Burst Compression Fractures of the Thoracolumbar Spine
Pathologic Anatomy and Surgical Management

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Introduction
The burst compression fracture of the thoracolumbar spine is probably the most common major spine fracture presenting to an orthopedic service. This fracture has been the focus of considerable attention in the literature recently, with new information being presented on the classification, concepts of stability and instability, need for surgery, and selection of the most appropriate surgical implant. The upsurge in interest was spurred mainly by a better understanding of the pathological anatomy as shown by computerized tomography. The increased information generated has raised more questions than it has answered, and brought about a new complexity to the management of these fractures. It now seems harder to define and determine the stability. There is no generally accepted treatment plan for dealing with the retropulsed fragment. There is a bewildering array of spinal instrumentation systems advocated for reduction and fixation.

Most recent reports on surgical treatment are prefaced with an exhortation that the techniques are exacting and should be performed only in centers accustomed to managing spinal column injured patients and by surgeons with demonstrated expertise in the surgical treatment of spinal problems. In reality, however, in the United States the majority of these fractures are managed in the community hospital to which they first present and by orthopedic surgeons with widely varying experience and training. The goal of this article, therefore, is to review and hopefully clarify some of the newer concepts in the management of the burst compression fractures, with emphasis on the pathologic anatomy and selection of surgical instrumentation in unstable fractures.

Pathologic Anatomy
A clear understanding of the pathologic anatomy is essential for the treatment of burst compression fractures. In 1981, a detailed study was carried out of the radiologic anatomy of a series of 20 consecutive burst compression fractures. A basic pattern was found which has been confirmed in over 50 additional cases. Both plane films and high quality CT scans are required in all cases; experience has not yet been accumulated with MRI scanning. Perhaps MRI scanning will be most beneficial in more clearly delineating the neural structures and soft tissues, particularly in cases with a neurologic deficit. At present, this author believes that the bony anatomy is best seen on the CT scan and that in the future, the CT scan and MRI will be regarded as complementary rather than mutually exclusive.

Vertebral Body
The “crush cleavage fracture” has been proposed as a separate fracture classification. In this fracture, the upper third of the vertebral body is crushed and circumferentially expanded and the lower third of the vertebral body is split with a sagittal fracture extending down through the body and the cartilage endplate. This basic pattern is standard in all fractures that truly fit the burst compression pattern. The compressive force is delivered to the vertebral body by the intact cephalic disk. As the cephalic half of the centrum is crushed down, the rim of cortical bone is broken into a number of fragments which displace circumferentially outward. The vertical height of the vertebral body will be diminished, while the longitu-
ordinally running ligaments (the anterior and posterior longitudinal ligaments) and the outer layers of the annulus fibrosis will be vertically shortened, but bowed out around the expanded bone. They must also be stretched circumferentially and any cross-links between the longitudinally running fibers must be ruptured. In the large majority of the cases, the CT scan shows a symmetrical radial array of the vertebral body fragments indicating that the fragments are restrained by the intact fibers of the longitudinally running ligaments (Fig. 1). The residual functional integrity of these vertically bowed and circumferential expanded ligaments have not been tested. Clinically we have only once seen a case of gross disorientation of the bony fragments in a nonradial pattern possibly indicating more serious disruption of the ligaments. These ligaments must perform the function of restraint that allows correction on a three or four point bending force which is the basis of most reduction maneuvers. Gross over-distraction due to total loss of integrity of these ligaments is probably only seen with flexion rotation or translational fractures. Minor degrees of over distraction, however, may be seen quite commonly postoperatively in burst fractures, possibly indicating some weakening or plastic deformation of these ligaments. Therefore, they must also be radially displaced with this bone or if the posterior ring remains intact, they must shear off from this bone at their base. The cortical bone between the pedicles is usually thin and concave posteriorly. It will also be displaced circumferentially leading to the retropulsed fragment or fragments.

The majority of burst compression fractures have an element of kyphosis. There is a greater crush of the vertebral body anteriorly than posteriorly due to the fact that the pedicle attachment will tend to stabilize the posterior third of the vertebral body leaving the anterior two-thirds more unprotected from the injurious force. The cleavage fracture along with a vertical fracture through the posterior elements effectively splits the vertebra into two halves. This is not accounted for in surgical implants, rods, or plates, that are confined each to one half. This anatomical fact makes a case for rigid cross linking of spinal fixation devices.

