ABSTRACT

Purpose. To evaluate the outcome of single screw-rod anterior instrumentation for thoracolumbar burst fractures with incomplete neurological deficit.

Methods. 16 men and 5 women aged 22 to 55 (mean, 34) years underwent single screw-rod anterior instrumentation for thoracolumbar burst fractures with incomplete neurological deficit. The vertebrae involved were T10 (n=2), T11 (n=2), T12 (n=7), L1 (n=8), and L2 (n=2). No patient had disruption of the posterior ligament complex. Postoperatively, a thoracolumbar sacral orthosis was used until solid fusion. Outcome measures included neurological recovery, degree of kyphosis, complications, and pain and functional status of the patients.

Results. The mean follow-up duration was 36 (range, 13–50) months. All patients recovered neurologically by at least one grade. Of the 21 patients, 6 improved from grade B to grade C (n=4) or grade D (n=2), 13 from grade C to grade D, and 2 from grade D to grade E. The mean degree of kyphosis improved from 23º±5º to 7º±3º. Seven patients had complications including ipsilateral basal atelectasis (n=3), urinary tract infection (n=1), haematuria (n=1), postoperative ileus (n=1), and superficial wound infection (n=1). None had iatrogenic visceral or vascular injury, pseudoarthrosis or hardware-related complications. Only one patient had severe back pain persistently.

Conclusion. Single screw-rod anterior instrumentation supplemented with an orthosis can be an alternative for double screw-rod anterior instrumentation for thoracolumbar burst fractures in patients with smaller vertebral bodies.

Key words: instrumentation; spinal fractures; spinal fusion

INTRODUCTION

Thoracolumbar burst fractures account for 21 to 58% of all thoracolumbar fractures, and are characterised by failure of the anterior and middle columns.1,2 Anterior decompression and reconstruction of the vertebral body with strut grafts or cages is the

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Address correspondence and reprint requests to: Dr Siddhartha Sharma, Department of Orthopaedic Surgery, Government Medical College, Bakshinagar, Jammu, India. Email: sids82@gmail.com
treatment of choice for fractures in which the vertebral body is extensively comminuted and yields a load sharing classification (LSC) score of >6. Screw-rod anterior constructs are readily available, easy to use, and can apply compression across the graft site. Double screw-rod anterior constructs provide better stability for early mobilisation, compared with single screw-rod anterior constructs. However, they may have higher risks of iatrogenic injury to the great vessels and have limited utility in patients with relatively small vertebral bodies. The anterior screws may end up close to the aorta despite a lot of dissection. We evaluated the outcome of single screw-rod anterior instrumentation for thoracolumbar burst fractures with incomplete neurological deficit (according to the American Spinal Injury Association (ASIA) Injury Score) and a LSC score of >6.

MATERIALS AND METHODS

This study was approved by the ethics committee of the hospital. Informed consent was obtained from each patient. Between January 2006 and July 2010, 104 patients presenting to our hospital with thoracolumbar (T10 to L2) fractures were prospectively studied. According to the AO classification, of these had burst fractures (type A3). 41 of these were excluded from analysis because they had a complete neurological deficit (ASIA Injury Score grade A) [n=15], had a LSC score of ≤6 (n=21), had severe co-morbidities (pulmonary tuberculosis or ischaemic heart disease) that precluded anterior surgery (n=3), or were lost to follow-up (n=2).

The remaining 16 men and 5 women aged 22 to 55 (mean, 34) years who had a LSC score of >6 and ASIA Injury Score grades B, C, or D neurological deficits. Their injury mechanisms were falls from height (n=13), motor vehicle accidents (n=5), and being struck on the back by a heavy object (n=3). The vertebrae involved were T10 (n=2), T11 (n=2, Fig. 1), T12 (n=7), L1 (n=8), and L2 (n=2). The fracture types were A3.1 (incomplete burst fractures involving only one endplate) [n=4], A3.2 (complete burst fractures involving both endplates) [n=13], and A3.3 (burst split fractures) [n=4]. Associated injuries included cerebral contusion (n=1), calcaneum fracture (n=1), and C1 arch undisplaced fracture (n=1). No patient had disruption of the posterior ligament complex on magnetic resonance imaging.

