Surgical approaches for the correction of unstable thoracolumbar burst fractures: a retrospective analysis of treatment outcomes


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The authors retrospectively studied 49 nonparaplegic patients who sustained acute unstable thoracolumbar burst fractures. All patients underwent surgical treatment and were included in this study. The inclusion criteria were set to include patients with neurological deficits and radiographic evidence of mechanical instability associated with burst fractures. Three treatment groups were studied: the first group of 16 patients underwent anterior decompression and fusion with instrumentation; the second group of 27 patients underwent posterior decompression and fusion; and the third group of six patients had combined anterior–posterior surgery. The authors found that posterior surgery was as effective as anterior or anterior–posterior surgery when treating unstable thoracolumbar burst fractures. Posterior surgery took the least time, caused the least blood loss, and is the least expensive of the three procedures.

**Key Words** • thoracolumbar burst fractures • anterior decompression • transpedicular decompression • distraction instrumentation • annulotaxis

**Clinical Material and Methods**

**Patient Population**

In the period from January 1, 1990 to December 1, 1993, 130 patients were treated for major traumatic fractures of the thoracolumbar junction (T12–L2) at the University of Virginia Health Sciences Center by three attending physicians, two orthopedic surgeons, and one neurosurgeon. From this group of 130, all neurologically normal and incompletely paraplegic patients who sustained unstable burst fractures and were treated surgically were selected. The surgical procedures performed were determined by each individual’s attending physician. There were 49 patients selected: six had combined anterior decompression and fusion, 16 underwent anterior decompression and fusion with anterior instrumentation; 27 underwent posterior decompression and fusion; and six underwent combined anterior–posterior decompression and fusion with posterior instrumentation. The causes of injury were as follows: 22 automobile accidents; 20 falls from heights; four motorcycle accidents; and three light aircraft accidents.

**Inclusion Criteria**

All patients who were incompletely paraplegic with thoracolumbar burst fractures were treated operatively and included in this study. The authors also included patients with no neurological deficits who sustained burst fractures and were treated surgically. The authors did not exclude patients based on level of injury, percentage of canal compromise, neurological function, and kyphosis. Patients treated with posterior surgery had a statistically significant diminution in operative time and blood loss and number of units transfused. There were no significant intergroup differences when considering postoperative kyphotic correction, neurological function, pain assessment, or the ability to return to work. Posterior surgery was found to be as effective as anterior or anterior–posterior surgery when treating unstable thoracolumbar burst fractures. Posterior surgery, however, takes the least time, causes the least blood loss, and is the least expensive of the three procedures.
the method of Cobb. Postoperative coronal and sagittal radiographs. Kyphotic deformity was measured using 978 All 49 individuals also received 10 mg of dexamethasone

Pharmacological Protocol

Patients who presented with neurological impairment were immediately given intravenous drugs according to the National Acute Spinal Cord Injury Study Protocol (bolus of methylprednisolone 30 mg/kg, followed by infusion of methylprednisolone 5.4 mg/kg/hr for 23 hours). All 49 individuals also received 10 mg of dexamethasone intravenously at the initiation of each surgical procedure.

Operative Technique

All 16 patients in the anterior group had their fractured vertebrae exposed via a left-sided transthoracic retroperitoneal approach, and subtotal corpectomies were performed. The spinal canal was fully decompressed. The dura was visualized throughout the craniocaudal expanse of the fractured vertebrae and mediolaterally from one pedicle to the other. After decompression, a tricortical iliac crest autograft and a morselized rib graft were set into the decompression defect. The Kaneda device was used in 15 patients, and one patient underwent instrumentation with a Z-plate.

Of the 27 individuals in the posterior group, 12 were treated by direct surgical decompression via a posterolateral transpedicular approach. The remaining 15 patients underwent indirect decompression with the aid of distraction forces, attributed to the ligamentotaxis of the posterior or longitudinal ligament. We believe that this phenomenon is more appropriately termed “annulotaxis,” as evidenced in the cadaveric experiments of Fredrickson, et al., because the fibers that reduce the intracanal fragments were found to originate mainly in the annulus of the superior vertebra. In all patients, iliac crest autografts or human freeze-dried bone (LifeNet Tissue Services, Virginia Beach, VA) allografts were used. The following types of instrumentation were used: 16 Steffee plates and pedicle screws; four Cotrel–Doubousset rods with a hook and claw system; four Harrington distraction rods with hooks; and three Luque rings with sublaminar wiring.

