



Surgical treatment of thoracic disc herniation: an overview

Charlie Bouthors¹ · Ahmed Benzakour¹ · Charles Court¹

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Abstract

Background Surgical treatment of thoracic disc herniation (TDH) is technically demanding due to its proximity to the spinal cord.

Methods Literature review.

Results Symptomatic TDH is a rare condition predominantly localized between T8 and L1. Surgical indications include intractable back or radicular pain, neurological deficits, and myelopathy signs. Giant calcified TDH (>40% spinal canal occupation) are frequently associated with myelopathy, intradural extension, and post-operative complications. Careful pre-operative planning helps reduce the risk of complications. Pre-operative CT and MRI identify the hernia's location and size, calcifications, and intradural extension. The approach must provide adequate dural sac visualization with minimal manipulation of the cord. Non-anterior approaches are favoured if they provide at least equal exposure than anterior approach owing to higher risk of pulmonary morbidity associated with anterior approach. A transthoracic approach is recommended for central calcified herniated discs. A posterolateral approach is often suitable for non-calcified lateralized TDH. Thoracoscopic approaches are less invasive but have a substantial learning curve. Retropleural mini-thoracotomy is an acceptable alternative. Pre-operative identification of the pathological level is confirmed by intra-operative level check. Intra-operative cord monitoring is preferable but warrant further studies. Magnification and adequate lightening of the surgical field are paramount (microscope, thoracoscopy). Intra-operative CT scan with navigation is becoming increasingly popular since it provides real-time control on the decompression. Indications of fusion consist of pre-operative back pain, Scheuermann's disease, multilevel resection, wide vertebral body resection (>50%), and herniation at thoracolumbar junction. Neurological deterioration, dural tear, and subarachnoid-pleural fistula are the most severe complications.

Conclusion Further improvements are still warranted in thoracic spine surgery despite the advent of minimally invasive techniques. Intra-operative CT scan will probably enhance the safety of the TDH surgery.

Keywords Thoracic disc herniation · Surgical treatment · Complications · Minimally invasive surgery · Thoracic spine approach

Introduction

Disc herniation is a subset of the degenerative spine disease characterized by loss of normal spinal structure and function affecting predominantly the lumbar spine [1, 2]. Symptomatic thoracic disc herniation (TDH) is a rare condition and thoracic spine surgery accounts for only 0.15 to 4% of the procedures performed for disc herniation [3, 4]. TDH has a particular

onset and progression mode with sometimes an impending risk of spinal cord compression. TDH surgery is challenging because of its technical difficulties as well as serious and hard-to-treat complications that may occur.

Generalities

Symptomatic TDH affects 1 in 1000 to 1 in 1000,000 people in the general population, accounting for 0.1 to 3% of all spinal disc herniation [3, 4]. Commonly, it affects the adults aged between 30 and 50 years old with equal distribution between genders. A history of trauma has been found in 3 to 37% of TDH cases. Scheuermann's disease patients are more susceptible to develop TDH [5]. The low incidence of thoracic disc herniation compared with lumbar herniations is mainly

✉ Charlie Bouthors
charlie.bouthors@hotmail.fr

¹ Orthopedic and Traumatology Surgery Department (Pr Ch Court), Bicetre University Hospital, Assistance Publique Hôpitaux de Paris, Paris-Sud University ORSAY, 78 Rue du Général Leclerc, 94275 Le Kremlin-Bicêtre, France

due to decreased mechanical demand and the splinting effect of the thoracic cage. Asymptomatic TDH is more frequent and evidenced incidentally in 11 to 37% of the imaging studies. TDH is located below the T7–T8 disc in 75% of the cases. Because of greater mobility and posterior longitudinal ligament at this level, the T11–T12 disc is the most exposed to degeneration. Only 4% of TDH are located above T3–T4 but it can occur as a complication of proximal junctional kyphosis following thoracolumbar posterior fusion [6]. Ossification of the posterior longitudinal ligament may have radiologic appearance that mimics a calcified disk prolapse. It may occur in a segmental fashion and cause thoracic cord compression [7].

Clinical features

Onset of TDH is usually progressive. Its diagnosis is made a mean 15 months within the first symptoms [3]. Thoracic back pain is the chief complaint present in 92% of the cases. Cervical pain may be symptomatic of TDH above T5 whereas lumbar pain may be experienced in TDH below T10. Stubborn headaches due to meningeal tension are less common. Scapular pain may be produced by T1–T2 locations with sometimes T1 radicular pain and Horner's syndrome due to T1 nerve root impingement [8].