Kypnosis was measured on lateral radiographs using the Cobb method. The LSC score was based on computed tomography. It classifies the severity of anterior and middle column injury based on the severity of vertebral body comminution, degree of kyphosis, and the spread of fragments. Three vertebral body morphometric parameters were assessed on coronal and sagittal computed tomography using 3-mm cuts (Fig. 2). The first

Figure 1 (a) T11 burst fracture and grade C neurological deficit, (b) anterior decompression, autologous tricortical iliac crest grafting, and single screw-rod anterior instrumentation, and (c) solid fusion and improvement to grade D neurological deficit.

Figure 2 Vertebral body morphometry on computed tomography: (a) mid-sagittal view and (b) mid-coronal view of the vertebral body.
one was the vertebral body length (the distance between the most anterior and the most posterior parts of the vertebral body in the mid-sagittal plane). Measurements were taken at the level of the upper end plate and the lower end plate. The second one was the vertebral body width (the distance between the lateral most parts of the vertebral body in the mid-coronal plane). Measurements were made at the level of the upper end plate and the lower end plate. The third one was the vertebral body height. It is measured at the level of the anterior margin of the vertebral body and posterior margin of the vertebral body.

The transdiaphragmatic approach was used for fractures involving T11, T12, and L1 vertebrae, whereas the transthoracic approach was used for T10 fractures, and the anterior retroperitoneal approach was used for L2 fractures. One lung ventilation with a double lumen endotracheal tube was used in all patients except for whom the anterior retroperitoneal approach was used. The patient was placed in a true lateral position, with a roll placed under the axilla and the fracture level positioned at the break of the table. All approaches were carried out from the left side to avoid retracting the liver and to avoid iatrogenic injury to the inferior vena cava. Decompression was achieved by removing the pedicle and by following the nerve root to the spinal cord. The entire vertebral body was then removed using a combination of rongeurs, curettes, and burrs, and only a thin shell of bone on the anterior and far lateral sides was preserved. This minimised the risk of iatrogenic injury to the great vessels. Decompression was extended to the contralateral pedicle in all patients. The posterior longitudinal ligament was not removed. The decompression was considered adequate when the posterior longitudinal ligament bulged anteriorly. The endplates were prepared by removing the cartilage until bleeding was seen. Care was taken not to remove too much of the bony endplate in order to provide a firm platform for seating of the graft. The anterior and middle columns were reconstructed using autogenous tricortical grafts harvested from the anterior iliac crest. The distance between the 2 endplates was measured with a ruler and 6 mm was added to this to calculate the length of the graft to be harvested. An oversized graft was used to ensure a snug fit and to allow 2 to 3 mm of the graft to be countersunk into the vertebral body. The corpectomy site was distracted by flexing the table. Once the graft was in place, flexion was decreased to allow the graft to fit in snugly. The tricortical graft was supplemented using the resected rib and the vertebral body autografts placed between the graft and the anterior shell of the vertebral body. Stabilisation was achieved with a single screw-rod construct. Single 7 mm or 8 mm USS (Universal Spine System, Synthes) screws were placed in the vertebral body immediately above and below the corpectomy site. Bicortical screw purchase was aimed for to achieve maximum screw pullout strength. Care was taken not to leave the screw tip protruding beyond the far cortex of the vertebral body by digital palpation and image intensifier guidance. Compression was applied across the graft before completion of the construct with a 6-mm connecting rod. A suction drain was inserted before wound closure.

Postoperatively, incentive spirometry and active and passive physiotherapy were started on day 1. The chest/abdominal drain was removed (usually on day 2) when the output in the preceding day was <50 ml. A thoracolumbar sacral orthosis was used in all patients until solid fusion was evident on radiographs (usually at month 3). All patients with bladder involvement (and their attendants) were taught clean intermittent self-catheterisation.

Patients were followed up 3 monthly for the first 6 months and 6 monthly thereafter. At the final follow-up, pain and work status was assessed according to the Denis pain and work scores. The pre- and post-operative scores were compared using the paired t-test. A p value of <0.05 was considered statistically significant.

RESULTS

The mean follow-up duration was 36 (range, 13–50) months. The mean injury-to-admission interval was 1.3 (range, 0–10) days. The mean injury-to-surgery interval was 6.5 (range, 4–14) days. The mean operating time was 298 (range, 240–370) minutes. The mean estimated blood loss was 548 (range, 400–1000) ml.

