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REVIEW ARTICLE

Thoracic disc herniation, avoidance, and management of the surgical complications

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Abstract
Thoracic disc herniations are a relatively rare occurrence compared to disc herniations in the cervical or lumbar spine. Surgical management of these thoracic herniations can be technically difficult with a wide array of reported complications. In this study, we aim to describe the most common complications that can occur during or after surgical management of thoracic disc herniations. Furthermore, we describe tips and tricks for avoidance and, if necessary, management of surgical complications. Common complications addressed in this review include vertebral column instability, neurologic injury, cerebrospinal fluid leak/pleural fistula, thoracic viscera injury, wrong level surgery, incomplete disk resection, and intercostal neuralgia.

Keywords Thoracic disc herniation · Complications · Avoidance of complications · Management of complications · Thoracic spine surgery

Background

Thoracic disc herniations represent only a small percentage of symptomatic intervertebral pathology [1]. Although cadaveric studies show higher incidence rates post-mortem, the currently accepted rate of clinically symptomatic thoracic disc herniations is between 1 in 1000 and 1 in 1000,000 patient-years [1, 2]. One potential difficulty in diagnosing these herniations is the wide spectrum of presenting symptoms [3]. The traditional method for surgical management of thoracic disc herniations was a standard posterior thoracic laminectomy, with early reported results demonstrating alarmingly high rates neurologic injury [4, 5]. In an effort to decrease the complications associated with management of these herniations, a wide array of surgical approaches have been described over a 40-year period in the mid to late twentieth century [6–12]. Currently, the accepted surgical approaches for access to thoracic disc herniations include transpedicular, costotransversectomy, pedicle-sparing transfacet, lateral extracavitary, and transthoracic approaches including video-assisted thorascopic discectomy [6–9, 11, 13–17]. With these advancements in surgical techniques, complication rates have decreased. However, complications including destabilization of the vertebral column, neurologic injury, incomplete resection, wrong level surgery, cerebrospinal fluid (CSF) leak, thoracic viscera injury, infection, intercostal neuralgia, and death can still occur [9–11, 18]. The purpose of this review is to highlight the most common complications associated with the surgical management of thoracic disc herniations as well as strategies to both avoid and manage these complications should they arise.

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Vertebral column instability

In the available literature, most reports of vertebral column instability occur following transthoracic approaches to disc herniations [6, 10, 11, 19]. This is biomechanically counterintuitive as the anterior and posterior columns of the spine should be unaltered [1]. This led to the hypothesis that patients with previous decompressive surgery may be at an increased risk of

vertebral instability following iatrogenic damage to the middle column support structures [6, 15, 16, 19–21]. Several studies have investigated the role of aggressive resection and subsequent instability [22, 23]. Animal models show that resection of the rib head and concomitant removal of the intervertebral disc leads to increases in lateral bending, axial rotation, and anterior–posterior translation of the thoracic spine [23, 24]. Another factor to keep in mind when treating patients for thoracic disc herniations is preexisting disorders portending spinal column instability preoperatively [1, 10, 20, 25]. As stated above, previous surgery compromising the posterior structures, in conjunction with a costotransversectomy approach to a disc herniation, would result in loss of the rib support and middle and posterior columns [21, 22, 24]. Similarly, patients with osteopenia or osteoporosis may be at higher risk for thoracic vertebral compression fractures following decompression surgery which could lead to progressive thoracic kyphosis [10, 19]. Pre-operative assessment of the patient's thoracic sagittal balance is important to take into consideration. Resection of the stabilizing structures of the thoracic spine has been proven to increase the mobility in all planes [20, 23]. A pre-existing kyphosis could be acutely worsened if the limited support structures are damaged or removed intra-operatively. As an example, Currier et al. reported a patient that developed progressive focal kyphosis following a transthoracic discectomy with interbody fusion and found that a previous multilevel laminectomy had been performed [6].

