J Neurosurg Spine 2:128–136, 2005

Surgical technique and results of endoscopic anterior spinal canal decompression

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Object. Decompression of the spinal canal in the management of thoracolumbar trauma is controversial, but many authors have advocated decompression in patients with severe canal compromise and neurological deficits. Anterior decompression, corpectomy, and fusion have been shown to be more reliable for spinal canal reconstruction than posterior procedures; however, traditional anterior-access procedures, thoracotomy, and thoracoabdominal approaches are associated with significant complications. Endoscopy-guided spinal access avoids causing these morbidities, but it has not been shown to yield equivalent results in spinal canal clearance. This study was conducted to demonstrate the effectiveness of endoscopic spinal canal decompression and reconstruction quantitatively by using pre- and postoperative computerized tomography (CT) scanning.

Methods. Thirty patients with thoracolumbar canal compromise underwent endoscopic anterior spinal canal decompression, interbody reconstruction, and stabilization for fractures (27 cases), and tumor, infection, and severe degenerative disc disease (one case each). The mean follow-up period was 42 months (range 24 months–6 years). Neurological examinations, Frankel grades, radiological studies, and intraoperative findings were prospectively collected.

Spinal canal clearance quantified on pre- and postoperative CT scans improved from 55 to 110%. A total of 25% of patients with complete paraplegia and 65% of those with incomplete neurological deficit improved neurologically. The complication rate was 16.7% and included one reintubation, two pleural effusions, one intercostal neuralgia, and one persistent lesion of the sympathetic chain.

Conclusions. The authors describe the endoscopic technique of anterior spinal canal decompression in the thoracolumbar spine. The morbidities associated with an open procedure were avoided, and excellent spinal canal clearance was accomplished as was associated neurological improvement.

KEY WORDS • anterior approach • anterior decompression • spinal trauma • endoscopy

COMPRESSIVE spinal lesions can cause dysfunction of various neural elements in the thoracolumbar region. Spinal cord, conus medullaris, and cauda equina injuries include simple contusion injury to complete disruption of the spinal cord. Unless the spinal cord is completely transected, recovery is possible. The results of animal studies indicate that the magnitude of the initial traumatic force and the duration of mechanical compression can influence the extent of neurological dysfunction and subsequent recovery potential.[10,28] Based on these results, it can be inferred that similar relationships should be present in humans. Analysis of several clinical studies indicates a relationship between mechanical decompression and potential neurological recovery.[2,17,19] Although this remains controversial and conclusive evidence is lacking in humans, many authors have advocated decompressive surgery for patients with incomplete deficits and severe canal compromise.[1,7,8,32]

In the thoracolumbar spine, anterior and posterior approaches have been developed to allow decompression and reconstruction of the spinal canal. Posterior approaches have the advantage of a single incision for decompression and posterior stabilization, and the thorax and abdomen need not be entered. Because thoracolumbar trauma–induced compression is most commonly anterior to the spinal cord secondary to retropulsed bone fragments, however, this approach only indirectly allows removal of the cause of the compression via ligamentotaxis. Alternatively, a more extensive posterolateral approach (costotransversectomy, lateral extracavitary) is needed. The authors of several clinical studies have demonstrated greater potential for effective spinal canal clearance and reconstruction when anterior-approach surgery is performed.[8,13,19] An anterior approach usually requires a more complex and invasive access procedure—namely, a thoracotomy or a more extensive thoracoabdominal incision. Although they are associated with significant morbidity and do not allow for placement of posterior instrumentation in the same sitting, anterior approaches allow for direct excision of the compressive lesion. In the case of thoracolumbar trauma, this involves the removal of the retropulsed bone and disc fragments. In a multicenter study, one group reported on 1223

Abbreviations used in this paper: CT = computerized tomography; PLL = posterior longitudinal ligament; VB = vertebral body.

open anterior approaches to the thoracic and lumbar spine.[15] The postoperative rate of pleural effusion, intercostal neuralgia, and pneumothorax was 14%, compared with 5.4% in our own series.[5,20] To avoid the morbidity of traditional anterior approaches and to maximize the effectiveness of spinal canal clearance compared with posterior procedures, we developed a minimally invasive endoscopic anterior approach. The goal of this study was to develop an endoscopic technique for spinal canal decompression that efficiently clears the spinal canal and avoids the morbidity of traditional open access procedures.