All patients recovered neurologically by at least one ASIA Injury Score grade. Of the 21 patients, 6 improved from grade B to grade C (n=4) or grade D (n=2), 13 from grade C to grade D, and 2 from grade D to grade E. Of the 18 patients with urinary retention, 16 had regained full bladder control and the other 2 were managed by clean intermittent self-catheterisation. The mean degree of kyphosis improved from 23°±5° before surgery to 4°±3° immediately after surgery to 7°±3° at the final follow-up. The improvement was significant (p<0.001).

Seven patients had complications. Three patients had ipsilateral basal atelectasis and were treated by chest physiotherapy and incentive
spirometry. One patient with urinary tract infection was treated with oral ciprofloxacin. One patient with haematuria (owing to right renal calculus) underwent percutaneous nephrolithostomy at month 1. One patient with postoperative ileus was managed conservatively; the ileus resolved within 2 days. One patient with a superficial wound infection was treated with parenteral ceftriaxone and antiseptic dressings. None had iatrogenic visceral or vascular injury, pseudoarthrosis or hardware-related complications.

18 patients reported no or minimal pain and did not need pain-relieving medications. Two patients complained of moderate pain at the iliac crest graft site and took occasional medications. One patient had severe back pain and was referred to a pain management clinic. All but 2 patients returned to full-time employment, although none could return to full-time heavy labour jobs (Table 1).

**DISCUSSION**

Anterior surgery for thoracolumbar burst fractures should be performed selectively. Patients with a complete spinal cord injury are unlikely to benefit from any form of decompression, and thus posterior instrumentation is preferred. Thoracolumbar burst fractures with extensive comminution treated with posterior instrumentation alone may result in kyphosis progression and hardware malfunction. Reconstruction of the anterior and middle columns by grafts or cages along with anterior instrumentation prevents the problem of collapse. The LSC takes into account the extent of vertebral body comminution, the extent of spread of the fragments, and the degree of kyphosis. A score of ≥6 indicates a high chance of failure after posterior stabilisation alone, and thus anterior stabilisation is preferred. Screw-rod anterior instrumentation restores sagittal balance and achieves compression across the tricortical iliac crest graft. Double-rod constructs resist deforming forces better than single-rod constructs. Nonetheless, the vertebral body morphology should be considered when choosing between single- and double-rod constructs. The aorta lies in relation to the anterior aspect of the vertebral body.

### Table 1
Postoperative pain and functional status of patients

<table>
<thead>
<tr>
<th>Pain and functional status</th>
<th>No. of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Denis pain score</strong></td>
<td></td>
</tr>
<tr>
<td>P1 (no pain)</td>
<td>9</td>
</tr>
<tr>
<td>P2 (occasional minimal pain, no need for medication)</td>
<td>9</td>
</tr>
<tr>
<td>P3 (moderate pain, occasional medications needed, no interruption of activities of daily living or work)</td>
<td>2</td>
</tr>
<tr>
<td>P4 (moderate-to-severe pain, occasional absence from work, and significant changes in activities of daily living)</td>
<td>1</td>
</tr>
<tr>
<td>P5 (constant, severe pain and need for chronic medications)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Denis work score</strong></td>
<td></td>
</tr>
<tr>
<td>W1 (able to return to previous employment, heavy labour or physically demanding activities)</td>
<td>0</td>
</tr>
<tr>
<td>W2 (able to return to previous employment, sedentary or heavy labour with restrictions)</td>
<td>13</td>
</tr>
<tr>
<td>W3 (unable to return to previous employment, but works full time at new job)</td>
<td>6</td>
</tr>
<tr>
<td>W4 (unable to return to full-time work)</td>
<td>2</td>
</tr>
<tr>
<td>W5 (no work, completely disabled)</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 2
Vertebral body morphometry in the current and previous studies