**Posterior Elements**

The most important factor in understanding the pattern of fracture of the posterior elements is understanding the displacement of the pedicles. The pedicle has been called the “force nucleus” by Steffee since it is at the confluence of the vertebral body, the superior articular process, the lamina, and the pars interarticularis and inferior articular process. At the time of impact, the pedicles are forced apart with the expanded vertebral body. Clearly, structures attached to the laterally displaced pedicles cannot remain intact. Therefore, widening of the pedicles seen on the AP plane film mandates that the posterior bony ring be fractured or the cephalic facet joints dislocated, usually in at least two places (Fig. 2). The exact nature of these fractures, however, is not always obvious on the plane films or even the CT scans. If the superior articular processes are forced apart, there must be disruption of one or both of the joint capsules or fracture to the posterior bony ring of the cephalic vertebra (Fig. 3). In a similar manner, the more caudal bony structures attached to the pedicle must fracture if the pedicles are forced apart. The most common pattern is a sagittal split passing up to the spinous process dividing the vertebra into right and left halves.

The posterior bony elements and facet joints sometimes remain rigidly intact. In this case, the pedicles also will remain rigidly together while the
vertebra body fractures around them. This produces the so-called stable burst compression fracture. A stable burst compression fracture still may have a large retropulsed fragment. Reduction of the fragment may be more difficult than in other fractures since it is locked between the “jaws” of the rigid pedicle base. A stable burst compression fracture has been observed in which the retropulsed fragment occupies greater than 90% of the spinal canal and the patient had a neurologic deficit.

Recoil Phase

The author postulates that following the initial impact in which the fragments burst out radially, there is a recoil of these circumferentially expanded vertebral bony fragments brought on by compression of the surrounding tissues. This recoil will not necessarily tend to restore the pre-impact anatomy. The pedicles that had been forced apart, will reapproximate. The base of the pedicle, often with a medially facing cortical rim, acts as a pincer that locks the retropulsed fragment in its posterior displaced position.

Distraction instrumentation will accentuate the recoil phase. The consequence is that even with an intact posterior longitudinal ligament the retropulsed fracture is rarely anatomically reduced. Attempting to manually retract the cord or cauda equina and impact the retropulsed fragment back into position is usually unrewarding as the “gate is closed.” Theoretically, often the only way to accurately reduce the retropulsed fragment would be to recreate the state of circumferential expansion of the vertebral body that was present at the time of impact, something which is obviously not practical. With distraction alone, however, in most cases the position of the retropulsed fragment is improved to the point where it occupies less than one third of the canal diameter. This position often is acceptable in the neurologically intact patient. The position can be checked with postoperative CT scans. Physicians making comparisons of the degree of retropulsion, pre- and postoperatively, should be meticulous to compare only scans taken at exactly the same level. Cuts just below or above the site of major retropulsion give an over optimistic view of the degree of reduction. If the retropulsed fragment remains prominent and the patient has a partial neurologic deficit, it is believed the cord should be decompressed. This is most adequately carried out by an anterior approach.

Too often the posterior or posterolateral approach, by excising the lamina and pedicle, does not give adequate visualization across the entire length of the spinal canal with a disappointing degree of reduction.

In the recoil phase, the posterior element fracture may reapproximate to an almost anatomic position in
which it may be unable to be seen on plane x-rays or CT scan, giving the impression that this was indeed a stable burst compression fracture. Indeed the fracture line may even be almost invisible to the naked eye at surgery. The author has seen nerve roots which appear to be emerging directly from the lamina. On carrying out partial laminectomy, the dura was found to be burst with free nerve roots in the canal. At the point of impact, both the dura and lamina had burst wide open. The nerve roots had passed through the fracture gap in the lamina, but in the recoil phase the fracture had closed anatomically trapping the nerve roots outside the canal.

The timing of the recoil phase is unknown. Probably much occurs in the minutes following the injury, but part may occur in the next few hours or days. It is the opinion of some European surgeons that better reduction is obtained if surgery is carried out less than 24 hours after the injury. A further finding in this series was that in every case where the pedicle was seen to be widened on the AP x-ray, retropulsed fragments were found on the CT scan.

