Thoracolumbar Burst Fractures Treated with Posterior Decompression and Pedicle Screw Instrumentation Supplemented with Balloon-Assisted Vertebroplasty and Calcium Phosphate Reconstruction

Surgical Technique

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ABSTRACT FROM THE ORIGINAL ARTICLE

BACKGROUND: The treatment of unstable thoracolumbar burst fractures with short-segment posterior spinal instrumentation without anterior column reconstruction is associated with a high rate of screw breakage and progressive loss of reduction. The purpose of the present study was to evaluate the functional, neurologic, and radiographic results following transpedicular, balloon-assisted fracture reduction with anterior column reconstruction with use of calcium phosphate bone cement combined with short-segment posterior instrumentation and a laminectomy.

METHODS: A consecutive series of thirty-eight patients with an unstable thoracolumbar burst fracture with or without neurologic deficit were managed with transpedicular, balloon-assisted fracture reduction, calcium phosphate bone cement reconstruction, and short-segment spinal instrumentation from 2002 to 2005. Twenty-eight of the thirty-eight patients were followed for a minimum of two years. Demographic data, neurologic function, segmental kyphosis, the fracture severity score, canal compromise, the Short Form-36 score, the Oswestry Disability Index score, and treatment-related complications were evaluated prospectively.

RESULTS: All thirteen patients with incomplete neurologic deficits had improvement by at least one Frankel grade. The mean kyphotic angulation improved from 17° preoperatively to 7° at the time of the latest follow-up, and the loss of vertebral body height improved from a mean of 42% preoperatively to 14% at the time of the latest follow-up. Screw breakage occurred in two patients, and pseudarthrosis occurred in one patient.

CONCLUSIONS: The present study demonstrates that excellent reduction of unstable thoracolumbar burst fractures with and without associated neurologic deficits can be maintained with use of short-segment instrumentation and a transpedicular balloon-assisted reduction combined with anterior column reconstruction with calcium phosphate bone cement performed through a single posterior incision. The resultant circumferential stabilization combined with a decompressive laminectomy led to maintained or improved neurologic function in all patients with neurologic deficits, with a low rate of instrumentation failure and loss of correction.

LEVEL OF EVIDENCE: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.


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INTRODUCTION

Patients with an unstable thoracolumbar burst fracture with or without a neurologic deficit can be treated with a laminectomy and circumferential spinal reconstruction through a single posterior incision with use of a transpedicular, balloon-assisted reduction of the fracture and calcium phosphate reconstruction of the anterior column combined with short-segment posterior spinal instrumentation reconstruction of the posterior column (Figs. 1-A, 1-B, and 1-C). This procedure obviates the need for a corpectomy in most patients with an unstable thoracolumbar burst fracture and therefore might be expected to decrease the inherent morbidity, blood loss, operative time, length of the hospital stay, and costs associated with an anterior thoracic or abdominal approach. The techniques required to perform this procedure are familiar to most spine surgeons and are outlined in this article.

SURGICAL TECHNIQUE

Reduction of the Kyphotic Deformity and Decompression of the Spinal Canal

The current approach to the reduction of the kyphotic deformity and decompression of the spinal canal emphasizes nearly anatomic reduction with use of a combination of proper positioning of the patient across transverse gel rolls on the operating table (Fig. 2-A) and the placement of long Schanz pedicle screws into the vertebrae immediately above and below the fractured vertebral body1 (Fig. 2-B). Initial reduction of the kyphotic deformity is obtained by placing the patient in the prone position on transverse gel rolls at the level of the chest and pelvis, which encourages reduction of the kyphotic deformity by allowing the abdomen to sag between the rolls.

The patient is then prepared and draped in the usual sterile fashion from the upper thoracic spine to the top of the gluteal cleft. A longitudinal midline incision measuring approximately 12 cm is made from one or two spinous processes above the most cephalad vertebra to be included in the instrumentation to the tip of the spinous process of the most caudal vertebra to be included in the instrumentation. The subcutaneous tissue is incised with electrocautery to the midline raphe on the spinous processes. The raphe is longitudinally split in the midline and carefully dissected off of the spinous processes in a subperiosteal fashion. Careful dissection of the raphe off the spinous processes facilitates repair of the left and right aspects of the supraspinous ligament during closure. A subperiosteal dissection down the sides of the spinous processes to the lamina and over the tips of the transverse processes is performed with care taken to spare the facet capsules at any levels that are not to be included in the instrumentation.