Clinical Material and Methods

Patient Population

Endoscopically guided anterior access to the thoracolumbar spine has been performed in 550 patients since 1996 at our hospital. For the purpose of this study we prospectively selected 30 consecutive patients (seven women and 23 men) for endoscopic spinal canal decompression and reconstruction. The indication for anterior decompression was a neurological deficit associated with significant spinal canal compromise. The mean age of the patients was 39.4 years (range 19–69 years).

In the majority of selected patients (27 cases), a retropulsed bone fragment secondary to spine trauma was present. The mechanism of the traumatic fractures was as follows: 12 falls, 10 sports-related injuries, three traffic accidents, and two cases of violence. The fracture type was assigned according to the classification described by Magerl, et al.:[24] 17 Type A3, seven Type B, and three Type C injuries. There was also one case each of spinal canal compromise secondary to spondylitis, plasmacytoma, and severe degenerative disease. The distribution of vertebral involvement is illustrated in Fig. 1.

Twenty-five patients with severe traumatic deformities (kyphosis and dislocation) associated with the fracture initially underwent posterior fixation and stabilization to reestablish the sagittal and coronal spinal alignment. In addition, indirect decompression of the spinal cord was attempted via ligamentotaxis. All posterior procedures were performed urgently within 24 hours of trauma. In five patients, no posterior surgery was indicated.

Endoscopically guided spinal intervention was performed a mean of 10.6 days (range 2–27 days) after injury. At the time of the endoscopic surgery, 24 patients exhibited neurological dysfunction rated on the Frankel scale: four with Grade A, three with Grade B, seven with Grade C, and 10 with Grade D.[16]

Measurement of Spinal Canal Clearance

The record of the peri- and postoperative complications was supplemented by follow-up clinical and radiological examinations for 24 months. Spinal canal clearance was evaluated using pre- and postoperative CT scanning of the relevant, comparable VB heights. The measurement of the width of the spinal canal at the level of the fractured VB was conducted according to the method reported by Bradford and McBride,[8] whose system accounts for individual variations of the spinal canal size by averaging the normal anteroposterior spinal canal diameter at the level

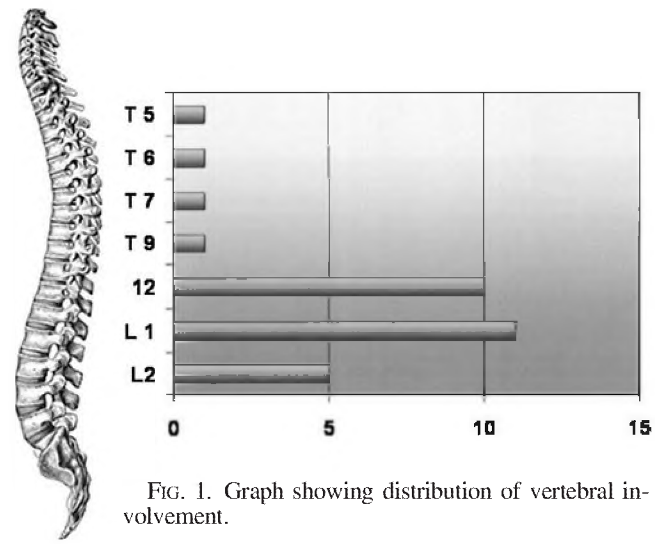

FIG. 1. Graph showing distribution of vertebral involvement.

of the VB above and below the injured segment and using this value to express the degree of canal compromise at the level of injury as percentage of normal.

Operative Technique

The thoracoscopic techniques of access to the thoracolumbar spine including equipment, portal placement, division of the diaphragm, and endoscopic plate fixation have been described in detail previously.[5,30] Briefly, the patient is placed on a radiolucent table in the true lateral position. A lateral fluoroscopic image is obtained to determine the level of pathological entity and the position of the four portals. The working portal is outlined directly over the affected VB. The portal site for the endoscopic camera is approximately two to three intercostals spaced in the cranial direction along the axis of the spinal column. The position of the suction irrigation portal is ventral and slightly cranial to the working portal. The retraction portal for the lung and diaphragm is ventral and slightly caudal to the working portal (Fig. 2). After access has been gained and all portals are in place, the diaphragm is split. An endoscopic partial opening of the diaphragm was necessary in 17 patients to gain access to the thoracolumbar spine. At this point we recommend placing the screws into the VBs above and below the level selected for corpectomy. This maneuver will provide the surgeon with intraoperative landmarks, which can be of great value because changing the camera position during endoscopic surgery is necessary and the surgeon can become disoriented without clear intraoperative landmarks. After this, the adjacent intervertebral discs are incised and removed, and the central part of the VB is resected with osteotomes and rongeurs. Initially, the posterior VB wall is preserved to avoid further canal compromise during the partial corpectomy. In addition, removal of the retropulsed fragment can cause significant epidural venous plexus bleeding. Therefore, we recommend completing the partial corpectomy and adjacent discectomies before undertaking canal decompression. The pedicle of the fractured VB is then identified. In cases of traumatic burst fracture, because the pedicles are nearly always preserved and the retropulsed fragment is usually medial to the fracture, the latter is trapped between the two pedicles and is difficult to remove or to reduce (Fig. 3). Therefore, we recommend resecting the ipsilateral pedicle prior to attempting to remove the retropulsed fragment. The base of the pedicle and the neural foramen can be localized using a small nerve hook.