The management of vertebral column instability following resection of a herniated thoracic disc focuses on realignment and restoration of physiologic anatomy. A common dilemma following thoracic disc resection focuses on which patients need arthrodesis to prevent instability. In simple terms, if an articular facet is violated during selected surgical approach to disk resection, fusion is often necessary [26]. Several additional indications have been described for post-discectomy arthrodesis. Several studies have described the necessity of instrumented arthrodesis following disk resection in the low thoracic region or thoracolumbar junction, as well as in patients with Scheuermann's kyphosis [10, 27]. Similarly, in the case of giant or calcified disc herniations where partial corpectomy is performed to avoid excessive cord manipulation, arthrodesis is utilized to prevent instability, especially if more than 50% of the vertebral body is resected (Fig. 1) [28]. Finally, if the patient with a herniated thoracic disc has pre-operative axial back pain with evidence of facet arthropathy, arthrodesis can be utilized to immobilize that arthritic segment and improve a potential pain generator [26, 28]. In contrast, a lateral approach that does not disrupt the integrity of the lateral aspect of the pedicle does not necessarily require arthrodesis. Furthermore, when utilizing anterior based approaches, it has been proven that unilateral disruption of the rib head and pedicle, does not necessarily cause instability and does not require fusion [29]. The authors recommend use of posterior spinal fusion with or without the use of an interbody device depending on necessity of sagittal plane correction needed if postoperative instability is a concern.

Fig. 1 T2-weighted sagittal MRI of large thoracic disc herniation with cord compression

Neurologic injury

Classically, neurologic injury represented the most common complication in the management of thoracic herniated discs with some series reporting as high as 75% rate of incidence [5, 30]. Over the decades following these initial reports, the traditional posterior laminectomy approach to these herniations was largely replaced with safer approaches and the incidence of neurologic injury dropped significantly [7]. One factor leading to increased risk of intra-operative nerve damage is whether the herniated disc is calcified [31–33]. Quint et al. looked at the their experience with surgical management of 168 symptomatic thoracic disc herniations and found a 42% rate of calcification or ossification of resected disc material [33]. While intradural invasion of disc material is exceedingly rare in soft herniations, it is reported that upwards of 70% of giant calcified herniations have some extent of intradural involvement [32]. Thus, the most common pre-operative presentation associated with increased risk of intra-operative neurologic injury is the presence of a giant (> 40% of spinal canal) calcified disc with radicular or myelopathy symptoms [26]. Recent studies report neurologic injury between 2 and 5% with no significantly increased risk with any one approach technique [34, 35].

Avoidance and management of neurologic injury is largely dependent on pre-operative imaging assessment and formulation of surgical plan. For large herniations with intradural extension, surgical approach and laterality can be helpful at finding the safest access plane to the dural tube. The authors recommend use of an extensile approach for this subset of

herniations, including a transthoracic or costotransversectomy. Utilizing an extensile approach, as opposed to transfacet or transpedicular, has been shown to reduce risk of iatrogenic neurologic injury [9, 31]. Vascular underperfusion following cord manipulation can lead to neurologic deterioration and thus, interdisciplinary planning with the anaesthesia providers regarding controlled hypertension can help prevent downstream sequelae [3, 13, 32, 36]. At the time of dural manipulation, a mean arterial pressure (MAP) of 80 mmHg can ensure adequate perfusion following necessary dural manipulation for disc resection. Additionally, some authors report the use of high dose systemic corticosteroids to mitigate the risk of inflammatory neurologic deterioration [36].

From an intra-operative perspective, the authors recommend routine use of neurologic monitoring for the duration of the case including somatosensory evoked potentials (SSEP) and motor evoked potentials (MEP). The use of intra-operative neuromonitoring has been well validated in the available literature to avoid neurologic injury and assess pre-operative surgical risk [3, 37].

