A new technique for the surgical management of unstable thoracolumbar burst fractures: a modification of the anterior approach and an outcome comparison to traditional methods

Gregory C. Wiggins, M.D., Michael J. Rauzzino, M.D., Christopher I. Shaffrey, M.D., Russ P. Nockels, M.D., Richard Whitehill, M.D., Mark E. Shaffrey, M.D., James Wagner, M.D., and Tord D. Alden, M.D.

Departments of Neurosurgery and Orthopaedic Surgery, Henry Ford Hospitals, Detroit, Michigan; and Departments of Neurological Surgery, and Orthopaedic Surgery, Division of Spine Surgery, University of Virginia Health Sciences Center, Charlottesville, Virginia

This study was conducted to determine the safety, efficacy, and complication rate associated with the anterior approach in the use of a new titanium mesh interbody fusion cage for the treatment of unstable thoracolumbar burst fractures. The experience with this technique is compared with the senior authors' (C.S., R.W., and M.S.) previously published results in the management of patients with unstable thoracolumbar burst fractures.

Between 1996 and 1999, 21 patients with unstable thoracolumbar (T12-L3) burst fractures underwent an anterolateral decompressive procedure in which a titanium cage and Kaneda device were used. Eleven of the 21 patients had sustained a neurological deficit, and all patients improved at least one Frankel grade (average 1.2 grades). There was improvement in outcome in terms of blood loss, correction of kyphosis, and pain, as measured on the Denis Pain and Work Scale, in our current group of patients treated via an anterior approach when compared with the results in those who underwent a posterior approach.

In our current study the anterior approach was demonstrated to be a safe and effective technique for the management of unstable thoracolumbar burst fractures. It offers superior results compared with the posterior approach. The addition of the new titanium mesh interbody cage to our previous anterior technique allows the patient's own bone to be harvested from the corpectomy site and used as a substrate for fusion, thereby obviating the need for iliac crest harvest. The use of the cage in association with the Kaneda device allows for improved correction of kyphosis and restoration of normal sagittal alignment in addition to improved functional outcomes.

Key Words * thoracolumbar burst fractures * trauma * spinal instrumentation * titanium cage * Kaneda device

The surgical treatment of thoracolumbar trauma and instability continues to evolve with advances in
surgical techniques and instrumentation. In 1995, the senior authors (C.S., R.W., and M.S.) reported a retrospective analysis of treatment outcomes for surgical approaches in the management of patients with unstable thoracolumbar burst fractures.[11] At that time their data indicated that a posterior-approach decompressive procedure in which segmental instrumentation was used was either equal or preferable to an anterior-approach or a combined anterior-posterior-approach procedure. The kyphosis correction and outcome based on the Denis Pain and Work Scales as well as neurological recovery achieved were not statistically different. Therefore, because the posterior approach was a quicker, less costly procedure that was associated with less morbidity, they concluded that the posterior approach is preferable. Over the last several years, however, advances in such surgical materials as titanium mesh interbody fusion cages as well as our increased use of an anterior approach for corrections of deformity have led us to modify our surgical approach. We now preferentially treat unstable thoracolumbar burst fractures via an anterolateral thoracoabdominal approach in which we use a titanium mesh cage (DePuy-AcroMed, Raynham, MA) packed with autologous bone to reconstruct the vertebrectomy and the Kaneda device (DePuy-AcroMed) for anterior fixation. We report our series of 21 patients with nonpathological thoracolumbar burst fractures who were treated with this approach, and we compare their treatment outcomes with our previously reported results.

**CLINICAL MATERIAL AND METHODS**

*Patient Population and Inclusion Criteria*

Twenty-one patients (Table 1) with nonpathological thoracolumbar fractures (T12-L3) were surgically treated by the senior authors (C.S., R.W., R.N., and M.S.) between January 1997 and May 1999. Inclusion criteria included patients with thoracolumbar burst fractures with: 1) incomplete paraplegia (motor and/or sensory deficit or bowel/bladder dysfunction) or 2) radiographic evidence of mechanical instability. Mechanical instability was defined by one or more of the following: 1) 20° or more of kyphosis, 2) greater than 40% canal compromise; and 3) greater than 50% loss of vertebral body height. Neurologically intact patients whose therapy involved wearing a brace or those who underwent other surgical approaches were excluded from this study. Patients who had sustained thoracolumbar trauma that was primarily ligamentous in nature, with minimal bone compromise, such as Chance fractures, were also excluded.
Neurological Assessment and Radiographic Evaluation

