Surgical intervention is indicated in the treatment of burst fractures involving the anterior and posterior halves of the VB when the individual presents with associated deficit, pain, or spinal instability. The goal of surgical intervention is decompression of the neural elements, restoration of VB height, correction of angular deformity, and stabilization. Such decompression and stabilization can be performed anterolaterally through the retroperitoneal flank approach or posteriorly with decompression through laminectomy or the transpedicular–transfacetal route. The anterolateral retroperitoneal flank approach allows the surgeon to perform corpectomy and fusion, reconstructing the anterior and middle columns of the spine. Bone fragments can be removed from the canal under direct vision. Following corpectomy, the vertebral column is reconstructed by inserting a graft or prosthesis, correcting angulation and loss in VB height. When placing anterior instrumentation for immobilization and fusion, the hardware generally incorporates one VB rostral and one caudal to the fracture.

When the posterior route is used, access to the canal is gained by laminectomy or the removal of the facet joints and pedicle, generally on one side, and decompression is achieved by disimpaction. Posterior stabilization generally requires that the instrumentation be placed two levels above and below the site of injury. Both anterolateral and posterior approaches have been associated with favorable results, as well as complications.

This study is a retrospective cohort investigation of cases in which T11–L2 burst fractures were treated with anterior instrumentation and corpectomy performed via the retroperitoneal flank approach or the midline posterior approach. Until 1998, most burst fractures were treated via the posterior approach. Thereafter, they were treated preferentially via the anterolateral approach. Outcomes in angulation, neurological status, patient-rated satisfaction, and cost analysis were examined and compared.
Clinical Material and Methods

Data obtained in 63 patients with T11–L2 burst fractures treated between July 1992 and April 2005 were reviewed. There were 45 males, and 18 females, and their levels of involvement are shown in Fig. 1. Neurological status was assessed using the Frankel motor score system. For ease of statistical analysis, the Frankel grade was converted into a numerical score in which A is equal to 1 (complete motor and sensory paralysis below the lesion), B is 2 (complete motor paralysis but some residual sensory perception), C is 3 (residual motor function but not of practical usefulness to the patient), D is 4 (useful but subnormal motor function below the lesion), and E is 5 (normal motor and sensory function). Results are expressed as the means ± the standard deviations.

On admission all patients underwent plain (AP and lateral) supine radiographs in CT and MR imaging. Spinal angulation was determined by evaluating lateral radiographs on which we measured the angle of intersection of the adjacent intact endplates rostral and caudal to the fracture. The AP canal diameter at the fracture site was measured on CT scans and it was expressed as a percentage of the average normal canal above and below the fracture site. Surgery was performed when the patient’s condition (related to other injuries) was deemed stable, and when there was neurological dysfunction or persistent pain associated with retropulsion of bone into the canal. Regardless of which approach was used, the intent of surgery was to decompress the canal, correct the kyphosis, and stabilize the spine.

Posterior Approach

Until 1998, the posterior route was the predominant approach; thereafter this approach was performed in only four of 25 patients. This approach was undertaken in 19 men and six women whose mean age was 42 ± 11 years (range 22–64 years) (Fig. 2). The period between admission and surgery was 4 ± 3 days (range 0–14 days). Pedicle screws were used in 18 patients, both PSs and hooks in six, and hooks alone in one. Decompression was achieved through a laminectomy and disimpaction in 10 patients, a transpedicular or transfacet approach in eight, and ligamentotaxis in seven. For fusion, bone harvested from the decompression site or iliac crest autograft augmented with demineralized bone matrix was used.

Anterolateral Approach

From 1998 onward, the anterolateral flank approach was favored; in only five of 38 patients had this approach been used prior to 1998. To avoid injury to the vena cava, the anterolateral approach was performed on the patient’s left side and with the patient in the decubitus position. Of the 38 patients in this group, 26 were men and 12 were woman whose mean age was 42 ± 15 years (range 18–70 years) (Fig. 3). The mean period between admission and surgery was 6 ± 12 days (range 0–20 days in all, but one patient in whom surgery was performed 73 days after admission because multiple injuries prevented earlier surgery). Stackable CFCs (DePuy Spine, Raynham, MA) were placed in 17 patients, allograft in 15, iliac crest autograft in four, and a telescoping titanium cylinder (Vertispan; Medtronic Sofamor-Danek, Memphis, TN) in two. Femoral allografts and synthetic anterior strut grafts were packed with autograft from the corpectomy site and augmented with autogenous rib. Grafts were impacted under distraction and held in place under compression. Lateral instrumentation involved the implantation of dual rods and screws in 31 patients (Antares [Medtronic Sofamor-Danek], etc.).

