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# Curative Effect of Lateral Transforaminal Endoscopy on the Treatment of Thoracic Disc Herniation

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**Abstract**

**Background:** The importance of lateral transforaminal endoscopic treatment of thoracic disc herniation lies in the fact that the use of a needle can remove some of the disc contents and cause the disc herniation to disappear. The present study aimed to evaluate the effect of percutaneous endoscopy on the treatment of patients with thoracic disc herniation.

**Objectives:** To investigate the clinical efficacy and feasibility of transforaminal endoscopic discectomy in the treatment of thoracic disc herniation

**Methods:** This retrospective analysis was conducted on patients with thoracic hernias between January 2014 and December 2019. A total of 13 operative cases were selected via census sampling. Lateral endoscopic treatment of thoracic disc herniation was performed on patients, and they were followed up for 6-18 months. All patients were assessed by the visual analog scale Visual Analogue Score (VAS) and Oswestry Disability Index (ODI) before the surgery, as well as one week, three months, and six months after the operation, respectively.

**Results:** The sample included 13 patients with a mean age of 60.3 years. The location of the thoracic disc herniation varied among the patients. The VAS scores before the surgery, as well as one week, three months, and six months after the surgery, were 7±0.8, 3.3±0.6, 2.3±0.8, 1.4±0.3, and 1.3±0.4, respectively, pointing to a significant decrease (P≤0.001). The ODI scores before the surgery, one day after surgery, one week after surgery, three months after surgery, and six months after surgery were 65.2±5.8%, 11.5±5.3%, 8.9±3.3%, 5.3±2.5, and 4.7±3.5, demonstrating a significant decrease (P≤0.001). The score of the Macnab standard, a rating system evaluating the effectiveness of spine surgeries, was also satisfactory.

**Conclusion:** As evidenced by the results of this study, percutaneous endoscopy in the treatment of patients with thoracic disc herniation was able to improve the clinical condition of patients and replace the previous methods of thoracic hernia surgery as an effective, efficient, and safe method.

*Keywords:* Complications, Disc herniation, Foraminal endoscopy, Technique, Thoracic disc herniation

## 1. Background

The incidence rate of thoracic disc herniation ranges from 0.25% to 0.75%. This disease presents with complex and non-specific clinical manifestations, often requiring surgery for effective treatment. Traditional approaches, such as anterior thoracotomy, posterior laminectomy, transpedicular approach, transverse costal process approach, or posterolateral extrapleural approach, are associated with large trauma, long recovery periods, and high complication rates (1). Nonetheless, in recent years, percutaneous foraminal endoscopic discectomy has emerged as a minimally invasive alternative that has yielded remarkable outcomes in the treatment of intervertebral disc herniation (2). This technique has also been extended from the lumbar to the cervical and thoracic spine.

The use of new diagnostic methods, such as magnetic resonance imaging (MRI), has reported an incidence rate of 15% for thoracic disc herniation in the community (3). Old surgical methods could bring challenges for the patient due to the anatomical condition of the chest. Central compressive laminectomy was used due to iatrogenic complications caused by the manipulation of the spinal cord, which led to the use of transpedicular and costotransversectomy, followed by anterior transthoracic, which used thoracotomy to perform discectomy, followed by potential fusion based on the amount of bone removal (4, 5).

Pain after thoracotomy has increased interest in minimally invasive techniques to approach thoracic disc herniation, such as mini-open, thoracoscopic, and transforaminal endoscopic approaches (5, 6). The transforaminal approach was first reported by Combin, who described a safe transforaminal triangle for percutaneous discectomy in 1973 (7). The thoracoscopic and transforaminal endoscopic approaches are usually performed under local sedation and anesthesia; moreover, postoperative pain is very low, and paraspinal muscles and chest structures are well preserved. The risk of epidural scar formation and instability during the postoperative period can be minimized (8).

Despite its success, the use of percutaneous foraminal endoscopy for thoracic disc herniation remains an area of limited research due to the considerable anatomical

differences between the thoracic and lumbar spine. The thoracic spinal canal has limited reserve space, and the spinal cord tolerance is relatively low, while the influence of the ribs and thorax can also limit the operation space. As such, there are few reports on the effectiveness of this technique in the treatment of thoracic disc herniation (9, 10).

## 2. Objectives

Therefore, the present study aimed to evaluate the effect of percutaneous endoscopy on the treatment of patients with thoracic disc herniation.

