of tissue separating it from the spine. The implications of such an access are that the spine is submitted to pure distraction forces. This assumption may be challenged for two reasons. Firstly, the lap belt acts as a fulcrum that becomes the access of flexion only if and when the bending strength of the "spinal beam" under consideration is nil at the point of application of the fulcrum. Secondly, indirect evidence of this was demonstrated by Gordon Armstrong, who pointed out that in the 15 Chance fractures in the present series there was a slight vertical shortening of the anterior vertebral body, demonstrating *post facto* that the instantaneous axis of flexion was somewhere in the anterior column at the time of injury (unpublished data). It should be added also that an instantaneous axis of flexion is dynamic, not static, and moves during the sequence of rupture from somewhere in the middle column to somewhere in the anterior column as the ligaments or bony parts rupture posteriorly to anteriorly. Panjabi *et al.*,[11] in an individual study conducted to establish the thresholds of thoracic spine stability, demonstrated that under flexion loads the thoracic functional spinal unit is on the verge of instability when all ligaments posterior to and including the posterior half of the discs are cut. Nagel *et al.*[9] tested five fresh human cadavers to determine range-of-motion measurements between the first and second lumbar vertebrae after progressive disruption of the motion segment. Their study showed that an anterior flexion of 20° or a lateral flexion of 10° seen on a routine roentgenogram indicated that all posterior ligaments and at least part of the annulus fibrosus must be disrupted.

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A Mechanistic Classification of Thoracolumbar Spine Fractures

RON L. FERGUSON, M.D.,* AND BEN L. ALLEN, JR., M.D.**

Thoracolumbar spinal injuries are classified on the basis of the mechanical mode of failure of the vertebral bodies. The fractures are presented in seven categories. Emphasis is placed on the injury component causing the fracture patterns. The choice of instrumentation for surgery is based on the surgeon's understanding of these injury patterns.

At the present time there is no universally accepted classification of thoracolumbar spine fractures. The schema suggested by Holdsworth[14] has perhaps been the most widely used in clinical reviews and has been the cornerstone for many subsequent classifications. However, this system ignores a number of variables that could be weighed in treatment decisions. What effect, if any, these variables might have on treatment outcome is a focus of current interest. However, until all recognizable variables are critically analyzed, the surgeon will be able to make only "educated" assumptions about them when deciding what therapeutic mode is most efficacious for a particular patient.

From the Department of Pediatric Orthopaedic and Spine Surgery, Division of Orthopaedic Surgery, University of Texas Medical Branch, Galveston, Texas.
* Assistant Professor of Surgery and Pediatrics and Associate Director of the Department of Pediatric Orthopaedic and Spine Surgery.
** Professor of Surgery and Pediatrics and Director of the Department of Pediatric Orthopaedic and Spine Surgery.
Reprint requests to Dr. Ron L. Ferguson, 63-67 Child Health Center, University of Texas Medical Branch, Galveston, TX 77550-2776.
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Approximately five years ago, in treating spinal fracture patients by the application of L-rod instrumentation, it became apparent that in a majority of operative cases there is bone in the neural canal. Thirty-four of 54 patients seen at the authors' hospital from October 1976 to August 1981 had bone from the posterior vertebral body encroaching on the neural canal. Twelve patients in this group had similar fracture patterns, but radiographic documentation was insufficient to decide if they had bone in the neural canal. On closer review, the authors noted that among their cases this retropulsed bone followed a consistent group of patterns. The most common among the patterns was the compressive flexion lesion in which the superior margin of the vertebral body rotated into the neural canal. This comprised 46% of the 54 fractures. Nine percent of this group had bone in the canal secondary to vertical compression injuries. The lesions had either a symmetrical bulging pattern of the posterior vertebral body wall into the neural canal or an enfolding pattern of failure. In both types of vertical compression lesions the posterior vertebral body height was shortened.

Review of the relevant literature suggested that either the phenomenon of bone in the neural canal had for the most part been ignored[8,12] or the frequency distribution of the types of thoracolumbar fractures had dramatically changed. Although there is no way to accurately discern these alternatives, the authors believe that in the absence of tomo-

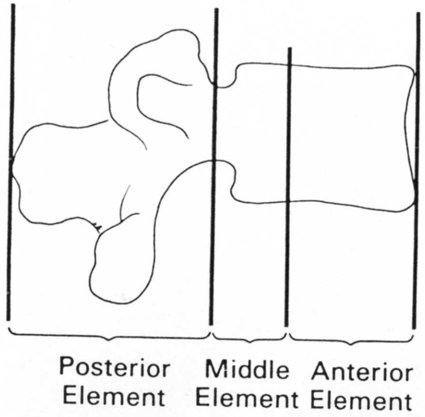


FIG. 1. Three-element concept of spinal anatomy.

graphic and computerized axial tomography (CAT) scan studies, bone in the neural canal was overlooked. The recent studies of Denis[7] and McAfee *et al.*[18] lend support to this hypothesis.