In the anterior–posterior group, anterior decompression was performed in six patients as described above, and fibular strut and/or morselized rib grafts were used for bone grafting anteriorly. In two cases, the Kaneda device was used for anterior internal fixation; posterior surgery was later performed to augment anterior stability that was deemed inadequate. In one, the Kaneda screw purchase was not thought to be satisfactory; in another, a complication resulted (see Postoperative Complications). For all patients in the anterior–posterior group, iliac crest autograft and/or human freeze-dried bone allograft were combined with posterior internal fixation as follows: one had Harrington rods with hooks; one had Cotrel–Doubousset rods with hooks; two had Luque rings with sublaminar wiring (one of whom also had a Kaneda device anteriorly); and two had Texas Scottish Rite Hospital rods with hooks (one of whom also had a Kaneda device anteriorly). In no case were both procedures performed during the same operative session. The average time between the two procedures was 9.5 days.

Postoperative Orthotic Use

All patients were fitted with custom-made thermally molded plastic shells that were fabricated by our certified orthotist. Orthoses were worn for approximately 3 months whenever the patient stood upright, and the decision to wean was made on an individual basis by the attending surgeon. The weaning process averaged 4 to 6 weeks.

Follow-Up Studies

The average follow-up period was 27 months (range 6–54 months). Patients were followed at varying intervals

Radiographic Analysis and Neurological Assessment

Preoperative anteroposterior and lateral radiographs of the thoracolumbar spine were obtained for all patients. Preoperative CT scans of the appropriate vertebral levels were used to determine the extent of canal encroachment and to further delineate fracture anatomy. To assess canal encroachment, the cross-sectional area of the fractured vertebra was calculated as a percentage of the normal canal area (normal canal area = the average of the cross-sectional areas of the adjacent normal vertebra above and below the fracture). Preoperative magnetic resonance imaging was obtained in patients with neurological deficits to assess the etiology of neural injury.

Fractures were categorized according to the Denis fracture classification system by reviewing the initial trauma radiographs. Kyphotic deformity was measured using the method of Cobb. Postoperative coronal and sagittal plane alignment, hardware position, and fusion mass were evaluated with anteroposterior and lateral radiographs. Lateral flexion and extension radiographs were obtained at 6-month intervals to evaluate the mechanical stability of spines in those patients who had undergone instrumentation. Solid fusion was determined radiographically by at least two of the following observations: 1) presence of a solid fusion mass spanning the involved vertebral segments (a continuous column of trabecular bone present between graft and adjacent vertebrae); 2) lack of motion on flexion and extension lateral radiographs; and 3) bone formation spanning disc spaces in instrumented areas.

The degree of neurological deficit was recorded on the basis of the Frankel grading system.

Pharmacological Protocol

Hospital charts, clinical notes, follow-up radiographic studies, and follow-up questionnaires were reviewed. The groups were compared in terms of age, gender, level of injury, radiographic fracture type, percentage of canal encroachment, kyphotic deformity (preoperatively, immediately postoperatively, and at final follow up), neurological function (preoperatively and at final follow up), intraoperative blood loss, units of blood transfused, duration of operative time, duration of postoperative hospital stay (beginning immediately after the first operation for patients in the anterior–posterior group), total hospital and physician charges, subjective well-being, and complications. Two patient populations were excluded from study: intact individuals with stable burst fractures who were treated solely with posterior spinal instrumentation and fusion.

Follow-Up Studies

The average follow-up period was 27 months (range 6–54 months). Patients were followed at varying intervals
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postoperatively as determined by individual need. In addition to reviewing all follow-up notes and radiographic studies, a final follow-up subjective questionnaire was administered to assess the pain and work scales of Denis. Forty-three of 49 patients completed this questionnaire. Six patients did not complete it: one was from the anterior group; one from the anterior–posterior group; and four were from the posterior group. They had been discharged from clinical follow up after achieving radiographic fusion and were unavailable to complete the questionnaire.

