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ORIGINAL ARTICLE

Minimally invasive transpedicular approach for the treatment of central calcified thoracic disc disease: a technical note

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Abstract

Purpose To assess the utility of stereotactic navigation for the surgical treatment of ossified, paracentral thoracic discs via a minimally invasive (MI) transpedicular approach.

Methods The authors performed a retrospective review of cases with paracentral thoracic disc herniation resulting in myelopathy where a traditional MI approach would be difficult, who underwent a stereotactic assisted MI transpedicular approach via a tubular retractor system between 2011 and 2016. Five cases of patients over the age of 18 were selected. Collected data included patient age at surgery, sex, preoperative Nurick grade, number of levels treated, calcified disc presence, length of surgery, estimated blood loss (EBL), length of stay (LOS), complication rate, postoperative Nurick grade, and length of follow-up.

Results Five patients had a stereotaxic assisted MI transpedicular thoracic discectomy for paracentrally located calcified disc herniation. Intraoperative navigational images were acquired using intraoperative CT scans (O-arm) to plan and guide the surgical procedure, and real-time navigation was used for precise navigation around the cord to access and remove all fragments. MIS surgery was successfully performed in these otherwise contraindicated cases due to the use of intraoperative real-time stereotactic navigation. All patients had a successful decompression around the anterior aspect of the cord.

Conclusion The traditional MI transpedicular thoracic discectomy approach can be further refined and enhanced by stereotactic navigation to expand the limitations of the MIS technique allowing for an increased number and types of patients eligible for minimally invasive surgery. Therefore, MIS via a tubular retractor system with stereotactic navigation is a novel, safe, and effective improvement in feasibility from the traditional minimally invasive transpedicular thoracic discectomy technique.

Keywords Minimally invasive surgery · Transpedicular thoracic discectomy · Tubular retractor · Outcome · Stereotactic navigation

Introduction

The general trend in surgical technique development and refinement has been toward less invasive surgeries while maintaining similar or better efficiency and outcome [1–5]. One such area where minimally invasive surgery has been gaining traction is in the treatment of symptomatic thoracic discs [2–4, 6–8]. Thoracic disc disease is a rare entity in clinical medicine and is treated via a number of different surgical approaches circumferentially orientated around the spine, from a traditional thoracotomy to less invasive posterior and posterolateral approaches [3, 6, 7, 9–14]. A less invasive technique in the treatment of thoracic disc disease is the posterior transpedicular approach toward the symptomatic disc [3, 6–9, 13, 15–18]. Retrospective studies have generally shown that this technique decreases the risks and morbidity of traditional thoracotomy, including blood loss, complication rate, duration of surgery, and length of stay [3, 6, 7, 9].

More recently, the traditional open transpedicular approach has been further refined by the introduction of a

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minimally invasive (MI) transpedicular approach via a tubular retractor system [8, 13, 16]. The MI technique generally yielded better clinical results than the traditional open technique [8, 13, 15–18]. Chi et al. demonstrated that the MI technique resulted in less blood loss and an overall decrease in surgical morbidity [16].

Although the development of the MI technique has improved operative outcomes, it still does present some limitations. The degree of difficulty associated with the surgery due to poor visualization through the tubular retractor system restricts its use to cases that allow for direct access to the affected disc, as operating around the spinal cord to access poorly visualized disc is technically challenging [19–21]. Cases with lateral herniation, as opposed to central disc, are better suited for the use of this technique [21]. This is even more difficult if the disc is paracentral and ossified. The overall complexity of the surgery and the rarity of the pathology limit the use of MI techniques [3, 6, 7, 9–14]. However, many of these obstacles could be circumvented or mitigated through supplementation of the MI technique with stereotactic navigation. Indeed, stereotactic navigation, initially used to assist in real-time localization and visualization during spinal instrumentation, has found utility in greatly improving determination of proper approach, limit tissue injury, and allow visualization and localization in real-time [19, 20, 22, 23]. In addition, radiation exposure to operating room personal with the use of stereotactic navigation can be minimized [23]. The purpose of this article is to determine if the utilization of advanced stereotactic navigation technique permits for a more accurate, extensive, and safe MIS approach for thoracic discectomies, specifically paracentral ossified discs.

Methods

Study sample

The authors performed a retrospective review of cases with paracentral thoracic disc herniation resulting in myelopathy that would present a surgical challenge, who did undergo MIS transpedicular thoracic discectomy via a tubular retractor system with stereotactic navigation between 2011 and 2016. Five consecutive cases of patients over the age of 18 were selected.