## 3. Methods

*3.1. Study design and participants*

This retrospective analysis was conducted on patients with thoracic hernia between January 2014 and December 2019. During this time period, 13 patients with thoracic disc herniation were referred to the hospital, and all of them were studied by census sampling method. All patients had American Society of Anesthesiologists (ASA) grade I or II and child Pugh grade A or B. The inclusion criteria were patients over 50 years of age, diagnosis of thoracic hernia using Magnetic resonance imaging (MRI), absence of mass and malignant disease, and no chest fracture. On the other hand, the exclusion criteria entailed severe hypertension, as well as a history of cardiovascular, cerebrovascular, and respiratory diseases.

*3.2. Surgical method*

*3.2.1. Preoperative preparation and positioning*

The approach direction, side opening angle, and side opening distance are designed in (Picture Archiving and Communication System) PACS system in advance (Figure 1). The patient takes the healthy side-lying position, and the Digital Subtraction Angiography (DSA) machine (GE Company of the United States) fluoroscopically locates the target intervertebral space, marks the central line of the spinous process, and marks the central line of the spinous process as the puncture point. The opening distance beside the puncture point is generally about 4.5-6 cm.1.2.2 puncture.

Local infiltration anesthesia with 0.5% lidocaine was used at the puncture point, and an 18G puncture needle was used to puncture the target intervertebral space. The puncture direction was from the outer upper part to the inner lower part, with an included angle of 40°-60° with the sagittal plane. After the puncture needle reaches the articular process bone, inject lidocaine 5 ~ 10 ml in all directions. Adjust the angle of the puncture needle so that the puncture needle slides over the ventral side of the superior articular process. The positive perspective needle tip is close to the connecting line of the inner edge of the pedicle. The lateral perspective demonstrates that the needle tip is to the front edge of the intervertebral foramen and the rear edge of the intervertebral space (figures 2 and 3).

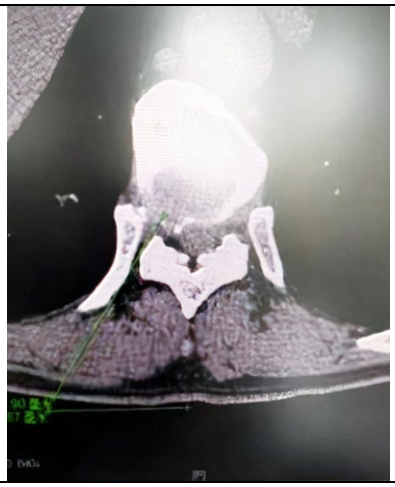

**Figure 1**. T8/9 intervertebral disc herniation with calcification


**Figure 2.** Puncture needle reaches the inner edge of the T7/8 pedicle line

*3.2.2. Intervertebral foramen plasty*

Place the guide wire, cut the skin about 8mm, expand step by step, and grind the upper articular process with a circular saw and a safety grinding drill. Ventral bone and enlarged intervertebral foramen (figures 4 and 5). When grinding, it shall not exceed the connecting line of the inner edge of the pedicle to avoid sudden stabbing into the spinal canal and damaging the spinal nerve. For the working channel tube placed after the enlargement and shaping of the intervertebral foramen, the anteroposterior fluoroscopy reaches the inner edge of the pedicle, and the lateral fluoroscopy is at the posterior edge of the intervertebral space (Figures 6 and 7).