<table>
<thead>
<tr>
<th>Vertebral body</th>
<th>Anteroposterior dimension (mm)</th>
<th>Vertical dimension (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Endplate depth (lower) in previous studies</td>
<td>Vertebral body length (lower) in current study</td>
</tr>
<tr>
<td>T9</td>
<td>31</td>
<td>26.9</td>
</tr>
<tr>
<td>T10</td>
<td>31.6</td>
<td>27.2</td>
</tr>
<tr>
<td>T11</td>
<td>31.8</td>
<td>27.1</td>
</tr>
<tr>
<td>T12</td>
<td>33.4</td>
<td>29.5</td>
</tr>
<tr>
<td>L1</td>
<td>35.3</td>
<td>30</td>
</tr>
<tr>
<td>L2</td>
<td>34.9</td>
<td>30.5</td>
</tr>
<tr>
<td>L3</td>
<td>34.8</td>
<td>30.2</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>33.3</strong></td>
<td><strong>28.8</strong></td>
</tr>
</tbody>
</table>
vertebral bodies, slightly to the left of the midline.\textsuperscript{22} To enable safe and secure placement of the screws, the instrumentation should be confined to the posterolateral corner of the vertebral body to avoid injury to the aorta and the great vessels.\textsuperscript{12,23,24} Vascular complications after anterior instrumentation are underestimated and underreported.\textsuperscript{25} A case of haemothorax secondary to aortic wall perforation by a long protruding anterior vertebral body screw was reported.\textsuperscript{26} In a review of 1223 anterior spinal procedures, only one aortic injury was reported.\textsuperscript{27} A case of delayed fatal aortic wall perforation and rupture during attempted screw removal was reported, in which the aortic wall had weakened owing to infection of a postoperative pleural haematoma.\textsuperscript{28} In another study, it was found that 15\% of the vertebral screws were within 2 mm of the aorta, yet penetration or rupture of the aortic wall was not observed.\textsuperscript{29} The aorta may be in contact with the anterior instrumentation, even though this may not be evident intra-operatively.\textsuperscript{29,30}

In our early experiences with the double screw-rod anterior instrumentation, there were difficulties in securing safe placement of the instrumentation. A lot of dissection was needed and the aorta had to be frequently moved away to ensure safe placement of both screws in the vertebral body. This resulted in prolonged operating time and blood loss. In addition, the anterior screws tended to be close to the aorta. We switched to single screw-rod constructs after analysing our patients’ vertebral body morphology, which was smaller than those reported in other studies.\textsuperscript{31,32} The safe zone for screw placement on the lateral aspect of the vertebral body is determined by the anteroposterior dimensions of the vertebral body (endplate depth or vertebral body length) and the vertebral body height. Among patients in the current and previous studies,\textsuperscript{31,32} there was a mean difference of 4.6 mm in the inferior endplate depth and 2.3 mm in the posterior vertebral body height (Table 2). Other studies also noted significant differences in anatomic parameters between Caucasian and Asian spines and recommended modifying spinal instrumentation accordingly.\textsuperscript{33–35}

In a study comparing single versus double screw-rod anterior instrumentation for adolescent idiopathic scoliosis, pseudoarthrosis occurred more frequently in the single screw-rod group (5/90 vs. 0/60, p>0.05), although deformity correction rates were similar.\textsuperscript{36} In the current study, only a subgroup of burst fractures (i.e. those most likely to benefit from the procedure) was included. The goals of surgery were to stabilise the spine, prevent recumbence, prevent deterioration in neurological deficit, and provide a safe milieu for the injured spinal cord to recover. Despite delayed presentation and treatment, the results were encouraging. All patients had neurological recovery by at least one grade, although the benefits of surgical decompression over conservative treatment in improving neurological deficit remain debatable.\textsuperscript{10,12} Although progression of kyphosis was noted in all patients, the mean degree of kyphosis at the final follow-up still improved significantly. The screw-rod constructs applied compression across the graft, and the orthosis enabled protected mobilisation and prevented hardware malfunction. This resulted in solid fusion in all patients.

One limitations of this study was the absence of a control group, which meant that the results could not be validated against double screw-rod instrumentation. In addition, the vertebral body morphometric data from 21 patients was too small to generalise. In conclusion, the choice of anterior instrumentation should be based on the vertebral body morphology. Preoperative measurement helps in decision making intra-operatively. Single screw-rod anterior instrumentation supplemented with orthosis bracing can be an alternative for double screw-rod anterior instrumentation in patients with smaller vertebral bodies to minimise the risk of iatrogenic damage to the great vessels.

**DISCLOSURE**

No conflicts of interest were declared by the authors.

**REFERENCES**