Minimally invasive surgical technique

Patient is positioned prone in the operating room on an open Jackson table, and a navigational image is acquired via intraoperative CT scans (O-arm) to guide localization. Using the navigational probe, a trajectory is planned and aligned to reach the joint of the level of interest, at the junction to the transverse process (Fig. 1). If the disc was ossified, it was

Fig. 1 Planning the trajectory of the dilator probes and tubular retractor using a navigational probe

easily visualized on the intraoperative acquired image and hence guided the navigation process to the correct level. Skin incision is made approximately 2 cm longitudinally, and the fascia is open with a Bovie before the first dilator probe is advanced with the navigational tool in place to dock on the inferior articulating process (IAP) of the superior level of interest (Fig. 2a). After confirming the trajectory and location of the tip of the dilator, subsequent dilators are placed and the tube is secured to the operating bed (Fig. 2b). After confirmation of the level, we performed a subperiosteal dissection exposing the costotransverse joint posterior-laterally and the facet; the take-off of the spinous process and the lamina was visualized. The IAP is removed using a high-speed drill exposing the underlying superior articulating process (SAP) (Fig. 3a). The removal of the SAP to get to the disc space requires the removal of the most cephalad portion of the pedicle that partially covers the disc space. Once the disc space is visualized, the discectomy is performed (Fig. 3b). The removal of the lateral aspect of the disc removes any decompression that may be present over that area and allows to create space to work on the medial compression. The navigation is used to precisely locate the extent of the compressive material and navigate around the spinal cord to access the fragment (Fig. 3c). The O-arm is used again to verify the complete removal of the disc, especially in the presence of ossification. Efforts were directed to areas that contained fragments and re-orientations done as needed to ensure the complete removal of compressive elements.

Collected data (Table 1)

Collected data included patient age at surgery, sex, preoperative Nurick grade, number of levels treated, calcified disc presence, length of surgery, estimated blood loss (EBL), length of stay (LOS), complication rate, postoperative Nurick grade, and length of follow-up. Nurick grades were scored for each patient, for myelopathy, according to the scale outlined by Nurick [24].

Minimally invasive patient cases

Case 1

Patient 1 is a morbidly obese 63-year-old male who presented with severe lower back pain and progressive left leg numbness and weakness. Upon imaging, an ossified T11/T12 intervertebral disc herniation with impingement on the

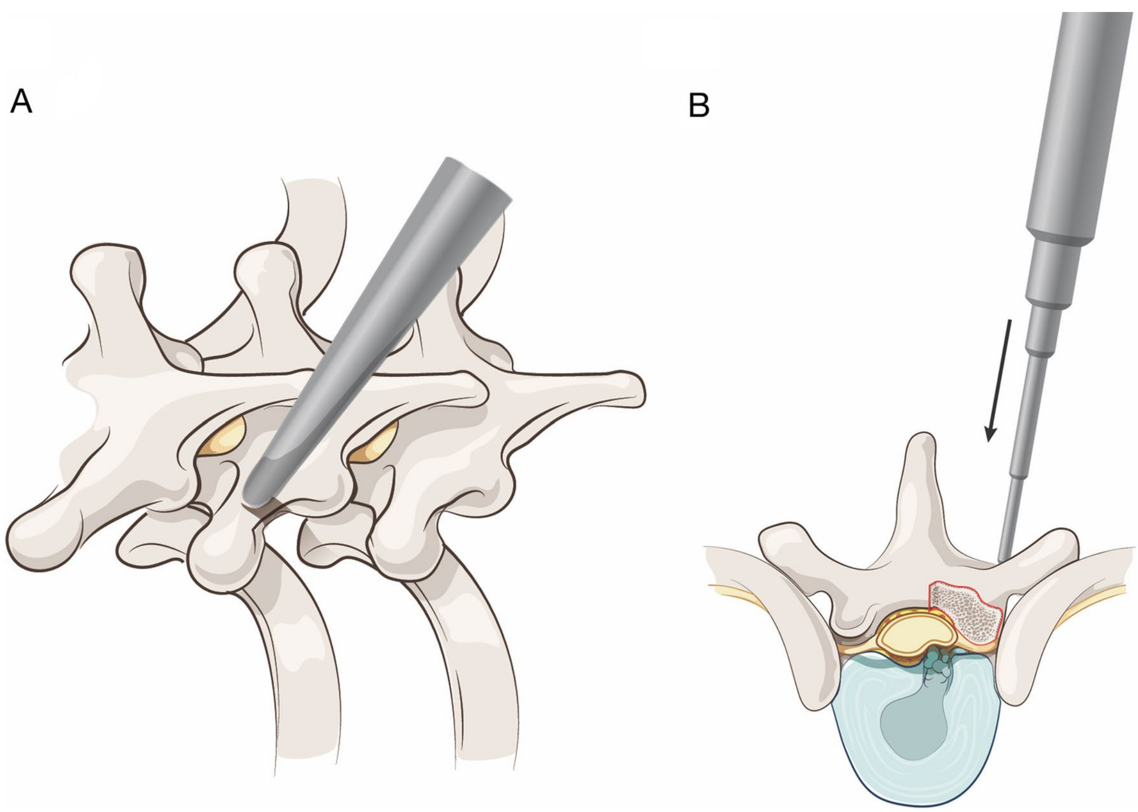

Fig. 2 **a** Dilator probe docked on the inferior articulating process of the superior level of interest, **b** retractor tube is guided into position by the dilator probes and secured to the area of interest

