

Transdiaphragmatic Approach as a Novel Less Invasive Retroperitoneal Approach at Thoracolumbar Junction: Comparison with Conventional Diaphragmatic Incision

Hiroaki Nakashima¹⁾²⁾, Tokumi Kanemura¹⁾, Kotaro Satake¹⁾, Kenyu Ito¹⁾, Satoshi Tanaka¹⁾, Naoki Segi¹⁾²⁾, Jun Ouchida¹⁾²⁾, Kei Ando²⁾, Kazuyoshi Kobayashi²⁾ and Shiro Imagama²⁾

1) Department of Orthopedic Surgery, Konan Kosei Hospital, Konan, Japan

2) Department of Orthopedic Surgery, Nagoya University Graduate School of Medicine, Nagoya, Japan

Abstract:

Introduction: Lateral corpectomy has been considered a minimally invasive surgery, allowing a “transdiaphragmatic approach” at the thoracolumbar junction. This approach allows for a small diaphragmatic incision directly in the retroperitoneal space and the affected vertebra. However, its effectiveness in comparison to a conventional approach remains unclear. Thus, in this present study, we compared the surgical outcomes between conventional diaphragmatic detachment and the transdiaphragmatic approach in patients with vertebral fracture at the thoracolumbar junction.

Methods: In total, 31 patients with a vertebral fracture at the thoracolumbar junction (T12-L2) were included in this study: 17 underwent a conventional approach, whereas 14 underwent a transdiaphragmatic approach, with a minimum 2-year follow-up. The effectiveness of surgery was evaluated in each category of the Japanese Orthopedic Association Back Pain Evaluation Questionnaire (JOABPEQ).

Results: Operative time and estimated blood loss were determined to be significantly shorter in the transdiaphragmatic than in the conventional approach. Perioperative complications were observed in the conventional approach (one atelectasis and one pleural effusion), while no complication was noted in the transdiaphragmatic approach. There were no significant differences in postoperative quality of life as assessed by JOABPEQ in terms of pain-related disorders, lumbar spine dysfunction, gait disturbance, social life dysfunction, or psychological disorders between the conventional and transdiaphragmatic approaches.

Conclusions: A “transdiaphragmatic approach” using lateral access surgery has been found to be associated with a shorter operative time and less blood loss with fewer complications than the conventional approach. Given that equivalent clinical outcomes were achieved in both conventional and transdiaphragmatic approaches, this “transdiaphragmatic approach” could be useful because of its minimal invasiveness.

Keywords:

Thoracolumbar junction, Transdiaphragmatic approach, Minimally invasive surgery, Surgical outcome, Complication, Lateral access surgery, Fracture

Spine Surg Relat Res 2021; 5(6): 405-411
dx.doi.org/10.22603/ssrr.2020-0191

Introduction

The thoracolumbar junction has been identified as the area most commonly affected (approximately 60-80%) in patients with traumatic fractures¹⁻³⁾, with anterior, posterior, and combined surgical approaches having been used to treat such fractures. The posterior approach is the most commonly used technique because of its advances in posterior

instrumentation systems; however, loss of correction and pseudarthrosis sometimes result in severe burst fractures^{4,5)}. Anterior approach has been determined to offer sufficient anterior decompression and reconstruction. However, these fractures in the thoracolumbar junction often require diaphragmatic detachment when using combined thoracoabdominal approaches, with possible complications including post-thoracotomy pain syndrome and herniation of the vis-

Corresponding author: Hiroaki Nakashima, hirospine@med.nagoya-u.ac.jp

Received: November 4, 2020, Accepted: January 21, 2021, Advance Publication: February 22, 2021

Copyright © 2021 The Japanese Society for Spine Surgery and Related Research

ceral contents into the thoracic cavity through a defect in the diaphragm^{6,7}). Conventional anterior approaches also require extensive exposure, with a skin incision up to 20 cm, which often results in cosmetic disfigurement. Also, loss of correction and revision surgery after anterior surgery are frequently required in older patients due to osteoporotic bone, in which combined surgery is required to maintain appropriate spinal alignment⁸).