**Figure 3.** Puncture needle reaches the rear edge of T7/8 intervertebral space

**Figure 4.** Safety grinding drill for T7/8 intervertebral foramen formation along the guide wire

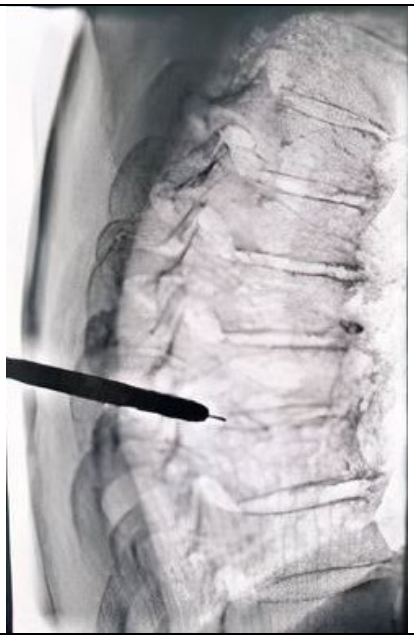

**Figure 5.** Safety grinding drill for T7/8 intervertebral foramen formation along the guide wire

**Figure 6.** Working passage tube inserted into the inner edge of T7/8 pedicle line

*3.2.3. Mirror operation*

Identify the anatomical structure in the spinal canal under the microscope, remove blood clots, polished debris, or small bone fragments with nucleus pulposus forceps, stop bleeding, and ablate some muscle tissues with bipolar radiofrequency knife head so as to make the surgical field of vision clear. If the working channel tube is blocked by small joints, a bone chisel or power grinding drill can be used to further expand the intervertebral foramen. A part of the ligamentum flavum was removed to expose the lateral dural sac. The posterior longitudinal ligament and the herniated intervertebral disc were explored from the ventral side of the dural sac. After the incision, the herniated nucleus pulposus was removed one by one until the dural sac became loose or there was spontaneous pulsation. The residual nucleus pulposus and the outer mouth of the fibrous ring were ablated and shrunk by a bipolar radiofrequency knife. The posterior edge of the hyperplastic vertebral body, ossified intervertebral disc, and posterior longitudinal ligament should be polished with a bone knife or power until the focus is completely removed (figures 8 and 9). Finally, the endoscope was removed, and the incision was sutured with one needle.

**Figure 7.** Working passage tube inserted into the posterior edge of T7/8 intervertebral space


**Figure 8.** DSA type CT reconstruction immediately after operation shows that T7/8 central calcification has been cleared


**Figure 9.** DSA type CT reconstruction immediately after operation shows that T7/8 central calcification has been cleared

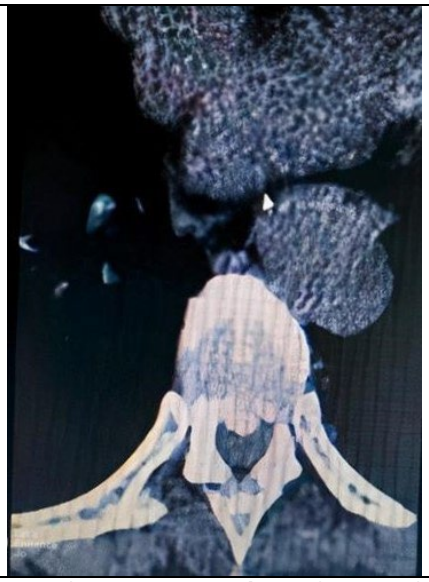

**Figure 10.** T7/8 protrusion with ossification of posterior longitudinal ligamen

*3.3. Postoperative management measures*

The patients were treated with dehydration and anti-inflammatory drugs after the operation. The patients could get out of bed within three days.

*3.4. Follow-up and observation indices*

All patients were followed up for 6-18 months (mean 12 months). The evaluation of pain level with visual analog scale (VAS) and function with Oswestry disability index (ODI) in all patients before surgery and after surgery on the first postoperative day, as well as one week, three months, and six months postoperatively, was performed after the operation. It is noteworthy that due to the fact that VAS and ODI criteria were routinely recorded for all patients, they were used in the evaluation of patients. The curative effect was evaluated according to the Macnab standard.

*3.5. Oswestry Disability Index and Macnab Index*

The functional disability of patients was measured by the Oswestry Disability Index (ODI). The ODI questionnaire evaluates the patient's functional disability level in 10 sections, including pain intensity, personal tasks, lifting objects, walking, sitting, standing, sleeping, sexual activity, social relations, and travel. Each section of this questionnaire includes six options, and in the worst case of disability, a score of 5 is given to each section, which will be equal to 50 in the total scores of the 10 sections. The total disability is calculated by multiplying the total scores of each section by 2.

In fact, this questionnaire values performance disability between 0-100. In this order, a score of zero indicates a person's complete health and functioning without pain, 0-25 is a mild disability, 25-50 is a

moderate disability, 50-75 is a high disability, and 75-100 is a severe disability, and it is quite acute that the person is not able to perform the intended activity. (11). The clinical results after surgery were evaluated using the modified Macnab criteria, including four categories (12), as displayed in Table 1.

**Table 1.** Modified Macnab criteria for the assessment of clinical outcomes

| Outcome | Characteristic |
|---|---|
| **Excellent** | No pain; no restriction of mobility; return to normal work and level of activity |
| **Good** | Occasional nonradicular pain; relief of presenting symptoms; able to return to modified work |
| **Fair** | Some improved functional capacity; still handicapped and/or unemployed |
| **Poor** | Continued objective symptoms of root involvement; additional operative intervention needed at index level irrespective of length of postoperative follow-up |

*3.6. Statistical analysis*

To analyze the data results, statistical processing will be conducted using SPSS software (version 26.0). For measurement data that follows a normal distribution, the mean and standard deviation (χ± s) will be used to express the data. Independent sample t-test will be utilized for the comparison between groups, and a P-value of less than <0.05 is considered statistically significant.

