THORACOSCOPIC MICRODISCECTOMY FOR DISC HERNIATION IN THE THORACIC SPINE: SURGICAL TECHNIQUE AND ANALYSIS OF EARLY RESULTS

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Objective. To describe the technique and analysis of early results of thoracoscopic microdiscectomy for disc herniation in the thoracic spine.
Material and Methods. A retrospective single-center study included 19 patients (15 women and 4 men) who underwent thoracoscopic microdiscectomy in 2018—2020. The median age of patients was 45 years (range 21—75 years); the median time from the onset of symptoms to the first visit to a neurosurgeon was 12 months (range 1—152 months). Before admission to the hospital, all patients complained of pain of varying intensity in the thoracic spine and/or along the lateral surface of the chest. Nine (47 %) patients had sensorimotor neurological deficit in the legs. The outcomes of operations were assessed using the modified MacNub scale, and postoperative complications were classified according to the Clavien — Dindo scale. Early results of treatment were evaluated at the first follow-up examination (on average, 2 months after the intervention). Data analysis was performed using the SPSS statistical program (IBM SPSS Statistics, version 27).
Results. The immediate postoperative period was mostly uneventful in 15 (79 %) patients. Four (21 %) Clavien — Dindo grade 1 complications were registered: 1 (5 %) case of purulent discitis, 1 (5 %) pneumonia, 1 (5 %) worsening of sensory disturbances in the leg, and 1 (5 %) deep vein thrombosis of the leg. The average length of hospital stay was three days. Favorable results (excellent, improvement or satisfactory) according to the modified MacNub scale were registered in 16 (84 %) patients in two months after surgery. In three (16 %) cases, the symptoms remained unchanged (unsatisfactory according to the MacNub scale). No deterioration was recorded in any of the cases. Statistical analysis of the data (Fischer's method, Mann — Whitney U-test) showed that the only prognostic factor affecting the outcome of the operation was the localization of the hernia in the lower thoracic region between the T8 and T12 vertebrae ($p = 0.007$). Thus, all nine patients with a hernia in the midthoracic region (T4—T8) had a favorable outcome of the operation, in 6 (67 %) of them there were no complaints. In three (30 %) out of 10 patients with a hernia in the lower thoracic region, there was no complete cure. All other factors (gender, age, hernia size, etc.) did not have a statistically significant correlation with the outcome.
Conclusion. Thoracoscopic microdiscectomy can be used in the surgical treatment of herniations of the thoracic spine. Additional studies are needed to confirm the effectiveness and safety of the technique in the long term.

Key Words: disc herniation, thoracic spine, thoracoscopic microdiscectomy.
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Thoracic disc herniation (TDH) is traditionally referred to as a rare manifestation of degenerative spinal pathology. Their prevalence is about 3 % of all spinal discs herniation [1]. Nevertheless, due to the wide spread and availability of MRI, the number of cases of TDH has grown substantially [2–4]. Most often, they are treated as asymptomatic. The typical localization of the TDH is the lower thoracic spine (between T8 and T12) that is most likely due to the greater anatomical mobility of this segment and the weakening of the posterior longitudinal ligament in the caudal direction [5–7]. Common clinical manifestation of TDH is local back pain or radicular pain on the lateral surface of the thoracic cage. Pain may be a symptom of spinal cord compression, varying from almost painless impaired sensation to rapidly progressing lower paraparesis and urinary sphincter dysfunction [2, 4]. The feature of TDH that distinguishes it from herniations of other localizations is the onset of such abnormal manifestations as abdominal pain as well as cardialgia-like sensations behind the sternum [8–11]. Difficulties to diagnose TDH, often cause long delays in establishing the correct diagnosis. According to their morphological characteristics, TDHs are prone to ossification, occurring in up to 70 % of cases. This also differs them from hernias in other locations [12, 13]. Most often, the TDHs are located centrally. In this regard, surgery through the posterior approach is associated with increased

risks of injuring spinal cord, in front of which the hernia is located.

