension. The terminal spinal cord segment is at risk at this level, and such cord damage is more likely to remain complete than at the L1–4 level, where the injury is to the sturdier cauda equina roots passing through this region.

In the midlumbar region (L1–2, L2–3, L3–4), the facets are also in the sagittal plane. This is usually true at L4–5, but rarely true at L5–S1, where the facet plane is like that in the thorax. The midlumbar spine is lordotic, and a vertical impacting force results in hyperextension.

The posterior elements may be thought of as a capital letter H, consisting of superior and inferior articular processes with the lamina as the cross-bar. The inferior processes often have a matching indentation in the lamina near the pars interarticularis of the next vertebra below. It is here that hyperextension drives in the wedge that fractures the pars interarticularis and lamina and drives the apophyseal joint-pedicle-body complex laterally (true traumatic spondylosis). Thus, certain aspects of this fracture are similar to the mechanism of Jefferson’s fracture of C-1, wherein vertical forces disrupt the ring of the vertebral system. It is our hypothesis that the resultant forces produce a vertical rent in the theca, possibly by lateral traction on the root sleeves, resulting in the particular pattern of dural tear and root herniation that characterizes this injury. The herniated cauda equina may be caught in the disrupted posterior elements. The vertebral body may burst, and posteriorly displaced fragments may impinge on the spinal canal from in front (Fig. 5).

There has been disagreement about the efficacy of operative intervention in these cases. 1, 2, 6, 11–13, 16, 20, 22, 26, 29, 34, 36, 38 Some authors advocate only postural reduction, bedrest, and external bracing. Others favor early laminectomy with neurolysis, internal fixation, and fusion. The advent of such devices as Harrington rods for internal fixation allows early immobilization of patients, even those with severe neurological dysfunction. More and more surgeons favor the latter approach. In our opinion, the danger of increased neurological deficit requires decompression of neural elements and favors early operative treatment. Furthermore, some hyperextension lumbar fractures have been classified as “stable,” when in fact they are not, although this instability may not be apparent for some weeks or months. 10, 31, 29, 39

**Summary**

1. A particular type of fracture of the lumbar spine with a high probability of dural tear and root herniation and entrapment, diagnosed by separation of the pedicular shadows on AP radiographs, is described.

2. This fracture requires surgical exploration because of the high likelihood of persistent and/or delayed damage to neural elements and because its inherent instability demands internal fixation.

3. The literature to date has not clearly identified this problem. The application of some current criteria can lead to less optimal management.
FIG. 5. Anatomical mechanical factors in impaction fracture of the lumbar vertebrae with dural rent. For details see above.

A. Normal articulation of lumbar vertebrae.

B. Compression fracture of L3.

C. Fracture sites of pedicles and laminae, and comminution of body.

D. Fracture of inferior articular process of L2 and pedicle and lamina of L3, with dural rent and root entrapment...

E. ...and herniation of cauda equina.

Fig. 5. Anatomical mechanical factors in impaction fracture of the lumbar vertebrae with dural rent. For details see above.
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References

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