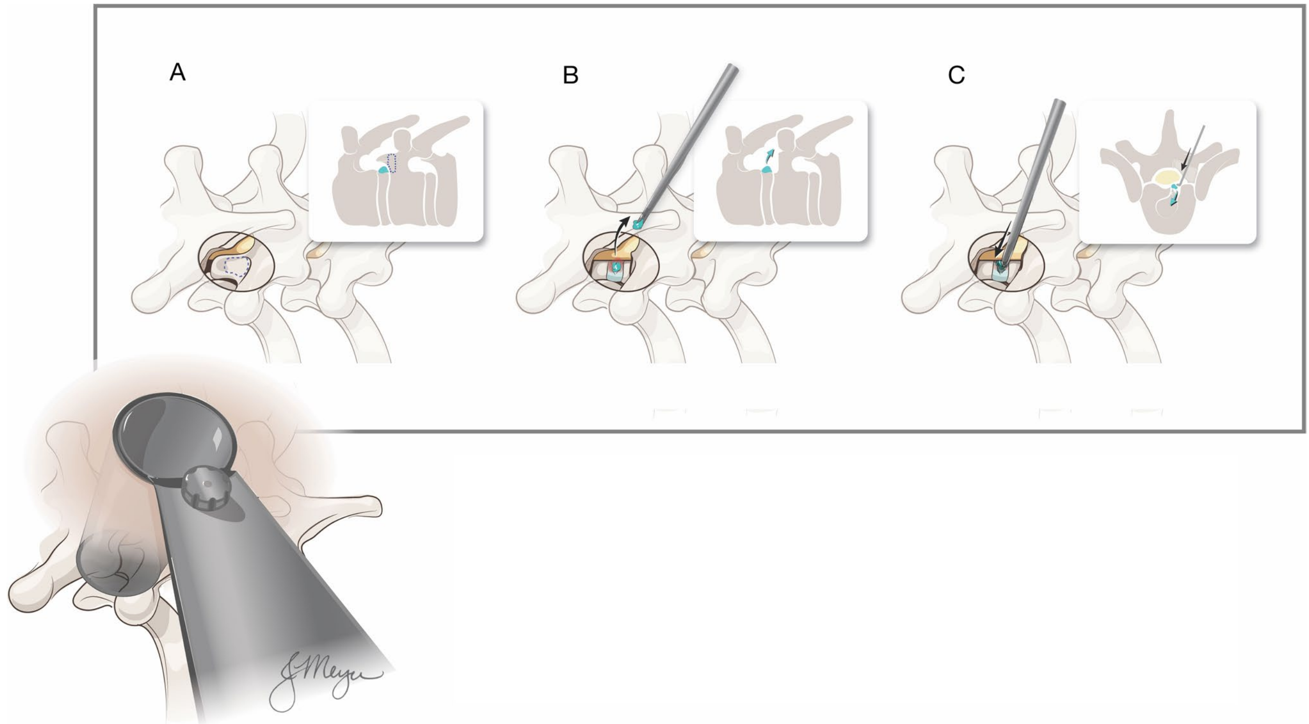

Fig. 3 **a** Removal of the inferior articulating process, exposing the superior articulating process of level of interest, **b** removal of the superior articulating process and the cephalad portion of the pedicle then follow the pedicle down to the disc to perform the discectomy to create a resection cavity, **c** gently push the centralized calcified disc into the resection space and remove it away from the spinal cord

Table 1 Patients' collected data

Variable	Case 1	Case 2	Case 3	Case 4	Case 5
Age	63	29	40	64	34
Sex (M/F)	M	M	M	F	F
Preoperative Nurick grade	4	3	3	2	2
Number of levels	1	2	1	1	2
Calcified disc (yes/no)	Yes	Yes	Yes	Yes	Yes
Surgery time (min)	221	332	149	269	581
EBL (mL)	20	350	10	250	40
LOS (days)	4	8	2	4	6
Complications (yes/no)	No	No	No	No	No
Postoperative Nurick grade	4	0	2	N/A	1
Follow-up (months)	3	4	10	1	5

spinal cord was found (Fig. 4). This patient underwent a right-sided MIS surgery with stereotactic navigation, which lasted 3 h and 41 min. The estimated blood loss (EBL) was 20 mL, and length of stay (LOS) was 4 days. Follow-up with the patient was maintained for 3 months, during which no major or minor complications were found. Postoperative imaging showed complete decompression of the spinal canal (Fig. 5).