Recognizing the need for categorization of thoracolumbar fractures but realizing that there was no thoroughly documented data base, the authors adopted the following groupings. While they are not definitive, experience has shown the system to be workable. The seven groups of injuries classified are: compressive flexion, distractive flexion, lateral flexion, translational, torsional flexion, vertical compression, and distractive extension injuries.

Each group is labeled according to a presumed mechanism of injury, which is deduced from the patterns of tissue failure. The assumptions essential to this approach have been previously published and will not be fully explored here.[1] Briefly, most injuries to the thoracolumbar spine are caused by injury forces resulting in compression, tension (distraction/shear), translation, torsion (rotation), or a combination of these forces acting upon a motion segment of the spine. In the present study, injury mechanism is based on the following definitions: (1) When an element of the vertebral body has been shortened it has been affected by a compression load. (2) If an element of the vertebral body has lengthened it has been loaded in tension. (3) Torsion forces cause rotation failure of the affected segment. (4) Translational failure causes anterior, posterior, or lateral displacement of the loaded segment. These conventions have been used to hypothesize the mechanistic groups and the patterns of fractures within the groups.

In agreement with others,[7,18] the authors believe that these fractures are accurately assessed by observing what happens in three anatomic regions of the vertebral column. These regions include the posterior elements (supra- and infraspinous ligaments, ligamentum flavum, articular processes, and joint capsules), the middle elements (posterior one-third of the vertebral body, posterior one-third of the annulus fibrosus, and the posterior longitudinal ligament), and the anterior elements (anterior two-thirds of the vertebral body, anterior two-thirds of the annulus fibrosus, and the anterior longitudinal ligament) (Fig. 1). Some have referred to these three regions as columns, but the authors believe that this is a poor semantic choice because these tissues do not anatomically or biomechanically resemble a column. The term, although appealing for its verbal ring, is anatomically and biomechanically incorrect.

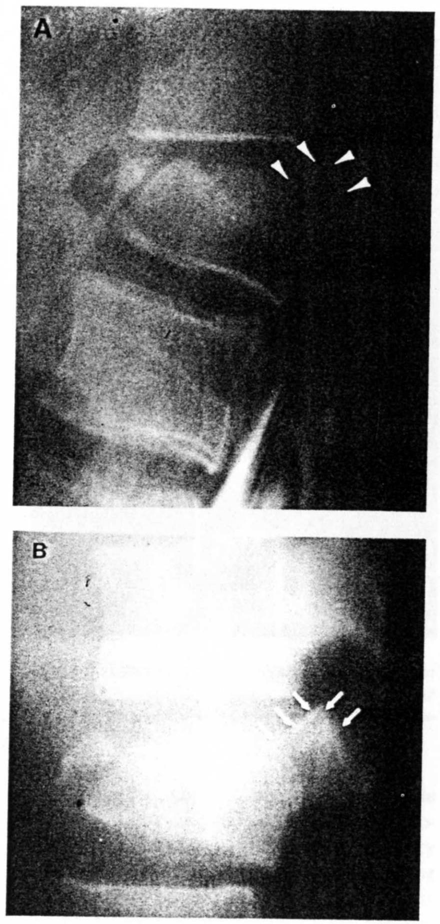
Because different thoracolumbar spine fracture classifications have been used by numerous authors, reports concerning the stability or lack of stability of a particular fracture pattern have varied. Indeed, even the definition of stability and instability varies widely. However, clinical definitions of spinal instability can be gleaned from clinical reports. These definitions address acute or chronic progression of the spinal deformity, long-term pain and its effects on the employment of the patient, the presence or absence of a neurologic abnormality, increasing neurologic abnormality either acutely or chronically, future demands to be placed upon the spine, and whether destabilizing posterior surgery has been performed. The authors believe that these

specific questions should be used when describing the long-term effects of thoracolumbar spine fracture, as more complete knowledge upon which to base assumptions of treatment can be obtained in this manner.

