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IS THE ROOT RETRACTION OR SACRIFICATION FEASIBLE FOR THE TREATMENT OF THORACOLUMBAR BURST FRACTURES WITH SINGLE STAGE POSTERIOR PEDICULOTOMY AND CORPECTOMY?

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ABSTRACT

Background: We retrospectively reviewed the surgical results of posterolateral transpedicular partial corpectomy, cage interbody fusion without anterior vertebral reconstruction in 91 consecutive patients with burst fractures due to spinal cord compression at the thoracic and lumbar spine.

Material and methods: From February 2009 to October 2015, the review included ninety-one patients (42 females, 49 males), operated on for the diagnoses of thoracic and lumbar burst fractures due to spinal cord compression who underwent unilateral transpedicular posterior partial vertebrectomy (UTPPV) with vertebral reconstruction. Canal decompression was provided by laminectomies, intracanalicular fragments were totally excised and vertebrectomy was provided via transpedicularly, additional adequate exploration provided by root sacrification in thoracal region and root retraction in lumbar region fractures. Neurologic assessment and progression of the patients were noted as Frankel classification preoperative, postoperative 6th and 12th month, and fracture type was noted as an AO classification.

Results: The mean age was 35.08 ± 9.33 years. Mean follow-up time was 15.42 ± 4.13 months, and there was significant correlation between canal encroachment and preoperative Frankel grade ($p<0.0001$). The mean kyphotic correction between preoperative and postoperative Cobb angle on anteroposterior radiographs were 27.33 degrees ± 3.51 to 4.38 ± 0.79, and restoration of vertebral height diameter was 42.68 ± 9.08 % to 84.32 ± 6.71 % postoperatively ($p<0.05$). Mean canal encroachment was 62.32 % ± 14.88. There were no intraoperative mortality or implant failures. There were no additional complications and neurologic sequel during these operations.

Conclusion: Unilateral pediculotomy performed through a posterior approach provides a reasonable exposure. Bony fragments can be accessed without the need for an anterior approach or the application of posterior instrumentation. The posterior approach has its advantages in emergency surgical conditions, and provides improved surgical exposure, compared to anterior or anterior/posterior approaches, and has a diminished rate of serious complications.

Key words: Unipedicular corpectomy, burst fracture, Frankel Grade, AO spine

Level of evidence: Retrospective clinical study, Level III

INTRODUCTION

Thoracic and lumbar vertebral injuries generally occur because of high-energy trauma. These injuries are most commonly seen after motor vehicle accidents in cases of blunt force trauma from a fall, or with an injury secondary to a gunshot wound. The most frequent motion etiology of trauma is flexion, though combined trauma forces such as compression, distraction and shear force trauma can be seen. When a vertical load on the corpus occurs, the ending plate compresses toward the vertebral corpus, and an increased direct load results in deformation of the ending plates. The result is a decrease for flow to the spongious bone of the vertebral corpus and a resulting decrease in the energy absorption of the bone. Fractures occur when the elastic limit of the vertebral corpus is exceeded [27].

Deformities occur at the end plates rather than the disk, when distraction or shear forces accompany flexion forces [10,12,14]. Neurological injury is classified as primary or secondary. Primary injuries occur as a result of direct damage to the tissues. Compression injuries can cause direct

nerve damage, in addition to secondary damage, by affecting vascular perfusion. In that manner, ischemic changes can occur.

Ischemic damage subsequently establishes a vicious mechanical and biochemical cycle. Mechanical ischemia begins as a result of primary traumatic damage, followed by cell damage and release of vasoactive material. The subsequent edema and vasoconstrictive processes result in increasing damage. Thoracic and lumbar vertebral injury is very rapidly diagnosed via radiodiagnostic methods. All patients with whole body injury are considered to have vertebral instability until proven otherwise. Vertebral injuries can be classified as major or minor injuries. Minor trauma classification could be considered in cases that involve fractures of the spinous and transverse processes, and the facet joint and pars interarticularis.

The mechanistic grouping known as AO classification, was published in 1994 by Magerl [22,23]. The classification was based on an analytic evaluation of 1445 cases, and consisted of three grades, categorized by increased importance of classical AO fractures, and based on 53 types of injuries [24].

The main treatment goal of thoracolumbar fractures are to protect neural tissue from further damage and rapidly returning a patient to usual activities through early mobilization and rehabilitation. This can be provided by neural decompression and reconstruction of the anatomic alignment of the spinal column. The surgery is conducted with anterior, posterior, and anteroposterior approaches. Anterior approaches are widely used for spine decompression. This technique requires experience and the interest of a surgeon. This technique provides a direct intervention to the spinal canal and more effective decompression [2,9].