Case 2

Patient 2 is a 29-year-old male who presented with progressive left leg weakness resulting in gait abnormality following a motor vehicle accident, 2 months prior. Additionally, he began to develop signs of myelopathy including urinary and bowel incontinence. Imaging demonstrated 2 calcified disc herniation at T6/T7 (Fig. 6) and T11/T12 with T2 signal changes, and compression of the spinal cord was discovered. He underwent MI surgery, as detailed above, for the T6/T7 disc and traditional open surgery for the T11/T12 disc. Surgery lasted for 5 h and 32 min and resulted in an EBL of 350 mL. The length of stay was 6 days. Follow-up was maintained for 4 months during which time no major or minor complications were found.

Case 3

Patient 3 is a 40-year-old male who was referred for evaluation of lower back pain. After imaging, a calcified and herniating T11/T12 intervertebral disc resulting in cord impingement was appreciated (Fig. 7). The patient underwent a right MI surgery which lasted for 2 h and 29 min. EBL and LOS were 10 mL and 2 days, respectively. Follow-up was

Fig. 4 Patient 1 T11/T12 intervertebral disc ossification and herniation resulting in cord impingement. **a** T2-weighted sagittal MRI, **b** T2-weighted axial MRI, **c** sagittal CT, **d** axial CT

Fig. 5 Postoperative imaging of patient 1 T11/T12 decompression. **a** Sagittal CT and **b** axial CT

maintained with the patient for 10 months, during which time no major nor minor complications were found.

Case 4

Patient 4 is a 64-year-old female was incidentally found to have a calcified and herniating T5/T6 intervertebral disc impinging on the spinal cord (Fig. 8). On exam, the patient was neurologically intact, complaining of symptoms related to her thoracic nerve root compression. This patient underwent MI surgery, as outlined above, which lasted for 4 h and 29 min and resulted in an EBL and LOS of 250 mL and 4 days, respectively. Follow-up was maintained for 1 month postoperatively, and no major nor minor complications were found. Postoperative imaging showed complete decompression of the spinal canal (Fig. 9).

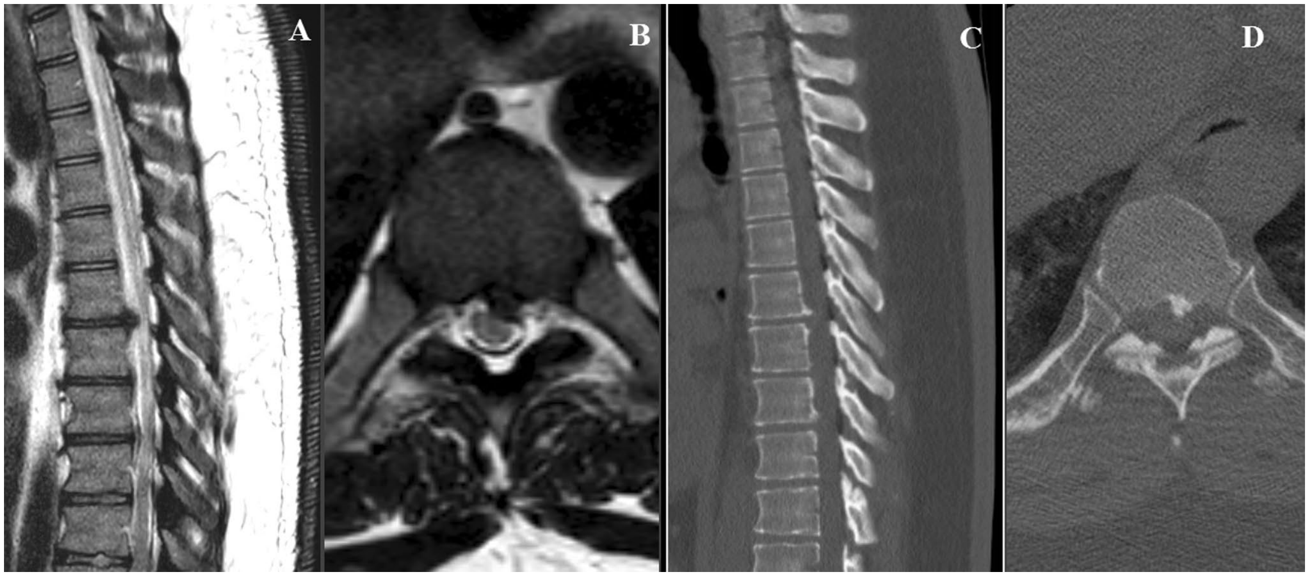

Fig. 6 Patient 2 T6/T7 intervertebral disc ossification and herniation resulting in cord impingement. **a** T2-weighted sagittal MRI, **b** T2-weighted axial MRI, **c** sagittal CT, **d** axial CT