Removal of TDHs of the central localization is one of the technically most difficult spinal surgeries due to the reason mentioned above [14]. Anterior and anterolateral transthoracic approaches to TDHs often result in complications and slow recovery after surgery. This was the reason for the development of minimally invasive thoracoscopic microdiscectomy. In 1993, Mack et al. described video-assisted thoracoscopic surgery (VATS) [15–17]. Nevertheless, despite the advantages of the minimally invasive procedure, this technique has not been widely used, primarily due to the long learning curve and the risk of injury to the thoracic organs [15, 18].

The objective of this study is to describe the technique and to analyze the early outcomes of thoracoscopic treatment of TDH.

Material and Methods

Design: a single-center retrospective study. The analysis included patients with TDH who underwent thoracoscopic surgery in 2018–2020. The indication for surgical treatment was the development of sensorimotor neurologic deficit as well as ineffective conservative treatment of severe pain syndrome. In one case, the patient suffered from acute lower paraparesis and sphincter dysfunction indicating the urgent surgery.

Surgical steps

Marking the spinal disc level. Intraoperative localization of the thoracic spine disc using C-arm, especially at the T4–T8 level, is not always reliable since the patient is in park bench position and the air in the lungs downgrades the quality of the images. Therefore, all patients underwent preoperative marking with the placement of a metal marker thread under CT guidance using the technique described by Cornips et al. [15]. The pleural cavity was punctured under local anesthesia in the CT unit before transportation of the patient to the surgery unit. The puncture was performed through the paraspinal musculature 13–15 cm from the midline on the side of the planned approach. A puncture needle was inserted over the upper edge of the rib, the number of which corresponded to the number of the lower vertebra in the index intervertebral disc. For example, if TDH was at the T7–T8 level, the puncture needle was placed above the upper edge of the 8th rib. The exact level was defined on CT scans. After verification of the ordinal number of the rib, a metal guide marker with a harpoon head was inserted through the puncture needle and administered into the lung tissue by 1–2 cm. This maneuver reduced the risk of migration of the marker from the pleural cavity during patient movements. During thoracoscopy, the surgeon followed along the edge of the rib marked with a marker in the medial direction towards the proximal head that is anatomically located in the projection of the index level. The exception is T11 and T12 levels, where the head of the rib is located caudally to the disc [15].

Placement of thoracoscopic ports. After the marker was placed, the patients were transported to the surgery unit. A double-lumen intubation was performed under general anesthesia to provide one-lung ventilation. Then the patients were positioned in park bench position (Fig. 1). The approach side was identified by hernia lateralization. A rigid video thoracoscope with a 0° viewing angle and a two-dimensional image was used in the first two cases in the series. Starting from the third case, a video thoracoscope with an adjustable camera angle on a flexible tip and a three-dimensional image was utilized.

After the surgical site skin preparation three short skin incisions were made on the approach side, and ports for the thoracoscope and instruments were placed into the pleural cavity using a trocar. The anesthesiologist preliminarily performed the lung deflation on the approach side, then switched the ventilator to one-lung ventilation mode. The first port was placed in the intercostal space in the projection of the outer part of the marker thread along the posterior axillary line. After placing the thoracoscope into the pleural cavity, the intracavitary part of the marker thread was visualized to identify the rib leading to the index disc in the medial direction. The degree of lung collapse was also defined in order to have an unhindered approach to the anterolateral surface of the vertebrae. Then two ports for surgical instruments were placed at a distance of 5–7 cm from each other (Fig. 1).