In the setting of progressive spinal cord compression, both sensory and motor dysfunction may occur corresponding to either a lesional syndrome (intercostal or abdominal radicular pain) or a sub-lesional syndrome. Often, presentation is atypical and encompasses more subjective symptoms such as ataxia (spino-thalamic tract), motor deficit in the lower limbs (pyramidal tract), and bladder symptoms. Some cases of sudden onset of neurological deficits have been described following trauma [3]. A few rare cases of transient or permanent paraplegia caused by occlusion of the anterior spinal artery by a central TDH were reported [9]. As described below, calcified TDH presents in 70 to 95% of the cases with myelopathy signs. Of note, radicular pain can mimic visceral pathology and further delay the diagnosis [10].

The thoracic spinal cord is particularly vulnerable owing to (1) potential intradural extension generating cord compression, (2) thoracic kyphosis pushing the cord against the disc, (3) denticulate ligament reducing cord mobility, (4) large thoracic cord diameter (6.5×8 mm) in relation to spinal canal diameter (16.8×17.2 mm), and (5) a poorly vascularized area in the cord (watershed zone).

Imaging modalities

Plain films may be useful in case of calcified protrusion (Fig. 1a, b). A whole-spine imaging must be obtained to rule out concomitant cervical and/or lumbar spine disc herniation/

canal stenosis. MRI and/or CT myelogram are equally important in determining exactly which vertebral segment is involved. Thoracic CT scan is obtained to evaluate the nature of the disc which can be soft (non-calcified) or hard (calcified) (Fig. 1c, d) Hernia location is analyzed, especially for surgical considerations, and can be described as central, posterolateral, lateral, or far lateral. Signs of myelopathy are best identified on MRI scan (intradural low signal on T1-weighted and hyper signal on T2-weighted sequences).

Calcification or even ossification [11] are frequent in TDH (Fig. 1). Calcified hernia was seen on 42% of the cases in a series of 168 TDH surgical patients [3]. The calcification mechanism remains unknown. Rarely, calcified hernia corresponds to a nucleus pulposus extension which is itself calcified. Those herniations may sometimes regress spontaneously [12].

The volume of herniated disc can be measured by either CT or MRI scan. A particular entity is the giant thoracic disc herniation (Fig. 1) defined as compromising more than 40% of the spinal canal as measured on axial computed tomography (CT) by Hott et al. [4]. This subset of TDH has frequently calcification and intradural extension (15–75%) causing myelopathy [13].

Nowadays, a significant amount of TDH are diagnosed incidentally due to the widespread use of MRI. TDH can be large but asymptomatic and without myelopathy signs. Those case are challenging due to the risk of progression, hence warrant regular clinical and imaging-based follow-up.

In case of surgery, we obtain a pre-operative arteriography in order to identify the dominant thoracolumbar artery (Adamkiewicz). Adamkiewicz's artery is the largest anterior medullary vessel supplying the spinal cord. Its location guides the choice in the side of a transthoracic approach. In fact, Adamkiewicz' artery usually arises from the left side between T9 and L1 [14], most common TDH location [15]. However, no clear benefit of this imaging study has been reported in the literature. Its invasive nature can be avoided by performing MR angiography (MRA) which unfortunately has limited resolution [16].

Surgical strategy

Surgical indications

Most patients will respond favourably to non-operative management, especially in case of isolated back pain or isolated radicular pain due to intercostal nerve root entrapment.

Surgical treatment for TDH is indicated if patients fail conservative measures (persistent axial back pain or intractable radiculopathy) and/or if they present with worsening neurological symptoms. According to us, certain patients in which myelopathy signs are evidenced on the MRI, even in the absence of neurological symptoms, may benefit from surgical

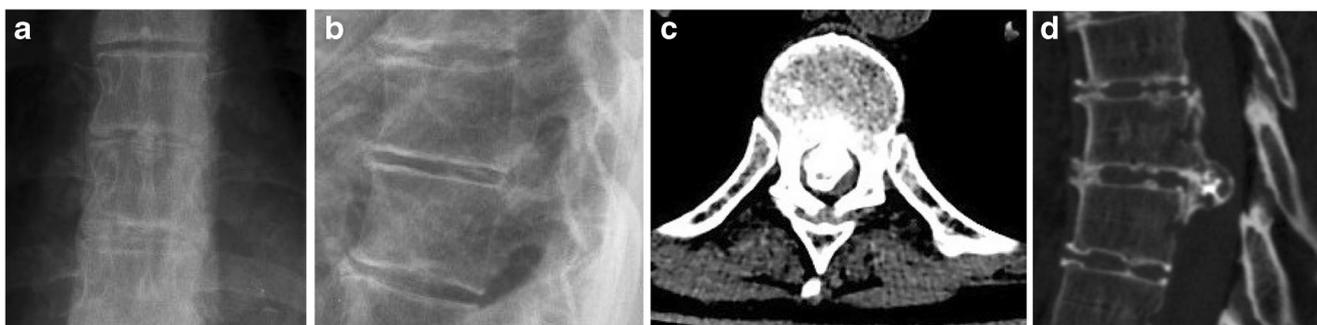


Fig. 1 T7/T8 giant calcified thoracic disc herniation. **a** Posteroanterior XR showing calcified disc with image projection between T7 and T8 spinous process. **b** Lateral XR showing calcified disc at the posterior