Patients were evaluated pre- and postoperatively based on the Frankel Paraplegia Grading Scale[18] (Table 2). In all patients preoperative anteroposterior and lateral radiographs were obtained to assess fracture level, fracture type (Denis fracture classification[14]), and degree of kyphosis (measured using the Cobb[10] method). Preoperative computerized tomography (CT) scans were obtained at the injured level to canal compromise and to assess delineate fracture morphology (Fig. 1).

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Injury Mechanism</th>
<th>Level</th>
<th>Surgeon</th>
<th>EBL (ml)</th>
<th>OR Time (min)</th>
<th>Follow Up (mos)</th>
<th>Preop</th>
<th>Postop</th>
<th>Work Score</th>
<th>Pain Score</th>
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</table>

This patient presented with bowel and bladder dysfunction. Abbreviation: MVA = motor vehicle accident.

### Table 2: Frankel Paraplegia Grading Scale

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>A</td>
<td>Complete: no motor or sensory function</td>
</tr>
<tr>
<td>B</td>
<td>Sensory only: motor function absent, includes sacral sparing</td>
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<tr>
<td>C</td>
<td>Motor useless: motor function present but not useful to patient</td>
</tr>
<tr>
<td>D</td>
<td>Motor useful: movement of lower extremities, patient may walk</td>
</tr>
<tr>
<td>E</td>
<td>Recovery: no weakness, sensory loss, or sphincter disturbance (abnormal reflexes may be present)</td>
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</table>
Canal compromise was measured as a percentage of the normal canal area as determined by comparing it with the average area of the two adjacent vertebral segments. Magnetic resonance imaging was performed to evaluate signal changes in the spinal cord in patients who presented with neurological deficit. Postoperative coronal and sagittal alignment, hardware position, and fusion mass were evaluated with anteroposterior and lateral radiographs (Fig. 2).
Lateral flexion-extension radiographs were obtained at 3 months and then at 6-month intervals to assess mechanical stability. Because all patients improved, neither postoperative CT nor magnetic resonance images were routinely obtained. For teaching purposes, one patient agreed to undergo a postoperative CT scanning study of the surgical area to assess the radiographic interference that might be associated with the interbody cage (Fig. 3).

**Pharmacological Protocol**

In both the present and the earlier study, all patients with neurological deficits were treated with intravenously administered methylprednisolone according to the National Acute Spinal Cord Injury protocol[5] (bolus of 30 mg/kg followed by continuous infusion of 5.4 mg/kg for 23 hours). All patients received 1 g of cefazolin, or vancomycin if they were allergic to penicillin, as perioperative antibiotic prophylaxis.

**Timing of Surgery**

The timing of surgery depended on the patient’s neurological status and associated injuries. Surgical treatment of patients who were neurologically intact was considered as elective surgery but was usually undertaken within 48 to 72 hours. Because studies have shown improved outcomes in cases in which early decompressive intervention is undertaken,[12,42,43] patients with incomplete paraplegia underwent surgery within 24 to 48 hours of admission.

**Operative Technique**

The fractured vertebra is typically exposed by a left-sided transthoracic retroperitoneal approach, which has been previously described in detail.[44] We prefer a left-sided approach to avoid retraction of the liver and inferior vena cava. We have found that exposure above and below the diaphragm is usually
needed to obtain an adequate working area for decompression and placement of the instrumentation.

The patient is placed in the true lateral position, with a sufficient axillary roll under the right armpit and the fracture level over the break of the table. The table is then flexed to open up the vertebral interspaces and allow for additional compression across the cage prior to our final tightening. A cell saver is employed to minimize transfusion requirements.