In order to minimize post-thoracotomy complications, cosmetic disfigurement, and surgical invasiveness in anterior surgery for corpectomy, a less invasive approach was sought. Minimally open approaches to the thoracolumbar junction, however, remain to be challenging because of difficulties with retractor placement for the diaphragm and lung. Also, limited working space due to small incision is highly associated with an insufficient surgical view and difficulty with instrument manipulation. In recent years, minimally invasive lateral access surgery using a special retractor has been developed⁹⁻¹⁴), which has the ability to reduce the size of the operative scar to approximately 5 cm. By splitting the diaphragm muscle approximately 2 cm using forceps, we can reach into a “retroperitoneal” space. After sufficient exposure of the retroperitoneal space, a good surgical view can be obtained in the thoracolumbar junction via special retractor placement. We referred to this technique as the “transdiaphragmatic approach,” which has already been used for fractures at the thoracolumbar junction since 2015.

However, it remains unclear whether this less invasive approach has advantages compared with a conventional approach. Thus, this study has aimed to examine the surgical outcomes and complications of using transdiaphragmatic approach and to further compare its outcomes with those in conventional approach for patients with osteoporotic vertebral fracture at the thoracolumbar junction.

Materials and Methods

We performed this present single-center study after receiving approval from our institutional review board. In this study, we have retrospectively reviewed 31 patients who underwent a single-level corpectomy for osteoporotic burst fracture in the thoracolumbar junction (from T12 to L2) from 2011 to 2017. However, those patients with tumors and those aged younger than 65 years were excluded from the study. Patients who underwent extrapleural surgery for a T12 vertebral fracture were also excluded. We began using the transdiaphragmatic retroperitoneal approach in 2015 after a lateral access approach, including extreme or oblique lateral interbody fusion, had been introduced in Japan in 2013; before that, only conventional diaphragmatic detachment had been performed. Conventional diaphragmatic detachment was used in 17 cases from 2011 to 2014, whereas the transdiaphragmatic approach was used in 14 cases from 2015 to 2017. The choice of surgical approach has depended on the period of surgery. All patients underwent a posterior-anterior approach, and posterior pedicle screw fixation was

performed approximately 1 week before the anterior approach for corpectomy.

Transdiaphragmatic retroperitoneal approach

We have used our transdiaphragmatic retroperitoneal approach in cases with fractured vertebra from T12 to L2. In contrast, the retropleural approach was utilized for the fractures on the cranial side of T12. For cases with T12 vertebral body fracture, we decided on the retropleural or transdiaphragmatic approach based on the attachment position of the crus of the diaphragm as per a preoperative coronal computed tomography (CT) image. Cases that have underwent the retropleural approach were excluded, and all subjects in this study underwent transdiaphragmatic retroperitoneal approach.

Standard lateral decubitus positioning and preoperative fluoroscopic targeting were then used. The operating table was flexed at approximately 15° in order to minimize tension on the psoas and associated neurological structures. An incision, measuring approximately 8 cm, was made over the 11th rib on the left lateral convexity of the thoracic wall (Fig. 1A). After subperiosteal exposure, approximately 5 cm of the rib was removed. At this stage, the left lateral convexity of the diaphragm became exposed at the caudal of the space with the removed rib (Fig. 1A).

To avoid any pleural injury during the transdiaphragmatic approach, we confirmed the position where the lung moved most caudally during respiratory fluctuations after the 11th rib resection and confirmed the caudal end of the pleura. By bluntly dissecting the diaphragm approximately 2 cm away from the caudal end of the pleura, we assured that the position of the diaphragm dissection was not close to the pleura, reducing the risk of pleural injury as much as possible. After gently splitting the diaphragm muscle approximately 2 cm using forceps, the fat in the retroperitoneal space under the diaphragm was exposed.

The retroperitoneal space was then gently dissected with a finger and blunt dissector to reach the lateral and anterior aspect of the affected vertebra (Fig. 1B). The superior and inferior discs were then identified, and a MaXcess 4 (NuVasive, Inc., San Diego, CA, USA) retractor was secured using a posterior shim in the annulus to prevent anterior migration of the retractor (Fig. 1C). After dissecting the segmental vessel, the vertebral body was subtotally resected using a chisel and rongeur, and a vertebral cage (X-Core2®; NuVasive, Inc., San Diego, CA) was placed in all cases (Fig. 1D). Allograft bones were used for grafting.