edge of the T7/T8 disc space. **c** Axial CT cut illustrating a giant calcified T7/T8 TDH that involves 90% of the spinal canal diameter. **d** Sagittal CT cut showing the same giant calcified T7/T8 TDH

treatment before symptoms appear or worst, become irreversible.

Prognostic factors for poor surgical outcomes in patients with myelopathy include longer pre-operative duration of symptoms, worse preoperative symptoms, ossification of posterior ligament or liamentum flavum, and large operative blood loss [17].

Pre-operative surgical level definition

Wrong level operation is not infrequent in thoracic spine surgery. Pre-operative surgical level definition may not be necessary in case of calcified hernia clearly visible on fluoroscopy. If not, various marking techniques have been described: (1) identification of adhesive radiographical markers on skin on sagittal MRI [18], (2) percutaneous needle injection of methylene blue dye into tissues surrounding the spinous process confirmed by AP radiograph [19], (3) vertebroplasty with PMMA [20], (4) micropuncture needle advanced to periosteum and coil deploying [21], (5) flexible hook-wire insertion into periosteum under CT guidance [22], and (6) intra-operative percutaneous K-wire placement into medial pedicle wall under image guidance [23].

In our department, a landmark is placed by the radiologist the day before the surgery at the superior edge of the rib leading to the herniated disc. Another method is to perform a coil injection during pre-operative arteriography in the intercostal artery at the pathological level (Fig. 2). Careful attention to counting spinal levels and ribs on pre- and peri-operative radiographs, as well as identifying osteophytes and other landmarks (Fig. 1) are all additional steps of the level check. Pre-operative level marking may be avoided by the use of intra-operative CT scan which provides accurate intra-operative level identification.

Intra-operative neurological monitoring

A study showed that severity of myelopathy correlated significantly with pre-operative abnormal spinal cord evoked potentials (SCEP), and early recovery of intra-operative SCEP may also predict neurological improvement [24]. However, there is

no consensus as to whether thoracic discectomy should be performed under intra-operative neurological monitoring. Some authors reported a reduction in the risk of permanent neurological deficit when using somatosensory evoked potentials (SEPs) in thoracic disc surgery and therefore recommended its use [25]. A study on high-risk TDH operated through anterior trans-thoracic surgery using motor evoked potentials (MEPs), showed that MEP signal deterioration had 100% sensitivity and 75% specificity [26]. In 2007, an expert panel proposed these indications for intra-operative MEPS in spine surgery: extensive anterior and/or posterior cervical spine decompression for spinal stenosis, thoracic and lumbar spine pathology causing myelopathy or cauda equina syndrome [27].

We advocate the use of intra-operative monitoring of the spinal cord during thoracic disc surgery especially in case of large and calcified herniation. Therefore, pre-operative evoked potentials are requested and serve as a baseline to timely identify spinal cord signal deterioration.