An anterior approach to the lumbar or thoracic spine has some difficulties in itself. Visceral organ or vascular damage complications can be seen in the course of the procedure. The presence of hemo-pneumothorax or intra-abdominal visceral organ complications in multi traumatic patients can alter mortality and morbidity rates for anterior approaches. Multiple studies showed that posterior stabilization and fusion allowed better anatomic fracture reduction. 360-degree fusion and kyphotic correction also can be established via a posterior approach with posterior vertebrectomy and posterior segmental instrumentation. Posterior approaches to the burst fractures are usually used for cases without neurological deficits. Contrarily to some beliefs, kyphotic angle correction, and reduction of canal encroachment through a posterior approach can be performed safely in neurologically injured patients.

We present the unilateral transpedicular posterior partial vertebrectomy (UTPPV) approach inthoracolumbar burst fractured for 82 patients.

MATERIAL AND METHODS:

Medical records of 91 patients operated due to thoracolumbar burst fracture in our clinics between years 2009 to 2015 have been evaluated retrospectively. These patients were treated with UTPPV and a cage insertion technique, with or without root sacrification.

The surgical indications include canal encroachment over 40 %, loss of vertebral body height exceeding 20 %, kyphosis more than 20 degrees; and with/without neurologic deficits [11].

Patients who had thoracolumbar fractures, but with less than 40 % canal encroachment were not included in this study, as they were likely treated conservatively (for stable burst fractures only). Some patients showed additional polytrauma complications such as hemo-pneumo thorax were included in this study. Fractures of all patients were evaluated before and after operations using anterior-posterior and lateral radiographs and by computerized tomography (CT) (Figure-1).

The midsagittal diameters of the spinal canal at the injury level were compared with the average diameter of one level above and one level below, and were expressed as canal compromise, which was a percentage of narrowing [3].

Cobb angle [18,25] was evaluated preoperative, immediate and 12th month postoperatively and measured from the superior end plate of the normal vertebral body just above the fracture to the inferior end plate normal vertebral body just below of the fractured vertebral body. The percentage of vertebral body height loss was reported as fractions of anterior height between fractured vertebra and normal height of the adjacent vertebra below the fractured vertebrae [15].

Surgical technique: A posterior midline skin incision was made to adequately expose the fracture, at least two levels above and below the level. Patients underwent long-segment posterior fusion, total laminectomy and unilateral pediculotomy. Total laminectomy with one segment below the hemilaminectomy of the affected segments was performed, followed by unilateral facetectomies and complete unilateral pedicle resection to the base of the vertebral body. Pediculotomy usually was performed from the paresthetic site. On the pediculotomy side, via excessive foraminatomy thoracic and lumbar nerves were exposed at one level below and above the fractured vertebrae. For intervertebral fusion, adjacent level intervertebral discs to the fractured vertebrae were removed by discectomy with endplates.

In exploration of upper and lower levels, spine remaining roots were seen at the fracture site. Bony fragments in the channel were removed. Above the T12 thoracic level, exiting roots generally were ligated and harvested to finish the corpectomy completely and maximize a better space for cage insertion. Thoraco-lumbar (T12 and L1) and lumbar nerve roots were preserved during the entire procedure. The plane between the posterior longitudinal ligament and the dura was identified, and the anterior fractured intracanalicular vertebrae fragments were resected piece by piece to achieve adequate circumferential decompression. The corpectomy was done for approximately 50 % of the vertebral body to create adequate space for cages (Figure-2).

We decancellated the vertebral body with curettes and finished the transpedicular corpectomy with a high-speed bur. The posterior and lateral cortices of the vertebral body were removed, and no residual compression of the thecal sac remained. After the corpectomy, the entire construct was slightly distracted to restore vertebral body height (Figure-3).

The distraction maintained the alignment and did not induce kyphosis. We then selected an appropriately sized expandable cage, based on the endplate size and the size of the window allowed by the nerve root. The cage was first inserted perpendicular to the spinal canal past the thecal sac and nerve root, rotated into the proper position, and then expanded under fluoroscopic guidance. Autograft from the corpectomy was used for arthrodesis.