Conventional diaphragmatic incision operative technique

An incision, measuring approximately 20 cm, was made over the 11th rib on the left lateral convexity of the thoracic wall. After subperiosteal exposure, approximately 10-15 cm of the rib was removed. After the fat in the retroperitoneal space was identified at the tip of the removed rib, the retroperitoneal space was dissected using a finger. The diaphragm was then opened along the thoracic wall, leaving a

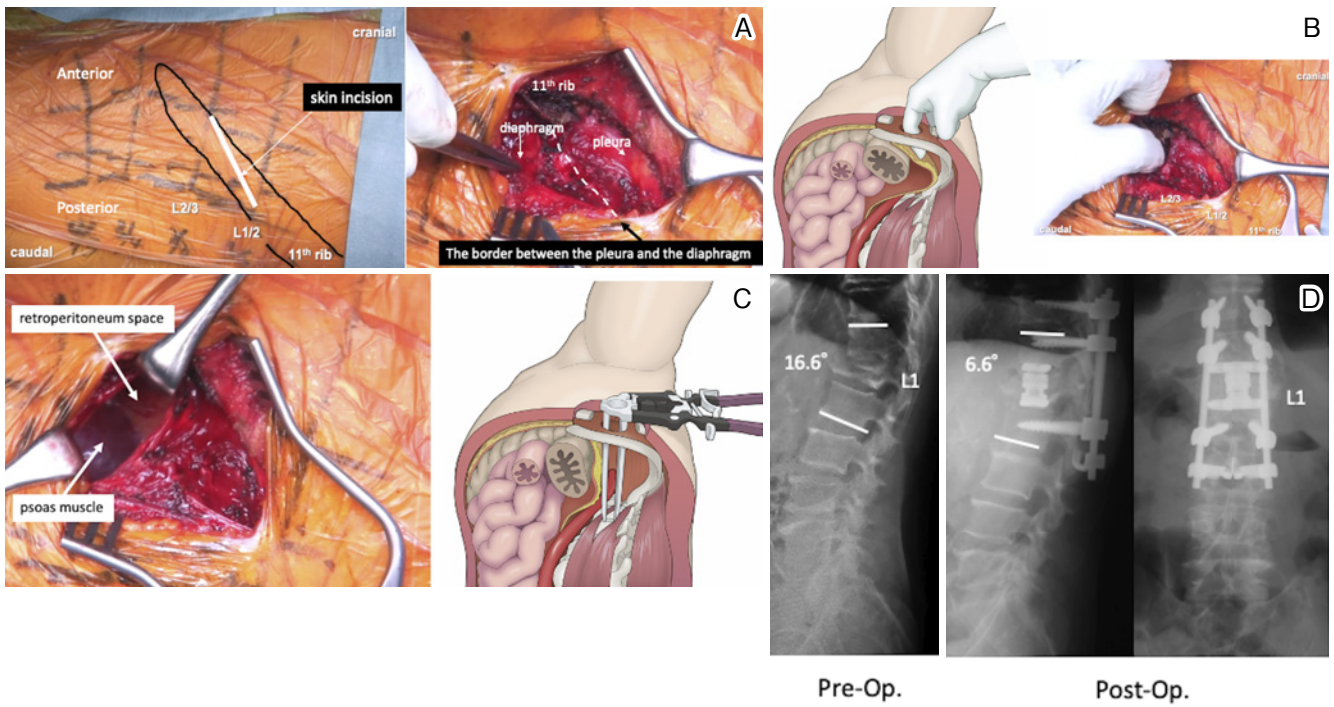


Figure 1. Transdiaphragmatic approach.

Skin incision measuring approximately 8 cm. The diaphragm was exposed at the caudal of the removed 11th rib, with muscle fibers of the diaphragm running in a cranio-caudal direction (A). After the retroperitoneal space was gently dissected using a finger (B), the retroperitoneal space was exposed, and a retractor was placed at the lateral of the affected vertebra (C). Pre- and postoperative X-rays of a case with L1 osteoporotic vertebral fracture (D).