## 4. Results

The sample included 13 patients, comprising 8 males and 5 females, ranging in age from 55-76 years with a mean age of 60.3 years. The location of the thoracic disc herniation varied among the patients. One case had T7/8 and T8/9 protrusion, two cases had T9/10 and T10/11 protrusion, three cases had T11/12 protrusion, and four cases had T12/L1 protrusion, including three cases with intervertebral disc calcification (Figure 1), two cases with ossification of the posterior longitudinal ligament (Figure 10), and one case with extreme lateral protrusion (Figure 11). The operation proceeded smoothly, with an average operation time of 1-2 hours. Importantly, no injuries were observed during the operation to the nerve root, spinal cord, or dural sac. Postoperative symptoms were immediately alleviated or significantly improved, and patients were discharged three days after the operation.

All patients' VAS score and ODI index displayed significant decreases on the first day, the first week, the third month, and the sixth month after the operation compared to pre-operation values (Table 2). The VAS scores before the surgery, one day after surgery, one week after surgery, three months after surgery, and six months after the surgery were 7±0.8, 3.3±0.6, 2.3±0.8, 1.4±0.3, and 1.3±0.4, respectively, demonstrating a significant decrease (P≤0.001). The ODI scores before the surgery, one day after surgery, one week after surgery, three months after surgery, and six months after surgery were 65.2±5.8%, 11.5±5.3%, 8.9±3.3%, 5.3±2.5, and 4.7±3.5, pointing to a significant decrease (P≤0.001).

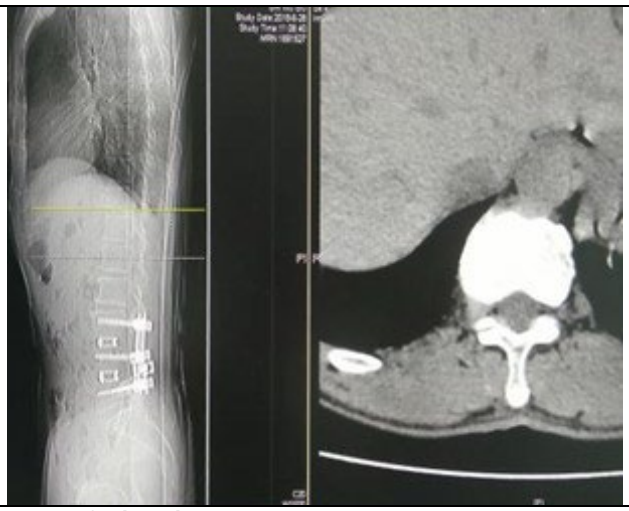

**Figure 11.** T11/12 lateral protrusion

**Table 2.** Comparison of VAS scores before and after operation (`χ±s)

| Time score | Preoperative | one day after the operation | One week after the operation | Three months after operation | Six months after the operation | P-value* |
|---|---|---|---|---|---|---|
| **VAS** | 7±0.8 | 3.3±0.6 | 2.3±0.8 | 1.4±0.3 | 1.3±0.4 | 0.001 |
| **ODI** | 65.2±5.8 | 11.5±5.3 | 8.9±3.3 | 5.3±2.5 | 4.7±3.5 | 0.001 |

*P-value repeated measure

**Table 3**. Postoperative macnab standard score of patients

| Number of cases MacNab | One day after operation | One week after operation | Three months after operation | Six months after operation |
|---|---|---|---|---|
| **Excellent** | 8 (61.5%) * | 10 (78%) | 12 (92.3%) | 12 (92.3%) |
| **Good** | 5 (38.5%) | 3 (22%) | 1 (7.7%) | 1 (7.7%) |
| **Fair** | 0 | 0 | 0 | 0 |
| **Poor** | 0 | 0 | 0 | 0 |

*Frequency (%)

The score of the Macnab standard, a rating system evaluating the effectiveness of spine surgeries, was also satisfactory. According to the modified Macnab standard to evaluate the effect, one day after surgery, 8 (61.5%) and 5 (38.5%) cases got excellent and good results, respectively. One day after surgery, 10 (78%) and 3 (22%) subjects obtained excellent and good results, respectively. Three months after surgery, 12 (92.3%) and 1 (7.7%) patients got excellent and good results, respectively. Six months after surgery, 12 (92.3%) and 1 (7.7%) cases obtained excellent and good results, respectively. Finally, six months after the operation, 100% of the patients had excellent and good results (Table 3).