Finally, from a technical standpoint, the authors utilize a partial vertebrectomy technique to safely resect large calcified herniations. Once the appropriate level is localized and the vertebral body is identified, a cavity is created in order to directly visualize not only the disc material but native dura above and below the herniation. It is critically important to create a circumferential cavity around the entirety of the disc both ventrally and laterally to ensure no untoward manipulation of spinal cord when performing the discectomy [7, 29, 31, 32].

Cerebrospinal fluid leak/pleural fistula

The rate of dural tears in the surgical management of thoracic herniated discs is higher than that of the lumbar spine [26, 38, 39]. Based on recent literature, the rate of dural tears during thoracic disc excision is approximately 10–15% compared to that in the lumbar spine which is closer to 5% [38, 39]. The risk of dural breach is increased exponentially if the disc material in question is calcified/ossified and adhered to the anterior dura. Given that the majority of these herniations are central in the neurologic canal, some form of anterior or anterolateral exposure is recommended to avoid over handling of the dura. Thorascopy leads to significantly less morbidity to the chest well compared to an open approach and should be utilized if possible [40]. Gille et al. reported a 39% rate of dural tears following transthoracic endoscopic management of herniated discs. They anecdotally reported that after adopting the technique of leaving a shell of calcified disc adhered to the anterior surface of the dura, no CSF leaks occurred [34].

A sequelae of dural breach in the setting of thoracic spine surgery is the development of a subarachnoid-pleural fistula (SPF) (Fig. 2). The rate of SPF is approximately 1.5% but occurs more commonly in anterior exposures to the thoracic spine compared to posterior exposures [41]. The pathophysiology of this complication hinges on the pressure differences between the subarachnoid space and the thoracic cavity. The thorax experiences as routine drop in pressure during the inspiratory phase of respiration leading to a strong draw of CSF into the chest in the setting of a SPF. The continuous inflow of CSF into the thoracic cavity keeps the fistula open and leads to recurrent pleural effusions [42, 43]. Occasionally, dural tears are not recognized intra-operatively and a SPF is not high on the differential diagnosis post-operatively. Hentschel et al. recommend keeping a high clinical suspicion for SPF in any patient following thoracic surgery with high chest tube output, recurrent pleural effusions, or intracranial hypotension [41]. Once a SPF is clinically suspected, a radionuclide cisternography or a CT myelogram should be obtained to investigate [44].

If a dural tear is identified at the time of surgery, the authors recommend direct repair if possible. Given that a common approach to these herniations is anterolateral transthoracic thoracoscopic, direct suture repair may be technically difficult or impossible. If this is the case, diligent use of spinal sealant or barrier matrix should be utilized. If possible, augmenting this barrier repair with an interposition fat or fascia graft is also recommended. In the post-operative setting, patients should be kept flat supine in bed for 24–48 hours with gentle head-of-bed elevation with careful attention to positional headaches. In the case of post-operative headaches following a dural tear, titratable CSF siphoning through a thoracic drain or a temporary lumbar shunt can be utilized. In the case of a SPF following thoracic spine surgery, there are few non-operative treatment options. The rate of spontaneous resolution of SPF without operative management is approximately 20% [45]. There have been case reports using positive pressure ventilation to