Once the base of the pedicle is identified (Fig. 4 *upper left* and *right*), transecting it with a Kerrison rongeur will open the spinal canal (Fig. 4 *lower left* and *right*). We then resect the base of the pedicle, which makes it possible to visualize the retropulsed fragment (Fig. 5 *upper left* and *right*). It is usually necessary to remove the base of the pedicle completely to mobilize the retropulsed fragment. Under direct endoscopic visualization, the fragment is then dissected off the dura and carefully pushed into the corpectomy site (Fig. 5 *center left* and *right*). The fragment frequently needs to be released from the remaining attachments of the anulus fibrosis before its removal with a rongeur. Complete decompression of the dural sac is confirmed in the direct endoscopic view (Fig. 5 *lower left* and *right*) and with fluoroscopy. After completion of the decompression, the dura is covered with Gelfoam. The corpectomy defect can be reconstructed using an interbody bone graft or a cage. In 10 of our cases, the VB replacement involved an expandable titanium cage (Synex cage; Synthes, Solna, Sweden). In the remaining 20 patients, a tricortical iliac crest autograft was harvested via a separate incision in the lateral position from the ipsilateral iliac crest. The size of the graft was determined through a direct endoscopic measurement of the corpectomy site. After the graft was cut using osteotomes and removed, we reconstructed the iliac crest with a small plate.

We routinely perform an endoscopic anterior fixation, which involves a constrained screw/plate system (Fig. 6). Anterior instrumentation was performed using of the Z-plate (Medtronic, Inc., Minneapolis, MN) in 12 cases, and, since November 1999, 18 cases have been treated with the MACS TL constrained screw/plate system (Aesculap, Tuttlingen, Germany).[3] The partial corpectomy and canal decompression was combined in eight cases with monosegmental, in 21 cases with bisegmental, and in one case with trisegmental anterior plate fixation. Figure 7 illustrates a typical case of a burst fracture of the first lumbar vertebra.

FIG. 2. Photograph showing the standard setup for endoscopic spine surgery. The patient is placed in a true lateral position and four portals are positioned.

Results

Surgery-Related Results and Complications

The mean operative time was 5.42 hours (range 2.55–10 hours). Thoracic drainage was removed on average 16 hours after placement. The mean stay in the intensive care unit was 1.4 days (range 1–10 days). The mean estimated blood loss was 870 ml.

Complications occurred in 11 patients (36.7%). Five complications (16.7%) were associated with the donor site morbidity secondary to bone graft harvested from the iliac crest, including one case of wound infection and four of dysesthesias. We routinely extubate patients on the operating table immediately after the operation. Reintubation was immediately necessary in one patient for a period of 7 days because of worsening pulmonary insufficiency that was present preoperatively. Furthermore, there were two pleural effusions requiring drainage, one intercostal neuralgia, and a pulmonary embolism with deep leg venous thrombosis. In addition, one patient experienced a temporary brachial plexopathy related to positioning and there were three cases involving postoperative sympathetic chain lesions, of which two were completely resolved at the time of follow-up examination.

Spinal Canal Clearance and Neurological Outcome

The surgeon used an endoscope and fluoroscopy in all cases to judge the success of spinal canal decompression. Objective CT scanning–based measurements revealed mean postoperative spinal canal clearance of 110% (range 78–155%). The mean canal compromise prior to surgery was 55% (range 34–78%).

There was no deterioration of the neurological function in any patient. Based on the Frankel scale, 25% of patients with complete paraplegia (one of four) and 65% of those with incomplete neurological deficit (13 of 20) improved at least one level on neurological examination.

