23 Thoracoscopic Approaches

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The anatomy of the thoracic spine with a narrow thoracic spinal canal, the sensitivity of the spinal cord to minimal retraction, the ribcage, and the proximity to the lungs, heart, great vessels, and the diaphragm make selection of surgical approach to the thoracic spine of utmost importance. Spine surgeons first started treating patients with thoracic herniated discs through a posterior approach by laminectomy with or without discectomy. In 1969, Perot and Munro compiled 91 cases of thoracic herniated disc treated from a dorsal approach. Of the 91 patients, 16 became paraplegic and 6 died [1]. Of the patients with disc herniations in the central portion of the canal, the rate of paraplegia was 26 % and mortality was 9 %. The poor results highlighted the sensitivity of the spinal cord to retraction and the difficulty in treating anterior thoracic spine pathology. To obtain a more direct visualization and minimize retraction of the spinal cord, posterolateral (including transpedicular and transfacet), lateral (including costotransversectomy and extracavitary), and transthoracic approaches were developed.

Lesions in the vertebral body or located in the central anterior spinal canal benefit from a transthoracic approach for direct visualization of the pathology and the ventral dura to avoid retraction on the spinal cord. The transthoracic approach was initially done via open thoracotomy, in most cases requiring a thoracic surgeon to assist with the approach, a chest tube postoperatively, having a high rate of intercostal neuralgia (reported to be as high as 50 %), and having the risk of damage to the lung, heart, and great vessels [2, 3]. The open surgical approaches had significant morbidity related to the approach itself. Fessler and Sturgill reported the transthoracic approach was associated with intercostal neuralgia, pneumonia, atelectasis, hemothorax, and chylothorax [4]. In an effort to reduce the morbidity of the approach while retaining effectiveness and safety, minimally invasive alternatives to open thoracotomy have been developed, namely, thoracoscopic and mini-open transthoracic endoscopic approaches.

Minimally invasive alternatives to open thoracotomy were made possible by adoption of endoscopic and fiberoptic technology. The first endoscopic device for medical use was developed in Germany in 1806 by Philipp Bozzini and first adapted for thoracoscopy in 1910 by Hans Christian Jacobaeus [5, 6]. In the 1970s, fiberoptic and endoscopic video camera technology increased the use of thoracoscopy [7–9]. In 1993, Mack and colleagues and Rosenthal and colleagues were the first to perform spinal surgery with thoracoscopy [10, 11]. Since then, thoracoscopy has been applied to various spinal pathologies and shown to be advantageous over thoracotomy.

Thoracoscopic spinal surgery is performed with the patient in the lateral decubitus position with the ipsilateral arm abducted and placed on an armrest. The patient is intubated with a dual lumen tube for single-lung ventilation and

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collapse of the ipsilateral lung. The side of approach is dictated by anatomy and location of the lesion. Above T11, the side of approach is dictated by the location of the lesion and the anatomy of the aorta, vena cava, and azygos vein. At T11 and T12, the liver blocks downward retraction of the diaphragm and requires a left-sided approach unless a right-sided approach is absolutely required [12, 13]. C-arm fluoroscopy is used to localize the target level [2, 3]. Typically three to four ports are inserted through 1.0–1.5 cm skin incisions and blunt dissection over the superior aspect of the rib to avoid injury to the neurovascular bundle running underneath the rib [14]. One port is placed in the posterior axillary line directly lateral to the pathology, and the other ports are placed on the anterior axillary line [14]. The first port is placed blindly and has the greatest risk for injury to the lung. Risk is minimized by single-lung ventilation and collapse of the ipsilateral lung. The subsequent ports are inserted under endoscopic visualization from the first port. The patient is then rolled ventrally by 15–30° to let the lung fall away from the operative site, and a fan retractor can be used to hold the lung out of view. The operator stands on the ventral side of the patient with the first assistant. A second assistant stands opposite the main operator. Pleural adhesions are taken down, and the ribs are counted internally to localize the target level again in addition to use of fluoroscopy. At this point the spinal column is exposed for the operation. The camera can then be fixed to a table mounting system if desired. Subsequent spinal dissection is specific to the pathology addressed such as herniated disc, infection, scoliosis, tumor, or interbody fusion [14–17]. The critical concepts common to these surgeries are that the rib head articulates with superior aspect of the same numbered vertebral body, just below or at the level of the disc space. Dissection and drilling is done for adequate visualization of normal dura above and below the lesion and creation of defect into which pathology can be delivered away from the spinal cord to prevent any retraction on the spinal cord. Once the pathology is addressed, a chest tube is placed and the chest incisions closed. The chest tube is kept until output is less than 100 mL/day [3]. If a dural defect is encountered, the chest tube is kept on water seal only and a lumbar drain is placed.