Surgical technique of thoracoscopic microdiscectomy

After installing and fixing the thoracoscope in a stand and identifying the level of disc herniation, intrapleural intercostal block was performed with a long-acting anesthetic drug on the approach side (Fig. 2). After that the parietal pleura covering the anterolateral surface of the index disc, the surfaces of the bodies of adjacent vertebrae within 5–7 mm and the rib head were coagulated. Dissection of the rib head was often followed by sympathicotomy. If the intercostal artery and vein were close to the area of bone resection, these vessels were coagulated and cut. After the dissection of the surgical site the next stage of the procedure was performed in all cases by a neurosurgeon. Using the bimanual technique, the rib head, disc and adjacent vertebral endplates were partially resected at the level of surgery. While using the drill, only diamond heads were used to reduce the risk of damaging the surrounding structures. In the left-sided approach the surgical area was in close proximity to the aorta; hence, while using the drill, resection was performed only towards the middle line. After the formation of the bone canal, the posterior longitudinal ligament was identified. It was perforated with a blunt hook to visualize a herniated disc and dura mater. The hernia was excised until the anterior surface of the dura was completely decompressed and the premedullary space was relieved. At this stage the discectomy was completed. A drain was placed in the pleural cavity and externalized through one of the working ports. The wounds were sutured in two layers according to the standard procedure.

The surgery outcomes were assessed according to the modified MacNub

scale [19], postoperative complications were assessed according to the Clavien – Dindo scale [20]. Statistical analysis was performed using the SPSS software (IBM SPSS Statistics, version 27). Clinical features were shown in the form of fractions and percentages for categorical variables and in the form of medians indicating the range of values for continuous variables. The Fisher's method and the Mann – Whitney U-test were used to analyze the data. The value of statistical significance was $p < 0.05$.

Results

From 2018 to 2020, 19 patients underwent thoracoscopic microdiscectomy. There were 15 (79 %) women and 4 (21 %) men among them. The median age of patients was 45 years (aged 21–75 years). TDHs were located in the lower thoracic spine (T8–T12) in 10 (53 %) cases and in the middle thoracic spine (T4–T8) in 9 (47 %) cases. In the spinal canal, 10 (53 %) TDHs had a central location (Fig. 3), 7 (36 %) had lateralization to the right and 2 (11 %) had lateralization to the left. The mean size of hernia was 5 mm (range, 2 to 14 mm) in the sagittal plane and 8 mm (range, 5 to 16 mm) in the axial plane. In 2 (12 %) cases, hernias contained calcifications. In 5 (26 %) cases, hernia induced spinal stenosis. Eleven (58 %) patients had multiple hernias; one of them underwent simultaneous hernia excision at two levels (Fig. 4). In 2 (12 %) cases, hernias were described as giant (Fig. 5), i.e., occupying more than 40 % of the cross-sectional area of the spinal canal [21].

The median time from the onset of symptoms to the first visit to a neurosurgeon was 12 months (range, 1 to 152 months). Prior to the procedure, all patients complained of thoracic pain that could be accompanied by radicular pain on the sides along the thoracic cage. As a rule, the pain intensity with a long history varied significantly. In this regard, we decided not to use quantitative assessment of the pain syndrome (for example, the visual analogue scale), reflecting pain indicators only at a specific moment of the examination. Accordingly, patients' subjective assessment of trends and changes in pain syndrome throughout the duration of the history was considered first of all when establishing indications for surgery. In addition to pain, TDHs caused sensorimotor deficit in the legs ranging from mild numbness to paraparesis in 9 (47 %) patients; there was sphincter dysfunction and an overactive bladder in 6 (32 %) cases; and 4 (21 %) patients were followed up with a psychiatrist for chronic depression. In this group, the median duration of pain history was 80 months (range, 24 to 156 months). Due to intense pain in two patients, systematic use of opioid medications was required. In other cases, drug therapy included NSAIDs, muscle relaxants and neuropathic drugs in various combinations.

The median time of surgery was 145 min (range, 68 to 290 min) and the median blood loss was 50 ml (range, 7 to 950 ml). Immediately after surgery, most of the patients complained of intense pain in the approach area which required the use of opioid drugs (oxycodone chloride) at a mean dose of 30 mg per day. In 6 (32%) cases, a pump was used for patient-controlled analgesia, and in 5 (26 %) cases, we utilized serratus muscle block. Due to the pain not being

Fig. 1
Positioning the patient on the operating table: **a** – marking for installation of ports; **b** – location of the marker thread indicating the level of the operated disc

relieved by the above-mentioned drugs, epidural anesthesia was required in one patient. This was the patient with the longest history of preoperative pain in the entire sample (156 months) who had been using opioid drugs for many years.

