Management of burst thoracic and thoracolumbar fractures with thoracoscopically assisted anterior corpectomy and posterior short segment percutaneous stabilization

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Study design
This was a prospective observational study.
Objective
The aim of this study was to evaluate the role of thoracoscopically assisted corpectomy of burst thoracic and thoracolumbar fractures combined with posterior percutaneous transpedicular instrumentation.
Summary of background data
Because of the associated morbidities related to the combined open anterior and posterior approaches to thoracic and thoracolumbar spine, some surgeons prefer either the anterior-only or the posterior-only approach that is sometimes not sufficient to achieve the goals of surgery. The combination of two minimally invasive techniques enables the achievement of treatment goals and minimizes the associated morbidities.
Patients and methods
Between January 2008 and December 2008, 26 patients with acute burst spinal fractures were operated upon in our hospital. These patients underwent posterior percutaneous stabilization plus anterior thoracoscopically assisted corpectomy and fusion in the prone position. Clinical and radiological outcomes were evaluated after a minimum follow-up period of 2 years. The Oswestry Disability Index combined with clinical examination was used for clinical evaluation. Plain radiography in two views was used for the radiological evaluation.
Results
The mean operative time was 240 min. The average blood loss was 745 ml. Ten patients had preoperative neurological deficits ranging from Frankel A to Frankel D. One patient did not show any neurological improvement at the final follow-up. The mean Oswestry Disability Index at the final follow-up was about 7. The mean preoperative kyphosis angle was 26.2°, and improved to 9.2° postoperatively and to 14° at the final follow-up. One patient had a superficial wound-healing problem.
Conclusion
Thoracoscopic decompression and fusion plus short segment posterior percutaneous instrumentation showed good clinical outcomes and can be considered as an alternative to open procedures, with decreased rates of morbidities in the management of burst thoracic and thoracolumbar fractures.

Keywords:
corpectomy, percutaneous, thoracolumbar fractures, thoracoscopically assisted

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Introduction

Success in the diagnosis and management of thoracolumbar fractures is dependent on an accurate assessment of spinal stability, a concept that is defined at least in part by the integrity of the spine and its supporting structures as well as the neurologic status of the patient. Development of a standard treatment protocol for thoracolumbar fractures has been impeded by both the inherent complexity of these injuries and an incomplete understanding of their natural histories [1].

Since the early 1980s, operative treatment has moved to the forefront of fracture management in the spine. Evolved technologies and implants, improved imaging, a better understanding of fracture and implant biomechanics, and the introduction of a variety of new anterior and posterior fixation devices allow surgeons to plan definitive stabilizing procedures for any fracture pattern, allowing rapid mobilization and return to function. The goal of treatment 'operative or otherwise' remains to protect neural elements, restore or maintain neurologic function, prevent or correct segmental collapse and deformity, prevent spinal instability and pain, permit early ambulation and return to function, and restore normal spinal mechanics [2].

Surgical treatment restores sagittal alignment, corrects translational deformities, and restores canal dimensions more reliably than does cast treatment. Finally, surgical decompression more reliably restores neurologic function and decreases rehabilitation time [3–6]. The spinal cord must be decompressed at the site of compression if there is intent to relieve the source of pressure [7].

As the anterior approach enables unobstructed visualization of the thecal sac, it remains the most reliable method for achieving a thorough decompression and is ideal for the patient with an incomplete neurologic deficit who shows significant canal occlusion on axial imaging studies. Anterior procedures are also indicated for the stabilization of burst fractures with substantial vertebral body comminution in which anterior column reconstruction is performed using load-sharing strut grafts or other interbody devices to correct a collapsed, kyphotic segment. The widely accepted indications for anterior surgery currently include retropulsed fragments occupying greater than 67% of the total canal area, extensive comminution of the vertebral column in conjunction with a kyphotic deformity greater than 30°, and a delay in surgical treatment of more than 4 days [8,9]. In addition, any traumatic disk herniations causing symptomatic compression of the spinal cord or nerve roots are best managed with an anterior approach [1]. Added to these indications is a disk injury with subsequent degeneration and apoptosis leading to progressive kyphosis [10].

Unfortunately, approach-related morbidity of conventional thoracotomy or thoraco-phreno-lumbotomy such as pain syndromes ‘post-thoracotomy syndrome’, relaxation of the abdominal wall, or intercostal neuralgia can be high, markedly reducing the benefits of an anterior approach. As the thoracolumbar junction is the location that is most commonly affected in spine fractures, the morbidity of opening the chest is additionally increased by the required detachment of the diaphragm [11].