An example of these key surgical concepts is the procedure for removing a centrally located herniated disc as seen here in preoperative MRI (Fig. 23.1) and CT films (Fig. 23.2) of a patient treated with mini-open transthoracic endoscopic technique. The pleura over the target disc space is incised and the segmental vessels ligated and clipped. The proximal 2 cm of rib is then drilled

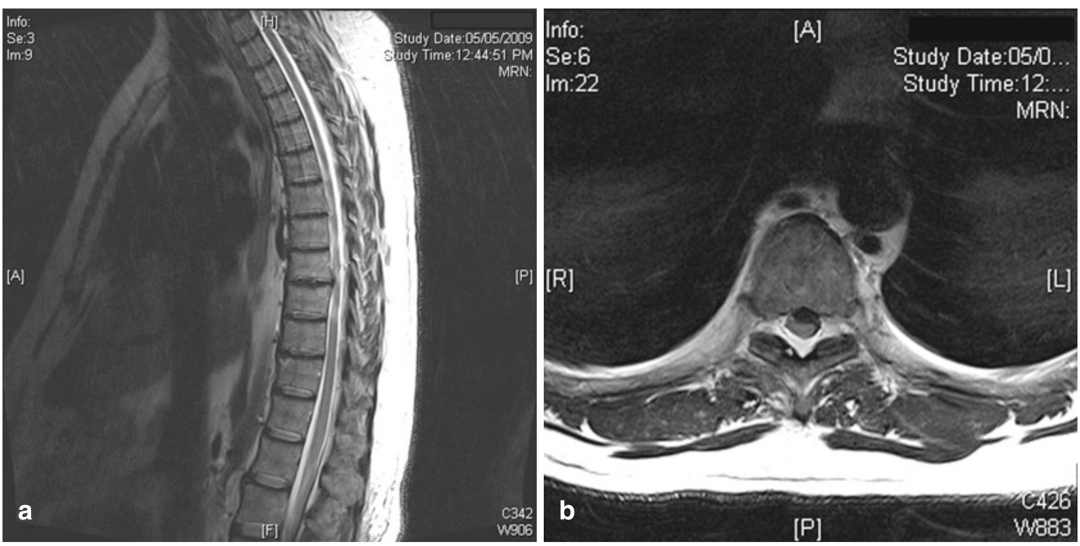

Fig. 23.1 Thoracic herniated disc on MRI. (**a**) A T8-9 herniated disc on sagittal MRI. (**b**) Axial MRI showing a left sided paracentral disc at T8-9 deforming the spinal cord without significant cord signal abnormality