The immediate postoperative period, with the exception of pain, was uneventful in 15 (79 %) patients. A total of 4 (21 %) Grade I complications on the Clavien – Dindo scale were registered: 1 (5 %) purulent discitis, 1 (5%) pneumonia, 1 (5%) deterioration of sensory impairments in the leg and 1 (5 %) deep leg vein thrombosis. The mean length of hospital stay was 3 days (range, 2 to 10 days).

During the control examination after 2 months, according to the modified MacNub scale, favorable outcomes (excellent, improvement or satisfactory) were registered in 16 (84 %) patients. In 3 (16 %) cases, the symptoms remained unchanged (unsatisfactory on the MacNub scale). There was no deterioration in any of the cases.

Statistical analysis of the data (Fischer's method and Mann – Whitney U-test) showed that the only predictive factor affecting the outcome of surgery was the localization of a hernia in the lower thoracic spine between the T8 and T12 vertebrae ($p = 0.007$). For example, all 9 patients with hernia in the middle thoracic region (T4–T8) had a favorable outcome of surgery and 6 (67 %) of them had no complaints. Nevertheless, three out of ten patients with hernias in the lower thoracic spine did not have a complete recovery. All other factors (gender, age, size of the TDH, etc.) had no statistically significant correlation with the outcome.

Discussion

The present article describes the advantages and disadvantages of thoracoscopic microdiscectomy in patients with TDH and analyzes the early postoperative outcomes. In our opinion, the efficiency of the technique is indicated by the fact that 84% of patients noted an improved condition after 2 months after surgery. Moreover, the symptoms could not be relieved before surgery by non-surgical therapy for an average of one year. This actually eliminates the possibility of co-existed spontaneous improvement. Of note, complications that developed immediately after surgery were not severe (Grade I according to Clavien – Dindo) and were temporary. Only in 1 (5 %) case, deterioration of the neurological status was observed that was directly associated with thoracoscopic excision of a giant hernia and procedures in the area of the compressed spinal cord. The complication rate in our sample fully corresponds to the literature data. For example, in the meta-analysis of outcomes of TDH treatment using the thoracoscopic technique, Brotis et al. [1]

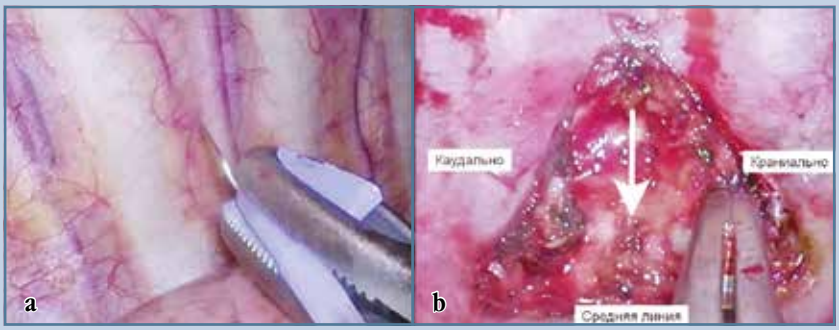

Fig. 2
Intraoperative images during thoracoscopic microdiscectomy: **a** – thoracoscopic conduction anesthesia; **b** – preparation of the disc area, dissection of the parietal pleura, the white arrow indicates the disc

Fig. 3
MRI of a patient with central T7–T8 disc herniation: from left to right (T2, sagittal and axial views); top row – before surgery, bottom row – follow-up at 1.5 years after thoracoscopic microdiscectomy; white arrow indicates the zone of resection of the end plates when accessing the hernia

revealed a complication rate being 24 %. In this regard, it is essential to consider the experience of surgeons who perform such surgery. Wait et al. [22] registered in their series a reduction in complications from 28.0 % during the first six years of performing such surgeries to 5.3 % in the next nine years of surgical experience.