In three cases, a central disk protrusion was seen cephalic to the fractured vertebra. Clinical significance of the disk protrusion in these cases is not known. They were seen on high resolution CT scans but possibly may be better seen with MRI.

**Rotation**

In six of 20 cases, there was a significant change in rotational alignment in the cross sectional plane above and below the fracture. This change in rotation appears to occur through the body of the vertebra and amounts to approximately 5° or 10°. It can be identified by establishing the alignment of the vertebra on the transaxial scan above and below the fracture. In cases that were operated, it did not appear to change following Harrington rod instrumentation. This change in rotation alignment needs to be kept in mind when one is considering transpedicular plate fixation particularly using methods in which the pedicles are drilled (Fig. 4).

**Reduction and Fixation**

The purpose of this section is to review the basic principles of reduction and fixation of thoracolumbar fractures and to compare fixation devices currently in common use with respect to these principles. The article will not attempt to cover the contentious subjects of determining stability and the indications for reduction or internal fixation.

**Basic Principles**

The basic principles of reduction of a burst compression fracture are similar to those learned by the most junior resident with reduction of the common Colles fracture of the distal radius. 1) Distraction, to
disimpact the fragments and tighten the intact periosteum. This alone will often correct translational deformity. 2) Corrective rotation using the intact periosteum as a hinge. 3) Maintenance of correction using the principles of three-point fixation, in a cast or a splint. Böhler and Watson-Jones applied these same principles to thoracolumbar fractures. Patients were suspended prone by their feet or ankles on a fracture table resting on their chests. Local anesthetic was injected in and around the fracture site as is commonly carried in a Colles’s fracture. Gravity simultaneously provided the necessary distraction and extension. Reduction could be aided by direct manual pressure over the apex of the gibbous, using the intact anterior longitudinal ligament as the hinge. A cast was then applied to hold the reduction using the three-point fixation principle. Böhler later ammended this technique to have the patient lying supine with the spine extended by a strap. Böhler's work makes very interesting reading for physicians interested in the management of patients with spine fractures. In particular, surgeons can learn from his attention to trunk musculature reconditioning as an essential part of the rehabilitation following a spine fracture. This is often overlooked with the current preoccupation with instrumentation. The first attempts at surgical correction utilized the same principles of reduction as Böhler, but sought to increase the accuracy and stability of reduction by internalizing the fixation device. Initial devices, however, were often of poor biomechanical design and the frequent failures gave added impetus to those who upheld the doctrine of conservative care.

The introduction of Harrington rods provided a much more reliable method of reduction and internal fixation and has been the standard treatment for many years. Lately, however, there has been a dramatic escalation in the number of implants that have been proposed for the use of burst compression thoracolumbar fractures. Selection of the appropriate implant depends on an accurate knowledge of the pathologic anatomy and the biomechanical forces needed to correct that pathology and maintain correction until bony healing. The preferred method would have the ability to perform as many as possible of the following functions: 1) reduction of sagittal rotation (kyphosis) with re-establishment of the anterior vertebral body height; 2) distraction, to restore height of the middle column; 3) correct rotational and translational malalignment; 4) immobilize as few noninjured motion segments as possible; 5) secure the damaged motion segment with a degree of rigidity which would allow optimum healing of the fracture and incorporation of bone graft; 6) fixation secure enough to allow a minimum of postoperative immobilization and early trunk muscle rehabilitation; and 7) can be accomplished by a single safe procedure and does not require a second procedure for implant removal.

Devices currently available may be loosely divided into three categories: 1) those with a principle design that is in the application of a three or four point bending force to gain reduction, 2) those which have a principle design to gain segmental fixation, and 3) those that employ a combination of 1 and 2.