The introduction of minimal invasive thoracoscopic approaches allowed gaining the advantages of anterior decompression and reconstruction of the anterior column without the approach-related morbidities.

Thoracoscopy has advantages (i.e. minimal muscular incisions, no rib retraction, and minimal rib resection) that both thoracotomy and costotransversectomy lack. Thoracoscopy reduces the morbidity and pain associated with the anterior transthoracic approach while preserving the broad, direct view and unobstructed surgical access to the entire ventral surfaces of the spine and spinal cord. Complex dissections of the spine, such as spinal cord decompression, reconstruction, and instrumentation, can be performed using thoracoscopy. Unlike costotransversectomy, thoracoscopy offers a direct, complete view of the entire ventral surface of the spinal cord [12].

Thoracoscopy requires several new skills, psychomotor strategies, and perceptions of the anatomy that differ considerably from open surgery. Portals provide narrow windows of restricted access (and no direct visualization) through the chest wall. Trajectories are restricted and confined, on the basis of the position and trajectory of the portals. A ‘virtual reality’ surgical environment is created. To become competent at endoscopic surgery, surgeons need to develop new skills: endoscopic navigation; triangulation (i.e. determining the trajectory: angulation and depth of tools toward the pathology on the basis of surface landmarks); operating while looking forward to watch a video screen; maintaining a stable, clear, oriented endoscopic image; stabilizing, controlling, and moving long tools precisely; controlling the amplification of movements; readjusting visual-motor and sensorimotor feedback loops; localizing the spinal levels on the basis of internal landmarks; coordinating the different phases of dissection performed by different surgeons working simultaneously with different tools; and relearning all phases of the operative dissection on the basis of these new technique parameters. Development of these skills requires dedicated practice in a surgical skills laboratory. The ‘learning curve’ for acquiring these psychomotor and technical skills for thoracoscopy is steep [12].

Conventional, open dorsal instrumentation of the thoracolumbar spine following trauma has been performed for more than 30 years. This approach requires extensive tissue dissection to expose the bony structures of the spine and for pedicle screw fixation, to provide enough space for lateral-to-medial orientation for optimum screw placement. Consecutively, paravertebral muscles are denervated and dissection leads to muscle and soft tissue ischemia, potentially contributing to some cases of failed fracture stabilization [13]. The open posterior approach can lead to atrophy of the posterior paraspinous muscles and a poor clinical result. It was also shown that physical compression by soft tissue retractors during surgery induces time-dependent muscular histological damage by increased intramuscular pressure [14]. Furthermore, the conventional approach to the spine is associated with extensive blood loss, risk of wound infection, and prolonged hospitalization [15].

The combination of minimally invasive surgical techniques allows gaining the advantages of these techniques and avoiding the morbidities related to the open approaches.

Patients and methods

Between January 2008 and December 2008, 26 patients (five women and 21 men) with acute burst spinal fractures were operated upon in Zentralklinik Bad Berka using thoracoscopically assisted corpectomy and posterior percutaneous transpedicular instrumentation. They were available for a minimum follow-up period of 2 years.

The average age of the patients at operation was 50.54 (20–77) years. In terms of the type of trauma, 18 patients (69%) had falls from heights, five patients (19%) sustained road traffic accidents, and three patients (11.5%) sustained other types of trauma. The most affected segment of the spinal column was the thoracolumbar junction; 16 patients (61.5%) had fractures between T10 and L1, (Table 1).

Eight patients had associated other injuries involving the head, chest, or extremities. Two patients were polytraumatized. Ten patients had neurological deficits ranging from Frankel B to Frankel D. The indications for corpectomy were not different from those mentioned above including burst thoracic or thoracolumbar fractures with a retropulsed fragment with spinal canal stenosis more than 50% or kyphosis more than 30° one day after trauma, and extensive comminution of the anterior column.

After the administration of general anesthesia using a single-lumen endotracheal tube, the patient was positioned in the prone position using a special frame. Sterilization and draping were performed ensuring that the anterior axillary line was in the sterile area at least on the side where the approach would be used. The iliac crest should be accessible for graft harvesting, although in most cases, we used the bone fragments obtained from corpectomy as a graft.

Posterior percutaneous instrumentation

Posterior percutaneous transpedicular instrumentation was used in all cases. All pedicle screws were placed under the control of two C-arm image intensifiers in two perpendicular planes (anteroposterior and lateral). The radiolucent operating table allowed radiography to be performed throughout a full range of 360°.

A 10-G vertebroplasty needle was inserted bilaterally through the pedicles of the targeted spinal levels percutaneously using techniques identical to those used during vertebroplasty and kyphoplasty procedures.