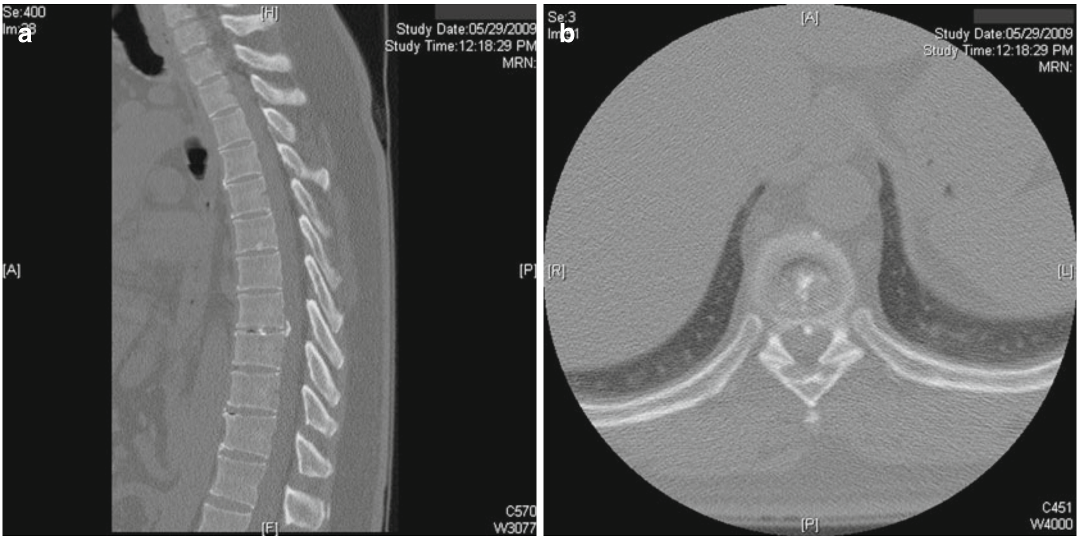

Fig. 23.2 Thoracic herniated disc on CT. (**a**) A T8-9 herniated disc on sagittal CT. (**b**) Axial CT showing calcification in the T8-9 disc herniation

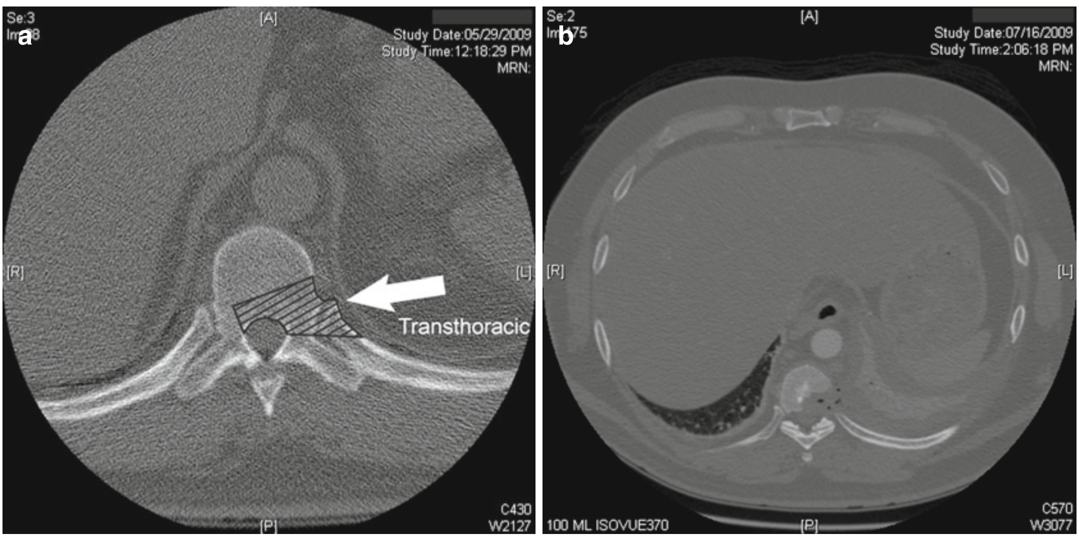

Fig. 23.3 Anterior transthoracic approach for discectomy. (**a**) The disc is removed and a wedge shaped cavity is drilled into the posterior aspect of the vertebral bodies above and below the disc space. This provides a cavity to safely deliver the calcified disc away from the dura, avoiding any manipulation or retraction the spinal cord. (**b**) Postoperative CT scan

and removed, saving the bone for autograft if needed. The superior half of the inferior pedicle is drilled down to define the lateral aspect of the spinal canal. Then the disc is incised and disc material removed, leaving the posterior aspect of the disc to be removed later. A wedge-shaped cavity is then drilled by removing the posterior aspects of the superior and inferior vertebral bodies until normal dura is seen above and below the herniated disc fragment. For a large herniated disc, this may require partial or full vertebrectomies above and below the disc interspace. After the cavity is formed, the herniated disc is carefully delivered into the cavity without manipulating the spinal cord. This bony defect can be seen in the postoperative CT scan in Fig. 23.3. If a dural erosion is found after herniated disc removal, the dura can be primarily repaired or a dural graft with fibrin glue can be placed. Placement of an interbody graft is not necessary for small bony defects, as few patients require reoperation for loss of stability [2, 3]. However, if a large defect is created, a rib graft can be placed. Some authors advocate standard placement of an interbody graft after discectomy to minimize risk of delayed postoperative kyphosis and axial pain [18–21].

