ORIGINAL ARTICLE

Posterior/anterior combined surgery for thoracolumbar burst fractures—posterior instrumentation with pedicle screws and laminar hooks, anterior decompression and strut grafting

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Study design: A prospective clinical study.

Objective: The purpose of this study was to evaluate prospectively a large group of patients with thoracolumbar burst fractures who were treated with a posterior/anterior combined procedure and to report on the surgical outcomes, complications and radiographic results.

Methods: A total of 100 consecutive patients were surgically managed with posterior instrumentation, anterior decompression and anterior strut grafting. There were 71 males and 29 females; the mean age was 36 years. Patients with osteoporotic delayed vertebral body collapse were excluded. The mean follow-up period was 30 months. Surgical outcomes such as operative time, blood loss and sagittal alignment were investigated. A neurological assessment was performed by a rating system based on the American Spine Injury Association impairment scale. An interbody fusion was judged using plain X-ray and computed tomographic scans.

Results: The mean operative time was 256 min and the mean operative bleeding was 985 ml. Most of the patients were ambulatory within 3 days after surgery. Of the 76 patients with neurological injury, 54 (71.1%) recovered function following surgery. The mean local kyphosis angle was 12.2° kyphotic preoperatively and 0.8° lordotic at the final observation. The mean correction angle was 15.7° and correction loss was 2.6°. No instrumentation failure was observed and the postoperative fusion rate was 99%.

Conclusions: Posterior/anterior combined surgery with posterior pedicle screws and hooks fixation, and reconstruction by simultaneous strut grafting and anterior decompression, achieved short segment fixation and can be a useful option for surgically treating thoracolumbar burst fractures.

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Keywords: posterior/anterior combined surgery; thoracolumbar burst fractures; surgical outcomes; posterior instrumentation; anterior strut grafting; prospective study

Introduction

Thoracolumbar burst fractures induce a loss of trunk support and neural injury of the spinal cord, conus medullaris or cauda equina. A significant amount of controversy exists regarding not only the need for surgical management of thoracolumbar burst fractures but also the approach and type of surgery, if operative intervention is chosen.^{1,2}

Posterior instrumentation devices have undergone many modifications. Canal size can only be improved by indirectly distracting the posterior longitudinal ligament or disc annulus, irrespective of the device used with posterior

approach alone.³ Failure to reconstruct the anterior and middle vertebral columns with a posterior approach alone may be associated with a greater incidence of instrumentation failure and late kyphosis.⁴

The anterior approach for treating thoracolumbar burst fractures entailed one-stage anterior decompression, strut grafting and internal fixation.⁵ In the presence of posterior column disruption, anterior instrumentation alone may not provide adequate support.

In unstable injuries with angular kyphosis, posterior column injury and marked canal compromise, management by posterior instrumentation and anterior decompression, and strut autografting, either as a combined or staged procedure, overcomes the difficulties of an isolated posterior or anterior approach.

This study reports the surgical outcomes of 100 consecutive patients with spinal cord and/or cauda equina lesions due to thoracolumbar burst fractures, who underwent a

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posterior/anterior combined procedure with instrumentation using pedicle screws, rods and hooks. To our knowledge, there have been only a few reports assessing the outcomes of patients treated with this procedure under the same anesthesia for a thoracolumbar burst fracture.^{6–8} The objective of this study was to prospectively evaluate a large group of patients treated with this procedure and report on the surgical outcomes, complications and radiographic results.

Patients and methods

Study population

A total of 100 consecutive patients (71 male and 29 female) who underwent surgery for thoracolumbar burst fractures between April 1995 and December 2008 were included in this study. The mean age of the patients at the time of surgery was 36 ± 17 years (range 15–79). The diagnosis of thoracolumbar burst fractures was established by plain X-ray, computed tomographic (CT) scan and magnetic resonance imaging. The exclusion criteria included major fractures at other sites and a significant associated injury to any other major organ system requiring hospital admission and active management, as well as pathological or osteoporotic delayed vertebral body collapse. After the Institutional Review Board approval was given, each patient signed a written consent form before surgery.