CLASSIFICATIONS

COMPRESSIVE FLEXION

In compressive flexion lesions, loading of the flexed spine causes compressive stress through the anterior elements and tension strain through the posterior and middle elements. There are three patterns of failure in this mechanism of thoracolumbar spinal injuries. The first pattern of injury (I) is the anterior wedge fracture in which the anterior elements fail in compression and the posterior and middle elements remain intact. Radiographically, a simple wedge compression fracture of the anterior element is seen, usually with less than 50% compression of the vertebral body height. A second pattern (II) in the compressive flexion mechanism occurs when the posterior element is disrupted by tension forces in conjunction with the anterior wedge fracture. Radiographically this posterior injury presents as widening of the spinous processes, subluxation or dislocation of the articular processes, or a fracture-dislocation of the articular processes. The third pattern (III) represents a middle element failure in conjunction with the other two elements disrupted as previously described. (Figs. 2A and 2B). The middle element is "blown out" and rotated into the neural canal between the two pedicles. Radiographic examination reveals the superior posterior margin of the vertebral body rotated into the neural canal. Whether this represents a tension failure of the posterior vertebral body wall alone, tension combined with a hydraulic blowout of the described fragment, or simply a hydraulic blowout without tension as a component of the failure mode has not been deduced at this time. The authors do not agree with others[7,18] that this represents a compression failure alone, since a compres-



FIGS. 2A AND 2B. Compressive flexion pattern III. The arrows point to the middle element that is rotated into the neural canal on (A) plain lateral roentgenogram and (B) lateral tomogram.

sion failure would shorten the posterior vertebral body wall height. In 25 cases of this fracture pattern, the posterior vertebral body wall height has been found to be equal to or increased when compared with adjacent inferior vertebral bodies. The authors ascer-

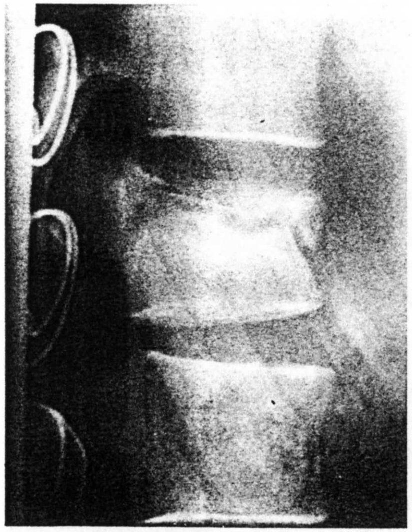


FIG. 3. Segmentally wired Harrington distraction rods accomplished this reduction of the middle element fragment in the neural canal in this compressive flexion pattern III lesion.

tained that although a CAT scan would demonstrate the middle element failure, it would not differentiate compressive flexion pattern III lesions (Fig. 3) from vertical compression injuries. This could be done only by high-quality lateral roentgenograms or lateral tomography. The authors believe that this lesion has a marked propensity for progressive neurologic injury and progressive spinal deformity. This is in contrast to vertical compression lesions, which are characterized by shortening of their middle elements and have little or no tendency for progressive injury or deformity.

Anterior wedge compression fractures with anterior element failure have been shown only to have no propensity for further progression of spinal deformity or progression of neurologic injury.[7,14,18,19,22] If more than 50% compression of the anterior elements has occurred, however, the posterior element may have failed in tension.[22] Neurologic injury rarely occurs unless multiple adjacent vertebrae are involved.[18] If tension failure of the posterior element has occurred (pattern II), then there may be progression of the deformity or acute neurologic deterioration.[7,15,18,19] In the third pattern in the compressive flexion mechanism, in which the middle element has been disrupted and rotated into the neural canal, all three elements have been disrupted. The weight-bearing capacity of the middle elements has been compromised, and thus any vertical loading of the spine may cause the middle element to be forced deeper into the neural canal. The authors believe that this lesion has a high probability of progression of spinal deformity or neurologic injury if not properly treated.

Distractive Flexion

Analysis of the multiple injury patterns in this mechanism demonstrates that failure occurs purely by tension failure of all three elements of the spine in a flexion mode. Examples of this mechanism are the Chance seat-belt fracture, in which the tension failure occurs through the bony spine, and the pure dislocation (Fig. 4), in which the tension failure occurs through the ligamentous structures

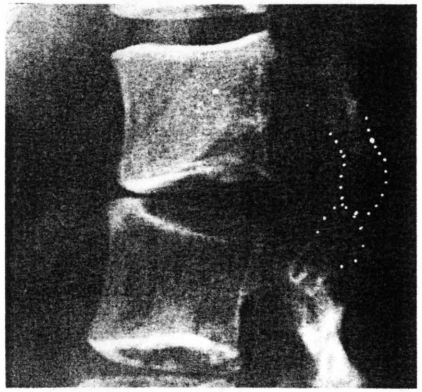


FIG. 4. Distraction flexion. This pure dislocation has no bony injury. The articular processes are subluxed and the posterior disc space is widened.

alone. A variation of these two patterns, with partial bony and ligamentous tension failure, is also possible. Radiographically, the Chance fracture shows a lengthening disruption through the body, pedicle, lamina, and spinous processes caused by a flexion force on the spine. Radiographs of the pure dislocation show that no bony fracture has occurred, but the separation of the vertebral bodies occurs through the ligamentous structures with widening of the interspinous distance, dislocation of the articular processes, widening of the disc space, and frequently translation of the vertebral bodies. Radiographs of the partial lesions reveal disruptions through a portion of the bony structure and a portion of the ligamentous structure.