A comparison of thoracoscopy and open thoracotomy was performed by Rosenthal and Dickman. They reported on 55 patients that underwent thoracoscopic herniated disc removal and 18 patients that underwent open thoracotomy [3]. They found that mean operative time for thoracoscopic disc removal was 3 h and 25 min, 1 h less operative time than thoracotomy. In addition, when compared to thoracotomy, thoracoscopy resulted in one-half the blood loss (327 vs. 683 mL), one-half the duration of chest tube drainage, and less than one-half of the length of hospital stay (6.5 vs. 16.2 days). Complications included hemothorax from intercostal vessel and segmental vessel bleeding, transient intercostal neuralgia, and two patients with retained fragments of disc material. Only 16 % of patients experienced intercostal neuralgia as opposed to 50 % of the patients who had a thoracotomy due to decreased intercostal retraction. Contraindications to thoracoscopy include patients unable to undergo single-lung ventilation or patients with significant pleural adhesions. The development of thoracoscopy alleviates much of the morbidity of the open thoracotomy approach while maintaining effectiveness in treating the pathology.

Despite showing clear benefits in reducing approach-related morbidity, thoracoscopy has been slow to be adopted by spine surgeons for a number of reasons: lack of 3D visualization, minimal tactile feedback, steep learning curve requiring specialized training in the lab prior to clinical use, and expensive equipment and instrumentation [22–25]. The mini-open transthoracic endoscopic approach was first described by Isaacs and colleagues to accomplish the same goals of reducing approach-related morbidity, but with tools and techniques more familiar to and readily adaptable by the minimally invasive spine surgeon [26]. Our study showed the feasibility and safety of using instrumentation developed for the eXtreme Lateral Interbody Fusion (XLIF) approach to treat a variety of pathologies including thoracic disc herniation, pathologic fractures from tumor, degenerative scoliosis, discitis, and adjacent level disease from prior fusions. The patient is positioned in the same way as for the thoracoscopic approach. The patient is then intubated with a single-lumen tube as the ipsilateral lung does not need to be collapsed for the procedure, allowing for both lungs to be ventilated throughout the procedure. A single 4 cm incision is made directly lateral to the level of interest, and the spine can be approached via either an extrapleural approach or transpleural approach. In the transpleural approach, the lung is deflated digitally and a dilator is slid down the posterior ribcage until it is safely docked on the spine. Sequential dilators are placed until a three-blade MaXcess XLIF-T system is inserted and docked on the spine with the help of fluoroscopy. An intraoperative photo of the mini-open transthoracic endoscopic setup is seen in Fig. 23.4. The view through the endoscope in the same setup is seen in Fig. 23.5. Limitations occur with tube technology as one proceeds more cephalad in the thoracic spine. Floating ribs do not provide a significant obstacle to distraction, but only limited intercostal distraction is possible as one moves higher into the thoracic spine. Some authors suggest using thoracoscopy to take down adhesions and directly visualize placement of the tubular retractor to avoid injury to the lungs [27]. Once the system is docked, a microscope can be used with bayonetted instruments to provide three-dimensional visualization of the anatomy, or a 30° endoscope can be inserted for visualization. A chest tube is inserted if the approach is transpleural. If the approach is extrapleural, a chest tube is not needed. If a chest tube is placed, it can be removed in the postoperative recovery room if a portable film shows no residual pneumothorax.

In a study by Uribe et al. examining the experience with mini-open transthoracic approach for disc herniation in 60 patients, the

Fig. 23.4 Mini-open transthoracic endoscopic equipment setup. The surgeon stands on the ventral side of the patient. At the top of the photograph is the patient's back. There are three blades with fiber-optic lighting attached to two blades. The discectomy can be seen in the bottom of the surgical site

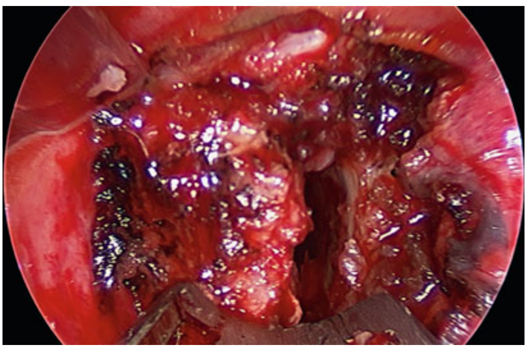

Fig. 23.5 Endoscopic view of the discectomy using a mini-open transthoracic endoscopic approach as seen with the same orientation and setup as in the photograph from Figure 23.4. The rib head overlying the disc space has been removed and the discectomy has been started