Anatomic landmarks are used to identify the starting points for the pedicle screws one level above and one level below the fracture as well as the starting point for the placement of the working cannulas within the fractured vertebra. The dorsal cortex overlying the pedicle screw entry site is entered with a matchstick burr or rongeur, and a curvilinear pedicle-finding probe aimed laterally is used to sound each pedicle to a depth of 15 to 20 mm. The pedicle finder is removed, and the hole is plugged with bone wax or Surgifoam (Johnson and Johnson-Ethicon, Somerville, New Jersey) mixed with thrombin. Pedicle markers are placed within the pedicles, and fluoroscopy is used to obtain orthogonal images in the anteroposterior and lateral planes. The placement of the markers provides visual cues regarding the ultimate trajectory of the pedicle screws in the axial and sagittal planes. The fluoroscopic images are studied, and then the pedicle finder is used to sound the remainder of the pedicle into the vertebral body. The ball-tip probe is then used to gently feel the medial, inferior, lateral, superior, and anterior walls of the pedicle to identify any evidence of cortical breakthrough. Long Schanz pedicle screws with a diameter of 6.2 mm and a thread length of 35 to 40 mm are placed in the pedicles above and below the fracture on the right side and only in the pedicle above the fracture on the left side. If the pedicles are too small to accommodate a
6.2-mm-diameter screw, then a 5.2-mm-diameter screw is placed and inclusion of an additional level in the instrumentation is considered, to decrease the likelihood of breakage of the small screws. The long Schanz screws have an extended, fixed lever arm, which facilitates manipulation of the spine during the reduction maneuvers. Screw placement is performed in this

**Fig. 1-A** Lateral radiograph of a twenty-four-year-old man with 12° of kyphosis, 51% loss of vertebral height, a T11-T12 flexion-distraction injury, a T12 burst fracture, and incomplete paraplegia (Frankel grade B). **Fig. 1-B** T2-weighted sagittal magnetic resonance image of the T12 burst fracture, demonstrating canal compromise of 41%, increased signal within the conus medullaris, and disruption of the posterior ligaments. **Fig. 1-C** Lateral radiograph made four years postoperatively showing nearly anatomic reduction with 0° of kyphosis and a 5% loss of vertebral height. The patient recovered neurologic function, to Frankel grade D.
fashion to minimize interference from the screw inserted in the ipsilateral caudal vertebra during the decompressive laminectomy when it is performed from the left side of the patient by a right-handed surgeon.

A wide decompressive laminectomy from pedicle to pedicle above and below the area compressed by the retropulsed fragments is then performed only in patients presenting with a neurologic deficit or who have compromise of >50% of the spinal canal. Direct decompression of the thecal sac can be performed by tapping the retropulsed fragments away from the thecal sac through a posterolateral approach in selected patients. However, we do not routinely perform a direct decompression of the anterior thecal sac because we have found this to increase operative time and blood loss. Additionally, we believe that restoration of normal sagittal alignment combined with a decompressive laminectomy adequately decompresses the neural elements. Canal remodeling usually occurs over time, which further reduces the degree of canal compromise. Some reduction of these fragments may occur through ligamentotaxis in patients with an intact posterior longitudinal ligament. However, patients with canal compromise of >50% probably have complete disruption of the posterior longitudinal ligament and thus do not benefit from ligamentotaxis. The ipsilateral caudal pedicle screw is placed after completion of the decompressive laminectomy.

A standard pedicle finder is used to create a bilateral transpedicular pathway within the fractured vertebral body under fluoroscopic guidance, with care taken to create a pathway that remains parallel to the superior end plate. Bilateral working
cannulas are then placed under fluoroscopic guidance into the posterior third of the fractured vertebral body through the previously created pathway. A drill is inserted through the working cannula into the anterior third of the vertebra.

The kyphotic deformity is further reduced by connecting the Schanz screws to the rods and using the leverage of the screws to restore anatomic alignment⁴. Wrenches are placed over the ipsilateral screws, and an additional reduction maneuver is performed by crossing the handles of the wrenches (Fig. 3). Restoration of the normal thoracolumbar sagittal alignment is confirmed with fluoroscopy, and the connectors are tightened to the pedicle screws, which secures the reduction in the sagittal plane. Vertebral body height is then partially restored with distraction of the pedicle screws on the rods (Fig. 4). Distraction along the screw-and-rod construct should not be performed in patients with a combined compression and distraction (type-B,A³) injury in order to minimize the risk of overdistracting the neural elements. The drill is removed, and bilateral deflated bone tamps (size 15/3 or 20/3) are placed through the working cannulas into the anterior portion of the fractured vertebra (Fig. 5). The bone tamps are then inflated bilaterally in 1-mL increments under fluoroscopic guidance (Fig. 6). Inflation of the tamp further restores vertebral body height.
and creates a cavity for placement of the injectable calcium phosphate cement. Less than 1 mm of posterior bone displacement should be expected with inflation of the bone tamp. The Schanz screws are cut to the appropriate length before the cement is placed, to minimize movement of the construct while the cement solidifies. The facets and laminae are decorticated to facilitate fusion.