Patients admitted for thoracoscopic microdiscectomy with already developed chronic pain syndrome (6 months or more) required the use of such additional measures as a pump for patient-controlled analgesia and a serratus muscle block. In one case, bacterial discitis manifested at the level of surgery and developed after a visit to a dentist for treatment of purulent pulpitis 2 weeks after microdiscectomy. Infectious changes in the disc were relieved by antibiotic therapy.

There is no single agreement or international standard regarding indications for surgical intervention in TDH. The criteria for selecting patients for thoracoscopic microdiscectomy and defining the optimal duration of treatment are most often subjective. In our sample, the median non-surgical treatment was one year. Meanwhile, this period was two years in 41 % of cases. These data are consistent with the previously published papers. For example, in the paper by Quint et al. [23], patients underwent non-surgical treatment for 14 to 17 months. Moreover, according to the article by Hott et al. [21], it took mean 7 to 21 months from the onset of symptoms to the first contact with a neurosurgeon. According to our findings, the severity of anatomical compression of the spinal cord does not correlate with the severity of sensorimotor impairment in the legs or bladder dysfunction before surgery. This data is consistent with the previously published paper by Nakajima et al. [5]. The authors analyzed data of 28 patients with a pathological MRI signal of myelopathy and spinal cord compression in TDH and found no connection with either the severity of preoperative symptoms or surgical outcome. In rare cases, symptoms in central TDH develop rapidly that is an indication for urgent surgery. It has not yet been reliably established what mechanisms underlie the acute deterioration of symptoms.

According to the literature, large and giant TDHs with elements of spinal cord compression are associated with a longer period of non-surgical treatment. Yuan et al. [24] in their series of 257 cases showed that if the TDH was large, the duration of non-surgical treatment averaged 24 months, and in the Wait et al. series [22] this number reached 32 months. These data differ significantly from the guidelines for the duration of non-surgical treatment of patients

Fig. 4
MRI of a patient with multiple hernias in the thoracic spine (T2, sagittal view); the patient was admitted for progressive lower paraparesis, thoracoscopic microdiscectomy was performed at two levels: T8–T9 and T10–T11

Fig. 5
Patient with a giant calcified T9–T10 disc herniation: preoperative MRI, sagittal slice in T2 mode **(a)**, axial slice **(b)**, axial CT slice **(c)**; follow-up MRI image after surgery **(d)**

with hernias in other parts of the spine. For example, for herniated discs in the cervical or lumbar spine manifesting radicular pain, the recommended optimal period of surgical treatment is 8–12 weeks that promotes the restoration of working capacity in 70 % of patients [25, 26]. The remarkable thing is that in the case of TDH, the question of the patient's return to work activity may correlate with the working status before surgery. Thus, according to the literature, up to 90% of patients returned to work after thoracoscopic microdiscectomy, but only 17% unemployed patients were able to begin working after the procedure [22].

In our sample all patients complained of back pain and/or radicular pain in the thoracic cage before surgery. Neurological prolapses in the form of sensorimotor paresis of varying severity were recorded in almost 50 % of cases, dysfunction of the urinary sphincter was found in every third patient. These data comply with the previously published ones [24]. It must be noted that in our series, the connection between the long period of the symptomatic phase and the presence of diagnosed depressive disorders has been revealed. Patients in this group were admitted to treatment mean after of 80 months from the onset of symptoms that is 6.5 times longer than in situations where depression was not present. The retrospective type of the study and a small sample do not permit us to conclude whether the development of depression is the result of chronic pain syndrome or whether the case in hand is a random combination of comorbidities in TDH. Literature data suggest a closer association of depressive disorders with chronic lower back pain compared with pain in other localizations [27]. Proceeding from this assumption, we assume that local pain in the spine when the TDH is localized in the lower segment may have similar features in relation to associated depression.