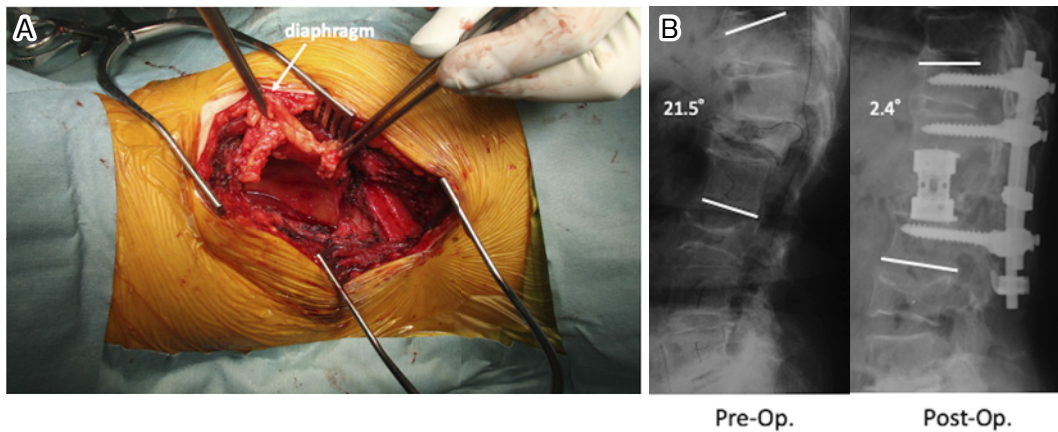


Figure 2. Conventional approach.

The diaphragm is opened along the thoracic wall with traction sutures every 2 to 3 cm in order to facilitate closure later on (A). Pre- and postoperative X-rays of a case with L1 osteoporotic vertebral fracture (B).

lateral 2 cm rim, with traction sutures every 2-3 cm in order to facilitate closure later on (Fig. 2A). The diaphragm was then incised using a monopolar electrode in an anteroposterior direction up to the lateral convexity of the spine. After confirming the correct level under lateral fluoroscopy and adapting the position of the retractor blades, the corpectomy and its reconstruction were performed (Fig. 2B). The following vertebral cages were used: T2 Altitude™ (Medtronic, Inc., Minneapolis, MN, USA), LIFT-J (Medtronic, Inc., Minneapolis, MN, USA), and SynCage® (DePuy Synthes,

Inc., Raynham, MA, USA) in nine, four, and four cases, respectively. Allograft bones were used for grafting.

Posterior fixation technique

The posterior fixation area was determined to be two levels above and one level below the injured vertebrae. In the vertebrae above the injured level, pedicle screws and sublaminar wirings were used, whereas pedicle screws and hooks were set one level below the injured vertebra.

Clinical assessments

The results of the Japanese Orthopedic Association Back Pain Evaluation Questionnaire (JOABPEQ) were evaluated preoperatively and at 2 years post-surgery. JOABPEQ contains 25 questions covering the 5 domains as follows: pain-related disorders, lumbar spine dysfunction, gait disturbance, social life dysfunction, and psychological disorders^{15,16}. The score for each domain was calculated according to the official guidelines, which can range from 0 to 100 points, with a higher score indicating a better health status. We have also collected information on perioperative surgical complications.

Radiographical assessments

Multiplanar CT reconstruction images were used for radiographical assessments at 2 years post-surgery. Bony union was defined on coronal and sagittal CT images, with bone bridges over the vertebral endplates and without a clear radiolucent zone at the border area. Meanwhile, cage subsidence was defined as significant when the cage sank into the vertebral endplate to a depth of ≥ 2 mm.

Statistical analysis

Student's t-test and Fisher's exact test were utilized in comparing the variables for the two groups. A p-value of < 0.05 was considered statistically significant. All analyses were conducted using SPSS version 26 (SPSS, Chicago, IL, USA).

Results

No significant differences were noted in terms of mean age (71.2 ± 7.9 vs. 65.2 ± 16.3 years; $p=0.21$), sex ratio (male/female 7/10 vs. 5/9; $p=0.31$), or fused vertebral levels between the groups (T12/L1/L2: 5/11/1 vs. 1/8/5; $p=0.06$) (Table 1). Osteoporosis treatment was performed via oral administration of bisphosphonate in three cases (17.6%) and one case (7.1%) before injury in the conventional and transdiaphragmatic approach groups, respectively ($p=0.61$), but osteoporosis treatment was not provided in the majority of cases.