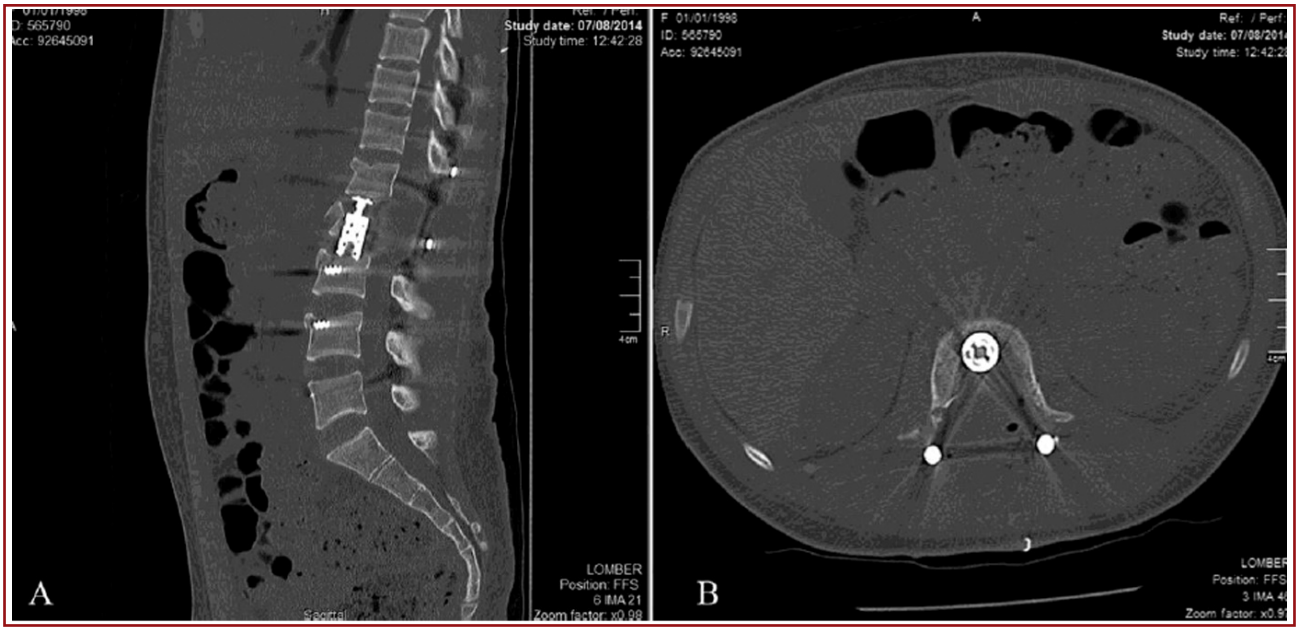

Figure-1.A,B. On sagittal 3D and axial CT images, burst fracture is seen in L2 vertebra. bone - fragments are seen in the spinal canal. Also there is grade 2 spondylolisthesis on L2 vertebra.

Figure-2.A,B. On sagital and axial CT images, there are posterior instrumentation materials from L5 vertebra to T11 vertebra. On axial images the right pedicle of L2 vertebra is not seen due to operation. There are no bone fragments in the spinal canal and no spondylolisthesis.