## 5. Discussion

Clinical manifestations of thoracic disc herniation

This study evaluated the effect of percutaneous endoscopy on the treatment of patients with thoracic disc herniation. The VAS score and ODI index of all patients showed significant decreases, which showed an improvement in patients' condition. Findings suggest that percutaneous foraminal endoscopy may be a safe and effective treatment option for thoracic disc herniation, with significant improvements in postoperative symptoms and no observed complications. In their study, J Bae et al. (2020) (13) investigated the clinical results of transforaminal thoracic endoscopic discectomy in patients with thoracic hernia. In this study, 92 patients were followed up for 38.4 months, and patients were evaluated using (VAS) and Oswestry (ODI). In line with the results of this study, it was shown that the patients showed a significant improvement in pain, and finally, endoscopic transforaminal thoracic discectomy is an effective and efficient method in the treatment of thoracic hernia.

Evaluation of percutaneous endoscopy for the treatment of thoracic disc herniation in the study of S Meng et al. (2023) (14) was also done. In this study, 12 patients were treated from January 2019 to December 2021. Patients were followed up for at least nine months. Visual analog scale (VAS) scores and modified Japan Orthopedic Association (m-JOA) scores were evaluated preoperatively, on day 1, as well as 3, 6, and 12 months postoperatively or at the last postoperative stage. Modified MacNab criteria were used to assess clinical efficacy at 12 months postoperatively or at last follow-up. The results of this study improved the average scores of VAS, improved scores (m-JOA), and based on MacNab criteria, scored good to excellent. And finally, the results of this study confirmed the results of the present study, demonstrating that percutaneous endoscopy is a safe, effective ,and efficient method for the treatment of thoracic disc herniation.

The beneficial effects of using percutaneous endoscopy in the treatment of patients with thoracic disc herniation were brought for patients, also shown in studies by G Choi and D Munoz-Suarez (2020) (15), K Houra et al. (2021) (16) and Z Cao et al. (2023) (17), in addition to improving the clinical condition of patients with minimal complications.

Thoracic disc herniation is mainly of central type and paracentral type, often accompanied by cartilaginous nodules (intraosseous cartilaginous nodules at the posterior edge of the vertebral body), irregular end plate, wedge-shaped degeneration of the vertebral body, atypical Scheuermann disease, and ossification of the ligamentum flavum, resulting in the progressive aggravation of thoracic spinal canal stenosis and spinal cord compression(18). According to different positions, thoracic disc herniation can be divided into the upper thoracic segment (T1 ~ 4), thoracic segment (T5 ~ 10), and thoracolumbar segment (T10 ~ L2). Upper thoracic segment and thoracic disc herniation are mostly characterized by weakness of lower limbs, increased muscle tension, damage of upper motor neurons, partial herniation, and compression of nerve roots, resulting in intercostal neuralgia; the level of thoracolumbar segment is from head to tail, including the spinal cord, conus, cauda equina, and other nerve structures. Therefore, according to the different positions of prominent compression, the clinical manifestations can be mixed damage of upper and lower motor neurons, or simply damage of upper or lower motor neurons, which is very easy to be misdiagnosed or missed (9). The most common symptoms are back pain, lower extremity root pain, lower abdominal wall pain, and lower extremity weakness. In severe cases, it even causes paraplegia and defecation dysfunction.

### *5.1. Surgical approach and treatment selection*

Thoracic or thoracolumbar disc herniation, once diagnosed, requires surgical treatment. The traditional surgical approach is divided into the anterior and posterior approaches. The posterior approach includes the laminectomy, transpedicular, transverse costal process, and posterolateral

extrapleural approaches (1) The posterior total laminectomy has been eliminated due to the high probability of spinal cord traction injury during the removal of anterior pressure objects. The posterior transpedicular approach can reduce the risk of spinal cord traction by removing the inferior pedicle and facet joint and exposing the lateral intervertebral disc; nonetheless, it is difficult to remove the central type, paracentral type, or intradural protrusion. At the same time, this operation causes considerable damage to the stable structure of the spine, and internal fixation is needed during the operation. The transverse costal process approach and posterolateral extrapleural approach can increase the exposure of the ventral side of the spinal canal by removing part of the ribs, transverse process, pedicle, and facet joints. However, this approach inflicts serious damage to the bone structure, surrounding muscle soft tissue, and the nerve root (19). The classic anterior transthoracic approach can expose the entire ventral dura mater and fully decompress. Nevertheless, thoracotomy exerts marked effects on the lung, and the postoperative pulmonary function is lost by at least 10% (20). The postoperative recovery time of patients is long. Although assisted thoracoscopy can reduce the incidence of complications in thoracotomy, thoracoscopy has high technical requirements and a long learning curve (21).