Harrington Distraction Rods

Harrington distraction rods rely on three or four point bending against an intact anterior longitudinal ligament hinge to gain reduction; distraction is of lesser importance. Distraction helps to restore height to the middle column, but its main function is to securely anchor the hooks. Unembellished Harrington rod fixation may be satisfactory in many cases. In a significant number of cases, however, there is incomplete correction at the time of surgery or more commonly a disappointing loss of the initial correction in the postoperative period. With creep and relaxation of the visco-elastic structures, the spine may often fall into an added kyphosis 10° to 15° greater than that gained at surgery. This has lead to a number of changes and embellishments in the standard Harrington rod pattern. These changes include the following points: 1) Incorporating lordosis into the rods, increasing the four point bending force and giving better correction. It must be accompanied by square-ended Moe hooks to prevent the rods from spinning around into kyphosis. 2) Increasing the number of levels instrumented: the previously recommended level were two above and two below the fractured vertebra. Jacobs has shown a significant increase in stability of fixation by instrumenting three above and three below the fractured vertebra. To avoid a long fused segment of the spine, only the levels adjacent to the fracture are fused and the rod is removed after this has occurred. It is hoped that near normal mobility will return to the facet joints instrumented but not fused. A disadvantage is the need for a second operation to remove the rod. The “rod long, fuse short” tech-
nique has also been adopted with some segmental fixation devices.\textsuperscript{25} 3) Increasing three-point bending: this is achieved by attaching a rod sleeve that levers against the intact posterior element of the vertebra immediately cephalic to the fractured vertebra. This sleeve is easy to apply, and has the same effect as rod contouring but allows easier insertion of round ended rods and hooks. The point of application of the force is also more precise; the sleeve lies in a gutter between the facet joint and the spinous process and has the biomechanical effect of conferring some stability to lateral bending and rotation.\textsuperscript{26}

4) Adding segmental fixation to the Harrington rod by means of sublaminar or interspinous wires applied to intact posterior elements above and below the fracture. Sublaminar wires are not recommended by this author in neurologically intact or incomplete patients, but may be used in patients with a total and complete neurologic deficit. Sublaminar wires adjacent to sublaminar hooks may depress the hooks into the canal where they impinge on the dura. Interspinous wiring carries the only disadvantage of taking up a valuable area usually utilized for decortication and placement of bone graft. It has the advantage of conferring significant added strength, and allowing a minimum of postoperative immobilization which is especially beneficial in patients with anesthetic skin.\textsuperscript{27}

**Segmental Spinal Instrumentations**

**Luque L-Rods Using Sublaminar Wires**

This technique has enjoyed some popularity but has fallen out of favor. By appropriately contouring the rods and using sequential wiring, kyphosis can be corrected very well. However, the lack of ability to distract leads to inadequate reduction of the compressed middle column. Mechanical testing has shown poor resistance to rotation (which is only partly improved by utilizing a closed box configuration instead of two Ls), and axial loading.\textsuperscript{20,27,29} In addition, there is a possibility of neurologic damage with sublaminar wires close to a cord which may be swollen or contused. There still may be a place for this instrumentation in translational injuries in which the anterior longitudinal ligament is ruptured. Although in these situations, transpedicular plate devices are probably superior.

**Transpedicular Plate Devices**

Roy-Camille, Steffee, and Luque plate systems mainly differ in the size of the screw and plate. The Roy-Camille system has set holes that the screw fits into whereas the Steffee and Luque systems use slotted plates allowing more freedom of screw placement. The Steffee screws are rigidly locked to the plate leaving a stress riser at the screw plate junction. These systems give very secure fixation,\textsuperscript{11} especially where two levels above and below the fractured vertebra are instrumented. Reduction of the fracture is usually achieved by positioning the patient on the table. Final reduction is gained by pressing the pre-bent plate into the spine until it conforms to the desired configuration of the spine. Distraction of the middle column is not achieved by the fixation. Roy-Camille recommends first reducing the fracture under anesthesia by Böhler's technique.\textsuperscript{25} These systems function as a posterior tension band and, therefore, will be affected by marked loss of bone stock anteriorly.

The author has carried out studies that suggest that the larger size screw of the Steffee system may be too large for the majority of lower thoracic and upper lumbar pedicles and there are some thoracic spines in which there is little or no medullary cavity inside the pedicle, eliminating the possibility of transpedicular fixation at that level.\textsuperscript{30} Careful radiographic assessment of pedicle size, therefore, is required prior to carrying out this instrumentation.