complication rate was 15 % compared to 28.4 % in previously reported minimally invasive approaches and 36.7 % in open approaches [28]. No patient in the study experienced intercostal neuralgia. Outcomes were consistent with previous reports in the minimally invasive literature with 80 % with excellent or good outcomes, 15 % unchanged, and 5 % with poor outcomes. This exceeds the reported outcomes for open approaches of 64.4 % with excellent or good outcome. The mini-open transthoracic approach avoids the approach morbidity of open thoracotomy while using techniques familiar to the minimally invasive spine surgeons, offering direct visualization of the ventral dura and achieving improved patient outcomes. Advantages of mini-open transthoracic endoscopic surgery over thoracoscopy are summarized in Fig. 23.6 and include surgeon familiarity with instrumentation, dual-lung ventilation, option of extrapleural dissection obviating the need for chest tube placement, and the freedom to choose endoscopic visualization or the use of the operative microscope with three-dimensional visualization. The disadvantages include inability to directly visualize retractor system placement and inability to take down pleural adhesions safely.

Both thoracoscopic and mini-open transthoracic endoscopic approaches have been applied to the treatment of idiopathic and degenerative thoracic spine deformity. Thoracoscopic anterior release has been used to treat large (>70° Cobb measurements) stiff curves, hyperkyphosis, or lordosis traditionally treated with open thoracotomy [29]. Sucato et al. described a technique of performing the thoracoscopic anterior release with the patient in the prone position, allowing for dual-lung ventilation and obviating the need to change patient position for the posterior instrumentation and fusion [30, 31]. The advantages of thoracoscopy over open thoracotomy for anterior release and fusion are decreased anterior operative time, decreased blood loss and chest tube drainage, and more complete disc excision with comparable correction of deformity and similar complication rates [32]. For an in-depth discussion of the indications and outcomes for treating idiopathic scoliosis with video-assisted thoracoscopic surgery (VATS), please refer to Al-Sayyad et al. retrospective Cincinnati series on 100 consecutive patients treated with VATS [33]. Degenerative, spondylitis, traumatic, and metastatic thoracic deformity have also been treated successfully with both thoracoscopic and mini-open transthoracic endoscopic techniques [26, 34, 35]. Kai-Michael Scheufler reported a series of patients treated with retropleural mini-open transthoracic endoscopic vertebral body replacement cages and ventrolateral plate fixation with equivalent correction of deformity, reduced perioperative morbidity and pain, expedited ambulation, no need

	Thoracoscopy	Mini-open transthoracic
Positives	Four 1–1.5 cm skin incisions Minimal retraction on the neurovascular bundle Direct visualization of intrathoracic approch and ability to take down pleural adhesions Internal counting of ribs for additional intra-op localization	One 4 cm skin incision Minimal retraction on the neurovascular bundle Tools are easily adapted by the spine surgeon familiar with the XLIF approach Flexibility of 2-D endoscope or 3-D operating microscope use Approach can be extrapleural, preventing need for a chest tube Dual lung ventilation during the case without need for lung collapse
Negatives	Step learning curve with instruments unfamiliar to the spine surgeon 2-D visualization Requires dual lumen ET tube intubation with lung collapse Thoracic spine cases are a minority making it difficult to maintain technical proficiency	Blind intrathoracic approach with risk of pleural injury there are adhesions Slightly more retraction of the ribspace is required as compared to thoracoscopy Narrower field of view of the intrathoracic anatomy

Fig. 23.6 Minimally invasive anterior thoracic approaches. Thoracoscopy and mini-open transthoracic endoscopic techniques have unique advantages and disadvantages but both offer decreased approached related morbidity as compared to conventional open thoracotomy

for chest tube placement, and earlier hospital discharge as compared to conventional open surgery [35]. These recent reports highlighted the ability to treat thoracic spinal deformity with minimally invasive techniques that achieve comparable deformity correction as compared to open thoracotomy with significant reduction in approach-related morbidity.

The surgical treatment of thoracic spinal pathology has evolved rapidly over the last 20 years. Thoracoscopic and mini-open transthoracic endoscopic approaches were developed from advances in optical and lighting technology to improve the safety and efficacy of thoracic spine surgery. Both techniques require appropriate training, practice, and continued use to maintain the operative skills learned. By adopting the thoracoscopic and/or mini-open transthoracic endoscopic whether with or without endoscopy techniques, today's minimally invasive spine surgeon can safely and effectively address anterior thoracic spine pathology and minimize the approach-related morbidity associated with open thoracotomy.