In most cases an 11th rib exposure is used, and the bone is saved for later use as part of the autograft. Ligating the segmental vessels exposes one vertebral level above and below the fracture. The neural foramen (and therefore the anterior wall of the canal) is identified to define the posterior extent of the corpectomy. The disc spaces are incised and a large Cobb elevator is used to scrape the endplates. Care is taken to avoid injuring the vertebral endplates of the adjacent vertebral bodies. The disc material is then removed using a combination of pituitary rongeurs and curettes. With the neural foramen as a posterior landmark, the bulk of the vertebrectomy is performed with an osteotome to preserve as much bone as possible for use as autograft. Along with the harvested rib, this quantity of bone has always been adequate to pack our cages fully and has obviated the need for harvesting iliac crest autograft. A high-speed drill is used to finish the corpectomy, drilling the bone to a thin layer of cortical bone ventral to the posterior longitudinal ligament, which is carefully removed by using the curette to push it ventrally into the corpectomy defect. The dura is always visualized from pedicle to pedicle, and epidural venous bleeding is controlled. The Kaneda device is placed, and distractive forces are applied to help reduce the kyphotic deformity. An appropriate-sized titanium mesh interbody cage is measured and cut to length. It is then tightly packed with the corpectomy bone and rib and tapped gently into place, and care is taken to avoid impinging on the dural sac. The cage and bone graft are placed under compression by removing the flexion from the table and compressing across the Kaneda device.

The wound is then irrigated with antibiotic solution and closed in layers. Prior to final closure of the pleura, we routinely thread a red rubber catheter into the pleural cavity and evacuate the air. This technique has obviated the routine need for placement of a painful thoracostomy tube postoperatively.

The surgical techniques employed in the previous study are described in the original paper detailing these techniques.[5] Briefly, the anterior approach in the original group (16 patients) was similar to our current approach except that a tricortical iliac crest bone graft was used to reconstruct the vertebrectomy defect, and we were less aggressive in trying to restore sagittal alignment. The posterior group (27 patients) was treated either with a direct decompressive intervention via a posterolateral transpedicular approach (12 patients) or via an indirect decompressive intervention in which distractive forces were used (that is, ligamentotaxis; 15 patients). Posterior stabilization was achieved with pedicle screw fixation and Steffee plates (16 cases), Cotrel-Doubousset rods and a hook and claw construct (four cases), Harrington Rods with hooks (four cases), or Luque rings with sublaminar wiring (three cases). In those treated via a combined anterior-posterior approach, all patients first underwent an anterior decompressive procedure in which a fibular strut and/or morselized rib grafts was placed as described above (in two patients a Kaneda device was also placed). This was followed by a posterior stabilization performed in a second operation to augment the anterior stability when it was deemed inadequate. Posterior constructs in this group consisted of rods with a hook and claw system (four cases) or with Luque rings and sublaminar wiring (two cases).

**Postoperative Orthotic Use**

All patients in both this and the earlier study were fitted with a custom-made thermally molded plastic
thoracolumbosacral orthosis and were encouraged to ambulate within 48 hours of surgery. Patients underwent brace therapy for 3 months postoperatively and were then weaned from the brace over an additional 2 to 3 weeks.

**Follow-Up Studies**

The average follow-up time in our study was 15 months (range 2-31 months). In all patients radiographic studies were performed at 3-, 6-, and 12-month follow-up visits and then as needed. For those patients without recent clinic visits and those discharged from clinic, a final follow-up interview was conducted via telephone to assess their status based on the Denis Pain and Work Scales (Table 3).[13] No patient was lost to follow up.

### TABLE 3

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<th>Scale</th>
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<tr>
<td>pain score</td>
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<tr>
<td>P1</td>
<td>occasional minimal pain; no need for medication</td>
</tr>
<tr>
<td>P2</td>
<td>moderate pain, occasional medications, &amp; no interruption of work or activities of daily living</td>
</tr>
<tr>
<td>P3</td>
<td>moderate-to-severe pain, occasionally absent from work; significant changes in activities of daily living</td>
</tr>
<tr>
<td>P4</td>
<td>constant, severe pain; chronic pain medications</td>
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<tr>
<td>work score</td>
<td>return to previous employment (heavy labor) or physically demanding activities</td>
</tr>
<tr>
<td>W1</td>
<td>able to return to previous employment (sedentary) or return to heavy labor with restrictions</td>
</tr>
<tr>
<td>W2</td>
<td>unable to return to previous employment but works full time at new job</td>
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<td>W3</td>
<td>unable to return to full-time work</td>
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<tr>
<td>W4</td>
<td>no work, completely disabled</td>
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**Statistical Analysis**