Neurologic injuries are proportional to the amount of translation of the injured segment either anteriorly or laterally. Smith and Kaufer reported four of 20 Chance fractures with paraplegia; they believed that this occurred because of the concomitant anterior or lateral translation. Denis's flexion distraction group was differentiated from his pure Chance fractures by the fact that in the flexion distraction group subluxation or dislocation of the vertebral body occurred. Three of four flexion distraction injuries in Denis's series were neurologically complete, whereas 19 patients in the Chance fracture group, in whom no anterior or lateral translation occurred, had no neurologic injury. Pure dislocations are thought to have a propensity for progression of deformity and progression of neurologic injury whether or not translation is present.[15,18] Lesions with partial bony or ligamentous injury that have translation of one segment on another may also have a propensity for progression of deformity or neurologic injury.

Lateral Flexion

Lateral flexion fractures occur when a compressive force caused by lateral bending of the spine results in compression of the vertebral body and posterior elements unilaterally (Fig. 5). Two fracture patterns may occur with this

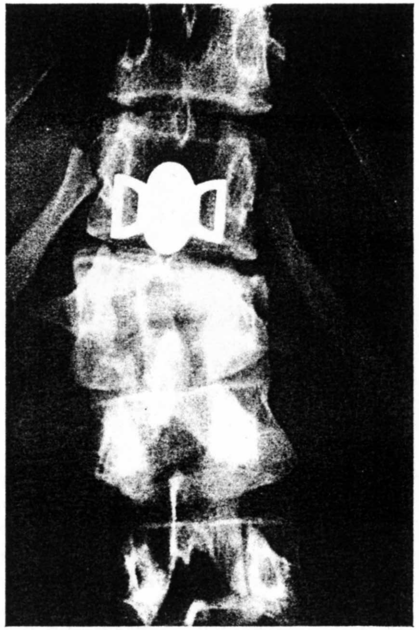


FIG. 5. Lateral flexion. Unilateral shortening of the vertebral body with tension disruption of the pars interarticularis on the opposite side of the posterior elements.

mechanism. In the first, anterior and middle elements alone may fail unilaterally. Radiographically, an acute lateral bending deformity in the spine is seen, with shortening of the vertebral body height unilaterally in the vertebrae. A second pattern occurs when the posterior elements are also involved, with compression failure on the compression side and tension failure of the bony and ligamentous structures on the tension side of the lamina. Radiographically, an acute lateral bending deformity is present and a unilateral articular process dislocation may be noted on the tension side of the injury. CAT scanning may demonstrate this with the vacant facet sign unilaterally.

If only the anterior and middle elements are involved, this lesion is unlikely to progress.

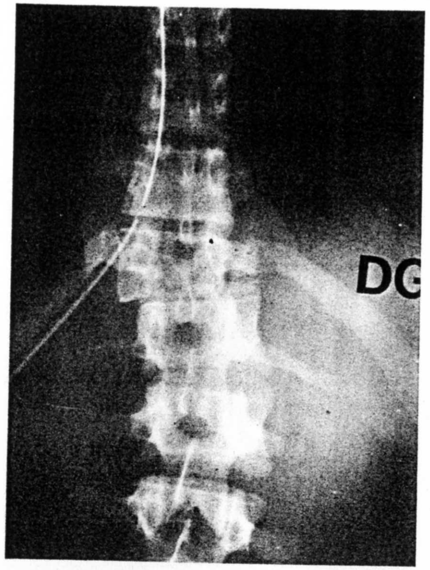


FIG. 6. Lateral translational injury.

However, if the posterior element also fails, the incidence of pain through the deformity increases.[19] Neurologic injury may occur if the middle element encroaches on the neural canal. This lesion may occur in conjunction with compressive flexion and vertical compression lesions.

TRANSLATIONAL

Translational injuries occur when the injury forces cause a straight displacement of the vertebral body anteriorly, posteriorly, or laterally. Radiographically, it is seen that the vertebral body has been translated a variable distance straight anteriorly, laterally, or posteriorly (Figs. 6 and 7). The articular processes and all ligamentous structures, including the anterior longitudinal ligaments, are often ruptured, with displacements of 25% or more.[18,23] Translational injuries are frequently associated with other injury mechanisms and rarely occur in the pure form.