Due to the special anatomical structure of the thoracic spine, physiological kyphosis, small mobility, relatively small volume of the spinal canal, rib obstruction in puncture path, pulmonary distention, and pleura in front, the operation of the thoracic spine is complex and difficult. In the early stage, due to the above characteristics and equipment limitations, the application of spinal endoscopy in the thoracic spine was affected to a certain extent. In recent years, due to the innovation of spinal endoscopy technology and the improvement of the endoscopic power system, Choi, Nie Jia, and other scholars have explored the treatment of thoracic disc herniation with intervertebral foraminal mirror and achieved certain curative effects. They believe that it can be used to treat thoracic disc herniation without calcification or sclerosis. For calcified or free thoracic disc herniation, the intervertebral foraminal mirror technology is not suitable due to the limitation of equipment (22). In fact, we have achieved satisfactory results in the treatment of patients with thoracic disc herniation with calcification or ossification of the posterior longitudinal ligament.

The primary technique of percutaneous foraminal surgery is the distance, angle, and direction of paracentesis. It is relatively easy in the lower lumbar spine since there is no rib block. Although there is the 12th rib block in the upper lumbar segment, the anterior and posterior diameter of the intervertebral foramen is large; therefore, the puncture can be completed without too much paracentesis distance. Nonetheless, due to the particularity of thoracic vertebra structure, when puncture to the diseased intervertebral space and intervertebral foramen, the upper rib tilts from the inside up to the outside down, blocking the traditional puncture approach from the outside up to the inside down. It makes the opening distance beside the puncture significantly smaller than that of the lumbar spine and the included angle with the sagittal puncture smaller so as to overcome the obstruction of the rib. With the increase of the thoracic vertebral lesion stage, the paracentesis distance and the included angle are becoming smaller and smaller. In this group, the paracentesis distance is between 4.5-6 cm, and the puncture angle is between 40-60 degrees. Both of them determine that the puncture needle and the final working channel tube do not easily reach the spinal canal, especially it is difficult to deal with the intervertebral disc with central protrusion and calcification and the ossified posterior longitudinal ligament (23). One case of thoracic intervertebral disc protrusion in this group was extraforaminal protrusion; therefore, the puncture difficulty was relatively small; nonetheless, most of them were central and paracentral protrusions. Therefore, the grinding of the articular process was very important without sufficient paracentesis distance and angle. If the grinding is difficult or unsatisfactory, it could be further polished under the microscope until the working channel tube can move to the head, tail, and center of the spinal canal; it is convenient to explore the spinal nerve and deal with the diseased tissue. One patient had central protrusion with ossification of the posterior longitudinal ligament and compression of the spinal cord. The calcification was completely removed after dynamic ...?

*5.2. Precautions for operation*

Some details need to be paid attention to in the treatment of thoracic disc herniation by percutaneous foraminal endoscopy: (1) foreign Hoogland, Yeung, and domestic Zhou Yue and Bai Yibing have different understanding and design of lumbar foraminal endoscopy approach (24, 25); therefore, lumbar surgery can flexibly grasp the lateral opening distance and puncture angle according to each operator's different habits or experience. However, the thoracic vertebra is different due to the obstruction of ribs; the puncture path is relatively fixed and cannot be changeable. Therefore, it is necessary to carefully read the film before the operation, measure the distance and angle on the imaging system, and design the puncture approach in advance, which can get twice the result with half the effort (2). Do not damage the pleura and lungs during the puncture, grasp the angle during the expansion and grinding of the intervertebral

foramen, and do not over-polish the small joints so as to avoid affecting the stability of the spine and causing new low back pain in the future (10). The action should be slow and gentle when forming and placing the tube in the intervertebral foramen to avoid sudden falling and damaging the spinal cord. If the power is used, the rotation speed of the grinding ball heads and the distance from the nerve and spinal cord should be controlled to prevent damaging the spinal cord nerve during grinding. Hemostasis under the microscope should be gentle. Pay attention to avoid direct contact between RF and the dural sac, resulting in spinal cord thermal injury. It is forbidden to damage the spinal cord nerve by blind operation of nucleus pulposus forceps when it is unclear under the microscope and unfamiliar with anatomy (4). Control the flow rate and pressure of irrigation fluid during operation to prevent spinal cord hypertension (10).