Statistical analysis was obtained using STATISTICA '98 (StatSoft, Inc., Tulsa, OK). The odds ratio for each group, compared with the posterior group, was estimated. A 95% confidence interval for each odds ratio was made using the Logit method. The Wilcoxon's sign rank sum test was used as a nonparametric method to compare groups with regard to blood loss, operative time, canal compromise, pre- and postoperative kyphosis, pre- and postoperative Frankel grade, postoperative length of hospital stay, and postoperative scores from the Denis Pain and Work Scales. The level of statistical significance was set at less than 0.05.

**RESULTS**

**Preoperative Variables**

**Patient Demographics.** Nineteen males and two females with a mean age of 34 years (range 16-59 years) formed the basis for the study. Ten patients sustained injuries from motor vehicle accidents and 11 from falling from heights. On admission 10 patients were neurologically intact and 11 patients had sustained neurological injury. The locations of the fractures in order of frequency were as follows: L-1 in 12 cases,
L-2 in four cases, T-12 in three cases, and L-3 in two cases.

Associated injuries in these patients included one with a Type II odontoid fracture, T-4 compression fracture, and a humerus fracture (Case 1; Table 1); one with multiple thoracic compression fractures and a cervical central cord syndrome (Case 7); three with a significant pulmonary contusion (Cases 3, 5, and 10); one with a femur fracture (Case 13); and one patient with a pelvic fracture and bilateral calcaneal fractures (Case 15). An interesting incidental finding was the presence of idiopathic thoracolumbar scoliosis in two patients.

**Canal Compromise.** The average extent of canal encroachment in our series was 65.5% (range 25-90%). In our previous study the results were as follows: anterior group, 52.5% (range 20-80%); posterior group, 52.6% (range 20-80%); and combined anterior-posterior group 50% (range 30-70%). Although the degree of canal compromise was larger in our present group, it was not statistically different from the other groups. We did not routinely obtain CT scans to assess the amount of residual canal compromise because all patients in our group improved.

**Preoperative Kyphotic Deformity.** The mean preoperative kyphotic deformity in our current group was 18.8° (range 5-36°). In our previous study these results were as follows: anterior group, 16.1° (range 5-35°); posterior group, 15.2° (range 0-32°); and combined anterior-posterior group, 26.0° (range 5-60°). There was no statistical difference among these groups.

**Operative Variables**

**Operating Room Time.** The mean operating room (OR) time from the initial incision to the time when the dressing was applied was 318 minutes (range 250-375 minutes). In our previous study the mean OR times were as follows: 438 minutes in the anterior group, 219 minutes in the posterior group, and 569 minutes in the anterior-posterior group. The difference in OR time in our current anterior group was statistically different from either the previous anterior group or the combined anterior-posterior group but not the posterior group (p < 0.05).

**Estimated Blood Loss.** The mean volume of estimated blood loss (EBL) in this study group was 727 ml. In our previous study the mean EBL results were as follows: 1878 ml in the anterior group, 1103 ml in the posterior group, and 2541 ml in the anterior-posterior group. The difference in mean EBL in our current anterior-approach group was statistically different from either the previous anterior-approach group or the combined anterior-posterior-approach group but not the posterior-approach group (p < 0.05).

**Postoperative Variables**

**Neurological Recovery.** In our study 10 patients were neurologically intact (Frankel Grade E) on admission, and all of these patients remained at Grade E without having sustained a surgery-related neurological injury. In one of these patients (Case 20) preoperative alteration in bowel and bladder function resolved postoperatively. Of the eight patients with Frankel Grade D paraplegia on admission, all had recovered full motor and sensory function (Frankel Grade E) at final follow-up examination. Of the two patients with Frankel Grade C paraplegia, one improved one grade and one improved two grades. There was one patient with Frankel Grade B paraplegia. Despite the short follow-up period, he has improved two grades and continues to improve.