If a significant degree of translation occurs, all ligamentous structures, including the anterior longitudinal ligament, may be ruptured, and the articular processes are usually fractured. This leaves little or no stabilizing structure in the spine, and acute and chronic deformities may result. These injuries have a high percentage of neurologic injury.[14,18]

TORSIONAL FLEXION

In these injuries, torsion and compression occur in the anterior elements and tension and torsion occur about the posterior elements. The middle elements are likely to be involved as well.[7] The articular processes are usually fractured and dislocated; a slice of the superior vertebral body is fractured and translated anteriorly (Fig. 8). Because flexion is combined with this lesion, the anterior longitudinal ligament is usually not ruptured but is stripped from the anterior border of the involved vertebrae.[3] Ligamentous structures are very susceptible to rotation and thus all other ligaments are usually ruptured.[20]

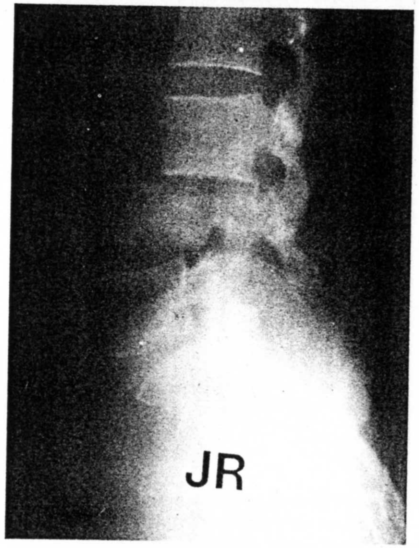


FIG. 7. Anterior translational injury with vertical compression.

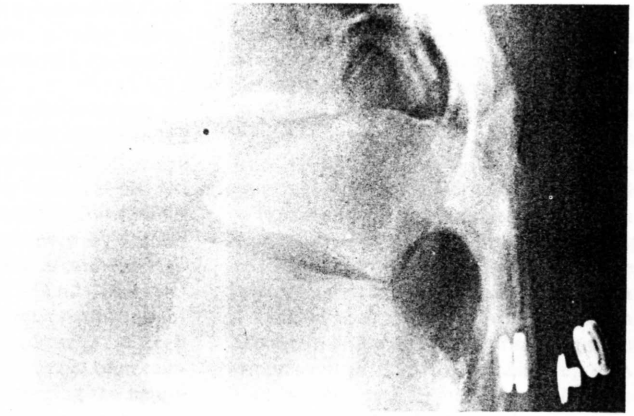


FIG. 8. Torsional flexion injury. Note fracture-dislocation of the posterior articular processes and anterior translation.

Because of the extensive ligamentous and bony injury in this fracture mechanism, it is thought to have both acute and chronic propensity to deform the spinal column and cause progression of the neurologic injury. Holdsworth[14] stated that rotational fracture-dislocations were the most unstable of all spine fractures and that they were almost invariably associated with paraplegia. This was the only injury for which he recommended open reduction and internal fixation. Furthermore, he pointed out that injudicious handling of the patients could lead to further neural injury. Dorr *et al.*[9] noted that 22 of 24 flexion rotation and shear lesions occurred in the thoracic spine. Sixteen of the 22 were neurologically complete and none demonstrated any neurologic recovery. It was stated that the most unstable lesions in this group were those with anterior subluxation. In the study of Roberts and Curtiss,[21] only one of 13 of these injuries showed spontaneous fusion; 10 of 13 demonstrated progressive deformity until surgically fused. They believed that if the fracture occurred above T8–9 the rib cage would prevent progression of the deformity.

VERTICAL COMPRESSION

In this mechanism the entire vertebral body undergoes compression and is shortened. A spectrum of injury, from a failure of either one or both end-plates alone to concentric or near-concentric compression of the anterior and middle elements, may occur. When the middle element is ruptured, the posterior vertebral wall will protrude into the neural canal. Two distinct patterns of this protrusion of the bony posterior wall are seen: the wall may bulge into the neural canal concentrically or may enfold, with the apex of the enfolding at the superior and inferior corners of the vertebral body. In both instances the middle element is shortened (Fig. 9). Posterior bony elements may be fractured by this mechanism, but the ligamentous structures will remain intact.