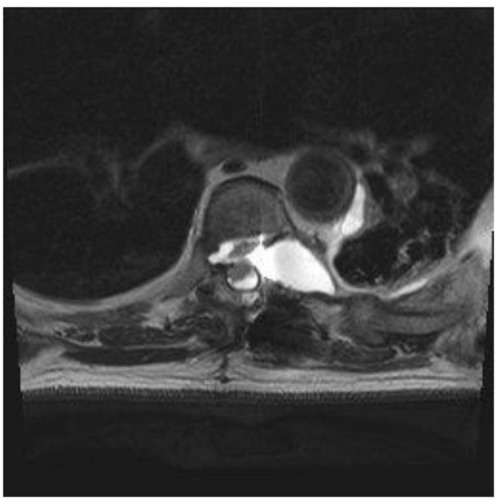

Fig. 2 T2-weighted axial MRI showing subarachnoid-pleural fistula (SPF) at T6–7

decrease the gradient between the chest cavity and the subarachnoid space to encourage closure of the fistula. Prolonged use of chest tube has also been described to facilitate fistula closure. With the direct conduit between thoracic cavity and neural tube, prophylactic IV antibiotics should utilized to prevent meningitis [8, 32, 41, 42, 45]. If non-operative measures fail, a salvage surgical option for recalcitrant SPF is a vascularized omental flap, which can be performed with the assistance of a plastic surgeon and has been described with positive results [46].

Thoracic complications

Recent literature has a paucity of information regarding iatrogenic thoracic viscera as this is exceedingly rare; however, even reports from decades ago report a low risk of occurrence. In the 1980's, Maiman et al. reported a 9% risk of pneumonia or post-operative atelectasis following a lateral extracavitary approach to the thoracic spine [8]. Several years later, this incidence was reported as less than 5% in larger series [26, 45, 47]. Pulmonary embolism has been reported as a complication in several series but no specific causality has ever been associated [6]. In reviewing the recent literature, there have been no reports of pulmonary complications from posterior based approaches. All reported complications come from anterior or anterolateral approaches as disruption of normal thoracic anatomy is required to gain access to the herniated disk material. Several studies report the incidence of pleural tears as a complication of thoracic disk surgery; however, anterior access requires disruption of the pleura for both surgeon access and post-operative chest tube placement.

The authors' recommend standard post-operative prophylactic antibiotics, in conjunction with early mobilization and aggressive pulmonary hygiene, to mitigate the risk of pneumonia and atelectasis. Furthermore, a comprehensive analysis of the patient's medical comorbidities should be performed to judge their risk of thromboembolic events with prophylactic anticoagulation being strategically administered accordingly. If the surgeon has a high clinical suspicion for unintended pleural tissue injury following thoracic disk excision, a technique of filling the operative field with saline and looking for air bubbles has been described and can dictate the need for a post-operative chest tube [1].

Wrong level surgery

Dickman et al. reported on their cohort of patients undergoing re-operation for symptomatic thoracic disc herniation and reported that 13 of 15 patients had either wrong level surgery or the primary surgeon was unable to visualize the disk material at the index operation [48]. The most common reason for incomplete visualization of the herniated disk material is suboptimal surgical approach. Most herniated thoracic discs (especially giant calcified type) are centrally located and thus adequate visualization of the ventral spinal cord is required [25, 31, 34, 48]. Wrong level surgery occurs most commonly due to inadequate pre-operative planning or inaccurate level marking prior to deep dissection [26, 38, 48]. The authors' recommend avoiding wrong level surgery by careful pre-operative planning with particular attention paid to costovertebral anatomy and diligent counting of lumbar and thoracic type vertebrae. Furthermore, in the case of revision surgery or patients with a complex surgical history resulting in severely altered anatomy, pre-operative placement of a radiopaque marker (i.e., gold seed) at the level in question can be utilized in order to quickly and easily find the correct level at the time of surgery. In patients with truncal obesity or complicated anatomy, the authors also recommend utilizing intra-operative CT navigation. Despite the paucity of long-term studies examining efficacy in large cohorts, intra-operative navigation has an immediate role for improved safety and confidence in adequate disc or bone resection [49].