In our previous study the results were as follows. Of the 16 patients in the anterior group, the eight
patients with Frankel Grade E status all remained at the same grade postoperatively. Of six patients with Frankel Grade D disability, two patients improved to Frankel Grade E. Of the two patients with Frankel Grade C paraplegia one improved to Frankel Grade D. Of the 27 patients in the posterior group, the 16 patients with Frankel Grade E dysfunction all remained at the same grade postoperatively. Of the three patients with Frankel Grade D paraplegia, two patients improved one grade. Of the six patients with Frankel Grade C disability, four improved one grade and two improved two grades. Of the six patients in the combined anterior-posterior group, three with Frankel Grade E status remained at the same sensory/motor level postoperatively. One patient with Frankel Grade D dysfunction improved one grade. Of the two patients with Frankel Grade C paraplegia, one patient improved two grades.

In summary, the average improvement in Frankel grades was 1.2 grades in our current anterior group, 0.4 grades in our previous anterior group, 0.9 grades in our previous posterior group, and 1 grade in our previous anterior-posterior group. There was no statistical significance among these groups although our current group was the only one in which every patient with a neurological deficit improved at least one grade.

**Duration of Postoperative Hospital Stay.** The mean postoperative length of hospital stay for the current group of patients was 8 days. In our previous study, the mean postoperative stays were as follows: 13 days in the anterior group, 10 days in the posterior group, and 22 days in the anterior-posterior group. Only the anterior-posterior group reached statistical significance (p < 0.003).

**Postoperative Kyphotic Correction.** The mean postoperative kyphotic deformity at final follow-up examination in our present group was 0.1° (range -10 to 16°). In our previous study these results were as follows: anterior group, 9.8°; posterior group, 9.5°; and combined anterior-posterior group, 18.5°. Although the follow-up period was short, no loss of correction has been observed in our present group. There was a trend toward the final degree of kyphosis being significantly more improved in the current patients in whom the anterior-approach surgery was performed and in whom a cage was placed than in any of our previous groups.

**Pain Status.** The results of the Denis Pain Scale are reported in Fig. 4 upper and Table 4. Analysis of outcomes on the Denis Pain Scale showed that there was significant reduction in pain in patients who underwent the anterior approach with placement of a cage compared with those who underwent the posterior approach. Patients were 11.25 times more likely to experience good pain relief if they had been treated with the anterior approach and cage placement when compared with the posterior approach.
Fig. 4. Graphs showing Denis Pain Scale (upper) and Denis Work Scale (lower) results in 64 patients who underwent surgical treatment for thoracolumbar fractures for our two study periods. See Table 3 for definition of grades.
Work Status. The results of the Denis Work Scale are reported in Fig. 4 lower and Table 4. There was a trend toward improvement in the Denis Work Scale with the anterior-approach group in whom the cage was placed when compared with the baseline group in whom the posterior approach was performed, but this did not reach statistical significance.

Postoperative Complications. There was one patient with premorbid thoracolumbar scoliosis in whom the inferior screw fractured without displacement of the Kaneda device, which was noted incidentally on a follow-up study. A solid fusion had already been achieved in this patient, and no additional treatment was required. Three patients required insertion of a thoracostomy tube postoperatively for a pleural effusion, each for a period of less than 72 hours. In all three of these patients a significant pulmonary contusion had been demonstrated on their admission chest radiograph. We have subsequently modified our technique and routinely place thoracostomy tubes in those patients with significant left-sided pulmonary contusions. Four patients developed postoperative ileus that required nasogastric suction. There was one case of postoperative pneumonia in a patient whose mobilization was impaired by associated pelvic and calcaneal fractures. There were no cases of infection or pseudarthrosis.

DISCUSSION

The optimum management for the treatment of unstable thoracolumbar burst fractures remains controversial. Bracing,[45] recumbency,[13,22] anterior approaches,[2,4,9,19,21,37,40,50] posterior approaches,[3,8,15,17,20,28,38,46,49,52] and combined procedures[2,16] have all been advocated. Despite a large number of publications, there are few good studies in which the authors have compared these surgical approaches in either a prospective or retrospective fashion.[17] Our surgical management of these injuries has evolved over the past 5 years because of advances in spinal instrumentation and increased surgical experience.