Fig. 1. Bar graph showing the distribution of thoracolumbar burst fractures by level in both anterior and posterior surgical groups.
Danek, Memphis, TN]; or Kaneda [Depuy Spine]), and plates and screws in seven (Profile [DePuy Spine]; anterior thoracolumbar locking plate system [ATLP; Synthes Spine, Paoli, PA]; or Z-plate [Medtronic Sofamor-Danek]). One patient with a T-12 burst fracture, T11–12 dislocation, and paraplegia required contemporaneous anterior–posterior instrumentation.

Follow-Up Data

Patients were mobilized gradually after surgery while wearing lumbar orthoses. A portable lateral radiographic system was used to obtain x-ray films, first at 45° angles and then upright or standing at 90°. Braces were generally worn for 3 months postoperatively. Follow-up examinations, including standing or upright AP and lateral radiography, were scheduled at 1.5, 3, 6, and 12 months and annually thereafter. The mean clinical follow-up period after discharge was 1.8 years (range 1.5–8 years). All patients were sent the Rand SF-36 questionnaire. The completed forms were received from 1.5 to 12 years (mean 5.8

Fig. 2. The posterior approach. Studies obtained in a 47-year-old man who fell off a grain truck and sustained an L-1 burst fracture. He was neurologically intact but complained of back and hip pain. A: Plain lateral radiograph revealing significant VB height loss and canal compromise. B: Axial CT scan showing canal narrowing, retropulsion of bone, and increase in interpedicular distance. C: Sagittal T2-weighted MR image demonstrating cauda equina compression. Three days following his injury, the patient underwent placement of posterior instrumentation comprising PSs, hooks, and an iliac crest graft. D and E: Five-year follow-up plain AP (D) and lateral (E) radiographs showing a solid fusion at T-12, L-1, and L-2. The rostral hooks are dislodged but stable. The patient remains neurologically intact but is disabled from pain.
years) after surgery. The responses were grouped into eight categories: physical functioning (the mean of Questions 3–12), limitations due to physical health (the mean of Questions 13–16), limitations due to emotional health (the mean of Questions 17–19), energy/fatigue (the mean of Questions 23–31), emotional well-being (the mean of Questions 24–30), social functioning (the mean of Questions 20 and 32), pain (the mean of Questions 21 and 22), and general health (the mean of Questions 1 and 33–36).

Statistical Analysis

Data were analyzed using analysis of variance, the Wilcoxon test, and the Fisher exact test. Significance was accepted at a probability value of less than or equal to 0.05.

Results

Clinical and Radiographic Parameters

Preoperative and postoperative neurological status, represented by Frankel scores, is summarized in Table 1. The mean preoperative Frankel scores in the anterior and posterior groups were 3.7 ± 1.1 and 3.5 ± 1.4, respectively (p = 0.4155). Preoperative angular deformity in the anterior and posterior groups measured 11.9 ± 9.7 and 4.1 ± 7.1°, re-
TABLE 1

Summary of pre- and postoperative neurological changes in patients who underwent either anterior or posterior surgery

<table>
<thead>
<tr>
<th>Preop Frankel Grade (score)</th>
<th>No. of Patients</th>
<th>Postop Frankel Grade (score)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A (1)</td>
<td>B (2)</td>
</tr>
<tr>
<td>Anterior op</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>B (2)</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>C (3)</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>D (4)</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>E (5)</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Posterior op</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>B (2)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>C (3)</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>D (4)</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>E (5)</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td></td>
</tr>
</tbody>
</table>

There were two patients in the anterior group in whom the construct failed and necessitated repeated surgery; thus, the failure rate was 5%. In a 37-year-old man with paraparesis and a plate-treated L-1 fracture, the femoral allograft migrated into the canal after the patient was mobilized. This was attributed to a three-column injury that had gone unnoticed. Eight days later, he underwent the placement of posterior PS instrumentation and adjustment of his strut graft. The second complication occurred in a 49-year-old man with an L-2 fracture who had undergone anterior surgery involving the placement of a strut graft (femoral allograft) and dual rod–screw instrumentation. Postoperatively, angulation increased due to the small size of the graft and its posterior location. Revision surgery was undertaken 11 days later and the femoral allograft was replaced with a large, stackable CFC and reinforced with posterior PSs.
group that ultimately required removal of the hardware 6 months postoperatively after failure to eradicate the persistent *Staphylococcus aureus* infection.