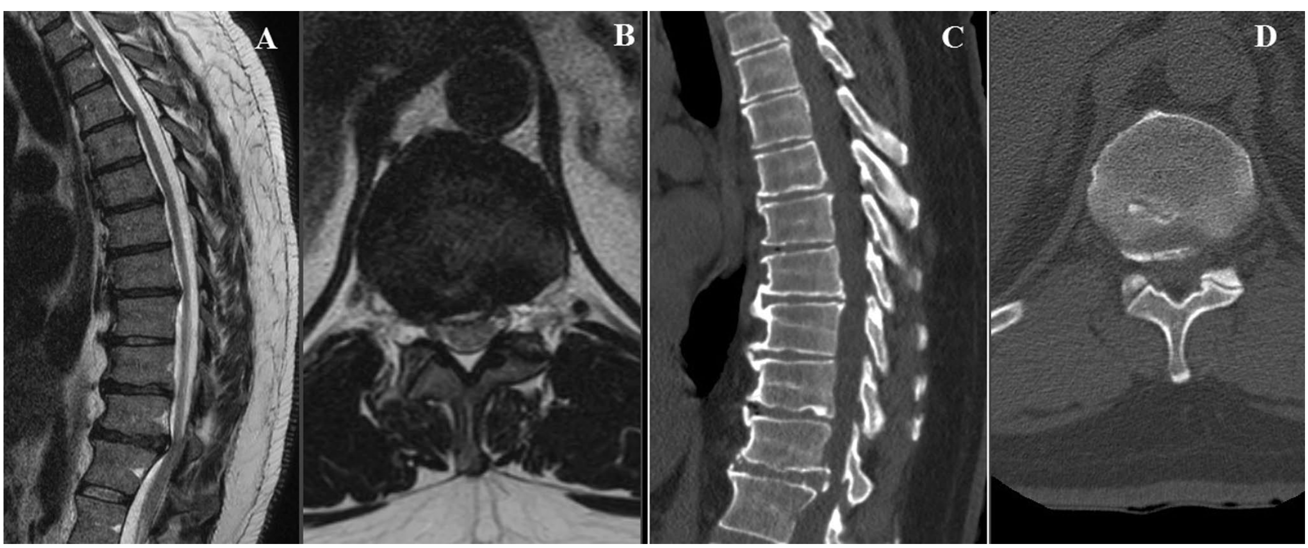

Fig. 7 Patient 3 T11/T12 intervertebral disc ossification and herniation resulting in cord impingement. **a** T2-weighted sagittal MRI, **b** T2-weighted axial MRI, **c** sagittal CT, **d** Axial CT

Case 5

Patient 5 is a 34-year-old female referred for evaluation of back pain that has persisted for over 1 year. On examination, she was found to have bilateral lower extremity discomfort and gait abnormality. Imaging studies demonstrated multilevel disc ossification and herniation, specifically at the T6/T7 (Fig. 10) and T7/T8 (Fig. 11) levels, resulting in cord impingement. She underwent right-sided, two-level MI surgery, as illustrated above, for both affected discs, which lasted for 9 h and 41 min. EBL and LOS were 40 mL and 6 days, respectively. Postoperative imaging showed complete decompression of the spinal canal (Fig. 12). Follow-up was maintained for 5 months, and no major nor minor complications were found.