The causes of the fractures were as follows: fall from a height (77 patients), motor vehicle accident (11 patients), a blunt contusion from a heavy falling object (eight patients), sledding accident (two patients) and sports accident (two patients). There were three cases with thoracic lesions (T6, T8 and T10), 75 cases with thoracolumbar lesions (T11–L2) and 22 cases with lumbar lesions (L3–5) (Figure 1).

In addition, the fracture severity type was formulated on the basis of Denis's classification⁹ and Magerl's classification (AO classification).¹⁰ Distributions of the fractures according to Denis's classification and Magerl's classification were similar. According to Denis's classification there were 28 cases of typeA, 48 cases of typeB, 7 cases of typeC, 10 cases of typeD and 7 cases of typeE. According to Magerl's classification there were 59 cases of typeA, 22 cases of typeB and 19 cases of typeC.

Figure 1 Cases and levels of thoracolumbar burst fractures.

Indications for need for procedure

Stability of the vertebral column in the thoracolumbar region is dependent on the integrity of the osseous and ligamentous components. Once these structures are disrupted, the stability of the vertebral column can become compromised, resulting in an unstable spine.

The indication for the need for this surgery are thoracolumbar burst fractures with at least one of the following four criteria:

1. neurological deficits.
2. spinal canal stenosis (stenotic ratios T11, 12: 35%, L1: 45%, L2: 55%).¹¹
3. segmental kyphotic deformity $>20^\circ$ and anterior vertebral height $<50\%$ of posterior vertebral height.
4. posterior column injury (three-column injury according to Denis's classification⁹).

Contraindications for the procedure

If the patient had a previous lung or retroperitoneal surgery, the opposite side approach should be selected. Elderly patients with severe pulmonary dysfunction or patients with abdominal aortic aneurysms are not candidates for this procedure.

Surgical technique

The combined posterior/anterior procedure consisted of a posterior fixation with a pedicle screw and hook system, followed by an anterior decompression and interbody fusion under the same anesthesia.¹² First, the posterior pedicle screw and hook fixation was performed at one level above and one level below the injured vertebra.¹³ The anterior procedure was performed through a retroperitoneal or extrapleural approach in the right decubitus position. The lateral and anterior aspects of the vertebral body of the injured spine were exposed. The collapsed body was mostly resected after removal of the discs above and below it. After anterior decompression, anterior interbody fusion was performed using an anterior strut autografting from the left iliac tricortical bone.

Postoperative considerations

Ambulation and rehabilitation were started on the day of drain removal, which is usually 2–5 days after the operation, and patients were encouraged to walk or move with a polypropylene thoracolumbosacral orthosis, which was usually worn for about 3 months. A patient who was suspected to have a delayed union wore the brace for more than 3 months. After removal of the brace, the patients who were not manual laborers were allowed to perform normal activities of daily living without any special restrictions. The manual laborers returned to their jobs 4–6 months after operation.

Clinical outcome

Operative time, blood loss, postoperative recumbency period and complications during the perioperative period were investigated. A neurological assessment was performed on

each patient by a rating system based on the American Spine Injury Association impairment scale.

Radiographic evaluation

The preoperative, postoperative and final follow-up radiographs were evaluated. Plain radiograph analysis included measurements of local kyphosis to determine the severity of the deformity. The local kyphosis angle (LKA) on the lateral view of plain radiographs was measured between the superior endplate of the upper and inferior endplate of the lower non-injured vertebra by the Cobb method. Sagittal alignment (kyphosis angle in the fusion region) before and after surgery, as well as at the final follow-up observation, was measured from plain radiographs to obtain image findings from which the corrective forces were estimated (correction angle = ((preoperative LKA) – (postoperative LKA)), loss of kyphosis correction (LKC) = ((LKA at final follow-up) – (postoperative LKA))).