Along with classic clinical manifestations, TDH can manifest as atypical symptoms [8–11]. In our sample, 2 patients complained of nonspecific epigastric pain and dysphagia that were combined with local thoracic spine pain. Examination of the gastrointestinal tract and cardiovascular system did not reveal any abnormalities. We assumed the vertebrogenic nature of the symptoms. Consequently, after thoracoscopic microdiscectomy, abdominal symptoms completely disappeared in both cases.

Statistical analysis of the data showed that the localization of a herniated disc in the mid-thoracic spine is associated with a more favorable outcome 2 months after surgery. Almost 70 % of the patients showed complete recovery during the follow-up examination. However, the TDHs located below the T8 level had worse outcomes, and none of the patients from this group had fully recovered by the time of the follow-up examination. This correlation is most likely explained by the different anatomical and biomechanical features of the middle thoracic spine and lower thoracic spine. Functionally, the entire thoracic spine is a part of a larger bone complex that unites the chest, sternum and scapulae. Each of the components of this complex contributes to the characteristics of its mobility while maintaining the stability of the entire locomotor chain. There is no exact data on how greatly the thoracic cage affects the mobility of the thoracic spine, but its stabilizing role in combination with the sternum is evident [5, 28]. According to cadaveric studies by Watkins et al. [28], the thoracic cage and sternum provide 40 % stability with flexion-extension movements, 35 % with side bends and 31 % with rotational movements. Anatomical articulation of the bone and cartilaginous parts of the ribs (symphysis) is typical for true ribs from I to VII; articulation of the anterior end of its cartilage with the lower edge of the suprajacent cartilage (syndesmosis) is typical for false ribs from VIII to X. The two lower ribs (XI and XII) are floating since their anterior edges are located in the soft tissues and are not fixed. In the proximal part, the ribs from I to X are connected to the vertebrae by costotransverse joints, and XI and XII do not form true joints [29]. The scapula is usually located at the level between T4 and T8 of the thoracic vertebrae. In this regard, the segment between the T4 and T8 thoracic vertebrae, along with the true ribs, scapula and sternum, may be considered the most stable of the entire thoracic bone complex [5]. In our opinion, the anatomical stability of the mid-thoracic spine reduces the irritative effect of walking and breathing movements on the operated disc that explains a more favorable outcome in this area with respect to pain. Considering that the morphological characteristics of the TDH (size, lateralization, calcifications) did not correlate with the outcome, the critical role of anatomical and biomechanical aspects in recovery obviously prevails.

Limitations. Our study is limited by the retrospective type of data analysis, a small sample, a wide range of patients' ages, a different period of symptomatic manifestations before surgery, and a short period of postoperative follow-up. The article describes the surgical outcomes performed in the same medical institution by the same surgeon. This is associated with the risks of biased selection of patients, the establishing of indications for surgery and the interpretation of outcomes. A more reliable assessment of the efficacy and safety of the thoracoscopic microdiscectomy in the long term implicates the analysis of long-term outcomes in a larger number of patients.

Conclusion

Thoracoscopic microdiscectomy may be used in the treatment of thoracic disc herniations. Despite the potential risks associated with the anterolateral transthoracic thoracoscopic approach, we recorded a favorable outcome 2 months after surgery in 84 % of patients. Localization of a herniated disc between the T4 and T8 vertebrae is associated with more favorable outcomes than in the lower thoracic spine. We consider that this effect may be related to the anatomical rigidity of the mid-thoracic spine that is anatomically more stabilized by the true ribs, scapulae and sternum. It is reasonable to perform additional studies to confirm the effectiveness and safety of thoracoscopic microdiscectomy in the treatment of TDH in the long term.

The study had no sponsors.
The authors declare that they have no conflict of interest.

The study was approved by the local ethical committees of institutions.
All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.