In the authors' experience, this lesion has not led to further deformity and no increasing neurologic injury has been seen. Other authors have reported progressive neurologic injury or the propensity for progressive deformity with this lesion.[6,17] However, they defined any middle element failure as representing a vertical compression injury and did not separate compressive flexion pattern III lesions. Denis[7] found few neurologic injuries in which the canal was compromised 50% or less. McAfee *et al.*,[18] however, believed that there was no reliable predictor for the amount of canal encroachment and neurologic injury. Holdsworth pointed out that this lesion occurred

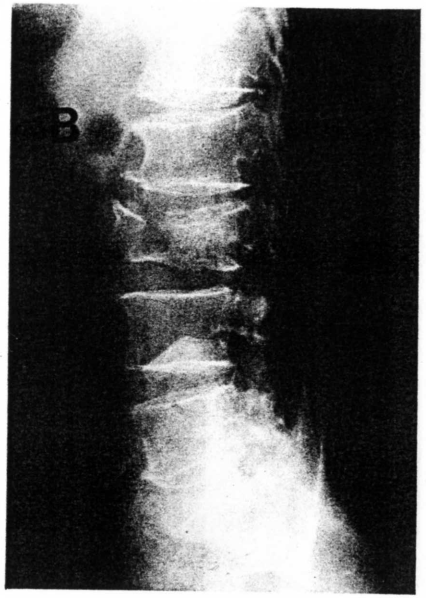


FIG. 9. Vertical compression injury. Note shortening of the anterior middle elements.

where the spine could be placed into a relatively straight position, that is, the lumbar and cervical spine.

DISTRACTIVE EXTENSION

In this injury mechanism there is usually tension disruption of the anterior element and compression failure of the posterior element (Fig. 10). These injuries are very rare in the thoracolumbar spine and are considered to have no propensity for the progression of deformity or neurologic injury. After injury they may completely reduce and be difficult to appreciate on roentgenograms. Holdsworth[14] stated that these injuries were confined to the cervical spine, but Dorr reported 4/51 thoracolumbar extension injuries. Bedbrook and Clark[3] presented 47 extension injuries, and there were 1/54 extension injuries in the thoracolumbar spine in the authors' study.

MINOR ISOLATED INJURIES

Injuries to the transverse processes, spinous processes, pars interarticularis, and articular processes may occur as isolated injuries.[7,9,19] They frequently occur secondary to direct trauma or extreme muscle pull. They are almost never associated with neurologic injury, and unless they are bilateral pars interarticularis fractures below L3[19] or bilateral pedicle fractures below L3,[22] deformity will not progress.

TREATMENT

The ideal treatment for fractured thoracolumbar spines would realign bony disruption. This would provide the best chance for healing of the spine so that deformity would be prevented and back pain due to altered spinal biomechanics or excessive motion at the fracture site would not be a problem. Furthermore, the neural elements would incur no further injury and would not be compressed chronically, which might lead to late neurologic damage. Presently, the authors attempt

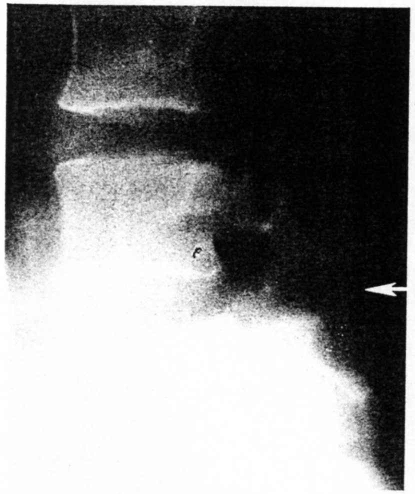


FIG. 10. Distractive extension injury. The arrow points to bony fracture through posterior elements. Anterior and middle elements failed through ligamentous portions.

to attain these goals either conservatively with bed rest, closed reduction, turning frames, casts or orthoses, or operatively by surgical realignment of the spine.

Conservative treatment usually entails periods of bed rest (six to 12 weeks) followed by mobilization in casts or orthoses for several months.[3,13,19] If the patient is kept at bed rest long enough, he will eventually become stable. This has been pointed out even by authors with diametrically opposite treatment regimens, such as Frankel[13] and Dickson.[8] Whether attempted anatomic reduction by positioning is necessary in conservative treatment has been debated and has not been completely resolved.[3,19] In comparing the neurologic outcome of patients with neurologic injury secondary to thoracolumbar injuries, most authors would agree that there is little or no difference between the posterior surgical treatment and the conservatively treated groups of thoracolumbar spine injuries.[6,8] Reports by Larson,[17] Dunn,[10] and Bradford[4] on improved neurologic recovery after decompression of the neural canal anteriorly when middle element encroachment has occurred have been equivocal.