Bony fusion was evaluated using functional plain radiographs and reconstructed CT scans. The plain radiographs, including flexion-extension views, were obtained to assess the progress of the fusion at 1 month, 3 months, 6 months and 1 year after surgery. CT scans including flexion-extension views were obtained to assess the progress of the fusion at 6 months and 1 year after surgery. A fusion was confirmed by a progressive increase in interspace bone density and blurring of the adjacent endplate, as well as by the presence of bridging posterolateral trabecular bone on flexion-extension radiographs and CT scans. The fusion was finally decided on the basis of the imaging information by an experienced spinal surgeon. The evidence of instrumentation loosening or motion was evaluated using flexion-extension radiographs and CT scans. Instrumentation failure was defined as an increase of 10° or more in local kyphosis in the final follow-up radiographs compared with the measurement on the initial postoperative radiographs.

Results

All patients underwent a posterior/anterior combined procedure with posterior instrumentation using pedicle screws, rods and hooks, as well as anterior decompression and strut grafting. The mean operative time was 255.6 ± 50.3 min (including time taken in changing body position) and mean blood loss was 985.4 ± 726.1 ml. The mean postoperative recumbency period was 2.8 ± 1.5 days. The mean postoperative follow-up period was 30.0 ± 20.6 months (range 12–77).

The American Spine Injury Association impairment scale showed results as follows: A in seven patients, B in six patients, C in 35 patients, D in 28 patients and E in 24 patients preoperatively, and A in six patients, B in one patient, C in 17 patients, D in 19 patients and E in 57 patients postoperatively (Figure 2). Of the 76 patients with neurological injury, 54 (71.1%) recovered function following surgery. Of these 54 patients, 43 improved by 1 grade and 11 improved by 2 grades on the American Spine Injury Association scale.

Figure 2 Preoperative and postoperative American Spinal Injury Association (ASIA) impairment scale. Diagram showing change in the ASIA impairment scale between the preoperative status (vertical axis) and the status at last follow-up (horizontal axis).

The LKA was $12.2 \pm 10.5^\circ$ kyphotic preoperatively, $3.5 \pm 11.5^\circ$ lordotic post operatively and $0.8 \pm 10.8^\circ$ lordotic at the final observation. For all fractures in this series, the operative correction angle for sagittal kyphosis was $15.7 \pm 9.2^\circ$. A slight correction loss (loss of kyphosis correction; $2.6 \pm 3.3^\circ$) was observed because of sinking of the grafts.

The postoperative fusion rate was 99% and non-union was observed in one case. This one case was treated by revision surgery of posterolateral fusion and obtained fusion consequently. No evidence of instrumentation failures such as instrumentation loosening or motion was observed in the final follow-up radiographs and CT images.

Three cases of superficial minor infection, two cases of transient intestinal obstruction and one case of postoperative neural deterioration were seen. The American Spine Injury Association impairment scale of this case with neural deterioration was D preoperatively, but it was C at final observation (Figures 3 and 4).

Discussion

The management of thoracolumbar burst fractures has been a matter of debate, and the controversy is mostly related to the determination of fracture stability. The major goals of injury treatment include correction of the deformity, reduction of neurologic deficit and limiting progression of the deformity and neurologic deficit by stabilizing the fracture. This may ultimately lead to a decreased length of rehabilitation.

The posterior/anterior combined procedure has several merits as follows: 360° observation, direct decompression, strong fixation with posterior instrumentation and anterior strut reconstruction.^{6,7,12} Because the posterior reduction and fixation is performed first during this surgery, direct decompression can be performed under a stable condition after indirect decompression. Postoperative complications are very rare in these extrapleural approach treatments with no dissection of the diaphragm. On the other hand, this surgery has a few demerits as follows: it requires two skin

Figure 3 (a) Preoperative X-ray images: anterior-posterior view (left) and lateral view (right). (b) Preoperative CT images: sagittal view (left) and axial view (right). (c) Preoperative T2-weighted magnetic resonance images (MRI T2WI): sagittal view (left) and axial view (right). (d) Postoperative X-ray images: AP view (left) and lateral view (right). (e) Postoperative CT images: sagittal view (left) and axial view (right). The patient was a 37-year-old man who suffered from a T12 burst fracture (a). The cause of the fracture was a fall from a height. His neurological state was ASIA-A (complete palsy). The fracture severity type was according to Denis's classification Type A and Magerl's classification Type B2.3 (b, c). Posterior/anterior combined surgery (T11–L1) was performed. Fixation was performed one level above and below using pedicle screws and hooks from the TSRH-RP system (Medtronic Sofamor Danek, Minneapolis, MN, USA). The preoperative local kyphosis angle (LKA) of 32° was corrected to 6° postoperatively and the neurological state was ASIA-A (d). The vertebra of the patient achieved fusion in 6 months (e).