Discussion

The role of spinal canal and neural decompression remains debated. Although there are currently no prospec-

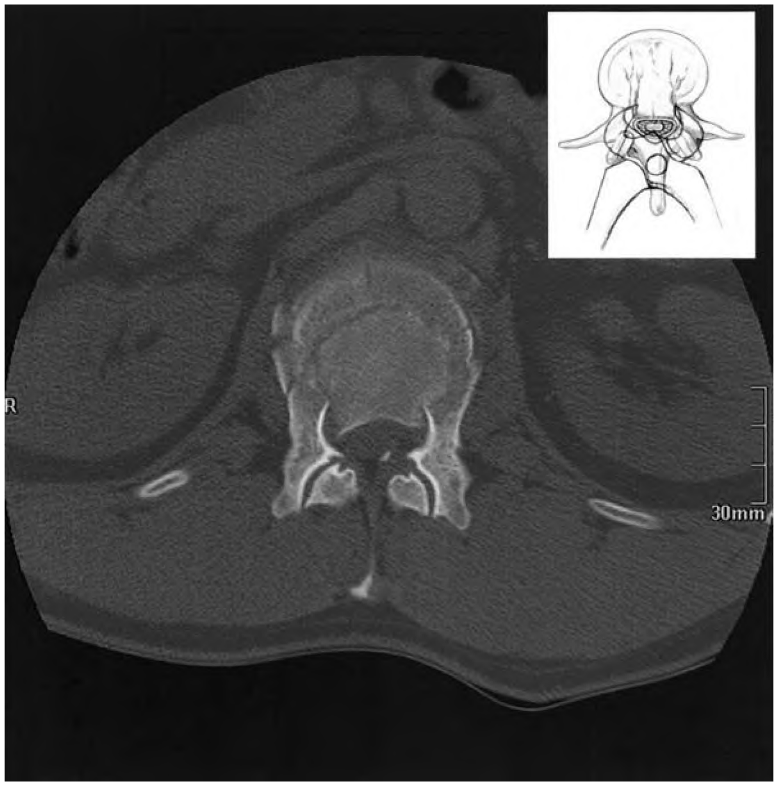

FIG. 3. Axial image demonstrating typical VB fracture with an associated retropulsed fragment, which is entrapped between the pedicles.

tive randomized data that support decompressive surgery in the management of spinal trauma,[7] many authors have advocated spinal canal decompression in patients with significant canal compromise and associated neurological deficit.[2,7,8,32] More controversial indications include severe canal compromise in neurologically intact patients and decompression prior to correction of severe traumatic deformities. It is thought that decompression of the spinal cord and the cauda equina can prevent secondary damage and potentially improve the physiology for recovery.[29] We consider the development of a syrinx to be significantly associated with spinal canal stenosis in the sagittal and axial planes; thus, we recommend that the vertebral lesion be sufficiently reduced to prevent syrinx development. The quality of the initial treatment of the vertebral injury must be the first step in preventing a syrinx. In the treatment of a syrinx, in addition to drainage techniques, one should also take into account the spinal realignment. The investigators of several nonrandomized clinical studies have documented the benefits of decompression and neurological function.[2,17,19]

Decompression of the spinal canal can be accomplished via anterior or posterior approaches. Indirect reduction of the retropulsed fragment and subsequent placement of posterior instrumentation and the application of distraction are possible. The success of the reduction via ligamentotaxis depends on an intact PLL and anulus fibrosis. In addition, the retropulsed fragment can be trapped between the two intact pedicles and prevent repositioning despite an intact PLL.[23]

Reduction of the retropulsed fragment can be accomplished via a closed postural reduction, open indirect reduction with placement of posterior instrumentation, or direct posterior lateral and anterior surgery. Closed postural reduction is rarely performed because it involves postural hyperextension and distraction requiring a specialized table and bracing. Closed reduction depends on the process of ligamentotaxis, which requires an intact PLL and anulus fibrosis.[31] In addition, in many cases the retropulsed fragment is trapped between the relatively intact pedicles.[23,31] Open indirect distraction with pedicle screws and connecting rods is more effective in achieving reduction with ligamentotaxis. When using this method, spinal canal clearance ranges from 10 to 43% (mean 28.6%).[9,14,22,32] The placement of instrumentation for reduction and stabilization of the spine is preferred over simple laminectomy alone. Decompressive laminectomy without instrumentation in patients with VB fracture–induced canal compromise results in additional instability that can cause neurological worsening.[25–27,33]

The success of instrumentation-augmented indirect canal decompression can be assessed immediately by using intraoperative myelography or ultrasonography or by using postoperative CT scanning. An anterior procedure for direct decompression can be considered in a patient with persistent neurological deficit and inadequate canal clearance.