References

1. Perot Jr PL, Munro DD. Transthoracic removal of midline thoracic disc protrusions causing spinal cord compression. J Neurosurg. 1969;31(4):452–8. Epub 1969/10/01.
2. Burke TG, Caputy AJ. Treatment of thoracic disc herniation: evolution toward the minimally invasive thoracoscopic technique. Neurosurg Focus. 2000;9(4):e9. Epub 2006/07/13.
3. Rosenthal D, Dickman CA. Thoracoscopic microsurgical excision of herniated thoracic discs. J Neurosurg. 1998;89(2):224–35. Epub 1998/08/04.
4. Fessler RG, Sturgill M. Review: complications of surgery for thoracic disc disease. Surg Neurol. 1998;49(6):609–18. Epub 1998/06/24.
5. Bush RB, Leonhardt H, Bush IV, Landes RR. Dr. Bozzini's Lichtleiter. A translation of his original article (1806). Urology. 1974;3(1):119–23. Epub 1974/01/01.
6. Hc J. Possibility of the use of the cystoscope for investigation of serous cavities. Munchen Med Wochenschr. 1910;57:2090–2.
7. Miller JI, Hatcher Jr CR. Thoracoscopy: a useful tool in the diagnosis of thoracic disease. Ann Thorac Surg. 1978;26(1):68–72. Epub 1978/07/01.
8. Newhouse MT. Thoracoscopy: diagnostic and therapeutic indications. Pneumologie. 1989;43(2):48–52. Epub 1989/02/01.