**Reconstruction of the Anterior Column**
The volume of contrast material within the bone tamps is used to approximate the amount of cement required to fill the cavitary defect. Calcium phosphate bone cement mixed with 2.5 mL of powdered barium sulfate (Biotrace; Bryan, Woburn, Massachusetts) measured in a 5-mL syringe is mixed with 1.2 mL of...
sterile water for every 10 mL of Norian SRS cement (Synthes, West Chester, Pennsylvania) or HydroSet cement (Stryker, Kalamazoo, Michigan) and placed in a 10-mL syringe, which is used to fill the bone-void-filling cannulas. The extracorporeal working time for the calcium phosphate cement ranges from seven to ten minutes, depending on the ambient operating-room temperature. However, the cement solidifies within thirty to forty-five seconds once the bone-void-filling cannulas are placed within the vertebral body through the working cannulas. The balloons are deflated and are removed from the working cannulas. The tip of the bone-void-
The cement must not be injected too slowly or too rapidly. Rapid injection of the cement causes early cement crystallization at the tip of the bone-void-filling cannula, which impedes subsequent cement injection. If there is crystallization at the tip of the cannula, a gentle tap with a mallet will disrupt it and allow the cement to be injected into the cavitary defect. If the cement is injected too slowly, it will solidify within the cannula. A bone-void-filling cannula containing solidified cement is unusable and must be replaced with a fresh cannula. Approximately 2 to 3 mL of cement is injected into each cavitary defect over a thirty to forty-five-second time period. Because the capacity of each bone-void-filling cannula is 1.5 mL, 1.5 to two bone-void-filling cannulas are needed to fill each cavitary defect. Cement injection is stopped when cement extravasates outside the vertebral body or reaches the posterior one-third of the vertebral body. The cement is allowed to cure for at least ten minutes, with the tip of the bone-void-filling device placed at the tip of the working cannula without probing the cement, moving the patient, or adjusting the instrumentation. It is important to not disturb the cement during this time since doing so can disrupt the crystallization process. The compressive strength of calcium phosphate cement is nearly 90% of its maximum value after ten minutes and 100% after twenty-four hours. The working cannulas and bone-void fillers are then removed from the fractured vertebra (Figs. 8-A and 8-B). Crosslinks are not routinely used. Local bone graft and iliac crest bone graft are placed to facilitate the posterior fusion.
AFTERCARE
Patients are mobilized the next day while wearing a polypropylene thoracolumbosacral orthosis, which they continue to wear for three months. They are seen at three, six, nine, twelve, and twenty-four months postoperatively and then every year thereafter. All patients are asked to refrain from tobacco use.

CRITICAL CONCEPTS

INDICATIONS:
- Unstable thoracolumbar burst fractures with and without neurologic deficits

CONTRAINDICATIONS:
- Metabolic bone disease is a relative contraindication to the procedure because the response of abnormal bone to the calcium phosphate cement is unknown.
- Coronal split fractures with disc fragments interposed between the fracture fragments are not ideally treated with this technique because these fractures do not usually heal without a corpectomy.

PITFALLS:
- Familiarity with balloon-assisted vertebroplasty facilitates the creation of the cavitary defect within the vertebral body during the reconstruction of the anterior column.
- The handling properties of calcium phosphate cement differ from those of polymethylmethacrylate. Calcium phosphate behaves more like a paste. The cement is isothermic during the curing process and provides a seven to ten-minute working time outside the body. However, the cement cures faster within the vertebra as a result of the increased temperature within the body. The cement also solidifies at the tip of the bone-void-filling devices unless a steady rate of injection is maintained; however, injecting the material too quickly leads to crystallization at the tip of the bone-void filler. A gentle tap with a mallet usually breaks up the crystallization and allows injection of the remainder of the cement within the cavitary defect.
- One should avoid the temptation to probe the cement while the cement is solidifying because disruption of the cement during this time weakens it. The cement must be allowed to cure for at least ten minutes before the patient is moved. Cutting the long Schanz screws before placement of the cement minimizes movement of the patient while the cement is curing.

AUTHOR UPDATE:
Norian XR was previously utilized for this procedure, but it is no longer available for use. Norian XR in the injectable state may interact with blood and cause serious adverse events when injected into a vertebral body without a bone void. HydroSet calcium phosphate cement or Norian SRS cement mixed with 2.5 mL of powdered barium and 1.2 mL of sterile water for every 10 mL of cement is now used to reconstruct the cavitary defect. The risks and benefits as well as alternative treatment options are discussed with all patients before calcium phosphate is used to reconstruct the anterior column.

In an effort to assess the risk posed by an anterior approach, Kaneda et al. reviewed their series of patients. They observed several anterior-approach-specific complications, including a laceration of the inferior vena cava, genitofemoral nerve dysesthesias, sympathetic chain injuries, and atelectasis. None of these complications developed in the patients in the current series. Additionally, a corpectomy performed through an anterior or posterior approach requires nearly complete removal of the fractured vertebra, which increases blood loss. In the current series, the median estimated blood loss (300 mL), operative time (120 minutes), and length of hospitalization (six days) were substantially lower than the values reported by Okuyama et al. and Korovessis et al. following a corpectomy with or without posterior stabilization. An obvious advantage of the decreased blood loss is that it decreases the need for homologous blood component transfusions, which in turn decreases the risk of transmission of blood-borne pathogens, immunosuppression, and transfusion reactions.
REFERENCES