The literature supports the idea that anterior decompression has advantages over posterior surgery in reconstructing the spinal canal. Bradford and McBride[8] studied the results in 59 patients with thoracolumbar fractures who underwent posterior surgery. Thirty-nine patients underwent posterior or posterolateral canal reconstruction.

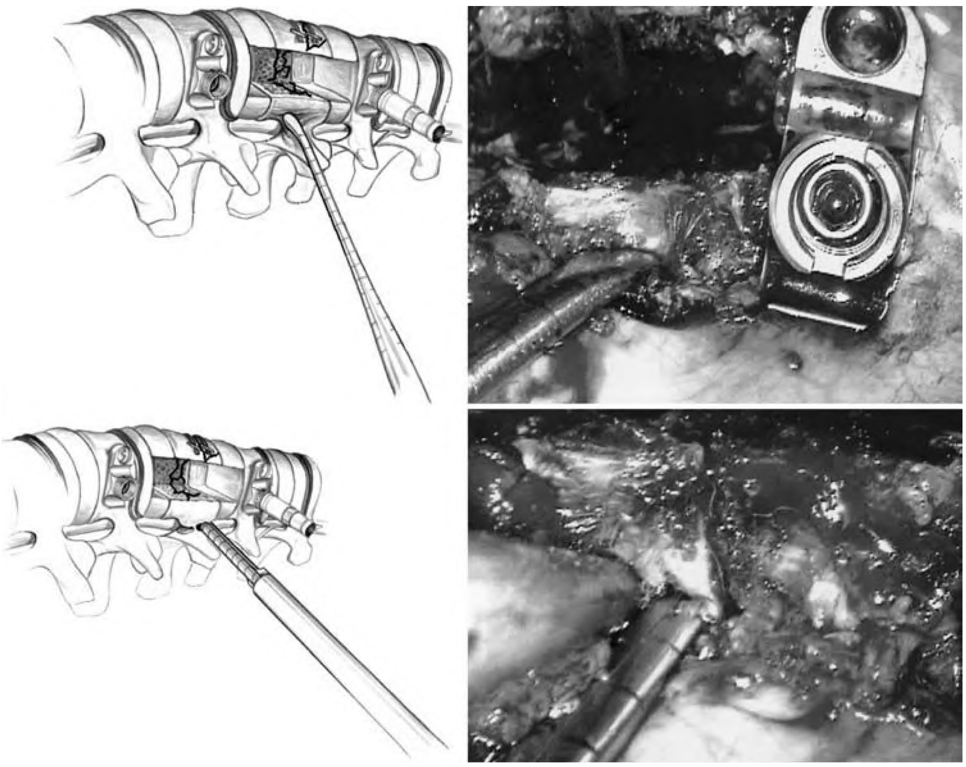

FIG. 4. *Upper Left* and *Right:* Screws are placed into the VBs above and below the involved segment. Schematic *(upper left)* and thoracoscopic view *(upper right)* showing exposure of the pedicle after partial corpectomy. *Lower Left* and *Right:* Schematic *(lower left)* and thoracoscopic view *(lower right)* showing resection of the pedicle in order to expose the lateral dural sac.

The postoperative residual spinal canal compromise was 26%. Esses, et al.,[13] also compared posterior and anterior surgery and found postoperative residual stenosis in 16.5 and 4% of patients, respectively. Several groups have reported the almost complete clearance of spinal canal compromise after anterior decompression.[8,13,19] The importance of the degree of canal compromise or residual stenosis and neurological outcome is controversial, although a correlation has been demonstrated in some studies.[8] In contrast, Esses, et al., and Korovessis, et al.,[21] were unable to find a difference in neurological outcome and completeness of the canal reconstruction.

This study expands the application of endoscopic anterior spinal surgery, which has been used at the Trauma Center Murnau since 1996 for the management of more than 500 patients with thoracolumbar fractures.[3,5,20] The endoscopic procedure is based on a four-portal technique and requires single-lung ventilation. Another critical component is the use of a 30°-angled endoscope, which allows for visualization of different angles of the operative site without interference with other endoscopic tools. Endoscopic incision of the diaphragm allows for access to the retroperitoneal space, and fractures of the second VB can be stabilized.[6] Although screws can be placed with this approach into L-3 for an L-3 fracture, we usually perform a mini-retroperitoneal approach to avoid opening the diaphragm and pleural cavity. For interbody reconstruction, we use either an iliac crest autograft or an expandable cage. Anterior stabilization involves a polyaxial screw/plate system specifically designed for endoscopic placement.[4]