Table 1 Distribution of patients according to fractured level

	Frequency [*n* (%)]
T1–T4	1 (3.8)
T5–T9	8 (30.8)
T10–L1	16 (61.5)
L2	1 (3.8)
Total	26 (100)

We used a technique modified from that described by Wiesner *et al.* [16] for needle insertion. The image intensifier is oriented in a perfect anteroposterior direction. In the first step, the tip of the needle is positioned lateral to the oval image of the pedicle until bony contact with the transverse process is made. The needle is angled 10–20° medially, with its tip being in the center of an imaginary second oval that is exactly lateral to the true oval pedicle image. The needle is then adjusted in the lateral view in terms of the cephalocaudal direction so that it is parallel to the endplates. The needle is then advanced forward through the entire pedicle until the dorsal wall of the vertebral body is reached. At this point, in the anteroposterior view, the tip of the needle should be in the center of the true oval pedicle image.

Once the tip of the needle has been advanced into the anteromedial portion of the vertebral body, the stylet of the needle is removed and replaced by a 1.57-mm guidewire that maintains a safe transpedicular pathway. After insertion of all needles, the anteroposterior C-arm is removed, and the rest of the procedure is continued under control of one image intensifier in the lateral plane.

After insertion of the guidewire, the needle is removed and a 1 cm transverse skin incision is performed with the guidewire in the middle. A metal sheath with its central dilator is inserted; through this sheath, a cannulated pedicle opener is used to open the pedicle and the pedicle is then tapped using a cannulated tap. The cannulated polyaxial screw is then inserted and the guidewire is removed. After insertion of all screws, their position is checked using the C-arm in both anteroposterior and lateral views. Short screws were used for the pedicles of the fractured vertebra. The rods are then applied usually after completion of the anterior procedure and tightened to the screws; compression is also applied when needed.

The incisions are then closed, closing the deep fascia and subcutaneous tissues, and adhesive strips are then applied.

Thoracoscopic corpectomy

The thoracoscopic surgical technique includes two incisions: the first is about 2.5 cm minithoracotomy performed in the midaxillary line and the second is about 1 cm in the posterior axillary line for the 30° thoracoscopy optic. We depend on cooperation with the anesthetist to momentarily deflate the lung during the first few minutes of the approach [17,18].

The aimed level is determined and checked radiographically or by passing a paraspinal or a trans-screw wire through the posterior approach at a defined level to view it thoracoscopically. The prevertebral parietal pleura is incised and pealed using a blunt ball-tipped hooked dissector. For lesions below T12, the vertebral attachment of the diaphragm is minimally disinserted in a caudal direction using a Cobb periosteal elevator. The segmental vessels can be identified, ligated, and cut. The disk spaces above and below the vertebra to be removed are identified, incised, cleaned thoroughly, and the endplates of the vertebrae above and below are scraped. Corpectomy is carried out, and anterior column reconstruction is performed using a tricortical iliac graft (two cases) or a vertebral body replacement cage filled with corpectomy bone material (22 cases) or filled with cement (two cases) (Fig. 1). Spinal canal decompression was performed in all cases.

At the end of the operation, the prevertebral pleura is closed, the thoracic cavity is inspected, and an intercostal tube is inserted. The posterior instrumentation is then completed and the posterior approach is closed.

The follow-up protocol in this study included subjective patient satisfaction indicated by Oswestry Disability Index, and clinical examination including range of motion, local tenderness, scar condition, and detailed neurological examination. Radiologically, all patients had plain radiography in two planes (anteroposterior and lateral) to evaluate fusion, position of the implants, metal failure, loosening, Cobb angle, and sagittal index at the operated segment.

Fusion was evaluated according to the modified Brantigan–Steffee classification [19], these criteria include the following: the bone in fusion area is denser and more mature than originally achieved during surgery, no interspace between the cage and the vertebral body, and mature bony trabeculae bridging in the fusion area. If one of the three criteria was not fulfilled, we classified the patient as being in a nonfusion state. Although Brantigan cages were radiolucent and those used in this study were titanium that made radiological evaluation relatively difficult, we used these Brantigan–Steffee criteria to evaluate fusion. There is no available satisfactory classification for radiological fusion especially in cases after corpectomy and vertebral body replacement cages.