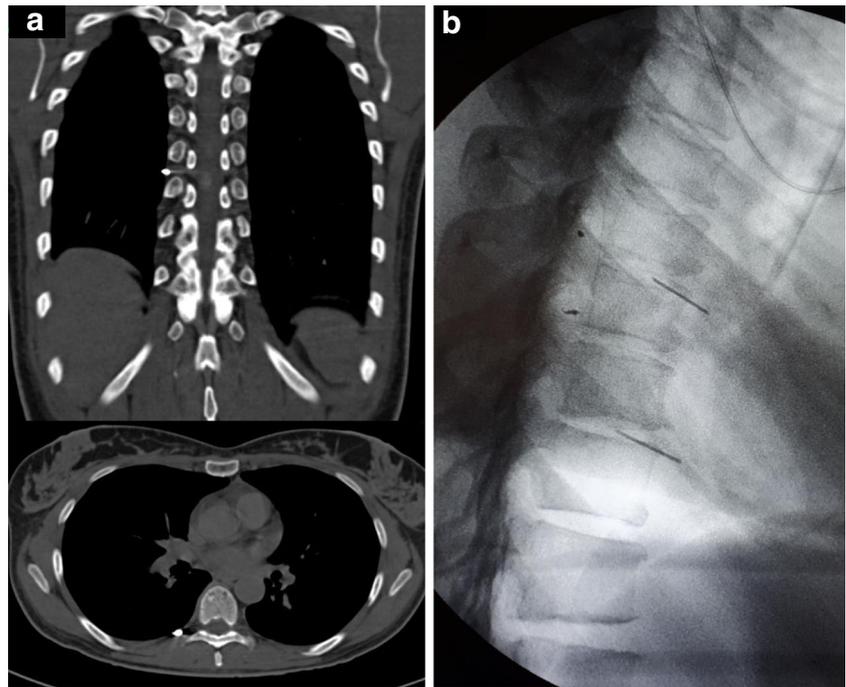
Intra-operative optical magnification

Adequate visualization through intra-operative magnification is paramount for dissecting the disc herniation off the dura. Thoracoscopy magnified the surgical field and provide good in situ lighting. Lung, aorta, and azygos vein can be safely controlled. We favour the direct binocular view of a microscope which not only provides excellent lighting and considerable magnification but also reduces the working distance. Some authors recommended to use both methods to enhance the safety of the approach [28]. Since locating the posterior edge of the herniated disc in relation to the spinal canal may be difficult intra-operatively, assessment of the decompression is further controlled by fluoroscopy. Certainly, the most accurate option is intra-operative CT navigation [29].

Surgical approaches and techniques

The optimal approach provides adequate decompression through minimized manipulation of an already compromised

Fig. 2 Pre-operative level identification by coil injection in the intercostal artery at the level of TDH (T5/T6). **a** Coronal view (above) and axial view (below) of the pre-operative CT after coil injection in the right intercostal artery at the T5/T6 level. **b** Intra-operative level check with lateral fluoroscopy showing the coil injected at the T5/T6 level



thoracic spinal cord. Posterior approach to perform laminectomy and thoracic discectomy has been abandoned overtime due to high rate of post-operative neurological deficits. Currently, spinal surgeons used three types of approaches: (1) posterolateral, (2) lateral, and (3) anterior approach.

Due to the evidence of increased in-hospital morbidity and mortality rates as well as health care burden, some authors have advocated the use of non-anterior approaches if they allow adequate hernia excision [30]. The last two decades has seen the application of minimally invasive methods in TDH surgery with the objective to reduce critical care requirements and discharge times. However, they are often technically demanding and invariably associated with learning curves.

Posterolateral approach

Posterolateral approach (Fig. 3a) is indicated in case of soft (non-calcified) lateral and posterolateral hernias [31] or multilevel compression from ossification of the posterior longitudinal ligament [32]. Patient is in prone position and skin incision is straight. Pedicle screws may be inserted. After lamina and transverse process exposure, unilateral or bilateral arthrectomy provides access to the disc space. Depending on the extent of the hernia, pedicle can be either preserved (transfacet pedicle-sparing) [33, 34] or burred (transfacet transpedicular) [35]. A hemilaminectomy may be also performed, which allows for visualization of the lateral aspect of the spinal cord. Ligature of the corresponding nerve root may be associated if required to facilitate the decompression. Thecal sac and designated disc are visualized from an oblique

angle. Discectomy is initiated. Anterior part of the dura can be separated from the hernia. The herniated portion of the disc is pushed down into the cavity created during initial discectomy. If the dura cannot be separated from the calcified disc, Kato et al. recommend to leave the calcified shell on the dura to avoid fistula formation [32] (Fig. 4b). Decompression is usually deemed complete with exposure of the superior pedicle wall of the caudal level and the inferior pedicle of the rostral level. Fusion is commonly performed at the end of the procedure.

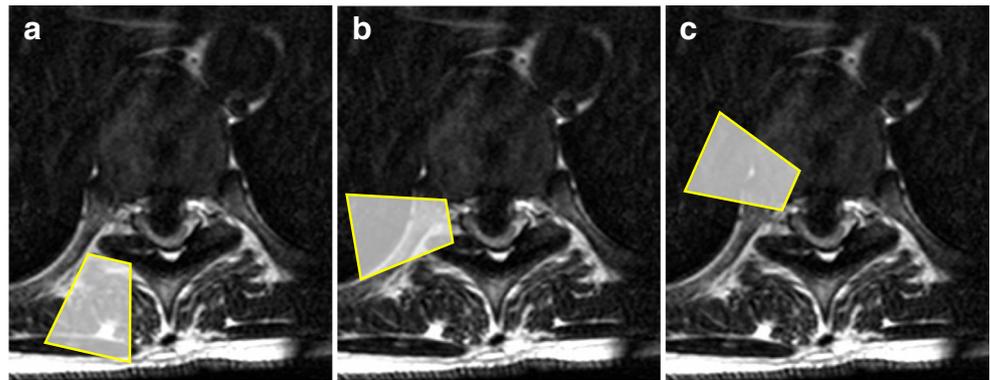
Xiaobing et al. [36] have recently described a new technique of endoscopic thoracic discectomy where decompression is performed through percutaneous transforaminal approach similarly to the technique describe for the lumbar spine [37]. They reported significant post-operative improvement in the JOA scores among the 14 patients and two cases of dural tear. Owing to minimal bony resection, no fusion was deemed necessary.