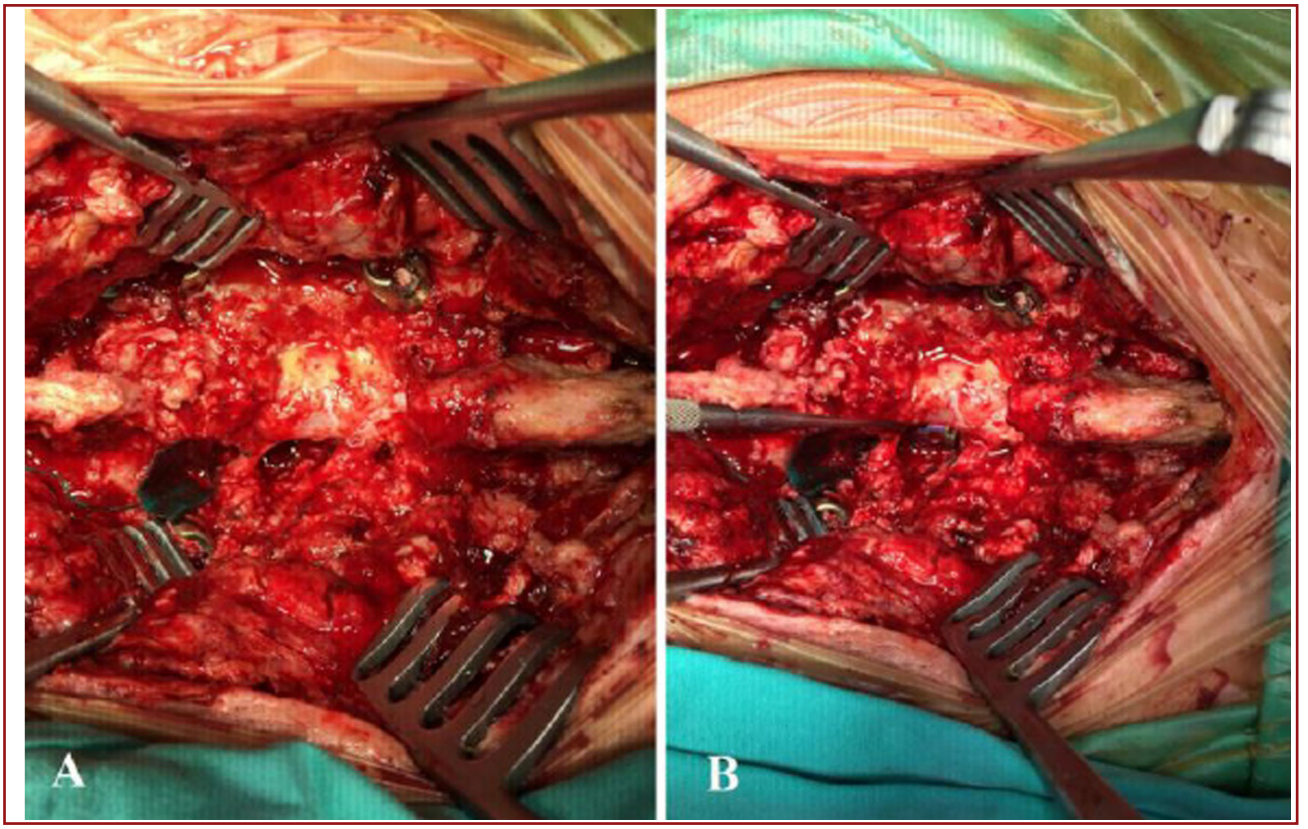

Figure-3. A. Intraoperative view of dural sac and nerve roots after corpectomy, **B.** inserted cage.

Statistical Analysis:

SPSS v21.0 for Windows (SPSS, Armonk, NY, USA) was used for statistical analysis. The variables were investigated using visual (probability plots, histogram) and analytical methods (Kolmogorov-Simirnov/Shapiro-Wilk's test) to determine whether or not they are normally distributed. Descriptive analyses were presented using means and standard deviations (SD) for normally distributed variables. The Student's t-test was used to compare the parameters. A p-value of less than 0.05 was considered to show a statistically significant result.

RESULTS:

Ninety-one patients (42 females, 49 males), who were operated for diagnoses of thoracic and lumbar burst fractures between 2009-2015, and were retrospectively evaluated. The mean age was 35.08 ± 9.33 (19–65) years. Patients with or without neurological deficit, as a result of an injury, were included in the study. Types of injuries included: motor vehicle accidents inside a vehicle (50 patients), falls from a height (21 patients), and motor vehicle accidents outside the vehicle (20 patients). Patients demographic results are shown in Table-1.

The spinal levels of injury were T11 (4 patients), T12 (15 patients), T12-L1 (3 patient), L1 (36 patients), L2 (27 patients), and L3 (6 patients). Neurologic deficits were seen in 66 patients. Twelve patients had paraplegia, 9 had paraparesis, 17 had monoparesis, 4 had bilateral foot drop and 24 had minor sensorial deficits. For severe neurological deficit, 10 (12.2 %) had their injuries in the thoracolumbar junction (4 patients T12, 6 patients L1). In the remaining 72 patients, the level of spinal trauma was unevenly distributed from T11 to L3 (Figure-4).

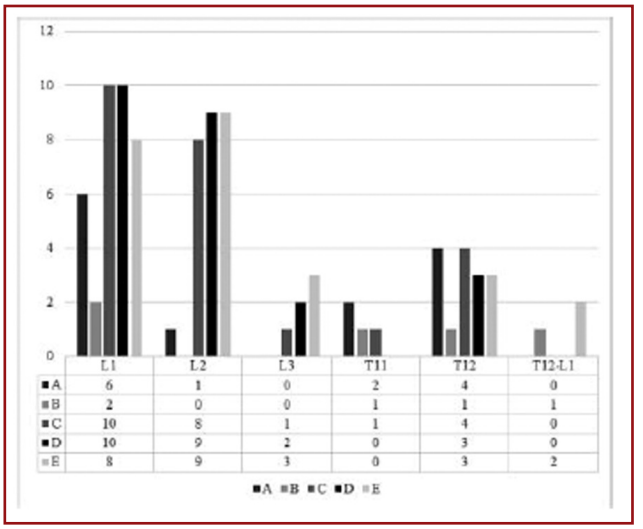

Figure-4. The distrubition of patients as fractured vertebrae levels and neurologic deficit- Frankel`s grades.