Using the method of Bradford and McBride[8] to measure the spinal canal, the mean postoperative canal clearance was 110%. The rate of more than 100% is explained by the fact that the resection of the posterior vertebral wall and the intervertebral disc results in some expansion of the spinal canal cross-sectional area compared with an intact vertebral segment. In contrast, the reported mean residual spinal canal compromise after posterior surgery was 25.9%.[8] It should be kept in mind that the literature is unclear as to what extent of decompression or what degree of residual compression or canal compromise is acceptable. Additionally, during an extended period of time it is well documented that spontaneous resorption of retropulsed bone and spinal canal remodeling (expansion of the cross-sectional area) can occur.[22]

Other advantages of anterior surgery include the direct removal of the retropulsed fragment, which is virtually always anterior to the spinal cord or cauda equina, and reconstruction of the anterior column, which prevents posttraumatic kyphosis. The disadvantages of anterior surgery include the complications associated with thoracotomy[11,15] and thoracoabdominal incision as well as the difficulty of correcting severe traumatic kyphosis via an anterior approach. In addition to the morbidities associated with anterior access, a posterior procedure is often necessary to correct the deformity. Based on these considerations, we developed a treatment protocol for thoraco-

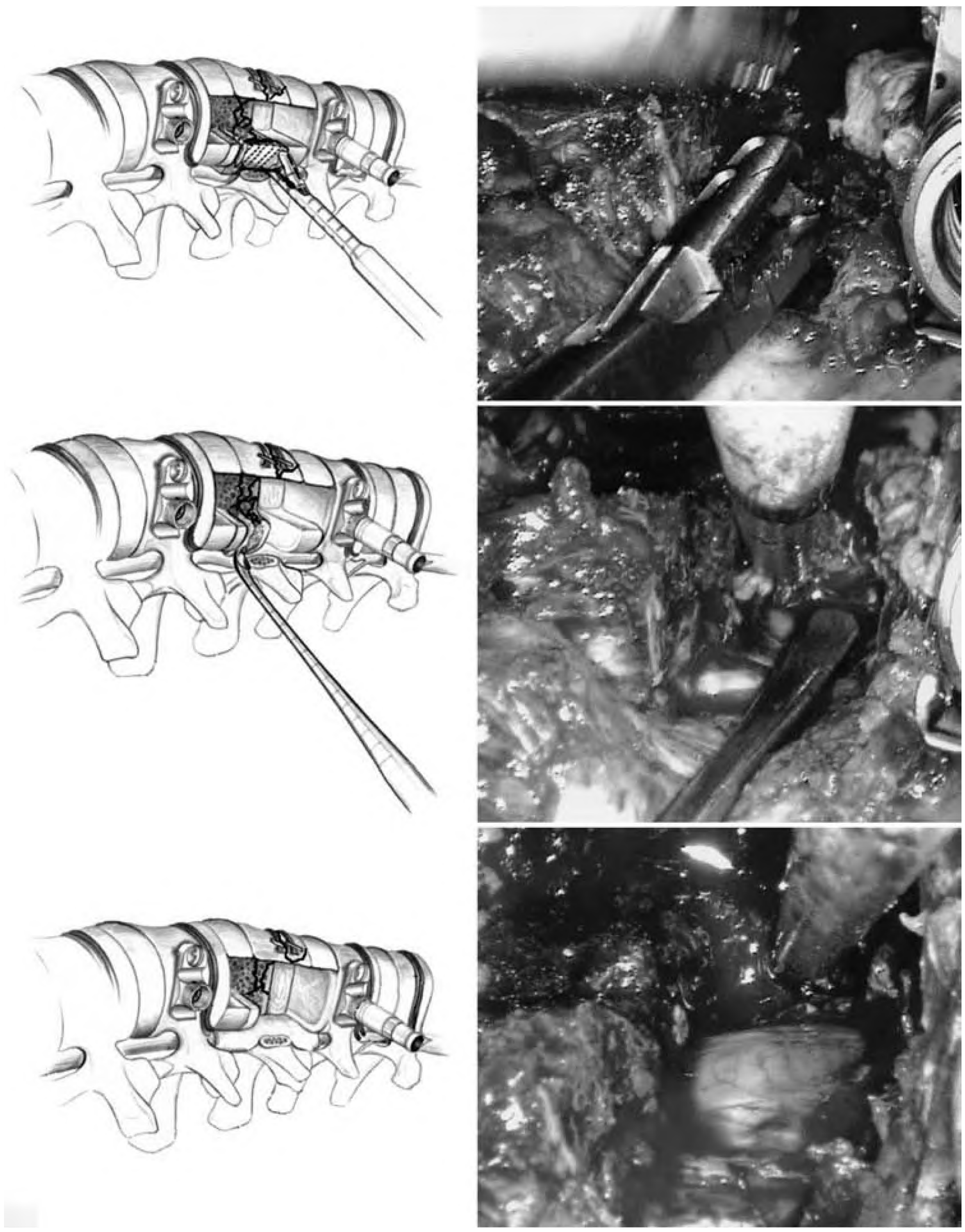

FIG. 5. *Upper Left* and *Right:* Schematic *(upper left)* and thoracoscopic view *(upper right)* demonstrating resection of parts of the posterolateral aspect of the VB. *Center Left* and *Right:* Schematic *(center left)* and thoracoscopic view *(center right)* revealing dissection of the retropulsed fragment under direct visualization of the dura. *Lower Left* and *Right:* Schematic *(lower left)* and thoracoscopic view *(lower right)* showing that decompression of the spinal canal is completed.

lumbar trauma that includes anterior endoscopic spinal surgery.