Statistical Analysis

Statistics generated for this paper include summary statistics, chi-square analyses, Kruskal–Wallis analyses, one-way analysis of variance (ANOVA), and covariate analyses (ANCOVA). Chi-square analyses were used for variables with an unordered categorical response, and Kruskal–Wallis analyses were used for variables with an ordered categorical response. For variables with a continuous response and no presurgery measurement, the data distribution was assessed for normality. If normality could be assumed, a one-way ANOVA was used to test for differences between the surgery groups; otherwise, a Kruskal–Wallis analysis was used. For variables with a continuous response and a presurgery measurement, an ANCOVA was used that tested for differences between the surgery groups after adjusting for the presurgery measurement. Unless otherwise specified, statistical tests were performed with a significance level of 0.05.

If the results of an ANOVA or ANCOVA were statistically significant, follow-up pairwise comparisons of the group means were made to determine which group means differed. To adjust for the multiple pairwise testing, a significance level of 0.0167 was adopted for each pairwise comparison. For reading ease, only the p values associated with the statistically significant pairwise comparisons will be reported, and it can be assumed that the main effect in the ANOVA or ANCOVA was statistically significant at the 0.05 level.

Results

Preoperative Variables

Demographics. The mean age for the anterior group was 35.4 years (range 19–62 years), for the posterior group the mean age was 37.7 years (range 19–75 years), and for the anterior–posterior group the mean age was 36.8 years (range 13–63 years). There were 11 men and five women in the anterior group; in the posterior group there were 19 men and eight women; and in the anterior–posterior group there were four men and two women.

Fracture Levels. One patient in the anterior group had a T-12 burst fracture, 13 had L-1 burst fractures, and two had L-2 burst fractures. Eight individuals in the posterior group had T-12 burst fractures, 16 had L-1 burst fractures, and three had L-2 burst fractures. All patients in the anterior–posterior group sustained L-1 burst fractures. One patient in this group had a contiguous nondisplaced T-12 vertebral body fracture.

Canal Encroachment. The extent of canal encroachment in the anterior group was 52.5% (range 20%–80%), in the posterior group 52.6% (range 20%–80%), and in the anterior–posterior group it was 50.0% (range 20%–70%).

Denis Classification. In the anterior group, there were nine Denis Type A burst fractures, five Type B fractures, one Type C fracture, and one Type D fracture. In the posterior group, there were 17 Denis Type A fractures, nine Type B fractures, and one Type C fracture. In the anterior–posterior group, there were four Denis Type A fractures, one Type B fracture, and one Type C fracture.

Frankel Grade. In the anterior group, there were eight patients with a Frankel neurological grade of E, six with Grade D, and two with Grade C. In the posterior group, there were 16 patients with Frankel Grade E, three with D, and eight with C. In the anterior–posterior group there were three individuals with Frankel Grade E, one with D, and two with C.

Kyphotic Deformity. The mean kyphotic deformity for the three groups was as follows: anterior group, 16.1˚ (± 8.1˚; range 5˚–35˚); posterior group, 15.2˚ (± 8.3˚; range 0˚–32˚); and anterior–posterior group, 26.0˚ (± 19.2˚; range 5˚–60˚).

Hospital Stay. The mean duration of hospital stay prior to surgery for patients in each group was as follows: anterior, 4.9 days (± 3.1; range 1–12 days); posterior, 4.2 days (± 2.9; range 1–13 days); and anterior–posterior, 6.3 days (± 5.0; range 0–14 days).

Differences between the three treatment groups relative to the above preoperative data were analyzed statistically and none was found to be significant.

Operative Time

The mean time from initial incision to dressing application was 438 minutes (± 60 minutes) in the anterior group, 219 minutes (± 61 minutes) in the posterior group, and the total time for both procedures in the anterior–posterior group was 569 minutes (± 121 minutes). Differences in operative time between all three treatment groups were found to be significant (p < 0.0003).

Blood Loss and Units Transfused

The mean volume of blood loss for the treatment groups was as follows: anterior group, 1878 cc (± 777 cc); posterior group, 1103 cc (± 793 cc); anterior–posterior group, 2541 cc (± 1439 cc). The means in the anterior group and the anterior–posterior group differed statistically from the posterior group mean (p < 0.008). Patients in the anterior group were transfused with a mean of 4.6 units (± 2.7 units) of packed red blood cells whereas those in the posterior group were transfused with a mean of 2.3 units (± 2.7 units). The anterior–posterior group was transfused with a mean of 4.3 units (± 3.6) of packed red blood cells. The anterior group mean differed statistically from the posterior group mean (p = 0.01).