Table-1. Demographic and clinical factors of patients

Male-Female	**49-42**
Cause of Injury (n)	
Fall	21
Traffic Accident	50
Other	20
Level Of Injury (n)	
T11	4
T12	15
T12-L1	3
L1	36
L2	25
L3	6
Fracture Type (AO classification)	
A3	29
A4	30
B1	7
B2	20
C-N2	2
C-N3	3

Type A injuries (exclusive anterior column injury with vertebral body compression) were seen in 64.8 % of the patients. Within these, group A4 (burst fractures with fragments retropulsed into the spinal canal) was the most dominant (30 out of 59, 32.9 % of all patients; 29 patients with A3 fracture, 31.8 % of all patients). Type B injuries (anterior and posterior ligament injury with distraction) were found in 29.6 % of all patients (7 patients with B1 type, 20 patients with B2 type fractures). Type C injuries (anterior and posterior ligament injury with rotation) were seen in only one patient, 6.1 % of all patients; (5 patients with C type fracture).

In our study, severe neurologic deficits were seen in A4 and C type injuries and these fractures were frequently seen at the L1 level (6 patients), and T12 level (4 patients). The presence of a neurological deficit was very significantly associated with a high percentage of spinal canal stenosis independently of the level of the burst fracture. In our study, mean canal compromise was 62.32 % ± 14.88. The presence of a neurological deficit remains very significantly correlated with the percentage of spinal 125

canal encroachment ($p<0.0001$). Moreover, there is now a marginally significant correlation with the level of injury (the higher the level of the fracture, the greater the probability of a neurological deficit).

We evaluated preoperative and postoperative Cobb angle and vertebral body height diameters. The mean kyphotic correction between preoperative and postoperative cobb angle on anteroposterior radiographs were 27.33 degree ± 3.51 to 4.38 ± 0.79, and restoration of vertebral height diameter was 42.68 ± 9.08 % to 84.32 ± 6.71 % postoperatively ($p<0.05$). There were significant improvements in Cobb angle and vertebral height restoration.

We evaluated neurologic outcome according to the Frankel system. Preoperative and postoperative sixth and twelfth month Frankel values and intracanalicular bony fragments in the computerized tomography of the patients were evaluated. Preoperatively, 13 patients were assessed as Frankel A, 5 were assessed as Frankel B, 24 were assessed as Frankel C, 24 as Frankel D, and 25 patients as Frankel E. Postoperatively, for 12-month scores of Frankel, 62 patients were assessed as Frankel E, 7 as Frankel D, 7 as Frankel C, 2 as Frankel B and 13 as Frankel A. Postoperative spinal CTs revealed no intracanalicular fragments within the decompressed canal. According to Frankel's grading scale 66 patients displayed neurologic deficit on admission. Neurologic deterioration did not occur in any patient after surgery. The preoperative and postoperative Frankel grades were compared with a Wilcoxon test, and the median (50th percentiles) preoperative Frankel grade means C to postoperatively D for sixth months and the median (50th percentiles) preoperative Frankel grade means C to postoperatively E for twelfth months. Fifty-three out of 91 (58.2 %) patients exhibited neurologic improvement in Frankel B,C, and D groups. Among the 13 patients who presented Frankel A preoperatively, none changed scores postoperatively. One out of 3 patients who were Frankel B improved to Frankel C, two improving to Frankel D, and two did not change in Frankel score. Among the 24 patients who were graded as Frankel C, 17 of them improved to grade E and one improved to grade D postoperatively. Of 24 patients who were Frankel grade D, 20 of them made full neurologic recovery to Frankel E (Figure-5).

There was a significant relationship between canal encroachment with preoperative Frankel grade ($p<0.0001$). Severe neurologic deficits were seen in severe canal encroachments.

Pneumothorax and hemothorax were seen in 12 patients with A4 type fractures that frequently occurs in the thoracolumbar junction. The difference in presence of hemo-pneumothorax, regarding fracture types and injury level, was statistically significant between two groups ($p = 0.05$, $p=0.0001$ respectively). Additionally, hepatic contusion in 24 patients (29.3%), spleen contusion in 1 patient (1.2 %), and renal contusion in 10 patients (12.2 %) were detected.