In this group, no adverse reactions and spinal cord nerve injury were found during and after the operation, and no low back pain was observed after the operation and discharge follow-up. The successful operation demonstrates that percutaneous foraminal endoscopy is safe and effective in the treatment of middle and lower thoracic disc herniation with posterior edge hyperplasia and posterior longitudinal ligament calcification. It is feasible in operation, with less trauma and rapid recovery; however, there are few previous literature reports on the treatment of thoracic disc herniation by percutaneous foraminal endoscopy, and there is a lack of more reference experience in the treatment of thoracic disc herniation by foraminal endoscopy. At present, daunting challenges are presented to free disc herniation and severe bony spinal canal stenosis. At the same time, the number of cases in this study is limited, and only some preliminary experience is obtained. More experience needs to be accumulated and summarized in clinical practice.

## 6. Conclusion

As evidenced by the results of the study, percutaneous endoscopy in the treatment of patients with thoracic disc herniation was able to improve the clinical condition of patients and replace the previous methods of thoracic hernia surgery as an effective, efficient, and safe method. Nevertheless, further research is needed to examine its effectiveness in severe cases. Overall, percutaneous endoscopy is a promising treatment option for thoracic disc herniation.

## Footnotes

**Conflicts of Interest:** The authors declare that they have no conflict of interest.

**Author's contributions:** Li Zhong-Ming: Conceptualization, Methodology, Data curation, Formal analysis, Writing–original draft, Writing–review and editing. Zong Chen-yu: Data curation, Formal analysis, Writing–review and editing. Lin Jun-fei: Data curation, Writing–review and editing. Du Jia-Shang: Conceptualization, Methodology, Supervision, Funding acquisition, Writing–review and editing. All authors have read and agreed to the published version of the manuscript.

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**Ethical considerations:** Informed consent was obtained from all participants before participating in the study. In this study, the Declaration of Helsinki was followed in order to comply with ethical principles.

## References

1. Oppenlander ME, Clark JC, Kalyvas J, Dickman CA. Surgical management and clinical outcomes of multiple-level symptomatic herniated thoracic discs. *J Neurosurg Spine*. 2013;**19**(6):774-83. doi: 10.3171/2013.8.SPINE121041. [PubMed: 24116677].
2. Jiang X, Zhou X, Xu N. Clinical effects of transforaminal and interlaminar percutaneous endoscopic discectomy for lumbar disc herniation: A retrospective study. *Medicine (Baltimore)*. 2018;**97**(48):e13417. doi: 10.1097/MD.0000000000013417. [PubMed: 30508947].
3. Lee SH, Musharbash FN. Uniportal, Transforaminal endoscopic thoracic discectomy: review and technical note. *Neurospine*. 2023;**20**(1):19-27. doi: 10.14245/ns.2346074.037. [PubMed: 37016850].
4. Bae J. Transforaminal endoscopic thoracic discectomy and decompression. Core Techniques of Minimally Invasive Spine Surgery. Springer; 2023. p. 111-8.
5. Amato MCM, Aprile BC, Esteves LA, Carneiro VM, de Oliveira RS. Full endoscopic thoracic discectomy: is the interlaminar approach an alternative to the transforaminal approach? A technical note. *Int J Spine Surg*. 2022;**16**(2):309-17. doi: 10.14444/8209. [PubMed: 35444040].
6. Bouthors C, Benzakour A, Court C. Surgical treatment of thoracic disc herniation: an overview. *Int Orthop*. 2019;**43**:807-16. doi: 10.1007/s00264-018-4224-0. [PubMed: 30406842].
7. Kim M, Kim HS, Oh SW, Adsul NM, Singh R, Kashlan ON, et al. Evolution of spinal endoscopic surgery. *Neurospine*. 2019;**16**(1):6-14. doi: 10.14245/ns.1836322.161. [PubMed: 31618807].
8. Khandge AV, Sharma SB, Kim JS. The evolution of transforaminal endoscopic spine surgery. *World Neurosurg*. 2021;**145**:643-56. doi: 10.1016/j.wneu.2020.08.096. [PubMed: 32822954].
9. Wang J, Zhou Y, Zhang ZF, Li CQ, Zheng WJ, Huang B. Disc herniation in the thoracolumbar junction treated by minimally invasive transforaminal interbody fusion surgery. *J Clin Neurosci*. 2014;**21**(3):431-5. doi: 10.1016/j.jocn.2013.04.029. [PubMed: 24225365].
10. Liu Y, XU B, JI N, Jiang H, Yang Q. Preliminary experience of percutaneous transforaminal endoscopic spine system in thoracic discectomy for disc herniation. *Tianjin Med J*. 2017:121-4.
11. Yates M, Shastri-Hurst N. The oswestry disability index. *Occup Med*. 2017;**67**:241-2. doi: 10.1093/occmed/kqw051.
12. Özger Ö, Kaplan N. Evaluation of clinical outcomes of 271 patients undergoing lumbar microdiscectomy in the light of literature. *Ann Med Res*. 2020;**27**:664-9. doi: 10.5455/annalsmedres.2019.11.739.
13. Bae J, Chachan S, Shin SH, Lee SH. Transforaminal endoscopic thoracic discectomy with foraminoplasty for the treatment of thoracic disc herniation. *J Spine Surg*. 2020;**6**(2):397-404. doi: 10.21037/jss.2019.11.19. [PubMed: 32656377].