**Fixateur Interne**

Fixateur interne is an attempt to gain secure fixation by the posterior route utilizing only the two vertebrae immediately adjacent to the fracture. Transpedicular Schanz screws are inserted and anchored to two threaded longitudinal rods with fully adjustable clamps. The Schanz screws may be used as levers to affect reduction while the rods allow distraction.20,31

The proponents of this fixation device advocate addressing the anterior bone defect with fine bone chips introduced through the pedicle of the fractured vertebra. With fixation at only three levels as opposed to five with Roy-Camille plates, the tension band is reduced, and anterior healing assumes more importance. This method of treatment has considerable promise. Success will depend on a low rate of loosening of the Schanz screws.

**Cotrell-Dubousset**

The Cotrell-Dubousset system has many advantages in the treatment of burst compression fractures. It accomplishes a three-point bending as with the Harrington system. It is rigidly attached to the upper most vertebra. Therefore, like the locking hook rod, firm hook placement can be gained without over distraction. Segmental fixation is gained by intermediate open hooks which again are firmly attached to the rod. Distraction can be carefully controlled. Rotational stability can be improved by locking connecting bars between the two rods. The implant is bulky and expensive but is gaining in popularity in fracture management.

**Anterior Devices**

The anterior approach for burst compression fractures has a number of theoretical advantages. Reduction of a severely crushed vertebral body often leaves a void anteriorly similar to that seen after reduction of a depressed tibial plateau fracture. This void is an important cause of late failure of posterior instrumentation. The anterior approach allows this void to be filled with solid bone graft. In addition, stabilization can be limited to one vertebra above and below the fractured vertebra. Lordosis can be preserved particularly in the mid to lower lumbar spine. Finally, if decompression of the cord or cauda equina is indicated, it can be best carried out from an anterior approach. Following anterior decompression, it would be preferable to firmly fix the spine anteriorly. A number of anterior devices have been advocated. Hall and Micheli have advocated use of a solid rod through the head of Dwyer screws;32 Kostuik used a Harrington distraction rod attached to similarly placed screws;33 and Kaneda developed a linked dual rod implant that appears to be more stable than the former devices.34 All three, however, have some stability against kyphosis but due to their lateral placement, very little protection against rotation and lateral flexion. Dunn devised a much more bulky implant that combines screw and staple fixation;然而, this device has been withdrawn from the market. It is this author's opinion that there are inherent anatomic and biomechanical problems in the development of a satisfactory anterior implant which as yet have not been overcome.

**Conclusion**

Burst compression fractures of the thoracolumbar spine are complex injuries. The pathological anatomy has been more clearly defined by state of the art imaging, and rational methods of reversing the major portion of the pathology and restoring function are available. At present, in unstable cases requiring surgical reduction and fixation, no one surgical implant may be used in all situations and in all patients. The factors which will affect the choice of implant include the severity of deformity, in particular, the degree of destruction to the anterior column, the presence or absence of neurologic deficit, the age of the patient, and degree of osteoporosis, and also the patients' wishes and needs. For example, Bunch noted that for patients undergoing scoliosis surgery the increased risk of neurologic deficit has much more importance to a patient than the need for postoperative brace or cast immobilization.35 The Scoliosis Research Society recently reported an increase in neurologic complications with transpedicular devices which generally do not require a postoperative orthosis; the more traditional Harrington rod techniques usually do. Other factors affecting choice will include availability, simplicity, ease of application, and probably most important, the level of the surgeon's training and expertise. The newest device on the market is not necessarily the best. Cotrell-Dubousset instrumentation has many attractive features. More studies with long-term follow up need to be reported. Transpedicular devices and the fixateur interne should only be used by surgeons who are well versed in transpedicular tech-

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niques. The future may belong to the pedicle, but at present dual Harrington rods contoured into lordosis using square-ended hooks, or used straight with Edwards' sleeves, remain a relatively simple and effective means of treating the majority of burst compression fractures and lies within the experience and expertise of many young orthopedic surgeons. These remain the standard implants at this time.

If more secure fixation is desired, spinous process wiring (Wisconsin system) is a relatively simple addition. Severe destruction of the anterior column, or persistent canal encroachment with retropulsed fragments, may require a second procedure for bone grafting or decompression. Whatever system is selected, for success, it must be carried out with care and precision. Complications of spine fracture surgery hindering the recovery of patients are being increasingly reported. These complications have been shown to have a high correlation with errors in technique. Staff, facilities, and backup must be adequate, spinal chord monitoring, or anesthesia staff must be well versed in the wake up test which must now be accepted as standard.

References