In our study, mean operation time 4.05 min ± 0.55 min (3.15-5.25 minutes) and mean blood volume was 1267.07 cc ± 387.24 (750-2200 cc).

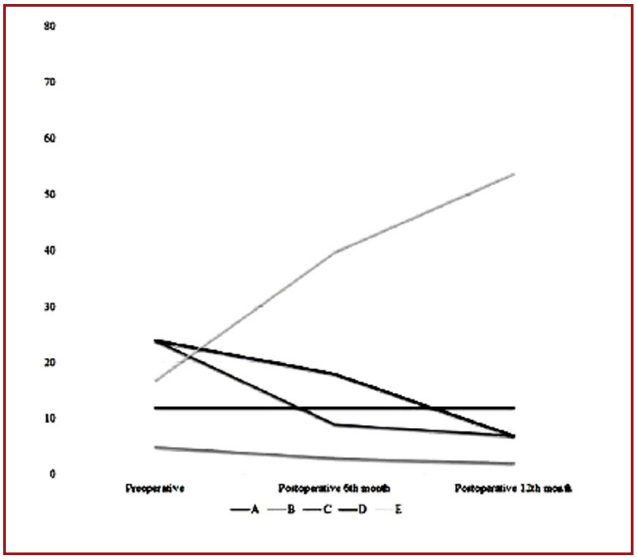

Figure-5. Patients preoperative, postoperative 6th and 12th month Frankel grade changes

DISCUSSION

Thoracic and lumbar vertebral fractures are commonly-seen injuries among neurosurgical emergencies. They are easily diagnosed by radiologic methods. With appropriate treatment strategies in spinal trauma, it should be possible to decompress the neural tissue, facilitate neurological recovery, restore spinal alignment and prevent loss of correction with neurological impairment. Urgent operations are planned according to the stability of the patient's vital signs and severity of the neurologic injury.

Surgical indications include: the presence of a neurological deficit, seatbelt injuries associated with posterior tissue damage, and burst fractures with two or more column injuries. Many surgical techniques have been identified in the literature. Among these, posterior instrumentation and decompression is the most frequently performed procedure. The anterior approach provides the possibility of a direct intervention to the intracanalicular fragments and more adequate decompression [2,9]. Although the anterior compression provides for effective decompression the spinal cord, an anterior approach to the lumbar or thoracal spine in itself presents some difficulties. Serious visceral organ or vascular damage and complications can occur during the course of the procedure. Moreover, additional polytrauma complications such as hemo-pneumothorax can aggravate co-morbidities.

Thoracotomy complications are divided into perioperative and postoperative complications. Injury to the lung parenchyma, superior and inferior vena cava and other vessels might be visualized during the thoracotomy procedure. Among postoperative complications, atelectasis, pneumothorax, pneumonia, and decreased diaphragmatic functions can be seen [29].

In comparison, with an anterior approach to the lumbar region, intraperitoneal organ injury, renal and ureteric injuries, peritoneal injuries, postoperative deep venous thrombosis, and ileus, and the development of incisional hernias may be observed [26]. Unilateral pediculotomy with a posterior vertebrectomy technique certainly could be used for burst fractures, especially in elderly patients in whom the anterior approach would be too morbid or alter patient co-morbidities. Surgeons should be comfortable with anatomy from an entirely posterior approach because the great vessels are just ventral to the limits of the corpectomy. The posterior approach for corpectomy provides a less risky approach for the thorax and abdominal wall through the intrathoracic and intraabdominal structures. A superior view is provided for posterior decompression (corpectomy and laminectomy), instrumentation and 360° fusion established with this surgical method. Posterior placement of expandable cages into the thoracic spine can be achieved with ligation of the nerve roots to maximize space for the corpectomy and cage insertion [5,28].

In addition, working medially ventral to the thecal sac is important, and comfort with the high-speed bur near dura is important. The goals of surgical treatment for unstable thoracolumbar burst fractures are to restore vertebral body height, kyphosis correction, decompress neural tissue, allow rapid mobilization and rehabilitation, decrease the complications of prolonged immobilization, prevent development of progressive deformity with neurologic deficit, and limit the number of instrumented vertebral motion segments [2-3]. Thus, with this single-staged procedure, we were able to obtain complete neural decompression, solid anterior column reconstruction with height restoration, and correction of kyphosis.

In contrast, posterior approaches to the thoraco-lumbar spine are less extensive and relatively simple. Complications of posterior instrumentation are evaluated as early and late complications. Inadequate decompression, iatrogenic injury, and complications occurring during instrumentation and fusion are among the early complications, while infection, pseudoarthrosis, atrophy in the paravertebral muscles, and pseudomeningocele are among the late complications.