Duration of Postoperative Hospital Stay

The mean duration of postoperative stay for the three groups was as follows: anterior, 13 days (± 4.5 days); posterior, 10 days (± 6.1 days); and anterior–posterior group, 22 days (± 7.0 days). The anterior–posterior group
mean differed statistically from the posterior and the anterior group means (p < 0.003).

Total Charges

The total mean charge for hospitalization and physician fees was $63,963 (± $18,203) for the anterior group. For the posterior and the anterior–posterior groups, the mean charges were $45,306 (± $15,808) and $111,750 (± $20,635), respectively. Significant differences were found among all three groups (p = 0.0012). In spite of the use of relatively inexpensive implants in approximately one-quarter of our posterior group (Harrington rods and Luque rings), these cost differences could not be ascribed to the various implants because their average percent contribution to total charges was as follows: anterior, 4.7%; posterior, 3.5%; and anterior–posterior group, 2.2%.

Postoperative Kyphotic Correction

In the anterior group, the mean kyphotic deformities measured preoperatively, immediately postoperatively, and at final follow up were 16.1° (± 8.1°), 6.1° (± 5.3°), and 9.8° (± 9.8°). In the posterior group, the mean kyphotic deformities measured at the same clinical settings were 15.2° (± 8.3°), 6.5° (± 5.9°), and 9.5° (± 6.8°). In the anterior–posterior group, the kyphotic measurements were 26.0° (± 19.2°), 12.0° (± 11.0°), and 18.5° (± 17.0°). No statistically significant differences could be found between the groups for immediate postoperative kyphotic correction or for kyphotic correction at final follow up.

Postoperative Neurological Function

No patient in this study suffered neurological deterioration. Of the 16 patients in the anterior group, eight were intact (Frankel Grade E) prior to surgery and remained so; six were Grade D preoperatively, two of whom improved to Grade E postoperatively. Two patients were Frankel Grade C preoperatively; one of them improved to Grade D. Therefore, of the eight neurologically incomplete patients, two of the three individuals who were Frankel Grade D preoperatively improved to Grade E postoperatively. Six of eight Grade C patients improved postoperatively, four to Grade D and two to Grade E. Thus, eight patients improved at least one Frankel grade and two patients improved two grades. When comparing indirect decompression to transpedicular decompression, five of the eight individuals who showed neurological improvement underwent the latter; whereas compression in the other three was reduced indirectly by annulotaxis. One patient improved two Frankel grades in each form of decompression.

Of the six patients in the anterior–posterior group, three patients were Frankel Grade E preoperatively and remained so. The one individual who was Grade D preoperatively improved to Grade E. One of the two Grade C patients improved to normal postoperatively. Therefore, two of the three neurologically incomplete patients improved at least one grade.

Neurological improvement as a function of treatment group was analyzed statistically. In spite of the apparent superior neurological recovery seen in the posterior group, significant differences between the groups could not be identified.

Subjective Analyses

With regard to pain, 67% of the anterior, 35% of the posterior, and 40% of the anterior–posterior group had either no or minimal pain (Fig. 1 left). With regard to work, 67% of the anterior, 60% of the posterior, and 60% of the anterior–posterior group returned to their previous employment or new employment which consisted of heavy labor (Fig. 1 right). The data of the subjective analyses were analyzed statistically as a function of treatment groups and no significant differences were found.

Postoperative Complications

There were no mortalities in our patient population. In the anterior group, there were four complications. Two patients suffered left apical pneumothoraces, but neither required reinsertion of a chest tube. One developed a painful iliac crest bone graft scar. A fractured inferior
Kaneda screw was found in one patient on routine radiography 1 year post-surgery. He was asymptomatic and his arthrodesis appeared radiographically solid; therefore, this complication was not treated.