Lateral approach

Lateral approaches provide dorsal and unilateral ventrolateral access to the spinal cord while allowing for posterior instrumentation through the same incision. The retropleural costotransversectomy was popular up to the 1980s since it provides a more lateral access than the posterior approach. Because of its damaging nature for the tissue, costotransversectomy was later abandoned.

Introduced in 1976, the lateral extracavitary approach (LECA) has the advantage to offer a more central view than the posterolateral approaches without the drawbacks the

Fig. 3 Access provided by the three principal approaches to the thoracic spine. **a** Posterolateral approach. **b** Lateral approach. **c** Anterior approach



anterior approaches [38] (Fig. 3b). Patient is in prone position and skin incision is curvilinear. A midline ipsilateral dissection is proceeded laterally to identify the facet complex and rib head at the pathological level. Pedicle screws may be inserted. The rib head belongs to the rib of the inferior level of the pathology (e.g., for T8–T9 pathology, the T9 rib head would be at the level of the pathology). Vertical dissection is performed under the latissimus dorsi muscle along the dorsal side of the ribs to allow muscle mobilization for rib resection. Superior-most portion of the rib is at the superior intervertebral disc space. Care is taken to preserve the neurovascular bundle which can be sacrificed for additional exposure. Surgeon can work beneath the latissimus bundle to obtain exposure to the lateral and ventral aspect of the thoracic spinal column. Ipsilateral facet complex, transverse process, and proximal rib head are resected. Under microscope, ipsilateral hemilaminectomy allows exposure of the dorsal and lateral aspects of the thecal sac from rostral to caudal pedicle. By working under the lateral edge of the thecal sac, the disc space can be directly visualized. Surgeon drills both above and below the disc space toward the ventral midline of the ventral

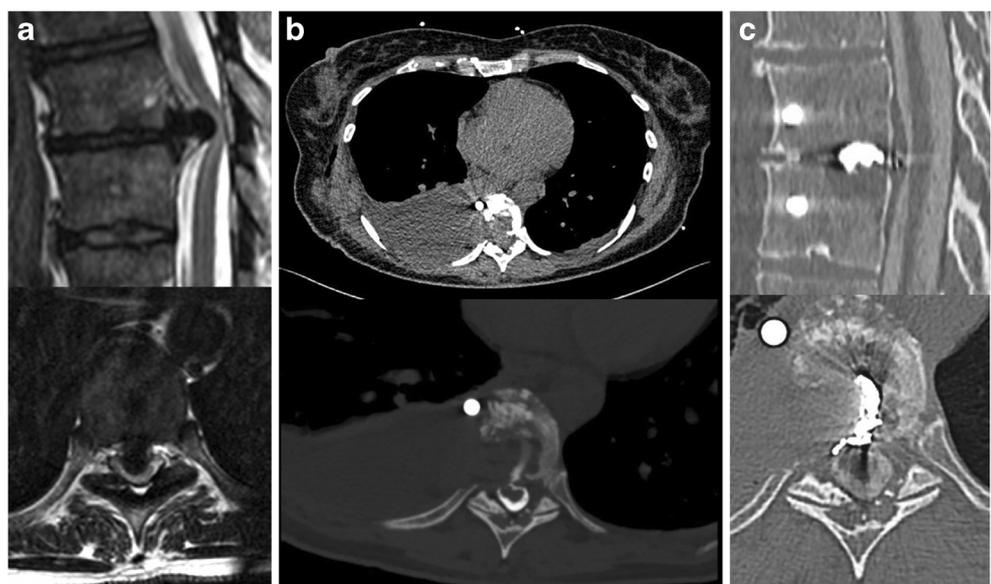
midline of spinal canal, thus accomplishing partial unilateral vertebrectomy on each side. The eggshell-thin remaining cortical mantle and calcified shell of the hernia are then pushed into the bony dissection cavity. After the decompression, grafting of the defect can be realized.