Although occupation of the channel has a weak relation with neurological deficit, successful results obtained with early decompression suggest that early decompression in channel occupation might be a viable option [4,13,17]. Hashimoto and Lemons described an association with occlusion of the spinal canal and neurological deficit. Conversely, Fontijne introduced a relationship between spinal channel occlusion and neurological deficit. Fontijne did not, however, observe an association between the degree of occlusion of the channel and Frankel scale [6-7,19]. Our study showed that the presence of a neurological deficit was very significantly associated with a high percentage of spinal canal stenosis independently of the level of the burst fracture.

Aebi et al. [1] and Wiberg and Hauge [30] recommended early spinal cord reduction procedures (4–10 h) and the operative fixation of spinal fractures associated with spinal cord injuries (SCI). The body of evidence presented in these studies was in

favor of early decompression surgery, as this can potentially enhance neurological recovery in selected patients.

Like our study, various other organ injuries often accompany multitrauma patients. Because of this factor, shorter operative times play an important role in reducing and/or preventing co-morbid conditions [8].

The posterior approach in thoracolumbar spine fractures has the advantage of being familiar to the spine surgeon, avoidance of vital visceral/vascular structures, and allowing for safe surgical exploration. By utilizing a unilateral pediculotomy performed via a posterior approach, good exposure is achieved with easy access to the corpus, minimal blood volume and short operation time. Bony fragments can be accessed with posterior instrumentation, without necessitating any anterior intervention. The spinal channel is decompressed and no additional intervention is required [16,20-21].

Our study demonstrated that hemilaminectomy, facetectomy and pediculotomy facilitate the management of thoracolumbar burst fractures using posterior surgical approaches. For surgeons who are not comfortable with anterior approaches, a one stage, short time operation with a posterior approach addresses the efficiency of canal decompression and fracture reduction. Yet, it is not our intention to argue that posterior approaches are superior to other surgical methods, as treatment strategies need to be individually designed considering the condition of a patient, types and complications of fractures, experience and interests of doctors, and timing of the operations.

Unilateral pediculotomy performed through a posterior approach provides a reasonable exposure. Intracanalicular bony fragments can be excised without the need for an anterior approach or the application of posterior instrumentation. The posterior approach has advantages in emergency surgical conditions, and improved surgical exposure, compared to anterior or anterior/posterior approaches, and a diminished rate of serious complications.