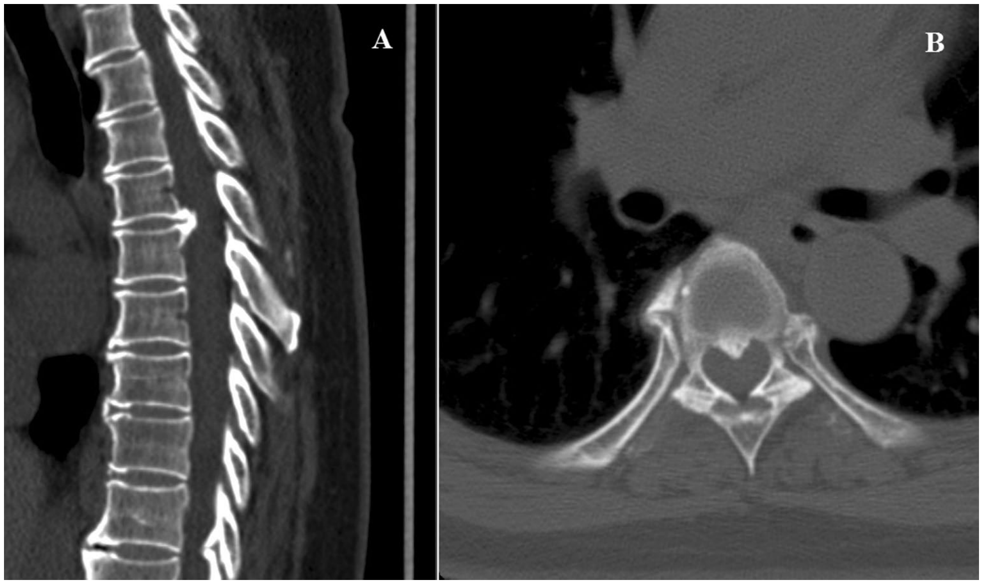

Fig. 8 Patient 4 T11/T12 intervertebral disc ossification and herniation resulting in cord impingement. **a** Sagittal CT, **b** axial CT

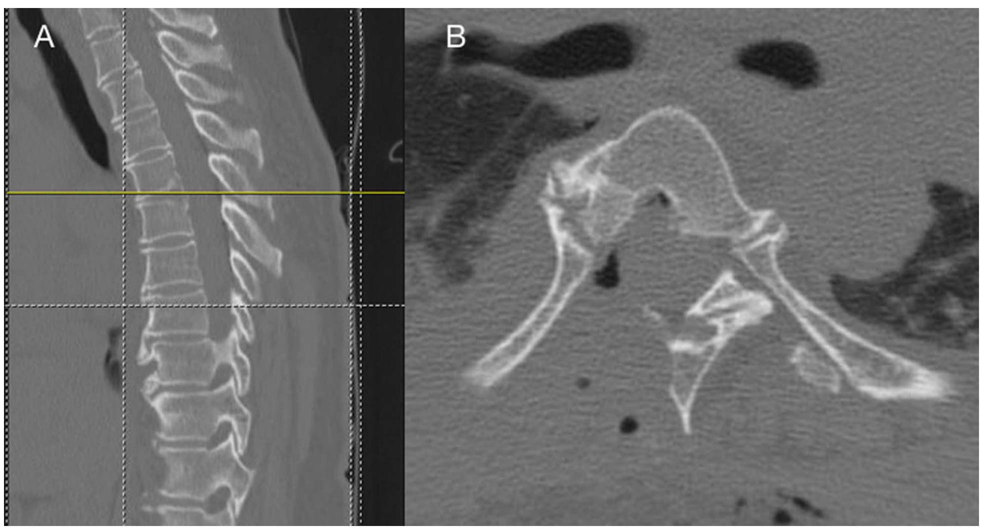

Fig. 9 Postoperative imaging of patient 4 T11/T12 decompression. **a** Sagittal CT and **b** axial CT

Discussion

Thoracic disc disease is a rare occurrence in clinical medicine and can be treated by a variety of surgical approaches including thoracotomies, open transpedicular approaches, and, more recently, transpedicular MI techniques using a tubular retractor system [3, 6–18]. The decision about which approach to use is multifactorial, but a strong predictor is the location and level of ossification of the disc herniation. From a posterior approach, there is currently limited data comparing the traditional open transpedicular discectomy to a minimally invasive transpedicular approach since MIS surgery is less commonly used for these infrequent thoracic disc herniations. With the advancement of stereotactic navigation, the ability to perform MI on these challenging pathologies, especially centrally located and ossified discs, has been made more feasible, both from a technical and safety standpoint. Therefore, the purpose of this study was to determine if this advancement would allow us to perform MIS on thoracic disc disease in an accurate, safe fashion with better circumferential visualization of the compression intraoperatively.

Fig. 10 Patient 5 T6/T7 intervertebral disc ossification and herniation resulting in cord impingement. **a** T2-weighted sagittal MRI, **b** T2-weighted axial MRI, **c** sagittal CT, **d** axial CT