Incomplete disk resection

With respect to avoiding subtotal resection of disc material, choice of surgical approach is paramount. Careful attention to pre-operative MRI or myelogram can allow the surgeon to understand the necessary exposure required to remove herniated disc. Extruded fragments located in the paracentral or far lateral regions of the vertebral canal can be accessed with a unilateral oblique exposure from a lateral or posterolateral plane (transpedicular, costotransversectomy) [2, 3, 7, 9, 34]. Conversely, centrally located herniations should be approached through a ventral, transthoracic approach to completely visualize the entire face of the spinal cord and ensure adequate resection of disc material [1, 48]. Additionally, the surgeon should have a low threshold to perform a complete or partial corpectomy including the posterior longitudinal ligament to visualize the entire herniation in the case of large calcified discs [48]. Post-decompression fusions should be used in these cases to avoid post-operative vertebral column instability as mentioned above. In a patient with a history of thoracic disc resection and recurrent symptoms, the authors recommend thorough clinical evaluation including determining pre-operative symptoms, previous operative reports with approach and other intra-operative details, and post-operative course for information on temporary symptom relief. Few reports have examined revision decompression of thoracic disc herniations but available literature describes the average time to recurrent symptoms of approximately five months with myelopathy or thoracic myeloradiculopathy as the most common complaints [38, 48]. Repeat advanced

imaging, including MRI and CT scan, should be performed with careful attention paid to altered anatomy, location of recurrent or neglected disc material, and integrity of spinal ligaments (anterior and posterior longitudinal ligaments) amongst other considerations [48].

Intercostal neuralgia

Intercostal neuralgia is relatively common complication following surgical approaches disrupting the anatomy of the rib [6, 34, 36]. Series reporting on patients undergoing open thoracotomy for exposure to the thoracic spine cite a three-fold increase in post-operative intercostal neuralgia when compared to patients undergoing thoracoscopy [6, 18, 33]. In a recent study by Strom et al., they reported a 100% incidence of intercostal neuralgia in patients undergoing an anterior approach; however, only 5% had symptoms lasting longer than three months. Furthermore, they reported a 0% rate of persistent intercostal neuralgia in those with standalone thorascopy or posterior based approaches [36].

The spectrum of intercostal neuralgia is broad but fortunately fleeting in most large series. For those that experience persistent neuralgia, non-operative treatments can start with a trial of neuropathic pain medications. For persistent neuralgia recalcitrant to medication, selective nerve blocks, radiofrequency ablations, or dorsal root ganglion excisions have been described in small numbers [36, 38]. Avoidance of this complication is worthwhile by utilizing thorascopy if possible or careful dissection along the inferior border of the rib around the neurovascular bundle with strategic retractor placement in the case of open thoracotomy.

Conclusion

Compared to managing disc herniations of the cervical or lumbar spines, the thoracic spine presents unique challenges. There exists a host of literature regarding novel surgical approaches and tips to access these elusive herniations; however, there exists very little data regarding specific surgical complications, how to avoid these, and how to manage them if they were to occur [12, 50]. In this review, we highlighted some of the most common complications that spine surgeons are likely to encounter while managing thoracic disc herniations. While the scope of pitfalls range from something as simple as intercostal neuralgia to severe as thoracic viscera injury or vertebral column destabilization, a prepared surgeon can largely avoid these complications and, if they are inevitable, have the armamentarium to control them effectively and efficiently.

This study has several limitations. While some high-quality randomized controlled trials were included in data analysis and retrospective review, many of the studies referenced for this review article had small sample sizes and lower levels of evidence. However, in order to compose a thorough review over a topic with relatively rare incidence, the numbers and quality of studies will inherently decline. Secondly, this study does not include all potential complications associated with surgical management of thoracic disc herniations. We chose to spend more time elaborating on the more common or more severe complications that surgeons may encounter rather than include all reported complications. Finally, this study does not at all emphasize or elaborate on surgical approaches or the details regarding disc resection. These topics and many others can be found in similar studies, as this review highlights only the potential surgical complications as well as how to avoid and manage them.

Surgical management of herniated thoracic disc material is a technically difficult undertaking ripe with potential complications. Careful pre-operative analysis and characterization of the exact location of herniated disc material are paramount to complication avoidance. Selection of appropriate surgical approach can help avoid complications and ensure adequate resection of disc material. Lastly, an understanding of the clinical presentation of the most common postoperative complications can lead to early intervention and improved outcomes when possible.

Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

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