Anterior approach

Anterior approach provides an unparalleled ventral exposure of the spinal cord (Fig. 3c), which not only creates a safe working channel adjacent to the spinal cord but also provide the optimal angle for removal of central and/or calcified hernia (Figs. 1, 4). It also permits multiple levels to be addressed via the same approach [39]. The amount of bone removal required to access the disk will not affect stability. Because of the thoracotomy, this approach is thought to be more invasive than non-anterior approaches and therefore may not be suitable for patients with significant comorbidities. Risk of injury to major vascular structures is also present.

The approach is usually performed on the opposite side of the Adamkiewicz's artery. A selective intubation is required

Fig. 4 Case of T9/T10 transthoracic discectomy complicated by right CSF-pleural fistula. **a** Sagittal view (above) and axial view (below) on MRI of a T9/T10 TDH prior to surgery. **b** CT scan showing a right pleural effusion (above) and CT myelogram showing dural tear with CSF leakage in disc space (below). **c** CT myelogram post interventional radiologist procedure. Axial cut (below) showing coil injection (Onyx) to seal the tear. Sagittal cut (above) showing adequate decompression



since the lung is deflated on the side of the approach to allow for good exposure of the spine and vascular structures. Patient is placed in lateral position. A curve incision is made over an interspace, two levels above the rib corresponding to the disk space involved. Rib is resected subperiosteally and may be used as graft if required. Under microscope, parietal pleura over the vertebral bodies is incised longitudinally. Care must be taken to preserve the intercostal bundle, sympathetic chain and azygos vein. The right thoracic lymphatic duct may be unintentionally divided but chyloma is an infrequent complication. Most of the rib head is drilled away as well as the vertebral bodies adjacent to the disc space. The lateral aspect of the annulus is excised to access and work on the disc space. Osteophytes arising from the posterior aspect of the discovertebral junction are fractured back into the disc space. The posterior longitudinal ligament is incised to ensure excision of all migrating disc fragments. At the end of the procedure, a channel should cross virtually the entire width of the spinal canal (Fig. 3). The use of a navigated drill gives a real-time virtual feedback on the decompression. The intraoperative post decompression CT scan acquisition is a real advantage to control the adequacy of the decompression especially in case of calcified disc herniation [40].

Retropleural approach has less morbidity than transpleural approach but still provides a direct approach to the thoracic spine [41]. The pleura is preserved, which acts as a barrier between the operated area and the thoracic cage. It avoids the lung-related consequences of the transpleural approach and the need of post-operative chest drain.

The risk of pulmonary morbidity has led to the development of thoracoscopic surgery which unfortunately does not offer ideal magnification. Therefore, thoracoscopy is preferentially indicated for small and non-calcified hernias located between T4 and T11, in not morbidly obese patients, who had never undergone previous thoracic surgery [42]. Efficacy and safety of the thoracoscopic discectomy have been reported as comparable to the open approaches [43].

Open mini-thoracotomy has been developed to override the challenges of thoracoscopy and decrease the morbidity associated with thoracotomy. Russo et al. believe that microsurgical mini-thoracotomy is the best approach for large TDH [44]. Bartels and Peul concluded that open mini-thoracotomy provides the same results as thoracoscopy when treating calcified thoracic hernia [45]. Some authors have advocated to combined endoscopic to mini-open surgery to increase safety with minimal trauma [46].

Indications for fusion

Unilevel anterior thoracic surgery does not necessarily require fusion since the approach should disrupt only the middle column of the thoracic spine, following Denis' three-column

theory. The intact anterior and posterior columns should thus stabilize the thoracic spine [47].

We tend to fuse patients who complain of severe thoracic back pain preoperatively. Patients with multilevel discectomy, with discectomy at the thoracolumbar area, or with Scheuermann disease may also need fusion [48, 49]. Otherwise, decision to perform arthrodesis is mainly based on the amount bone and disc that is removed [49, 50]. Interbody fusion may be necessary in case of wide resection of the vertebral body (> 50%), disc, and rib through anterior and lateral approach.

Fusion is also recommended in posterior approaches when arthroctomy is extended to pedicle. All these approaches allow for placement of pedicle screws and rods. Conversely, fusion may be avoided in transfacet pedicle-sparing approach by preserving the lateral aspect of the articular facet. Patients with previous laminectomy, kyphosis deformity, and osteoporosis may warrant fusion to prevent further deterioration.