In the posterior group there were four individuals with complications. Two developed deep back wound infections, and they were successfully treated with intraoperative irrigation and debridement followed by 6 weeks of intravenous organism specific antibiotic therapy. One patient who received a Luque ring developed back pain 8 months postoperatively. He was found to have hardware protruding into his subcutaneous tissues; in addition, his fusion had not solidly healed. He subsequently underwent hardware removal, debridement of his pseudoarthrosis, and further iliac crest bone grafting. Within 6 months he had solid radiographic fusion, was pain-free, and had gone back to prefracture activity. One individual was found to have a deep venous thrombosis in his right lower extremity 3 weeks post-surgery. He was initially treated with intravenous heparin infusion that was later converted to oral warfarin therapy, and the clot resolved uneventfully.

In the anterior–posterior group, there were three documented complications. One patient suffered an iatrogenic laceration of the thoracic duct that was immediately identified and repaired primarily. One person developed a left apical pneumothorax after chest tube removal; however, this resolved spontaneously. Finally, one osteoporotic patient with an L-1 burst fracture had displacement of her superior (T-12) Kaneda screws on the 5th postoperative day. She was found to have a contiguous nondisplaced T-12 fracture seen only on CT sagittal reconstruction. This necessitated a second anterior operation to reinsert the Kaneda device with superior fixation at T-11; a subsequent posterior fusion was performed to ensure mechanical stability.

**Discussion**

The results of three different surgical treatments for unstable thoracolumbar burst fractures have been compared and contrasted in neurologically intact and neurologically incomplete (incompletely paraplegic) patients. Age, gender, time to surgery, fracture level, Denis fracture type, extent of spinal deformity, canal encroachment, and neurological function were selected as preoperative factors that could influence postsurgical outcome. The treatment groups in this study were statistically indistinguishable in terms of these factors. Because of the preoperative equivalence and because all attending surgeons were capable of performing each of the procedures described, the statistically significant differences in outcome are believed to be directly related to the different treatments. The internal spinal fixation systems used in this study were, in general, thought to be equivalent in providing mechanical stability. There is no universally superior implant; most presently available systems are equally efficacious in restoring biomechanical rigidity. We used Luque instrumentation as sole fixation in four patients (three patients in the posterior group and one patient in the anterior–posterior group) early in 1990, but that practice was later abandoned because of the poor distraction force generated by that system.

We conclude that patients in the anterior–posterior group received treatment inferior to that of the other two groups. Early in this study, we were not using an anterior internal fixation system after anterior decompression, hence, the need for posterior stabilization and the main reason for the existence of the anterior–posterior group. One of the attending surgeons preferentially performed combined procedures for patients with what he considered radiographically severe spinal deformity. This is reflected only by the 10° greater mean kyphotic deformity seen in the anterior–posterior group compared to the other two groups. When tested for statistical significance, however, the three groups were found to be indistinguishable. Therefore, we do not believe that 10° of increased kyphosis contributed to a bias against the anterior–posterior group that led to its inferior results.

Because many patients in the anterior–posterior group sustained multiple organ system injuries, anterior decompression was performed as early as possible, allowing posterior stabilization to be performed semielectronically. The seemingly prolonged time interval between the two procedures, 9.5 days, corresponds to the time needed to stabilize the patient’s other injuries. This combination of procedures requires the longest total operative time and is associated with the most intraoperative blood loss. Blood transfusion requirements for patients were as high as or higher than for patients in other groups, and total hospital and physician charges were the highest. Anterior–posterior group patients, however, fared no better in terms of neurological recovery, correction of spinal deformity, fusion healing, pain relief, or work status than patients in the other groups. The complications encountered in this group were relatively minor, with one exception. We cannot recommend combined anterior–posterior surgery for primary treatment of unstable thoracolumbar burst fractures because better and more cost-effective results can be achieved with other procedures.

The treatment provided to patients of the anterior group is thought by many researchers to provide a complete and reliable decompression; this should correlate with superior neurological recovery and pain relief. In our study, anterior group patients underwent surgery an average of 4.9 days after injury; 67% of the patients reported good-to-excellent pain relief, but only three (38%) of eight neurologically incomplete patients improved one Frankel grade postoperatively. We were surprised by the relatively low rate of neurological recovery for patients in this group. Despite performing subtotal corpectomies, we believe our decompressions to have been as complete as those performed by the above-mentioned authors. The portion of vertebral body left behind was anterior and on the right side, but never included retropulsed bone. It is possible that with more than eight neurologically incomplete patients, an improved neurological recovery rate would become apparent. This is suggested by the fact that 67% of patients in this group rated their pain relief as good to excellent. We believe that the pain relief seen in patients undergoing anterior decompression and fusion is an indicator of adequate decompression, although this may also correspond to the limited number of motion segments that required fusion.