The operative time for the anterior surgery was determined to be 267.9 ± 50.5 and 220.2 ± 44.4 min in the conventional and transdiaphragmatic approaches, respectively, with the conventional approach being significantly longer ($p=0.01$) (Table 1). The estimated blood loss from the anterior surgery was 639.1 ± 511.7 and 275.5 ± 221.7 ml in the conventional and transdiaphragmatic approaches, respectively, with the conventional approach significantly larger ($p=0.03$) (Table 1). For the posterior surgery, the fusion level was found to be 3 ± 1.4 and 3.2 ± 1.1 levels in the conventional and transdiaphragmatic approaches, respectively ($p=0.63$), and no significant differences were observed in terms of the operative time and estimated blood loss.

When conventional approach was used, perioperative

Table 1. Patients' Demographic Data and Perioperative Complications.

	Conventional approach	Transdiaphragmatic approach	P
Number of cases	17	14	
Age (years)	71.2 ± 7.9	65.2 ± 16.3	0.21
Male/female	7/10	5/9	0.31
Operative time	267.9 ± 50.5	220.2 ± 44.4	0.01
Estimated blood loss	639.1 ± 511.7	275.5 ± 221.7	0.03
Complications			
Pleural effusion	1 (5.9 %)	0	
Atelectasis	1 (5.9 %)	0	

Table 2. Preoperative and Postoperative Japanese Orthopedic Association Back Pain Evaluation Questionnaire.

	Conventional	Transdiaphragmatic	P
Preoperative			
Low back pain	24.7 ± 12.7	31.4 ± 25.3	0.35
Lumbar function	22.9 ± 23.0	19.1 ± 23.5	0.65
Walking ability	19.3 ± 15.0	24.2 ± 31.0	0.57
Social life function	28.6 ± 19.1	30.4 ± 27.8	0.83
Mental health	37.4 ± 19.2	36.2 ± 23.8	0.88
Postoperative			
Low back pain	42.9 ± 37.5	55.6 ± 40.7	0.37
Lumbar function	47.7 ± 34.8	53.4 ± 31.4	0.64
Walking ability	57.4 ± 24.0	62.0 ± 29.0	0.63
Social life function	48.4 ± 22.7	57.5 ± 26.0	0.31
Mental health	45.7 ± 21.8	52.1 ± 15.2	0.36

complications such as pleural effusion and atelectasis were observed in one patient each, whereas no postoperative complications were noted when the transdiaphragmatic approach was used (Table 1).

As per radiographical assessments, cage subsidence was observed in 13 (76.5%) and 5 (35.7%) cases in conventional and transdiaphragmatic approach groups, respectively, which was significantly higher in the conventional group ($p=0.03$). Furthermore, bony union was observed in 10 (58.8%) and 14 (100%) cases in conventional and transdiaphragmatic approach groups, respectively, which was significantly higher in the transdiaphragmatic approach group ($p=0.009$).

JOABPEQ

The preoperative JOABPEQ scores in the conventional approach group were 24.7 ± 12.7 , 22.9 ± 23.0 , 19.3 ± 15.2 , 28.6 ± 19.1 , and 37.4 ± 19.2 in the low back pain, lumbar function, walking ability, social life function, and mental health domains, respectively, and 31.4 ± 25.3 , 19.1 ± 23.5 , 24.2 ± 31.0 , 30.4 ± 27.8 , and 36.2 ± 23.8 , respectively, in the transdiaphragmatic approach group (Table 2). The differences were deemed not significant.

JOABPEQ results at 2 years post-surgery were found to be significantly better in all domains in both groups than preoperative scores. Also, no significant difference was

noted between the conventional and transdiaphragmatic approach in all the domains on JOABPEQ at 2 years post-surgery (Table 2).