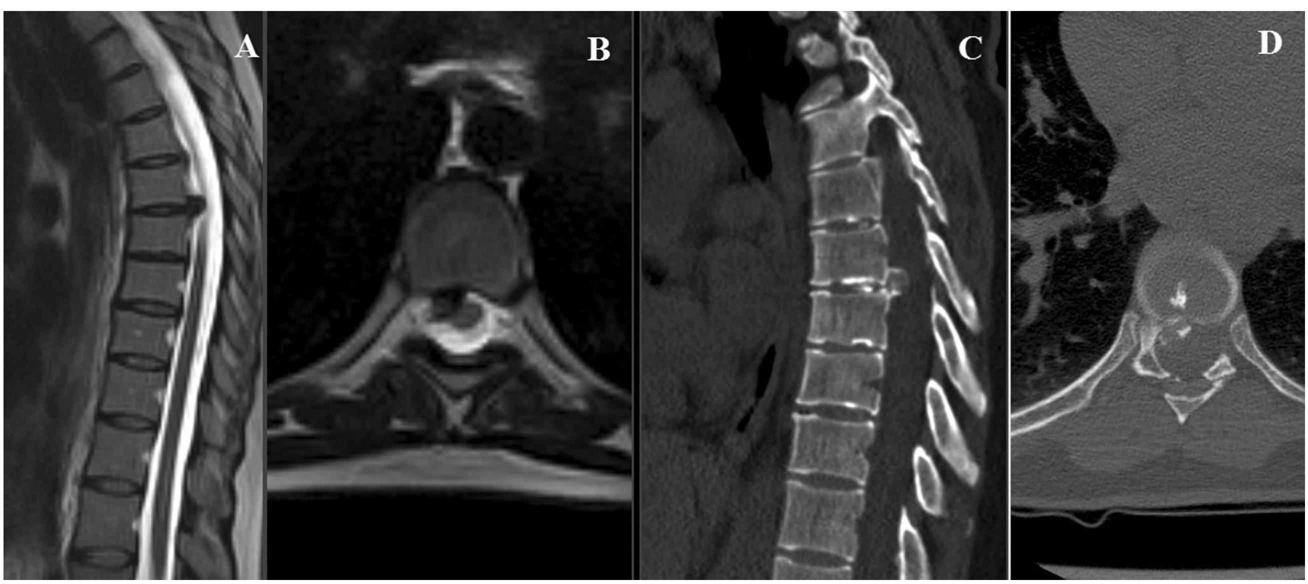

Fig. 11 Patient 5 T7/T8 intervertebral disc ossification and herniation resulting in cord impingement. **a** T2-weighted sagittal MRI, **b** T2-weighted axial MRI, **c** sagittal CT, **d** axial CT

The evolution of the surgical management of thoracic disc herniations is a complex one. Initially, surgeons approached these posteriorly via a traditional laminectomy. This approach was not well suited for the majority of disc herniations because most are centrally located and many are calcified. In addition, the risk of surgical morbidity can be very high: in the thoracic spine, especially with the small canal diameter, manipulation of the cord to reach anterior is not feasible due to the spinal cord leading to a high risk of neurologic injury. This is especially unfavorable for the central herniations, and with calcification, there is an increased risk of CSF leak from a dural tear. Subsequently, the approach transitioned anteriorly via an open thoracotomy and in the usual fashion in surgery, progressed to more MIS techniques such as endoscopy and video-assisted thoracoscopic surgery [25, 26]. The transition posteriorly comes at the advancement of the novel mini-open techniques via the transpedicular approach to reach the disc and subsequently