Posterior Technique

The posterior approach is attractive because of the neurosurgeon's familiarity with the anatomy and the approach. It can be performed rapidly, without the assistance of a general or vascular surgeon and it avoids complications associated with thoracotomy, such as a thoracostomy tube and the possibility of

<table>
<thead>
<tr>
<th>Variable</th>
<th>Posterior</th>
<th>Anterior</th>
<th>Combined</th>
<th>Anterior WW Cage</th>
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<tbody>
<tr>
<td>Denis Pain Scale</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>poor outcome</td>
<td>15</td>
<td>5</td>
<td>3</td>
<td>3</td>
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<tr>
<td>good outcome</td>
<td>8</td>
<td>10</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>odds ratio</td>
<td>1</td>
<td>3.75</td>
<td>1.25</td>
<td>11.25†</td>
</tr>
<tr>
<td>95% CI</td>
<td>0.95–14.82</td>
<td>0.17–9.09</td>
<td>2.53–50.09</td>
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<tr>
<td>Denis Work Scale</td>
<td></td>
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<tr>
<td>poor outcome</td>
<td>9</td>
<td>5</td>
<td>2</td>
<td>3</td>
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<tr>
<td>good outcome</td>
<td>14</td>
<td>10</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>odds ratio</td>
<td>1</td>
<td>1.29</td>
<td>0.96</td>
<td>3.86</td>
</tr>
<tr>
<td>95% CI</td>
<td>0.33–5.02</td>
<td>0.13–6.95</td>
<td>0.86–16.97</td>
<td></td>
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</tbody>
</table>

* CI = confidence interval.
† p < 0.05.
iatrogenic vascular or pulmonary injury. It is also useful when posterior bone compression is caused by fractured laminae. The posterior approach, however, is limited. Posterior-approach reduction measures rely on an intact posterior longitudinal ligament and annulus to be successful. This intervention should be performed within 48 to 72 hours to achieve optimum results. Even so, the amount of reduction is significantly less than that achieved in anterior procedures. Direct decompression via a transpedicular approach increases the amount of canal decompression but is still not as effective as a direct anterior decompressive intervention.[52] In a comparison between anterior and posterior decompression, Bradford and McBride[6] reported improved neurological outcomes in patients who underwent the anterior approach, which correlated with significantly less residual canal stenosis. Also, posterior systems with a hook and claw construct typically require involvement of two to three vertebrae above and below the fracture for fixation. Short-segment fusion with pedicle screws has been advocated, but hardware failure has been problematic.[27,48] Late loss of kyphosis correction has been reported to be associated with both techniques.[27] Late neurological deterioration has also been reported, presumably due to ongoing compression from incompletely reduced bone fragments.[13,14]

**Anterior Technique**

The literature supports the efficacy of the anterior or anterolateral approach both clinically and biomechanically. In several studies the authors have reported good recovery of neurological function after an anterior decompressive and fusion procedure.[9,25,29,43] These improved results are seen even when the patients undergo surgery in a delayed fashion.[51] In a number of biomechanical studies the authors have demonstrated the increased stability of an anterior construct with an anterior fixation device compared with posterior fixation systems.[32,47] Although there is a significant learning curve with the use of the anterior approach to the thoracolumbar junction, other authors have previously reported minimal complications.[25,26]

**Our Current Technique**

The goals of treatment should be to provide a painfree, functional spine and to maximize neurological and clinical recovery. In our earlier comparison we noted a trend toward improved pain and work outcomes in those patients treated with the anterior approach as compared with the posterior approach, despite a lack of statistical significance.[11] Using our earlier work as our starting point, we have modified our technique. We believed that, from an anatomical and biomechanical standpoint, it was best to treat an anterior and middle column problem anteriorly. Based on our experience in treating patients with spinal deformities, we hypothesized that restoration of normal alignment is an important factor in improving treatment outcomes. Therefore, an anterior approach was selected to maximize sagittal balance correction. The use of the distractive abilities of the Kaneda device and the ability to tailor the size of the titanium mesh cages precisely made this possible. The patient's own bone is the best fusion substrate, and this is supported in a study by Wimmer and associates[53] who described better outcomes in patients who underwent anterior lumbar interbody fusion in which their own bone was used, when compared with allograft bone. In our first series we had also noted patients complaining of donor-site pain after the large iliac crest struts had been harvested. The use of the cage, the harvested rib, and the technique with the osteotome to harvest the corpectomy bone has always provided abundant autologous bone to span the defect without disturbing the iliac crest. Careful patient selection as well as the evacuation of air prior to closure of the pleura have obviated the routine use of postoperative thoracostomy tubes. Additionally, the titanium implant allows for adequate postoperative imaging studies should they be necessary.
**Neurological Recovery**