Since both conservative and posterior surgical treatment will lead to essentially equivalent results, what are the indications for posterior surgical treatment? The authors believe that it should be used in cases in which more rapid mobilization and rehabilitation of the patient are warranted, where facilities for conservative care are not developed or where surgical facilities are satisfactory, and when conservative therapy has failed. In particular, the paraplegic will benefit from surgical correction in that it will allow unhindered rehabilitation at a much faster pace than in the conservatively treated patient. The authors believe that this is advantageous from a cost-effect standpoint as well as from the clinical and psychologic standpoint of the neurologically impaired patient.[5]

If surgical correction is thought to be necessary, the instrumentation that is appropriate for the fracture pattern and will address the specific needs of the injury must be chosen. No one instrumentation will successfully treat all fracture types. The basic posterior instrumentations used today to treat thoracolumbar spinal injuries are Harrington distraction and compression instrumentations, Knodt rods, Weiss springs, Merique-Williams plates, and segmental spinal instrumentation with L-rods or Harrington rods. Several anterior instrumentations have also been devised, including the Dunn anterior spinal instrumentation, Bradford anterior spinal instrumentation, and Harrington anterior spinal instrumentation. Harrington distraction rods, either Harrington compression or Knodt rods (Zimmer USA, Warsaw, IN), and segmental spinal instrumentation with L-rods are the three posterior instrumentation types the authors use to treat different fracture patterns. Each has advantages and disadvantages, which are discussed below. As the efficacy of anterior surgery has not been established, it is only briefly mentioned.

Harrington distraction rods have the capacity to lengthen shortened segments and thus counter axial compression forces with their distraction device. This is especially useful in preventing compression that occurs through a disrupted middle element. The rods can also counter increasing flexion moments by three-point fixation. The disadvantages of Harrington distraction rods are that they apply tension over the posterior elements where a tension failure may have previously occurred, they will stress bypass the segments instrumented, and they can be used only where the anterior longitudinal ligament is intact. However, the rods may be made more stable by segmentally wiring the hook and rods to the spine. If lordosis is needed in the system, the square Moe hook and rod (Zimmer USA, Warsaw, IN) may be used to prevent rotation of the Harrington distraction rod.

Compression systems have one basically useful component—they counteract tension failures by compressing the posterior elements into a reduced configuration. When these systems are used properly they often need span

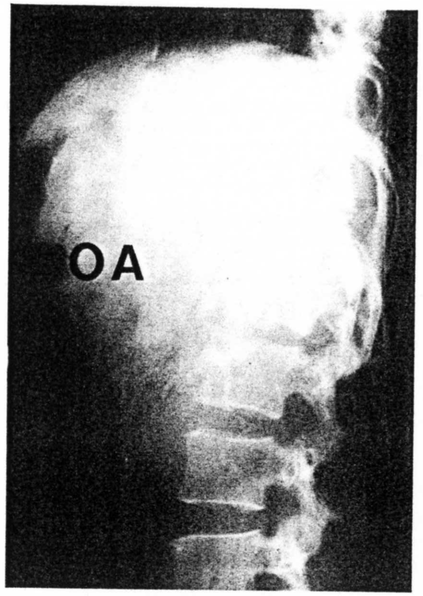


FIG. 11. Preoperative film of patient with complete neurologic lesion. Note kyphosis.

only one motion segment. Segmental spinal instrumentation with L-rods has the advantage of being able to re-create normal secondary spinal contours by means of the rod shape. This will give anterior element distraction and posterior element compression. Segmental spinal instrumentation with L-rods does not require ligamentous stability for use but can be anchored to the pelvis for low lumbar fractures by the Galveston technique of pelvic fixation.[2] Furthermore, postoperative immobilization is not required, which may be especially advantageous for the neurologically involved patient who can be rehabilitated more easily without the hindrance of a cast or brace (Figs. 11 and 12).[11] The disadvantage of compression systems is that they do not counter axial loads in the middle element and thus should not be used when middle element failure has occurred and when the probability exists for protrusion of the middle element further into the neural canal.[7,11]

In compressive flexion lesions in which the anterior and posterior elements have failed and the middle element is intact, either segmental spinal instrumentation or Harrington instrumentation may be used. Segmental spinal instrumentation with L-rods requires no postoperative immobilization and does not place tension over the posterior elements. Harrington instrumentation, however, does, and since these elements have previously failed in tension, this makes Harrington instrumentation less appropriate. In compressive flexion lesions in which all three elements have failed and the middle element has protruded into the neural canal, axial compression must be prevented. Harrington distraction instrumentation should be used in those cases for which the posterior approach is chosen (Fig. 3). This

FIG. 12. Postsegmental spinal instrumentation with L-rods. Note the reestablishment of normal spinal lordosis.

lesion may also be decompressed and stabilized by the anterior approach. The indications for an anterior approach in this fracture pattern are not agreed upon at this time but may involve progression of neurologic injury and slower-than-anticipated neurologic recovery.