Литература/References

1. **Brotis AG, Tasiou A, Paterakis K, Tzerefos C, Fountas KN.** Complications associated with surgery for thoracic disc herniation: a systematic review and network meta-analysis. World Neurosurg. 2019;132:334–342. DOI: 10.1016/j.wneu.2019.08.202.
2. **Cornips EM, Janssen ML, Beuls EA.** Thoracic disc herniation and acute myelopathy: clinical presentation, neuroimaging findings, surgical considerations, and outcome. J Neurosurg Spine. 2011;14:520–528. DOI: 10.3171/2010.12.SPINE10273.
3. **Wood KB, Garvey TA, Gundry C, Heithoff KB.** Magnetic resonance imaging of the thoracic spine. Evaluation of asymptomatic individuals. J Bone Joint Surg Am. 1995;77:1631–1638. DOI: 10.2106/00004623-199511000-00001.
4. **Wood KB, Blair JM, Aepple DM, Schendel MJ, Garvey TA, Gundry CR, Heithoff KB.** The natural history of asymptomatic thoracic disc herniations. Spine. 1997;22:525–530. DOI: 10.1097/00007632-199703010-00011.
5. **Nakajima H, Watanabe S, Honjoh K, Kubota A, Matsumine A.** Differences in clinical and radiological features of thoracic disc herniation presenting with acute progressive myelopathy. Eur Spine J. 2021;30:829–836. DOI: 10.1007/s00586-020-06485-6.
6. **Arce CA, Dohrmann GJ.** Herniated thoracic disks. Neurol Clin. 1985;3:383–392. DOI: 10.1016/S0733-8619(18)31043-0.
7. **Yoshihara H.** Surgical treatment for thoracic disc herniation: an update. Spine. 2014;39:E406–E412. DOI: 10.1097/BRS.0000000000000171.
8. **Fransen P, Collignon F, Van Den Heule B.** Foraminal disc herniation Th9–Th10 mimicking abdominal pain. Acta Orthop Belg. 2008;74:881–884.
9. **Papadakos N, Georges H, Sibtain N. Tolias CM.** Thoracic disc prolapse presenting with abdominal pain: case report and review of the literature. Ann R Coll Surg Engl. 2009;91:W4–W6. DOI: 10.1308/147870809X401038.
10. **Rohde RS, Kang JD.** Thoracic disc herniation presenting with chronic nausea and abdominal pain. A case report. J Bone Joint Surg Am. 2004;86:379–381. DOI: 10.2106/00004623-200402000-00026.
11. **Shirzadi A, Drazin D, Jeswani S, Lovely L, Liu J.** Atypical presentation of thoracic disc herniation: case series and review of the literature. Case Rep Orthop. 2013;2013:621476. DOI: 10.1155/2013/621476.
12. **Moon SJ, Lee JK, Jang JW, Hur H, Lee JH, Kim SH.** The transdural approach for thoracic disc herniations: a technical note. Eur Spine J. 2010;19:1206–1211. DOI: 10.1007/s00586-010-1294-0.
13. **Negwer C, Butenschoen VM, Krieg SM, Meyer B.** Posterior transdural resection of giant calcified thoracic disc herniation in a case series of 12 patients. Neurosurg Rev. 2021;44:2277–2282. DOI: 10.1007/s10143-020-01413-0.
14. **Hanna G, Kim TT, Uddin SA, Ross L, Johnson JP.** Video-assisted thoracoscopic image-guided spine surgery: evolution of 19 years of experience, from endoscopy to fully integrated 3D navigation. Neurosurg Focus. 2021;50:E8. DOI: 2020.10.FOCUS20792.
15. **Cornips E, Beuls E, Geskes G, Janssens M, van Aalst J, Hofman P.** Preoperative localization of herniated thoracic discs using myelo-CT guided transpleural puncture: technical note. Childs Nerv Syst. 2007;23:21–26. DOI: 10.1007/s00381-006-0223-3.