Results

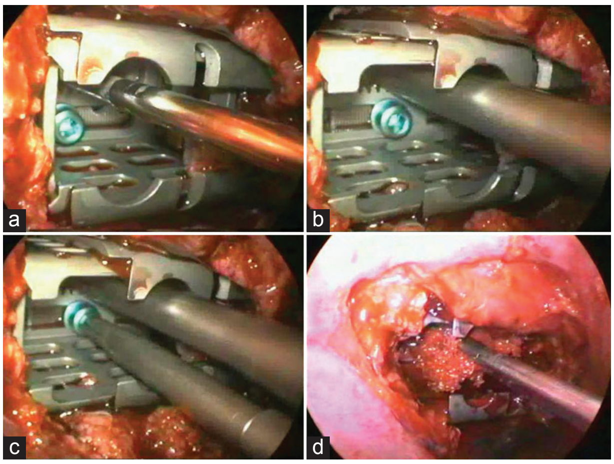
The mean total operative time was 240 ± 53 min; the mean operative time for anterior surgery was 148 ± 45 min; and the mean operative time for posterior surgery was 105 ± 38 min. The mean total blood loss was 745 ± 436 ml.

In terms of patients' distribution according to the fracture types using the AO classification system, A3 fractures were the most common type encountered (Table 2).

The Oswestry Disability Index was used for clinical evaluation of the patients at the final follow-up. It ranged from 0 to 34, with an average of 7.9. No local tenderness was detected in any patient, and all showed excellent scar condition. Nine patients showed neurological improvement by one or more Frankel grade.

At the 2-year follow-up, radiographic fusion was detected in 23 patients (88.5%), two patients had cement-filled cages, and one patient did not fulfill the three criteria of Brantigan, but he did not show any clinical symptoms or implant failure either anterior or posterior (Fig. 2).

Figure 1



The cage after insertion in place (a), after expansion (b), fixation in expanded position (c), and filling with bone graft (d).

Figure 2

Case example of a patient with an A3 fracture T12 treated with the described technique and the final followup radiographs 2 years after surgery.

The average preoperative, postoperative, and final follow-up radiographic measurements are shown in Table 3.

One patient had a superficial wound-healing problem. There were no cases of metal failure or loosening of the instrumentation. At the 2-year follow-up, there was no reoperation or relevant adjacent segment degeneration in this series.

Discussion

The treatment of spine injuries aims at prevention and limitation of neurological injury as well as restoration of spinal stability to regain a spinal column free of pain and ready for load bearing. Other issues include deformity correction, minimizing motion loss, and rapid rehabilitation to long-term unrestricted activity. These goals should be accomplished with the introduction of as little additional risk or morbidity as possible [20].

Many studies have reported on the use of video-assisted thoracoscopic surgery (VATS) in the management of thoracolumbar fractures, but in all of these, either anterior instrumentation systems were used or an open posterior stabilization was performed. We combined the anterior spinal decompression and reconstruction of the anterior column through a minimally invasive thoracoscopic approach in the prone position with the posterior percutaneous transpedicular stabilization. It is quite difficult to compare our results with similar studies because, to our knowledge, there are no available studies that combine the two above-mentioned techniques.

Table 2 Distribution of patients according to fracture type using the AO classification

AO classification	Number of patients [*n* (%)]
A1	4 (15.4)
A2	2 (7.7)
A3	12 (46.2)
B1	1 (3.8)
B2	4 (15.4)
B3	1 (3.8)
C1	1 (3.8)
C2	1 (3.8)
Total	26 (100)

The thoracolumbar region is the most commonly affected part of the vertebral column, with traumatic fractures being 68.8 [21] and 80% [22,23] in some studies, followed by the thoracic and then the lumbar region [21].

In this study, 61.5% of cases had fractures between T10 and L1; the second most commonly affected region of the vertebral column was between T5 and T9, representing 30.8%. This reflects the importance of thoracoscopic techniques as a valuable option in the treatment of these injuries.

Being normally kyphotic, the presence of 30.8% of cases in the region between T5 and T9 affected the mean Cobb angle and the degree of achieved correction compared with similar studies. This is why the use of the sagittal index to evaluate the radiographic results is recommended. On reviewing the literature, we did not find the use of the sagittal index as a radiographic parameter for evaluation of results of treatment of thoracolumbar fractures to be common. The main advantage of this is that it compares the measured post-traumatic kyphosis against an established baseline. This process transformed the measured angle from an absolute, detached value into a relative one. The result was a more useful parameter, which could be used to guide surgical indications as well as the amount of desirable correction during surgery [24].

Value of prone position

Traditionally, the lateral decubitus position has been used for video-assisted anterior thoracoscopic approaches. King *et al.* [25] and Lieberman *et al.* [26] reported that the prone position offered the following advantages during performing the surgical technique.