Discussion

As per our findings, the transdiaphragmatic approach using lateral access surgery could minimize surgical invasiveness, thus lessening surgical complications in patients with osteoporotic vertebral fracture at the thoracolumbar junction. Given that equivalent clinical outcomes were achieved in both the conventional and transdiaphragmatic approaches, this minimally invasive approach could be deemed a useful surgical procedure in treating vertebral fractures at the thoracolumbar junction.

Lateral access surgery has been introduced as a minimally invasive lumbar interbody fusion technique for axial low back pain and has been widely used for other indications such as spinal instability, including spondylolisthesis, spinal stenosis, and adult spinal deformity^{9-14,17}. Because of advances in surgical instrumentation, a good surgical view can now be achieved using an ergonomic retractor with an effective lighting system, and anterior spinal surgery can be performed with a small incision using this approach. Vertebral reconstruction can also be achieved with minimal invasiveness via this technique^{18,19}. By minimally splitting the diaphragm, we can access the retroperitoneal space and obtain a sufficient surgical view and operational space by using this transdiaphragmatic approach in combination with lateral access surgery.

With respect to another minimally invasive surgery performed anteriorly at the thoracolumbar junction, thoracolumbar and lumbar fractures were treated via video-assisted thoracoscopic surgery^{1,2,20-25}. A small diaphragmatic opening, measuring around 6-8 cm, exposes the thoracolumbar junction with the help of a thoracoscope. Mean operative time and blood loss ranged from 3 to 4 h and from 600 to 870 ml, respectively, in this video-assisted surgery^{1,2,20-25}. The complication rate was determined to be 1.3-9.4%, whereas complications such as superficial infection, transient pleural effusion, pneumothorax, and pulmonary atelectasis are commonly reported^{1,2,20-25}. Thoracoscopy-assisted minimally invasive spinal surgeries in thoracolumbar fractures have been reported to be associated with shorter operative time, lesser blood loss, and smaller incision size^{1,2,20-25}. However, respiratory complications are commonly noted^{1,2,20-25}, and the average blood loss is greater than 500 ml, although this blood loss was reportedly less than that of a conventional approach²². In our transdiaphragmatic approach using a retractor with lateral access, fewer respiratory complications were noted as this approach did not require a portal for a video-assisted camera at the thoracic level; in addition, there was also lesser blood loss because of sufficient visualization and direct hemostasis. Furthermore, practice using thoracoscopic surgery technique and two-dimensional endoscopic imaging is needed in video-assisted thoracoscopy, as the learning

curve is steep²⁴. The transdiaphragmatic approach has a learning curve to obtain a good surgical view within a small space as well; however, having a “direct view” using an ergonomic retractor and an efficient lighting system might be easier for spinal surgeons.

Two recent minimally invasive techniques for the thoracolumbar area using the same retractor and cage system with our transdiaphragmatic approach have been reported. Noureldine et al. have demonstrated a mini-open technique using a retropleural or retroperitoneal approach²⁶. Their method is different from our method; their retroperitoneal approach involved the blunt dissection of the external oblique, internal oblique, and transversus abdominis. Meanwhile, in our transdiaphragmatic approach, the diaphragm was blunt-dissected in the fiber direction in order to directly reach the retroperitoneal space, and we did not dissect the abdominis to reach the retroperitoneal space. Hence, our transdiaphragmatic approach is a more minimally invasive approach to the abdominal muscles. Christiansen et al. and Huang et al. reported another mini-open surgery using lateral combined retropleural/retroperitoneal approach, whereas our transdiaphragmatic approach is a pure retroperitoneal approach^{27,28}. Although their approach is superior in terms of access to a larger field of view, once perfected, our approach could provide a sufficient surgical field of view with less invasiveness for vertebral fractures distal to T12.

There are some limitations to this current study, and they are as follows: (1) cages used were different between the groups, and the radiographical and clinical outcomes were affected; (2) the number of cases is relatively small because we selected patients with only an osteoporotic vertebral fracture at the thoracolumbar junction. Thus, a proper comparative evaluation with larger series of patients will be required to definitively compare the results of minimally invasive lateral access spinal surgery with open procedures in patients with fractures. Also, we started this transdiaphragmatic approach in 2015 and had considerable experience in using lateral access surgery for lumbar interbody fusion. Given the transdiaphragmatic approach also uses lateral access, spinal surgeons need to become familiar with this approach and with the instruments used, including a retractor, before using it in clinical practice.