Complications in thoracic disc surgery

Complication rate in thoracic disc surgery ranges from 20 to 30% [43, 51]. Anterior approaches seem to yield more complications than non-anterior approaches. Yoshihara et al. analyzed 25,413 patients of an American database who underwent surgical treatment for TDH between 2000 and 2009 [30]. In comparing anterior approach (22.4%) to non-anterior approaches (77.6%), they found higher complications rate (26.8% vs. 9.6%) and mortality rate (0.7% vs. 0.2%) associated with anterior approach. Also, they found in this group longer hospital stay (7.6 vs. 4.8 days) which resulted in higher costs (US\$84,199 vs. US\$46,837). However, type of disc herniation was not analyzed in this study which may have introduced a bias knowing that giant calcified TDHs are treated commonly through anterior approach.

Certainly, surgeon's experience influences the surgical outcomes since all these techniques are associated with a learning curve. In thoracoscopic surgery, Quint et al. reported a higher complication rate early in his practice compared to the latter stage (23% vs. 15%) [3].

Neurological deterioration

Studies reported a post-operative deterioration of the neurological condition at a rate of 2 to 5% regardless of the approach. Laminectomy had the worst neurological complication rate and therefore is no longer performed. Patients must be counseled preoperatively over the risk of neurological complications which can be severe (monoplegia, paraplegia). Pathogenesis of these deficits is unknown although several hypotheses have been suggested: medullary inhibition, spinal shock, medullary contusion, or vascular impairment. Patients with giant calcified TDH and

pre-operative neurology are the most at risk. Post-operative imaging requested to explore these complications may be difficult to interpret due to the usual post-operative haematoma (Fig. 5b, c). Recovery is possible in these cases. In our experience, all cases of neurological deficit recovered almost completely. One case of complete sensory and motor paraplegia recovered in a few months (Fig. 5).

Prevention of neurological deficits is based on several recommendations: (1) selecting the best approach that provides excellent exposure of thecal sac with minimum manipulation of the cord, (2) utilizing of microscope for magnification, (3) maintaining average systolic blood pressure around 80 mmHg for spinal cord protection, and (4) injecting high doses of corticosteroids at the start of the procedure [52].

Dural tear

Incidence of CSF leakage has been reported to range from 0 to 15% in published series. It is more common in thoracoscopic surgery. Cause can be either iatrogenic or related to intradural disc herniation. Pre-operative CT coupled with MRIs should be obtained for identifying the presence of calcification within the disc and possibility of intradural disc herniation. Risk of dural tear is higher with calcified disc for two reasons: they often invade the dura and their calcified shell adheres firmly to the dura. Gille et al. reported a 39% rate of dural tear in the treatment of giant calcified TDH by thoracoscopy [53]. In order to reduce this risk, it is recommended to leave a thick layer of hernia's shell against the dura (Fig. 5b).

If left untreated, anterior breach may result in the development of subarachnoid-pleural fistula (Fig. 4b) secondary to the aspiration created by intrapleural negative pressure (between -2 and -8 cm H₂O). Such a fistula cannot spontaneously seal itself. It is detected based on thoracic and/or neurological

signs. Thoracic signs include thoracic pain, dyspnea, tachypnea, or coughing in the case of profuse pleural effusion. This fistula can be confirmed measuring b2-transferrin levels in the pleural fluid with a sensitivity of 94 to 100% and a specificity of 98 to 100%. In some cases, the fistula is initially asymptomatic. If radiological monitoring is not performed regularly to look for pleural effusion (Fig. 4b), it can manifest itself suddenly. A chest CT scan will show the large pleural effusion volume. Neurological signs like headache, vertigo, and nausea and development of diplopia after several days or weeks due to paralysis of the VI cranial nerve related intracranial hypotension [54]. Brain CT shows a reduction of ventricle dimensions. Consciousness deterioration secondary to intracranial haemorrhage is possible at a more advanced stage.

Revision is required in 50% of the cases. Management of persistent CSF leaks often involves some combination of primary or graft closure [55], fibrin glue application, and lumbar continuous lumbar draining (10 mL/h or 300 mL/day) or by repeated lumbar puncture (spinal tap). To avoid surgical revision, some cases may be managed by the interventional radiologist (Fig. 4). We have successfully treated two cases by percutaneous coil injection in the disc space to seal the dural tear [56]. For such procedure, origin of the CSF leakage must have been identified by CT myelogram.

Thoracic drainage must be done with very little to no depression. Ventilation with positive and expiratory pressure (PEEP) is assured post-operatively while patient is intubated and followed by continuous positive airway pressure after being extubated.