The prone position saves time required for repositioning, sterilization, and draping the patient. It facilitates reduction of associated kyphosis simply because of body weight and maintains it intraoperatively. It also allows the great vessels to fall forward, exposing an area of areolar tissue between them and the anterior longitudinal ligament, so that the risk of vascular injuries might be minimized.

With the use of prone positioning, the back–front combined approach could be performed simultaneously, thus eliminating a need to stage the procedure.

Table 3 Preoperative, postoperative, and final follow-up radiographic evaluation parameters

		Preoperative		Postoperative		Final follow-up		
	N	Mean	SD	Mean	SD	Mean	SD	*P* value
Kyphosis Cobb angle	26	26.20°	10.98	9.20°	10.63	14.00°	10.43	0.001 (significant)
Sagittal index	26	12.16	6.3	0.54	2.766	2.9	2.132	0.004 (significant)
	26							

In the prone position, the blood and debris (disk or bony fragments) fall anteriorly away from the spine (area of highest interest for the surgeon) and are removed by suction and forceps at the end of the procedure before inflating the lung. This saves the time required for repeated suction and clearing the operative field near the cord.

Posterior instrumentation

Although percutaneous instrumentation is a demanding technique that requires a long learning curve, it is recommended for fracture stabilization as it is associated with minimal blood loss, paraspinal muscle trauma, and approach-related morbidities, without any significant decrease in safety compared with the open technique.

Some drawbacks of percutaneous instrumentation have been detected. It does not allow placement of cross-links, which would be the precondition for stabilization of longer-ranging and seriously unstable segments. This did not present any disadvantage for us as we have always instrumented the pedicles of the fractured vertebra with short pedicle screws to allow for better biomechanical stability of the construct. In comparison with fixed monoaxial implants, the system has limited capability for closed reduction. Although compression handles allow for distraction and compression of the instrumented segment, the polyaxial screw design directs compression/distraction forces to the posterior column only. Therefore, excessive reposition maneuvers are not feasible and sufficient reduction of the fracture should be achieved using optimized posture and manual reduction including axial leg tension or direct sagittal manipulation of the injured segment. As we did not apply the rods posteriorly, except after finishing the anterior approach, and thanks to the expandable character of the cage used, we did not encounter problems in terms of reduction or correction of kyphosis.

Thoracoscopic corpectomy

Thoracoscopy has greater technical demands in terms of the required equipment and surgical expertise. Gaining appropriate experience involves a large investment of time and effort on the part of the surgical team and operating support staff. Experience with the open technique is one of the demands for performing any procedure endoscopically [18].

The aim of minimally invasive surgery is to minimize physical trauma to patients and achieve maximal therapeutic benefits and maximal safety. This also means reduction of operative and postoperative morbidities. The clinical comparison showed the advantages of reduced early postoperative pain, improved shoulder girdle function, reduced impairment in the early postoperative pulmonary functions, and shortened ICU stay.

Comparisons between thoracoscopy and open thoracotomy have indicated that endoscopic techniques improve postoperative pain, shoulder girdle function, and morbidity, while reducing blood loss, time required in an ICU, and overall hospital stay [27,28].

Khoo *et al.* [22] summarized the advantages and disadvantages of VATS. The advantages of VATS treatment of thoracic fractures include the following: (a) small intercostal incisions without the need for rib resection or rib retractors; (b) excellent direct intraoperative visualization of the abnormality with a magnified 30° optical lens; (c) treatment of multisegmental abnormality without the need for additional rib resection; and (d) significantly reduced injury to the chest wall. (e) The magnified anterolateral view afforded during thoracoscopic visualization outstrips even that of standard open thoracotomy because it places the operative viewing distance within a few centimeters of the abnormality. Furthermore, the surgeon's view of the operative field is not obscured by either his or her hands or the surgical instruments, thus allowing for improved continuous surveillance of the procedure. The disadvantages of VATS procedures include a slightly increased anesthetic complexity with the need for double-lumen ventilation, and a very steep operating learning curve for the surgeon and the operative team. This learning curve was reflected in their own operative times over the last 5 years.

In this study of thoracoscopically assisted treatment of thoracolumbar fractures, thoracoscopy was associated with fewer complications compared with studies that used open thoracotomies. We also used the normal single-lumen endotracheal tube; this decreased the anesthetic complexity required for double-lumen endotracheal intubation.

Meticulous preoperative evaluation and planning is the keystone for successful treatment of thoracic and thoracolumbar trauma. Our experience clearly shows that thoracic and thoracolumbar spinal fractures can be treated safely and effectively through a minimally invasive thoracoscopic technique combined with percutaneous posterior instrumentation.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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