REFERENCES

1. Aebi M, Mohler J, Zach GA, Morscher E. Indication, surgical technique, and results of 100 surgically-treated fractures and fracture-dislocations of the cervical spine. *Clin Orthop Relat Res* 1986: 244-257.
2. Aydin E, Solak AS, Tuzuner MM, Benli IT, Kis M. Z-plate instrumentation in thoracolumbar spinal fractures. *Bull Hosp Jt Dis* 1999; 58: 92-97.
3. Been HD, Bouma GJ. Comparison of two types of surgery for thoraco-lumbar burst fractures: combined anterior and posterior stabilization vs. posterior instrumentation only. *Acta Neurochir (Wien)* 1999; 141: 349-357.
4. Cengiz SL, Kalkan E, Bayir A, Ilik K, Basefer A. Timing of thoracolumbar spine stabilization in trauma patients; impact on neurological outcome and clinical course. A real prospective (rct) randomized controlled study. *Arch Orthop Trauma Surg* 2008; 28: 959-966.
5. Chou D, Lu D, Chi J, Wang V. Rib-head osteotomies for posterior placement of expandable cages in the treatment of metastatic thoracic spine tumors. *J Clin Neurosci* 2008; 15: 1043-1047.
6. Fontijne WP, de Klerk LW, Braakman R, Stijnen T, Tanghe HL, Steenbeek R, van Linge B. CT scan prediction of neurological deficit in thoracolumbar burst fractures. J Bone Joint Surg 1992; 74-B: 683-685.
7. Hashimoto T, Kaneda K, Abumi K. Relationship between traumatic spinal canal stenosis and neurologic deficits in thoracolumbar burst fractures. *Spine* 1988; 13: 1268-1272.
8. Hebert JS, Burnham RS. The effect of polytrauma in persons with traumatic spine injury. A prospective database of spine fractures. *Spine* 2000; 25: 55-60.
9. Hitchon PW, Al Jurf A, Kernstine K, Torner JC. Management options in thoracolumbar fractures. *Contemporary Neurosurgery* 2000; 22: 1238-1244.
10. Horal J, Nachemson A, Scheller S. Clinical and radiological long term follow-up of vertebral fractures in children. *Acta Orthop Scand* 1972; 43: 491-503.
11. Huang TJ, Hsu RW, Fan GF, Chen JY, Liao YS, Chen YJ. Two-level burst fractures: clinical evaluation and treatment options. *J Trauma* 1996; 41: 77-82.
12. Hubbard DD. Injuries of the spine in children and adolescents. *Clin Orthop Relat Res* 1974: 56-65.
13. Kaneda K, Abumi K, Fujiya M. Burst fractures with neurologic deficits of the thoracolumbar-lumbar spine. Results of anterior decompression and stabilization with anterior instrumentation. *Spine* 1984; 9: 788-795.
14. Kewalramani LS, Tori JA. Spinal cord trauma in children. Neurologic patterns, radiologic features, and pathomechanism of injury. *Spine* 1980; 5: 11-18.
15. Kim HY, Kim HS, Kim SW, Ju CI, Lee SM, Park HJ. Short segment screw fixation without fusion for unstable thoracolumbar and lumbar burst fracture: A prospective study on selective consecutive patients. *J Korean Neurosurg Soc* 2012; 51: 203-207.
16. Kong W, Sun Y, Hu J, Xu J. Modified posterior decompression for the management of thoracolumbar burst fractures with canal encroachment. *J Spinal Disord Tech* 2010; 23: 302-309.
17. Kostuik JP. Anterior fixation for burst fractures of the thoracic and lumbar spine with or without neurological involvement. *Spine* 1988; 13: 286-293.
18. Kuklo TR, Polly DWJ, Owens BD, Zeidman SM, Chang AS, Klemme WR. Measurement of thoracic and lumbar fracture kyphosis: evaluation of intraobserver, ınterobserver, and technique variability. *Spine* 2001; 26: 61-66.
19. Lemons VR, Wagner FC, Jr., Montesano PX. Management of thoracolumbar fractures with accompanying neurological injury. *Neurosurgery* 1992; 30: 667-671.
20. Maciejczak A, Barnas P, Dudziak P, Jagiello-Bajer B, Litwora B. [Minimally invasive posterior corpectomy of the lumbar spine with transpedicular fixation]. *Neurol Neurochir Pol* 2004; 38: 511-516; discussion: 517.
21. Maciejczak A, Barnas P, Dudziak P, Jagiello-Bajer B, Litwora B, Sumara M. Posterior keyhole corpectomy with percutaneous pedicle screw stabilization in the surgical management of lumbar burst fractures. *Neurosurgery* 2007; 60: 232-242.
22. Madsen Iii PW. Dorsal approach for treatment of thoracolumbar spine fractures. *Tech Neurosurg* 2003; 8: 101-114.
23. Magerl F, Aebi M, Gertzbein SD, Harms J, Nazarian S. A comprehensive classification of thoracic and lumbar injuries. *Eur Spine J* 1994; 3: 184-201.

24. McCormack T, Karaikovic E, Gaines RW. The load sharing classification of spine fractures. *Spine* 1994; 19: 1741-1744.
25. Okuyama K, Abe E, Chiba M, Ishikawa N, Sato K. Outcome of anterior decompression and stabilization for thoracolumbar unstable burst fractures in the absence of neurologic deficits. *Spine* 1996; 21: 620-625.
26. Ref M. Surgical approaches to the lumbar spine. In: Frymoyer JW, Ducker TB (Eds). The Adult Spine: Principles and Practice. Lippincott-Raven, Vol.2, Philadelphia 1997; pp: 2329-2341.
27. Roaf R. A study of the mechanıcs of spınal ınjurıes. *J Bone Joint Surg* 1960; 42-B: 810-823.
28. Shen FH, Marks I, Shaffrey C, Ouellet J, Arlet V. The use of an expandable cage for corpectomy reconstruction of vertebral body tumors through a posterior extracavitary approach: a multicenter consecutive case series of prospectively followed patients. *Spine J* 2008; 8: 329-339.
29. Sundaresan N, Teinbeger AA. Principles of Spinal Surgery, In: Menezes AH (eds). *Surgical Approaches to the Thoracic Spine*. McGraw-Hill, Vol 2, New York 1996; pp: 1263–1277.
30. Wiberg J, Hauge HN. Neurological outcome after surgery for thoracic and lumbar. *Acta Neurochir* (Wien) 1988; 91(3-4): 106-112.