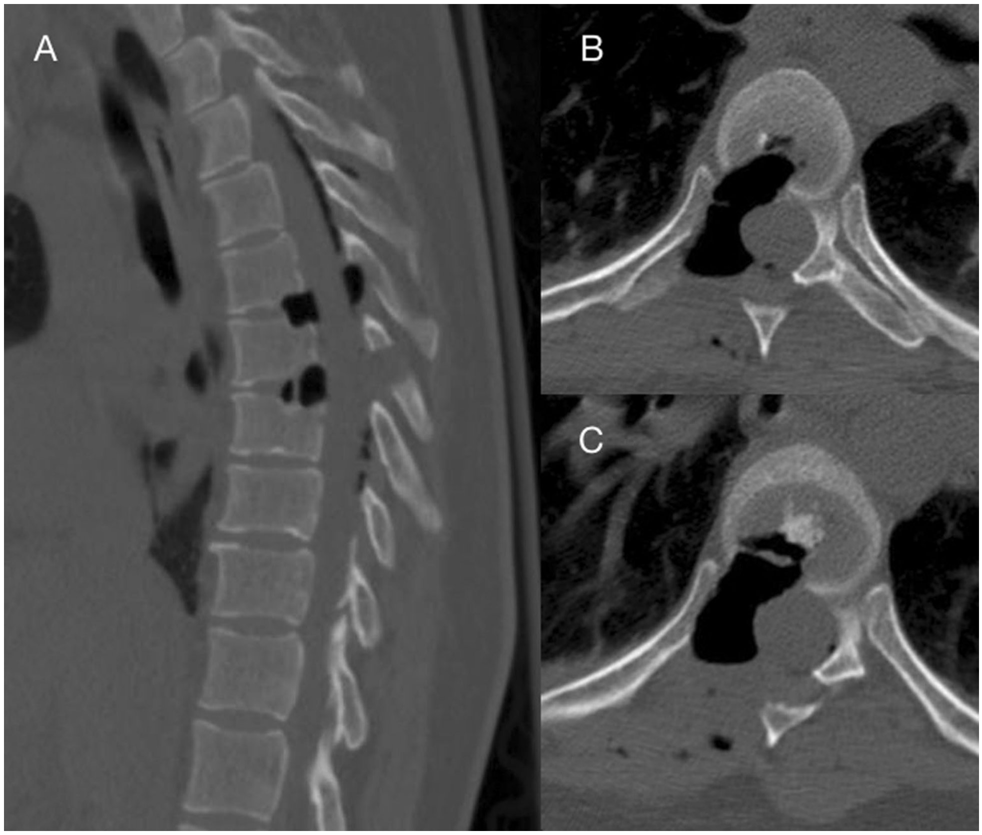

Fig. 12 Postoperative imaging of patient 5 T6/7 and T7/8 decompression. **a** Sagittal CT with **b** T6/7 axial CT and **c** T7/8 axial CT

progressed to MIS with the use of navigation [17, 27]. Dalbayrak et al. described a transforaminal microdiscectomy for thoracic disc herniation. The authors describe the technique using the surgical microscope, radiolucent operation table, C-arm, microsurgical instruments, Landolt separators used in pituitary surgery, and Meyerding separators used in lumbar microdiscectomy. They removed the facet to gain access laterally, and this mini-open technique was successful for medial thoracic disc herniations in their case series [28].

According to Chi et al., the ideal use of the mini-open transpedicular approach is in cases of dorsolateral soft disc herniation. However, they indicated that a mini-open approach is not optimal for large, central, calcified discs because of limited access to the center of the spinal canal afforded by this approach [16]. With the use of stereotactic navigation, we have supplemented the less than adequate view anteriorly and are able to reach this difficult area safely. Using MI tubular retractors and stereotactic navigation, we were able to navigate around the thoracic spinal cord and decompress the spinal cord safely and effectively even with paracentrally located, calcified discs.

The results of surgery were highly favorable (Table 1). The pros of the MIS approach with navigation guidance include less blood loss, shorter surgery times, and decreased length of stay. Furthermore, all cases experienced resolution of myelopathic symptoms without any post-surgical complications; however, case 4 was lost to follow-up preventing observation of symptom resolution. The navigation guidance allows for a targeted approach with intraoperative visualization of the osseous anatomy, resulting in targeted bony decompression and disc removal to minimize potential destabilization. In addition, a post-decompression intraoperative image acquisition can verify that the entire calcified fragment has been removed. Using the drill with limited visualization to the reach anteriorly to the spinal cord for the complete removal of more paracentrally located, calcified discs has a learning curve and is a critical step of the procedure.

The use of stereotactic navigation was highly effective in the surgical management and complete removal of symptomatic soft as well as calcified disc herniations. To be able to safely place instruments anterior to the dura to perform the decompression, the navigated probe was paramount in guiding our trajectory to (1) make a corridor anterior to the spinal canal in the bone and disc space; and (2) to separate the disc fragments from the dura with all forces directed anterior and away from the spinal cord. Furthermore, the use of intraoperative imaging, especially useful with calcified discs, allowed radiographic evidence of complete disc removal by repeating the intraoperative acquisition of O-arm images.

Without stereotactic navigation, this technique is limited to patients with more lateral and hence more visible herniations, since safe maneuvering around the spinal cord is not possible and extremely perilous [21]. All of our patients had central disc herniations, but still successfully underwent MIS surgery, with full resection of ossified and soft herniating disc. The real-time 3D spatial orientation of the disc to the cord allowed a safe and feasible operation. This greatly enhances the potential of MIS surgery by increasing the breadth of numbers and types of patients that can undergo MIS, thereby pushing and expanding previous limitations of MIS. In addition, stereotactic navigation greatly reduces radiation exposure to operating room personnel and limits tissue injury via a minimally invasive approach [23]. Technical challenges remain; however, despite the advantages of navigation, care needed to be taken for precise navigation around the cord as to avoid injury, which extends operative times. Moreover, given the rarity of this disease, one of the limitations of this study is the limited sample size which can result in sampling bias [29].

Conclusion

Thoracic disc disease is a rare phenomenon in clinical medicine and can be treated via stereotactically guided minimally invasive transpedicular thoracic discectomy. The traditional MI approach can be further refined and enhanced via stereotactic navigation to expand the limitations of the MI technique allowing for an increased number and types of patients eligible for MIS.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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