incisions and relatively high surgical invasiveness; however, it does not require a circular incision of the diaphragm, and the invasiveness is almost similar to anterior surgery alone.⁵

In general, the stabilization options are anterior fusion or posterior fusion. Posterior spinal surgery has been a popular method for restoring spinal stability.^{14–16} Posterior surgery alone improves canal dimensions by indirect methods.³ Although some reduction may occur, improvement in the canal dimension is never complete and may be inadequate. One problem inherent to isolated posterior surgery alone is the failure to address three-column instability, because it does not fully reconstruct the anterior or middle columns. There are still some studies that report adequate results with

isolated posterior surgery, including acceptable pseudoarthrosis rates and minimal late kyphosis.⁴ When there is traumatic damage to the anterior column, a long segmental fusion decreases the range of motion and leads to troubles in the activities of daily living.¹⁷ A short segmental fusion cannot share enough load and could induce correction loss or instrumentation failure postoperatively.¹⁸

The anterior approach, via a thoracotomy or retroperitoneal dissection, facilitates direct and complete decompression of the spinal canal and allows for the reconstitution of the anterior and middle columns via a strut graft. Although an anterior corpectomy allows for an excellent visualization and decompression of the spinal canal, there is difficulty

Figure 4 (a) Preoperative X-ray images: anterior-posterior view (left) and lateral view (right). (b) Preoperative CT images: sagittal view (left) and axial view (right). (c) Preoperative T2-weighted magnetic resonance images (MRI T2WI): sagittal view (left) and axial view (right). (d) Postoperative X-ray images: anterior-posterior view (left) and lateral view (right). (e) Postoperative CT images: sagittal view (left) and axial view (right). The patient was a 17-year-old girl who suffered from an L1 burst fracture (a). The cause of the fracture was a fall from a height. Her neurological state was ASIA-C (incomplete palsy). The type of fracture severity was Denis's classification Type D and Magerl's classification Type C2.1 (b, c). Posterior/anterior combined surgery (T12–L2) was performed. Fixation was performed one level above and below using pedicle screws and hooks from the TSRH-RP system. The preoperative LKA of 30° was corrected to 0° postoperatively and the neurological state was ASIA-E (d). The vertebra of the patient achieved fusion in 6 months (e).

achieving immediate spinal stability. This lack of adequate anterior instrumentation, therefore, limits the application of an isolated anterior approach alone in the face of posterior column disruption. However, direct decompression provides better neural recovery than indirect decompression.^{19,20} The key finding was that the anterior approach is twice as effective for canal decompression compared with the posterior approach.^{5,21} This has clear ramifications for the neurologically compromised patient.

Some authors recommend the combined posterior/anterior approach for managing thoracolumbar fractures with a significant posterior column injury.^{7,8} The advocacy of the combined approach has been supported by the findings of *in vitro* biomechanical studies.²²

Another purpose of this study was to review the effectiveness and outcome of the combined posterior and anterior approach to overcome the shortcomings of each procedure

performed separately. Initially, the procedures were staged, but later it was possible to perform both procedures, that is, anterior decompression and strut grafting, as well as posterior instrumentation, sequentially without increased morbidity or mortality. Specific advantages of the anterior approach include immediate complete spinal canal decompression and restoration and reconstruction of the anterior and middle columns. The posterior approach overcomes the shortcomings of anterior instrumentation by completing the stability restoration across all three columns of the spine. The operative time and blood loss in this series of patients were not greater than that of other reported series using anterior or posterior surgery alone. The combined surgery achieved a high union rate and low instrumentation failure (Table 1).^{4,5,7,14,23–26} We reviewed the clinical results reported for short-segment pedicle screw fixation and for other anterior decompression procedures for treating thoracolumbar