**Economic Impact**

The duration of hospitalization from admission to discharge in the anterior group was 17.0 ± 14.0 days and that in the posterior group was 19.0 ± 8.0 days (p = 0.444). This difference is less a reflection of the technique than of the efficiency in recent years of transferring patients to rehabilitation. To compare costs, the expenses incurred by the last 10 patients who underwent posterior surgery between May 1997 and May 2002 were compared with those incurred by nine patients who underwent anterior surgery between January 1998 and January 2000. The mean operating times between entering and exiting the operating room were 413 ± 81 and 415 ± 118 minutes for posterior and anterior groups, respectively (p = 0.823). Operating room expenses for supplies and expendables were $8668 ± 2500 and $7973 ± 2710 for the posterior and anterior groups, respectively (p = 0.53). The implant cost averaged $8665 ± 4760 for posterior instrumentation and $6265 ± 4120 for anterior instrumentation (p = 0.269). The mean total of the surgeon’s fees was $18,270 ± 6980 for posterior surgery, whereas it was $27,940 ± 4395 for anterior surgery (p = 0.0024). Total hospital charges collected were $80,040 ± 32,535 for posterior surgery and $89,090 ± 27,340 for anterior surgery (p = 0.523) (Fig. 7).

**Discussion**

In the posterior group, angulation decreased only 0.7° between admission and discharge, whereas it progressed to 9.8 ± 9.4° at the final follow-up examination (Fig. 4). In the anterior group, however, angulation was corrected by 9.9° between admission and discharge, and the correction persisted at 4.5 ± 9.3° at follow up. At the follow-up evaluation, the angulation in the posterior group was significantly greater than that in the anterior group (p = 0.024). The anterior approach allows removal of retro-pulsed bone from the canal under direct vision as well as reconstruction of the anterior column with a strut graft. This approach protects the integrity of the posterior column and is associated with a sustained correction of angular deformity.12,20,24 Anterior graft materials have included autografts,6,28 allografts,13,22,29 titanium mesh cages,10,11 and stackable CFCs.3,24 We favor CFCs because they can be easily stacked to span the corpectomy defect and, with appropriate instruments and fluoroscopic guidance, can be impacted easily into place. These cages are available in different sizes, allowing adaptation to the adjacent endplates. The largest endplate is selected to reduce the incidence of subsidence and telescoping of the graft within the VBs adjacent to the fracture.

Complications necessitating repeated operation occurred in five patients (20%) in the posterior group. Two of these five complications involved hooks. Posterior approaches in cases of burst fractures may entail laminotomy or laminectomy, as well as sacrifice of the facet joint on at least one side, if disimpaction of the canal is to be undertaken. This complication rate associated with poste-
rior instrumentation has been underscored by other published data. In one series of 70 patients with thoracic and lumbar fractures, 25% of the screws adjacent to the fracture bent or broke, and in four patients hardware was removed for pain or when it became prominent—that is, when it could be felt through the skin. Alvine and colleagues also used PS fixation in the treatment of 41 thoracolumbar fractures from T-11 to L-5. In their study, implant breakage occurred in 16 (39%) of the 41 fractures. In seven cases the implant breakages necessitated repeated surgery. In the retrospective review of thoracolumbar fractures conducted by Danisa and associates, posterior instrumentation was shown to be safe, simple, and cost effective in 27 patients compared with anterior surgery in 16 patients.

Two (5%) of our 38 patients treated with the anterolateral approach required repeated surgery that involved posterior instrumentation-augmented fusion. The rates of repeated operation in the anterolateral and posterior groups were not significantly different (p = 0.097). In the 150 cases reported by Kaneda, et al., there were 10 cases (7%) of pseudarthrosis necessitating posterior instrumentation and fusion. McAfee reported on complications associated with the anterior approach when used in patients with thoracolumbar fractures undergoing decompression and stabilization with various implants. The failure rate was only 6% (two of 35 implants) in cases in which the Kaneda dual rod–screw construct was used. The anterior approach in patients with VB fractures requires fixation of only one level rostral and caudal to the fractured VB, whereas in the posterior approach instrumentation may span five or more levels where the anterior column has been disrupted with secondary deformity. To optimize fusion, bone grafts are better maintained under compression, and this is achieved more effectively by using an anterior approach and the insertion of dual rods and bicortical screws. The authors of in vitro biomechanical tests in cadaveric spines have shown that the stiffness of the construct (that is, that afforded by the spine and the implant combined) was attributable to many factors, including the constraint of the screws to the plate or rods, the bicortical engagement of the screws, and the ability of these devices to compress the graft between the vertebral endplates. Furthermore, although surgeons’ fees for the anterior approach were nearly $10,000 higher, our cost analysis showed no significant difference between the two approaches in the duration of the procedure, cost of the implant, or overall hospital charges.