Urgent anterior decompressive surgery is offered if the neurological deficit does not resolve and is associated with residual canal stenosis. In a neurologically intact patient, if severe canal compromise is demonstrated on the postoperative CT scan, we perform the anterior endoscopic decompression on a semielective basis depending on the extent of coexisting injuries and recovery after the first surgery. Thus, on average, we perform endoscopic anterior decompression 11 days after occurrence of the trauma.

Our surgical technique, with its endoscopic anterior decompression of the spinal canal, has been developed based on typical fracture patterns and the particular features of the endoscopic procedure. Vertebral fractures associated with spinal canal stenosis almost always exhibit several typical changes. The posterior VB wall (middle column) is fragmented and dorsally displaced (retropulsed) into the spinal canal, causing spinal cord and cauda equina compression. The retropulsed fragment is frequently trapped between the two relatively intact pedicles. In burst fractures, the retropulsed fragment frequently remains attached to the anular fiber of the cranial intervertebral disc space.

Several special features make endoscopic surgery chal-

FIG. 6. Anterior reconstruction involving placement of an expandable titanium cage for VB replacement and constraint anterior plating system (MACS TL). The dura is covered with Gelfoam.

lenging. First, the operative site is visualized only in two dimensions, which makes the accurate assessment of distances and the position of surgical instruments relative to the spinal canal and neural structures difficult. Second, because of the changing camera positions, anatomical landmarks for orientation can get confusing, which lead to serious vascular and neurological complications. In particular, in cases involving endoscopic decompression of retropulsed fragment in areas where neurological structures are in proximity with each other, proper orientation is crucial.

The important step is the identification and resection of the ipsilateral pedicle. This allows for the movement of the trapped, retropulsed fragment compressing the spinal canal and provides a direct endoscopic anterior view of the dural sac. The high-resolution 30°-angled optic provides an excellent view of the PLL and the dural sac. At this stage, bleeding from the venous epidural plexus can occur. This can be controlled with the same hemostatic agents used in open spinal surgery, such as bone wax and Gelfoam, and surgically by using endoscopic tools.