Despite an increase in the average improved Frankel grade in our current group as compared with that in the previous groups, the difference was not statistically significant. Importantly, all patients with an incomplete deficit improved postsurgery. We would attribute this success to direct and complete decompression of the thecal sac.

**Functional Outcomes**

Malcolm and colleagues[34] have reported an association between low-back pain and kyphosis after thoracolumbar trauma that was improved after correction of the sagittal-plane deformity. In our present study there was a significant improvement in patients' pain levels and also a positive trend in their ability to return to work. We believe, in part, that the reason for this difference was due to our ability to restore our patients to normal sagittal alignment. Avoiding harvesting of iliac crest may also have led to lower levels of postoperative pain. A procedure involving an anterior decompression, instrumentation, and arthrodesis also usually saves lumbar motion segments as compared with most posterior instrumentation constructs.

**Titanium Mesh Interbody Cages**

The use of solid titanium interbody fusion cages placed in the anterior column has been shown to be efficacious to span a single disc space and promote arthrodesis at that level.[30] In a number of biomechanical studies the authors have shown that these cages, when placed in the anterior column, are able to resist forces in all planes, particularly in axial rotation, whereas posterior segmental instrumentation is least effective.[23,24,33,39,41] These cages are being used with increasing frequency in surgery to correct deformity in patients with adult and juvenile scoliosis after an anterior release is performed to maintain disc height and prevent subsequent kyphosis.[7,31,36] The use of interbody cages in the treatment of traumatic instability has been rarely described. In a review of complications associated with the Kaneda device, McAfee[35] has briefly reported on 10 patients with thoracolumbar burst fractures whose vertebrectomies were reconstituted using carbon fiber cages packed with autologous bone. To our knowledge, no report has described the use of titanium mesh cages packed with autograft for vertebral reconstruction in patients after traumatic injury.

**CONCLUSIONS**

We appreciate the limitations of this study. The present study provides a retrospective analysis, and our results are compared with those of previously published surgical groups from another time period. We appreciate the difficulties of comparing the results from one time period with another. However, we are comparing the work of the same senior surgeons in an academic setting. Whereas comparisons can be made with our previous groups treated via an anterior approach with iliac strut and those treated via a posterior approach, it is especially difficult to do so with those who underwent a combined anterior-posterior approach because of the limited number of patients included in this group. Currently we reserve a combined anterior-posterior approach for patients with severe kyphotic deformity or with severe posterior column or facet disruption.

Nonetheless we believe that the results of this study reaffirm the value of the anterior approach in the management of unstable thoracolumbar burst fractures. In addition we offer details on the use of a titanium mesh cage for vertebral reconstruction. This technique:
1) allows for safe and increased decompression of neural structures to promote maximal neurological recovery;

2) provides immediate stability and allows for early mobilization that should reduce perioperative complications;

3) involves a minimum number of motion segments, possibly minimizing current and subsequent back pain;

4) corrects deformity and restores sagittal alignment, which may also reduce the incidence of low-back pain;

5) allows for compression across the construct to promote arthrodesis;

6) uses the patient's own bone to promote arthrodesis;

7) allows for interpretable postoperative imaging studies;

8) has a minimal complication rate compared with other treatment options; and

9) has results that compare favorably with all previous published reviews of management of thoracolumbar fractures.

In this study all patients with neurological impairment showed neurological recovery, sagittal alignment was restored and maintained, there were no cases of pseudarthrosis, and improved pain control and ability to return to work were demonstrated in all patients postoperatively.

References


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Address reprint requests to: Michael J. Rauzzino, M.D., Department of Neurosurgery K-11, Henry Ford Hospital, 2799 West Grand Boulevard, Detroit, Michigan 48202.