Our preliminary results have demonstrated that the transdiaphragmatic retroperitoneal approach can aid in the treatment of a vertebral fracture at the thoracolumbar junction. Although careful surgical exposure in a small surgical field of view is required, this approach is minimally invasive at the thoracolumbar junction.

Conflicts of Interest: Tokumi Kanemura is a consultant for Medtronic and NUVASIVE. All other authors declare that there are no conflicts of interest.

Sources of Funding: Nothing

Author Contributions: Hiroaki Nakashima analyzed and

wrote the manuscript, and all other authors participated in acquisition or analysis of data and drafting of the article. All authors have read, reviewed and approved the article.

Ethical Approval: 2019-006 [0339] in Konan Kosei Hospital

Informed Consent: Informed consent was obtained from all individual participants included in the study.

References

- Shawky A, Al A-MARZ, El-Meshtawy M, et al. Thoracoscopically assisted corpectomy and percutaneous transpedicular instrumentation in management of burst thoracic and thoracolumbar fractures. *European Spine Journal*. 2013;22(10):2211-8.
- Khoo LT, Beisse R, Potulski M. Thoracoscopic-assisted treatment of thoracic and lumbar fractures: a series of 371 consecutive cases. *Neurosurgery*. 2002;51(suppl_2):S2-104-S2-17.
- Siebenga J, Leferink VJ, Segers MJ, et al. Treatment of traumatic thoracolumbar spine fractures: a multicenter prospective randomized study of operative versus nonsurgical treatment. *Spine (Phila Pa 1976)*. 2006;31(25):2881-90.
- Berven SH, Deviren V, Smith JA, et al. Management of fixed sagittal plane deformity: outcome of combined anterior and posterior surgery. *Spine*. 2003;28(15):1710-5.
- Machino M, Yukawa Y, Ito K, et al. Posterior/anterior combined surgery for thoracolumbar burst fractures—posterior instrumentation with pedicle screws and laminar hooks, anterior decompression and strut grafting. *Spinal cord*. 2010;49(4):573-9.
- Dajczman E, Gordon A, Kreisman H, et al. Long-term postthoracotomy pain. *Chest*. 1991;99(2):270-4.
- Niraj G, Kelkar A, Kaushik V, et al. Audit of postoperative pain management after open thoracotomy and the incidence of chronic postthoracotomy pain in more than 500 patients at a tertiary center. *J Clin Anesth*. 2017;36:174-7.
- Nakashima H, Imagama S, Yukawa Y, et al. Comparative Study of 2 Surgical Procedures for Osteoporotic Delayed Vertebral Collapse: Anterior and Posterior Combined Surgery Versus Posterior Spinal Fusion With Vertebroplasty. *Spine*. 2015;40(2):E120-E6.
- Ozgun BM, Aryan HE, Pimenta L, et al. Extreme Lateral Interbody Fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. *The Spine Journal*. 2006;6(4):435-43.
- Fujibayashi S, Hynes RA, Otsuki B, et al. Effect of indirect neural decompression through oblique lateral interbody fusion for degenerative lumbar disease. *Spine (Phila Pa 1976)*. 2015;40(3):E175-82.
- Phillips FM, Isaacs RE, Rodgers WB, et al. Adult degenerative scoliosis treated with XLIF: clinical and radiographical results of a prospective multicenter study with 24-month follow-up. *Spine (Phila Pa 1976)*. 2013;38(21):1853-61.
- Isaacs RE, Hyde J, Goodrich JA, et al. A prospective, nonrandomized, multicenter evaluation of extreme lateral interbody fusion for the treatment of adult degenerative scoliosis: perioperative outcomes and complications. *Spine (Phila Pa 1976)*. 2010;35(26 Suppl):S322-30.
- Castellvi AE, Nienke TW, Marulanda GA, et al. Indirect decompression of lumbar stenosis with transpoas interbody cages and percutaneous posterior instrumentation. *Clin Orthop Relat Res*. 2014;472(6):1784-91.