Our institution is a teaching facility, but one with a rel-
atively low volume of spinal trauma, and there is a learning curve for the entire operating team in performing such a technically demanding procedure. For this reason, long operative times, increased blood loss, and transfusion requirements were not surprising. Insertion of the so-called first generation Kaneda device, used in all but one patient, was particularly time-consuming and explains why these anterior procedures took longer than those of the anterior–posterior group (mean surgical time for the anterior–posterior group was 90 minutes less than the sum of the means of the anterior group and the posterior group). Four patients in the anterior group suffered complications but these were relatively minor.

We recognize that the thoracolumbar spine can be decompressed by an anterior extracavitary approach. It would seem logical that the morbidity associated with this procedure in which the pleura and diaphragm are left intact would be less than our more extensive transthoracic transdiaphragmatic procedure. We believe, however, that the latter procedure makes decompression of T-12 and L-1 easier. In addition, superior vertebral body screw insertion for internal fixation without incision of the diaphragm is extremely difficult and results in at least traumatic stretching and sometimes tearing of this structure. The procedure of anterior decompression and fusion is very expensive; however, the correction of spinal deformity that is achieved does not appear to be superior to the treatment described for our other groups.

Advocates of posterior decompression (performed indirectly or via a transpedicular approach) have published impressive results on the efficacy of the decompression and the neurological improvements seen in their patients.1,17,26 Others, however, have compared anterior decompression to posterior decompression, and they reported no differences in postoperative neurological improvement between the two.18,22 In this study, posterior group patients underwent surgery an average of 4.2 days after injury. Eight (73%) of 11 neurologically incomplete patients demonstrated at least one Frankel grade improvement between the two.18,22 In this study, posterior group patients reported good or excellent pain relief; this may be partially explained by the relatively long motion segments that were fused in some of the patients in this group. In addition, disruption of facet joint capsules and posterior ligamentous structures apart from the fusion area may have contributed to early degenerative joint changes. We believe that the results and the data presented in this study demonstrate that posterior decompression and fusion for unstable thoracolumbar burst fractures is as efficacious as anterior decompression and fusion for kyphotic correction and neurological recovery. Although some patients in this group were treated with less costly instrumentation than is currently used, we do not believe this played a significant role in our financial analysis. Therefore, we conclude that posterior decompression and stabilization is the least expensive procedure when taking into account hospital and physician charges. In this era of cost containment, this finding should prove very important.

Conclusions

Posterior instrumentation and fusion is a safe, effective, and relatively inexpensive treatment for acute unstable thoracolumbar burst fractures. This study has resulted in a uniform approach in treating unstable thoracolumbar burst fractures by all attending surgeons at our institution. Because we used stainless steel implants for the patients reported in this series, we did not routinely image their canals postoperatively. Most of our instrumentation now is made of titanium, which causes less metal artifact on CT scan. Significant reduction of canal compromise can be achieved with early posterior distraction instrumentation, as reported by Edwards and Levine47 (within 14 days from injury) and by Willen, et al.44 (within 3 days from injury). At present, the protocol at our institution is to treat patients on postinjury Days 0 to 5 with posterior distraction instrumentation and fusion, although we suspect that a longer time interval would be acceptable. These patients then undergo CT scanning postoperatively to assess canal compromise and adequacy of decompression. Patients without resolution of neurological deficit after a posterior procedure and who have greater than 20% canal compromise on CT are advised to undergo anterior decompression and fusion without instrumentation.

Patients who present more than 5 days after injury are treated by either transpedicular posterior decompression or, more commonly, by anterior decompression and fusion. Late kyphotic deformity, persistent pain, or neurological deficit in referred patients are evaluated radiographically for instability or residual canal compromise. These patients are candidates for anterior decompression and fusion.

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