14. Meng S, Han J, Xu D, Wang Y, Han S, Zhu K, et al. Fully endoscopic transforaminal discectomy for thoracolumbar junction disc herniation with or without calcification under general anesthesia: Technical notes and preliminary outcomes. *Front Surg*. 2023;**9**:1067775. doi: 10.3389/fsurg.2022.1067775. [PubMed: 36684323].
15. Choi G, Munoz-Suarez D. Transforaminal endoscopic thoracic discectomy: technical review to prevent complications. *Neurospine*. 2020;**17**(1):58–65. doi: 10.14245/ns.2040250.125. [PubMed: 32746518].
16. Houra K, Saftic R, Knight M. Five-Year outcomes after transforaminal endoscopic foraminotomy and discectomy for soft and calcified thoracic disc herniations. *Int J Spine Surg.* 2021;**15**(3):494-503. doi: 10.14444/8071. [PubMed: 33963033].
17. Cao Z, Li ZZ, Zhao HL, Zhu JL, Hou SX. Technical notes and clinical outcomes of full-endoscopic interbody fusion via transforaminal approach for hard disc herniations in thoracolumbar junction. *Orthop Surg*. 2023;**15**(7):1893-903. doi: 10.1111/os.13759. [PubMed: 37259903].
18. Iwasaki M, Akino M, Hida K, Yano S, Aoyama T, Saito H, et al. Clinical and radiographic characteristics of upper lumbar disc herniation: ten-year microsurgical experience. *Neurol Med Chir (Tokyo).* 2011;**51**(6):423-6. doi: 10.2176/nmc.51.423. [PubMed: 21701105].
19. Lubelski D, Abdullah KG, Steinmetz MP, Masters F, Benzel EC, Mroz TE, et al. Lateral extracavitary, costotransversectomy, and transthoracic thoracotomy approaches to the thoracic spine: review of techniques and complications. *J Spinal Disord Tech.* 2013;**26**(4):222-32. doi: 10.1097/BSD.0b013e31823f3139. [PubMed: 22143047].
20. Zhao Y, Wang Y, Xiao S, Zhang Y, Liu Z, Liu B. Transthoracic approach for the treatment of calcified giant herniated thoracic discs. *Eur Spine J*. 2013;**22**(11):2466-73. doi: 10.1007/s00586-013-2775-8. [PubMed: 23771552].
21. Wait SD, Fox DJ, Jr., Kenny KJ, Dickman CA. Thoracoscopic resection of symptomatic herniated thoracic discs: clinical results in 121 patients. *Spine*. 2012;**37**(1):35-40. doi: 10.1097/BRS.0b013e3182147b68. [PubMed: 21336237].
22. Miao X, He D, Wu T, Cheng X. Percutaneous endoscopic spine minimally invasive technique for decompression therapy of thoracic myelopathy caused by ossification of the ligamentum flavum. *World Neurosurg*. 2018;**114**:8-12. doi: 10.1016/j.wneu.2018.02.152. [PubMed: 29524712].
23. Sharifzad F, Yasavoli-Sharahi H, Mardpour S, Fakharian E, Nikuinejad H, Heydari Y, et al. Neuropathological and genomic characterization of glioblastoma-induced rat model: How similar is it to humans for targeted therapy? *J Cell Physiol*. 2019;**234**(12):22493-504. doi: 10.1002/jcp.28813. [PubMed: 31120149].
24. Qian JX. Development and future of transforaminal endoscopic spine system. *Zhongguo Gu Shang.* 2018;**31**(4):297-301.
25. Wang H, Huang B, Li C, Zhang Z, Wang J, Zheng W, et al. Learning curve for percutaneous endoscopic lumbar discectomy depending on the surgeon's training level of minimally invasive spine surgery. *Clin Neurol Neurosurg*. 2013;**115**(10):1987-91. doi: 10.1016/j.clineuro.2013.06.008. [PubMed: 23830496].