Lateral flexion injuries may be treated by either Harrington distraction instrumentation or segmental spinal instrumentation with L-rods. If middle element failure has caused neural canal impingement, then Harrington distraction instrumentation is the instrumentation of choice in order to prevent axial loading and possible further encroachment on the neural canal by the middle element.

In distractive flexion injuries in which a pure tension failure has occurred, a device that counters this tension failure by compressing the posterior elements should be used. In the neurologically intact individual the authors prefer that a Harrington compression system or a Knodt rod system be used over the shortest possible number of motion segments possible. Where an immediate complete lesion has occurred with no signs of recovery, segmental instrumentation with L-rods may be used, since the patient will not be encumbered by postoperative immobilization and rehabilitation may be facilitated.

In translational injuries that are displaced more than 25%,[23] the anterior longitudinal ligament may be ruptured. If this has occurred, segmental spinal instrumentation with L-rods is the instrumentation of choice, as it requires no ligamentous stability from the anterior longitudinal ligament. In a translational injury with compressive flexion, the anterior longitudinal ligament is usually spared and Harrington distraction instrumentation may be used as well. Torsional flexion injuries may be treated by either Harrington instrumentation or segmental spinal instrumentation with L-rods.

If surgical care is necessary for a vertical compression lesion, Harrington distraction instrumentation should be used where the posterior surgical repair will be performed. This will lengthen the middle element and prevent axial compression forces from shortening this element, possibly causing further encroachment of it into the neural canal. As in the compressive flexion pattern III lesion, the neural canal in vertical compression lesions may be compromised by the middle element. The possibility of anterior decompression, stabilization, and anterior fusion of the spine can be considered.

Injuries with no likelihood for progression of the spinal deformity or neurologic injury are usually treated conservatively. Treatment varies but may entail bed rest until pain has resolved, immobilization for a period of time in a cast or brace, and extension and flexion exercises using the muscles to splint the stable fracture instead of a brace or cast.[22]

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The Mechanics of Thoracolumbar Fractures Stabilized by Segmental Fixation

DENNIS R. WENGER, M.D., AND JAMES J. CAROLLO, M.S.

Patients with unstable thoracolumbar spine fractures greatly benefit from the rapid mobilization made possible by surgical reduction and secure internal fixation. The Harrington distraction method provides excellent hook fixation to the spine but is attached only to the proximal and distal ends of the instrumental segment and is dependent on an intact anterior longitudinal ligament. Because the spine is multisegmented and viscoelastic, a distraction method alone may not provide persistent tension on the anterior longitudinal ligament. Segmental spinal instrumentation (Luque) is less efficient in obtaining reduction because it has no built-in distractive mechanism. In addition, the lack of laminar hook attachments is a significant disadvantage in maintaining a distractive force. A combined system consisting of Harrington distraction rods segmentally attached to all available motion segments improves the currently available mechanical construct for obtaining and maintaining reduction in unstable thoracolumbar fractures.

Surgical stabilization of unstable thoracolumbar fractures provides rapid mobilization of patients postinjury, thus preventing the complications associated with prolonged bed rest. Recent advances in internal stabilization methods have further reduced the need for postoperative cast immobilization. The purpose of this review is to present the mechanical features of segmental spinal instrumentation (Luque *et al.*[4]) when used to stabilize unstable thoracolumbar fractures. This method will be compared with Harrington instrumentation, a more traditional fixation method.[1]

From the Texas Scottish Rite Hospital, Dallas, Texas.
Reprint requests to Dennis R. Wenger, M.D., 8008 Frost St., Suite 308, San Diego, CA 92123.
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TERMINOLOGY

For clinical purposes, spinal motion has traditionally been defined in reference to the three principal anatomic planes—the frontal, sagittal, and transverse planes. At the intersection of these planes lie the three principal axes by which dimensional motion is defined (X, Y, Z) (Fig. 1). For the purposes of this paper, the authors will define the X-axis as the intersection of the frontal and transverse planes, the Y-axis as the intersection of the sagittal and transverse planes, and the Z-axis as the intersection of the frontal and sagittal planes. In the discussion that follows, this coordinate system will be referred to in order to define motions characteristic of each fracture type.

FRACTURE TYPES

In addressing the mechanical concepts used in an instrumentation method for obtaining and maintaining reduction of spinal fractures, the instability associated with different fracture types will be considered. After determining the type of instability present, the authors will assess instrumentation methods according to the ability of each to provide and maintain reduction.

Kaufer,[3] expanding on Holdsworth's[2] earlier work, has delineated the following injury patterns: (1) flexion, (2) extension, (3) lateral-