Intercostal neuralgia

With a rate ranging from 17 to 21% [57, 58], this is a common complication especially in approach that involves rib

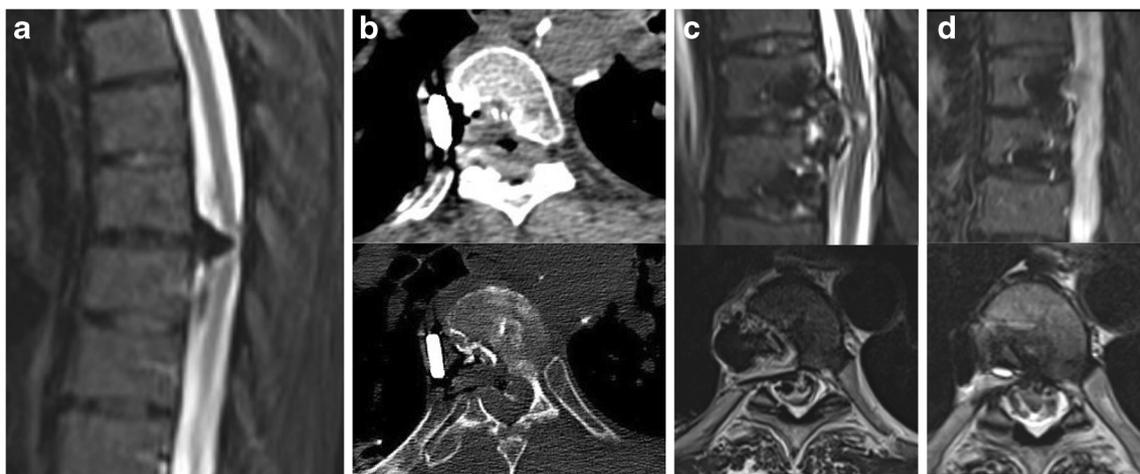


Fig. 5 Case of patient with post-operative paraplegia following T8/T9 transthoracic discectomy who recovered spontaneously. **a** Sagittal MRI view of a T8/T9 TDH compressing on the spinal cord. **b** Immediate post-operative CT showing calcified hernia' shelf left attached to thecal sac

(below) and no evident residual compression despite post-operative haematoma affecting signal. **c** Immediate post-operative MRI showing cord edema (above) and false aspect of residual compression. **d** Post-operative MRI at 1 year showing adequate decompression

resection. Care should be taken to carefully dissect the intercostal neurological bundle when resecting the rib. Cases following thoracoscopy are usually regressive. Dietz et al. [47] have advocated the use of mini lateral extracavitary approach to preserve the neurovascular supply and minimize intercostal nerve retraction and injury.

Lung-related complications

Lung-related complications are associated primarily with anterior approach but may occur with the other approaches [59]. Occurrence was not reduced significantly when comparing thoracoscopy to mini-thoracotomy. Most of them are reversible but result in prolonged hospital stay. They include atelectasis, pneumonia, pleural effusion, and pulmonary embolism. Cases of pleural effusion by CSF-pleural fistula following transthoracic discectomy were reported and required re-exploration, dural closure, and application of fibrin glue [60]. Obviously, pleural tear cannot be classified as complication of transthoracic discectomy which involves a pleural disruption managed by chest tube placement at the end of the surgery. However, it can occur unintentionally in 13% of the lateral extracavitary approach [61]. In such case, Dietze et al [47] have recommended filling the operative field with saline prior to wound closure, as the presence of air bubbles would indicate a pleural rent. If present, a paediatric chest tube is then placed and brought out dorsolaterally behind the musculocutaneous flap.

Incomplete disc resection

Re-operation may be required in case of incomplete disc resection. The most difficult hernia to resect are calcified, large, broad-based, centrally located, or transdural thoracic disc herniations [62]. Centrally located and calcified discs are best resected through a ventral transthoracic approach which provides a non-oblique line of sight [43]. Transpedicular and lateral extracavitary approaches should be avoided in such lesions. In all cases, removal of the posterior ligament assists in ensuring complete spinal cord decompression [47]. Certainly, intra-operative CT scan will prove to be the most useful tool to control the decompression.

Conclusion

Although rare, TDH is an anatomically challenging condition. Deteriorating neurological symptoms and/or myelopathy signs are surgical indications. Rigorous pre-operative planning and choice of the optimal approach will reduce the risk of post-operative complications. Minimally-invasive spine surgery has led to substantial improvements in thoracic disc surgery but further developments are still warranted.

Compliance with ethical standards

Conflict of interest C. Bouthors and A. Benzakour declare that they have no conflict of interest. Ch. Court has received financial supports from Medtronic® and Safe Orthopedics® for educational programs and has investment interest in NeuroFrance® and SpineGuard®.

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