Table 1 Summary of representative reports for the surgical treatment of thoracolumbar burst fractures

	Cases	Follow-up (months)	Operation time (min)	Blood loss (ml)
<i>Posterior</i>				
Ebelke <i>et al.</i> ¹⁴	13	17	330 (222–642)	1450 (500–2500)
Carl <i>et al.</i> ⁴	38	23	200 (150–285)	1160 (550–2200)
Benson <i>et al.</i> ²⁴	24	22	—	—
Alanay <i>et al.</i> ²³	20	32	134 (—)	436 (—)
<i>Anterior</i>				
Haas <i>et al.</i> ²⁵	18	—	—	2280 (500–4800)
Kaneda <i>et al.</i> ⁵	150	96	238 (125–400)	1182 (230–2205)
McDonough <i>et al.</i> ²⁶	35	27	295 (160–520)	1750 (250–5000)
<i>Combined</i>				
Dimar <i>et al.</i> ⁷	69	41	342 (—)	1455 (—)
Authors	100	30	256 (136–408)	985 (125–2560)

	Level	Implant	Correction loss (°)	Instrument failure (%)	Pseudo (%)
<i>Posterior</i>					
Ebelke <i>et al.</i> ¹⁴	T12-L4	VSP	8.0	53.8	15.4
Carl <i>et al.</i> ⁴	T12-L5	CD	6.5	23.7	0
Benson <i>et al.</i> ²⁴	T10-L5	AO-FI	9.7	25.0	0
Alanay <i>et al.</i> ²³	T11-L3	Isola, CDI	9.9	45.0	0
<i>Anterior</i>					
Haas <i>et al.</i> ²⁵	T4-L5	DCP	7.0	5.1	0
Kaneda <i>et al.</i> ⁵	T6-L5	Kaneda	1.0	6.0	6.7
McDonough <i>et al.</i> ²⁶	T7-L3	Z-plate	4.0	0	3.4
<i>Combined</i>					
Dimar <i>et al.</i> ⁷	T6-L5	CD	7.0	1.4	4.3
Authors	T6-L5	TSRH	2.6	0	1

Abbreviations: AO-FI, AO fixateur interne; CD, Cotrel Dubosett instrument; DCP, dynamic compression plate; Kaneda, Kaneda device; pseudo, pseudoarthrosis (non-union); TSRH, Texas Scottish Rite Hospital; VSP, Steffe VSP.

Posterior, posterior spinal fusion only with instrumentation (short segment); anterior, anterior spinal fusion only with instrumentation; combined, posterior/anterior combined surgery.

burst fractures. The loss of kyphosis correction and the rate of instrumentation failure were higher in the series that used pedicular screw fixation^{4,7} than in our series. The mean loss of kyphosis correction ranged from 3° to 12° in the reported series that we reviewed, whereas the mean loss of kyphosis correction in our series was only 2.6°. The rate of failure of posterior instrumentation ranged from 9 to 54% in the previous series, whereas the rate was 0% in the present report. The rate of non-union was surprisingly low (1%) in the present report.

This study had several potential limitations. The patient-based objective outcome based on quality of life, such as Short Form health survey 36 (SF-36), and subjective satisfaction were not assessed in this study. Back pain according to the Visual Analog Scale was not evaluated either. We did not compare the surgical outcomes of patients who underwent combined surgery and those who underwent either anterior or posterior surgery. However, in this study, a relatively large number of patients who underwent the same single procedure could be observed for an average of 30 months in a prospective manner. A randomized case-control study would be ideal, although it is very difficult to conduct.

Conclusion

Posterior/anterior combined surgery with posterior pedicle screws and hooks fixation, and reconstruction by simultaneous strut grafting and anterior decompression, achieved short segment fixation. This procedure can be a useful option for surgically treating thoracolumbar burst fractures.

Conflict of interest

The authors declare no conflict of interest.

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