- Baghdadi YM, Larson AN, Dekutoski MB, et al. Sagittal balance and spinopelvic parameters after lateral lumbar interbody fusion for degenerative scoliosis: a case-control study. *Spine (Phila Pa 1976)*. 2014;39(3):E166-73.
- Fukui M, Chiba K, Kawakami M, et al. Japanese Orthopaedic Association Back Pain Evaluation Questionnaire. Part 3. Validity study and establishment of the measurement scale: Subcommittee on Low Back Pain and Cervical Myelopathy Evaluation of the Clinical Outcome Committee of the Japanese Orthopaedic Association, Japan. *J Orthop Sci*. 2008;13(3):173-9.
- Fukui M, Chiba K, Kawakami M, et al. JOA Back Pain Evaluation Questionnaire (JOABPEQ)/JOA Cervical Myelopathy Evaluation Questionnaire (JOACMEQ). The report on the development of revised versions. April 16, 2007. The Subcommittee of the Clinical Outcome Committee of the Japanese Orthopaedic Association on Low Back Pain and Cervical Myelopathy Evaluation. *J Orthop Sci*. 2009;14(3):348-65.
- Nakashima H, Kanemura T, Satake K, et al. Indirect decompression on MRI chronologically progresses after immediate post-lateral lumbar interbody fusion: The results from a minimum of 2 years follow-up. *Spine (Phila Pa 1976)*. 2019;44(24):E1411-18.
- Smith WD, Dakwar E, Le TV, et al. Minimally invasive surgery for traumatic spinal pathologies: a mini-open, lateral approach in the thoracic and lumbar spine. *Spine (Phila Pa 1976)*. 2010;35(26 Suppl):S338-46.
- Theologis AA, Tabaraee E, Toogood P, et al. Anterior corpectomy via the mini-open, extreme lateral, transpoas approach combined with short-segment posterior fixation for single-level traumatic lumbar burst fractures: analysis of health-related quality of life outcomes and patient satisfaction. *J Neurosurg Spine*. 2016;24(1):60-8.
- Beisse R. Video-assisted techniques in the management of thoracolumbar fractures. *Orthopedic Clinics of North America*. 2007;38(3):419-29.
- Le Huec J-C, Tournier C, Aunoble S, et al. Video-assisted treatment of thoracolumbar junction fractures using a specific distractor for reduction: prospective study of 50 cases. *European Spine Journal*. 2010;19(1):27-32.
- Peng M, Cao X, Peng G, et al. Retrospective study on treating thoracolumbar fractures with video-assisted thoracoscopic surgery and traditional anterior approach surgery. *Zhongguo gu shang=China journal of orthopaedics and traumatology*. 2012;25(9):747-50.
- Ray WZ, Krisht KM, Dailey AT, et al. Clinical outcomes of unstable thoracolumbar junction burst fractures: combined posterior short-segment correction followed by thoracoscopic corpectomy and fusion. *Acta neurochirurgica*. 2013;155(7):1179-86.
- Kim SJ, Sohn M-J, Ryou J-Y, et al. Clinical analysis of video-assisted thoracoscopic spinal surgery in the thoracic or thoracolumbar spinal pathologies. *Journal of Korean Neurosurgical Society*. 2007;42(4):293.
- Kim DH, Jahng TA, Balabhadra RS, et al. Thoracoscopic transdiaphragmatic approach to thoracolumbar junction fractures. *Spine J*. 2004;4(3):317-28.
- Noureddine MHA, Pressman E, Krafft PR, et al. Minimally invasive lateral retropleural and retroperitoneal approaches in patients with thoracic and lumbar osteomyelitis: description of the techniques and a series of 14 patients. *World Neurosurg*. 2020;139:e166-81.
- Christiansen PA, Huang S, Smith JS, et al. Mini-open lateral retropleural/retroperitoneal approaches for thoracic and thoracolumbar junction anterior column pathologies. *Neurosurg Focus*. 2020;49(3):E13.
- Huang S, Christiansen PA, Tan H, et al. Mini-Open Lateral Cor-

pectomy for Thoracolumbar Junction Lesions. Oper Neurosurg. 2020;18(6):640-7.

Spine Surgery and Related Research is an Open Access journal distributed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. To view the details of this license, please visit (<https://creativecommons.org/licenses/by-nc-nd/4.0/>).