16. **Mack MJ, Regan JJ, Bobechko WP, Acuff TE.** Application of thoracoscopy for diseases of the spine. Ann Thorac Surg. 1993;56:736–738. DOI: 0003-4975(93)90966-L.
17. **Das K, Rothberg M.** Thoracoscopic surgery: historical perspectives. Neurosurg Focus. 2000;9:e10. DOI: 10.3171/foc.2000.9.4.10.
18. **Abedi A, Formanek B, Hah R, Buser Z, Wang JC.** Anterior versus posterior decompression for degenerative thoracic spine diseases: a comparison of complications. Global Spine J. 2021;11:442–449. DOI: 10.1177/2192568220907337.
19. **MacNab I.** Negative disc exploration. An analysis of the causes of nerve-root involvement in sixty-eight patients. J Bone Joint Surg Am. 1971;53:891–903. DOI: 10.2106/00004623-197153050-00004.
20. **Camino Willhuber G, Elizondo C, Slullitel P.** Analysis of postoperative complications in spinal surgery, hospital length of stay, and unplanned readmission: application of Dindo-Clavien classification to spine surgery. Global Spine J. 2019;9:279–286. DOI: 10.1177/2192568218792053.
21. **Hott JS, Feiz-Erfan I, Kenny K, Dickman CA.** Surgical management of giant herniated thoracic discs: analysis of 20 cases. J Neurosurg Spine. 2005;3:191–197. DOI: 10.3171/spi.2005.3.3.0191.
22. **Wait SD, Fox DJ Jr, Kenny KJ, Dickman CA.** Thoracoscopic resection of symptomatic herniated thoracic discs: clinical results in 121 patients. Spine. 2012;37:35–40. DOI: 10.1097/BRS.0b013e3182147b68.
23. **Quint U, Bordon G, Preissl I, Sanner C, Rosenthal D.** Thoracoscopic treatment for single level symptomatic thoracic disc herniation: a prospective followed cohort study in a group of 167 consecutive cases. Eur Spine J. 2012;21:637–645. DOI: 10.1007/s00586-011-2103-0.
24. **Yuan L, Chen Z, Li W, Sun C, Liu Z, Liu X, Yuan H.** Radiographic and clinical features of thoracic disk disease associated with myelopathy: a retrospective analysis of 257 cases. Eur Spine J. 2021;30:2211–2220. DOI: 10.1007/s00586-020-06688-x.
25. **Ren BO, O'Donnell JA, Anderson JT, Haas AR, Percy R, Woods ST, Ahn UM, Ahn NU.** Time to surgery affects return to work rates for workers' compensation patients with single-level lumbar disk herniation. Orthopedics. 2021;44:e43–e49. DOI: 10.3928/01477447-20201202-06.
26. **de Rooij JD, Gadjradj PS, Huygen FJ, Luijsterburg PAJ, Harhangi BS.** Management of symptomatic cervical disk herniation: a survey among dutch neurosurgeons. Spine. 2017;42:311–317. DOI: 10.1097/BRS.0000000000001743.
27. **Jaiswal A, Scherrer JF, Salas J, van den Berk-Clark C, Fernando S, Herndon CM.** Differences in the association between depression and opioid misuse in chronic low back pain versus chronic pain at other locations. Healthcare (Basel). 2016;4:34. DOI: 10.3390/healthcare4020034.
28. **Watkins R 4th, Watkins R 3rd, Williams L, Ahlbrand S, Garcia R, Karamanian A, Sharp L, Vo C, Hedman T.** Stability provided by the sternum and rib cage in the thoracic spine. Spine. 2005;30:1283–1286. DOI: 10.1097/01.brs.0000164257.69354.bb.
29. **Oda I, Abumi K, Cunningham BW, Kaneda K, McAfee PC.** An in vitro human cadaveric study investigating the biomechanical properties of the thoracic spine. Spine. 2002;27:E64–E70. DOI: 10.1097/00007632-200202010-00007.

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