9. Das K, Rothberg M. Thoracoscopic surgery: historical perspectives. Neurosurg Focus. 2000;9(4):e10. Epub 2006/07/13.
10. Mack MJ, Regan JJ, Bobechko WP, Acuff TE. Application of thoracoscopy for diseases of the spine. Ann Thorac Surg. 1993;56(3):736–8. Epub 1993/09/01.
11. Rosenthal D, Rosenthal R, de Simone A. Removal of a protruded thoracic disc using microsurgical endoscopy. A new technique. Spine. 1994;19(9):1087–91. Epub 1994/05/01.
12. Bohlman HH, Zdeblick TA. Anterior excision of herniated thoracic discs. J Bone Joint Surg Am. 1988;70(7):1038–47. Epub 1988/08/01.
13. Dickman CA, Rosenthal D, Karahalios DG, Paramore CG, Mican CA, Apostolides PJ, et al. Thoracic vertebrectomy and reconstruction using a microsurgical thoracoscopic approach. Neurosurgery. 1996;38(2):279–93. Epub 1996/02/01.
14. Oskouian Jr RJ, Johnson JP, Regan JJ. Thoracoscopic microdiscectomy. Neurosurgery. 2002;50(1):103–9. Epub 2002/02/15.
15. Lall RR, Smith ZA, Wong AP, Miller D, Fessler RG. Minimally invasive thoracic corpectomy: surgical strategies for malignancy, trauma, and complex spinal pathologies. Minim Invasive Surg. 2012;2012:213791. Epub 2012/08/14.
16. Visocchi M, Masferrer R, Sonntag VK, Dickman CA. Thoracoscopic approaches to the thoracic spine. Acta Neurochir (Wien). 1998;140(8):737–43; discussion 43–4. Epub 1998/11/12.
17. Rosenthal D, Marquardt G, Lorenz R, Nichtweiss M. Anterior decompression and stabilization using a microsurgical endoscopic technique for metastatic tumors of the thoracic spine. J Neurosurg. 1996;84(4):565–72. Epub 1996/04/01.
18. Khoo LT, Smith ZA, Asgarzadie F, Barlas Y, Armin SS, Tashjian V, et al. Minimally invasive extracavitary approach for thoracic discectomy and interbody fusion: 1-year clinical and radiographic outcomes in 13 patients compared with a cohort of traditional anterior transthoracic approaches. J Neurosurg Spine. 2011;14(2):250–60. Epub 2011/01/11.
19. Currier BL, Eismont FJ, Green BA. Transthoracic disc excision and fusion for herniated thoracic discs. Spine. 1994;19(3):323–8. Epub 1994/02/01.
20. Korovessis PG, Stamatakis MV, Baikousis A, Vasiliou D. Transthoracic disc excision with interbody fusion. 12 patients with symptomatic disc herniation followed for 2–8 years. Acta Orthop Scand Suppl. 1997;275:12–6. Epub 1997/12/31.
21. Otani K, Yoshida M, Fujii E, Nakai S, Shibasaki K. Thoracic disc herniation. Surgical treatment in 23 patients. Spine. 1988;13(11):1262–7. Epub 1988/11/01.
22. Ringel F, Stoffel M, Stuer C, Totzek S, Meyer B. Endoscopy-assisted approaches for anterior column reconstruction after pedicle screw fixation of acute traumatic thoracic and lumbar fractures. Neurosurgery 2008;62(5 Suppl 2):ONS445–52; discussion ONS52–3. Epub 2008/07/18.
23. McAfee PC, Regan JR, Fedder IL, Mack MJ, Geis WP. Anterior thoracic corpectomy for spinal cord decompression performed endoscopically. Surg Laparosc Endosc. 1995;5(5):339–48. Epub 1995/10/01.
24. McAfee PC, Regan JR, Zdeblick T, Zuckerman J, Picetti 3rd GD, Heim S, et al. The incidence of complications in endoscopic anterior thoracolumbar spinal reconstructive surgery. A prospective multicenter study comprising the first 100 consecutive cases. Spine. 1995;20(14):1624–32. Epub 1995/07/15.
25. Khoo LT, Beisse R, Potulski M. Thoracoscopic-assisted treatment of thoracic and lumbar fractures: a series of 371 consecutive cases. Neurosurgery. 2002;51 Suppl 5:S104–17. Epub 2002/09/18.
26. Karikari IO, Nimjee SM, Hardin CA, Hughes BD, Hodges TR, Mehta AI, et al. Extreme lateral interbody fusion approach for isolated thoracic and thoracolumbar spine diseases: initial clinical experience and early outcomes. J Spinal Disord Tech. 2011;24(6):368–75. Epub 2010/12/15.
27. Yanni DS, Connery C, Perin NI. Video-assisted thoracoscopic surgery combined with a tubular retractor system for minimally invasive thoracic discectomy. Neurosurgery 2011;68 (1 Suppl Operative):138–43; discussion 43. Epub 2011/01/06.
28. Uribe JS, Smith WD, Pimenta L, Hartl R, Dakwar E, Modhia UM, et al. Minimally invasive lateral approach for symptomatic thoracic disc herniation: initial multicenter clinical experience. J Neurosurg Spine. 2012;16(3):264–79. Epub 2011/12/20.
29. Newton PO, Wenger DR, Mubarak SJ, Meyer RS. Anterior release and fusion in pediatric spinal deformity. A comparison of early outcome and cost of thoracoscopic and open thoracotomy approaches. Spine. 1997;22(12):1398–406. Epub 1997/06/15.
30. Sucato DJ, Elerson E. A comparison between the prone and lateral position for performing a thoracoscopic anterior release and fusion for pediatric spinal deformity. Spine. 2003;28(18):2176–80. Epub 2003/09/23.
31. Sucato DJ, Erken YH, Davis S, Gist T, McClung A, Rathjen KE. Prone thoracoscopic release does not adversely affect pulmonary function when added to a posterior spinal fusion for severe spine deformity. Spine. 2009;34(8):771–8. Epub 2009/04/15.
32. Son-Hing JP, Blakemore LC, Poe-Kochert C, Thompson GH. Video-assisted thoracoscopic surgery in idiopathic scoliosis: evaluation of the learning curve. Spine. 2007;32(6):703–7. Epub 2007/04/07.
33. Al-Sayyad MJ, Crawford AH, Wolf RK. Video-assisted thoracoscopic surgery: the Cincinnati experience. Clin Orthop Relat Res. 2005;434:61–70. Epub 2005/05/03.
34. Krasna MJ, Jiao X, Eslami A, Rutter CM, Levine AM. Thoracoscopic approach for spine deformities. J Am Coll Surg. 2003;197(5):777–9. Epub 2003/10/31.
35. Scheufler KM. Technique and clinical results of minimally invasive reconstruction and stabilization of the thoracic and thoracolumbar spine with expandable cages and ventrolateral plate fixation. Neurosurgery 2007;61(4):798–808; discussion -9. Epub 2007/11/08.