In our case the duration of the surgery varied tremen-

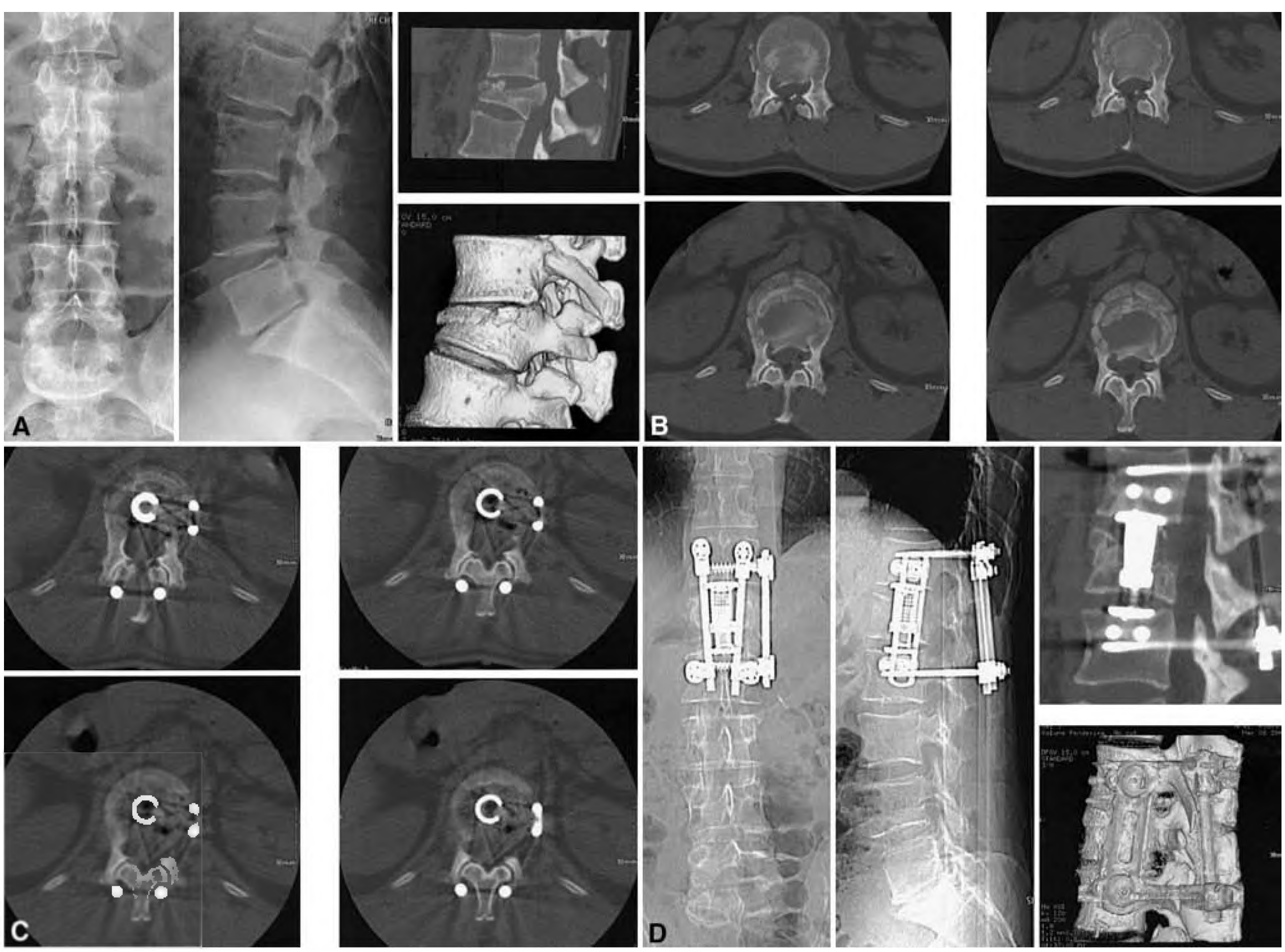

FIG. 7. Case example of a burst fracture L-1 (Type A 3.3) with incomplete neurological deficit and severe canal compromise. Preoperative x-ray films and CT scans (A–B); postoperative CT scans for the assessment of spinal canal clearance (C); and postoperative x-ray films and CT reconstructions (D).

dously (range 3–10 hours). This indicates that the initial learning curve is steep and that posterior instrumentation is necessary. The positioning-related complication of a transient brachial plexus irritation was related to the initial prolonged operative times and has not been observed in recent cases. We currently expect a mean operative time of 3.5 to 4 hours when conducting an endoscopic decompression involving one-level anterior reconstruction including partial corpectomy, discectomy, VB replacement, and placement of anterior instrumentation.

Corresponding to our rate of canal clearance of 110%, neurological improvement occurred in 25% of our patients with initial complete paraplegia and 65% of the patients with an incomplete neurological deficit. These results are in agreement with those in the literature.[12,14,18,19,21]

Of the 11 complications, five were associated with the harvesting of the bone graft used as VB replacement and should not be considered strictly related to the endoscopic procedure. In the last 2 years, we have increasingly used expandable titanium cages that can be placed endoscopically. Compared with iliac crest grafts, the cages are biomechanically more stable and have a lower risk for graft dislodgment. Because these cages can be filled with local bone harvested during vertebrectomy, we do not harvest iliac crest bone unless there is insufficient local bone available. Other complications that were associated with endoscopic surgery were pleural effusions and an intercostal neuralgia. The incidence of these complications is higher in cases treated with open thoracotomy.[15]

Conclusions

Our results demonstrate that endoscopic spinal decompression can be performed with an acceptable complication rate. The degree of spinal canal clearance was higher than for a posterior decompression procedure and was similar to that associated with open anterior procedures. Additional studies are needed to document the advantages of minimally invasive surgery and the correlation between spinal canal decompression and neurological improvement.

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Manuscript received January 20, 2004.
Accepted in final form October 22, 2004.
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