Analysis of our results and those of others demonstrates that several parameters need to be examined prior to the selection of treatment options. Rather than being random, this selection should be based on clinical and radiological criteria including neurological deficit, pain, deformity, angulation, residual canal diameter, and VB height. In flexion–compression fractures in which the anterior column alone is affected by loss of height but not canal compromise, surgery is generally not needed. For patients with burst fractures who are neurologically intact, in whom angular deformity is less than 20°, and in whom the residual spinal canal is greater than 50% of normal, nonoperative treatment is sufficient. Surgery is undertaken when neurological deficits—either complete or incomplete—and persistent pain are present. If the fractured VB is sufficiently preserved to provide some load sharing, then posterior instrumentation may be sufficient. When significant fragmentation of the VB exists and there is poor apposition of the fragments and loss in height, anterior grafts and instrumentation are necessary.

Neurological improvement was documented in our patients regardless of which approach was used (Tables 1 and 2; Fig. 5); the same was shown in the Scoliosis Research Society Multicenter Spine Fracture Study. In the latter, functional recovery at 2 years in patients in whom either an anterior and posterior approach was used was shown to be comparable when using the Frankel or motor score grading system. When using the Manabe

Fig. 6. Bar graph illustrating the distribution of mean SF-36 scores obtained in 22 patients who underwent anterolateral surgery (black bars) and 18 patients who underwent posterior surgery (white bars). No significant intergroup difference in scores is noted.
Scale, which incorporates neurological function and pain, however, significantly greater improvement was documented in 183 patients in whom the anterior approach was used (p < 0.00001, chi-square test) than in the 163 individuals in whom the posterior route was used. Additionally, unsatisfactory results at 1 year appeared more prevalent in patients treated with a posterior approach. In our study, Rand SF-36 scores in the anterior group were slightly higher than those in the posterior group, but statistical significance in any category was not achieved. Higher scores in the anterior group were in part a reflection of the shorter length instrumentation, lower rate of repeated operation, and sustained deformity correction.

Currently, guidelines based on randomized trials for the treatment of thoracolumbar burst fractures are unavailable. Verlaan, et al., conducted a literature review of 132 papers, involving 5748 patients with thoracic and lumbar fractures treated with posterior, anterior, or combined approaches. They concluded that evidence-based guidelines for the treatment of these fractures were absent and suggested that, for a better comparison of surgical techniques, randomized controlled trials were necessary. We agree with their conclusions but recognize, as others do, the advantages of the anterior approach.\textsuperscript{1}

Conclusions

Our results and those of others demonstrate that angular deformity is more successfully corrected and maintained, and fewer spinal segments are immobilized, when using the anterior approach. In cases of burst fractures in which neurological deficit and angular deformity are present, the anterior approach with anterior-column reconstruction appears to be advantageous.\textsuperscript{1,15} The supplementation of an anterior construct with posterior instrumentation is generally unnecessary, but it may be indicated in unique cases in which there are two adjacent VB fractures or three-column injuries.

Acknowledgments

We thank Marge Rogers, R.N., Melanie Freee, B.S.N., Hayan Dayoub, M.D., and Arnold Entame, M.D., for their help in data collection and in the preparation of this manuscript.

References


TABLE 2

\textit{Summary of SF-36 scores obtained in patients undergoing anterior and posterior surgery for thoracolumbar burst fractures}

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of Cases</th>
<th>Physical Function</th>
<th>Health Limitations</th>
<th>Emotional Limitations</th>
<th>Energy/Fatigue</th>
<th>Emotional Well-Being</th>
<th>Social Function</th>
<th>Pain</th>
<th>General Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>anterior*</td>
<td>22</td>
<td>51.8 ± 33.9</td>
<td>35.2 ± 43.4</td>
<td>62.1 ± 45.2</td>
<td>52.7 ± 24.5</td>
<td>72.7 ± 19.0</td>
<td>65.3 ± 27.5</td>
<td>52.0 ± 29.0</td>
<td>59.1 ± 24.9</td>
</tr>
<tr>
<td>posterior*</td>
<td>18</td>
<td>40.3 ± 26.8</td>
<td>36.1 ± 38.6</td>
<td>64.8 ± 45.0</td>
<td>46.9 ± 20.2</td>
<td>64.9 ± 18.8</td>
<td>61.1 ± 30.6</td>
<td>51.1 ± 25.7</td>
<td>55.0 ± 17.0</td>
</tr>
</tbody>
</table>

\* Values are presented as the means ± standard deviations.
Approaches to thoracolumbar burst fractures


Manuscript received December 9, 2005. Accepted in final form May 8, 2006. Address reprint requests to: Patrick W. Hitchon, M.D., Department of Neurosurgery, University of Iowa Hospitals and Clinics, 200 Hawkins Drive, Iowa City, Iowa 52240. email: patrick-hitchon@uiowa.edu.