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Advances in Minimally Invasive Surgical Treatment of Thoracic Disc Herniation

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Abstract: *Currently, minimally invasive surgical treatments for Thoracic disc herniation (TDH) mainly include Thoracoscopic Surgery, Thoracic Microscopic Discectomy(TMD), Thoracic Microendoscopic Discectomy (TMED), Transforaminal Endoscopic Thoracic Discectomy (TETD), and Unilateral Biportal Endoscopic(UBE) for thoracic disc excision. Compared to traditional open surgery, minimally invasive surgeries offer advantages such as smaller incisions, less intraoperative blood loss, lighter postoperative pain, faster recovery, reduced hospital stay, and cost savings. Different minimally invasive surgical approaches for thoracic disc herniation have their own strengths and weaknesses. When patients have clear surgical indications, the optimal surgical treatment should be chosen based on the patient's specific symptoms and signs, as well as imaging findings, and tailored to their individual circumstances.*

Keywords: *Thoracic Disc Herniation, Thoracic Disc Excision, Minimally Invasive Spinal Surgery*

1. Introduction

Thoracic disc herniation (TDH) is relatively uncommon, accounting for approximately 0.25% to 0.75% of all disc herniations [1]. Historically, the diagnosis of TDH heavily relied on patients' medical history and physical examination due to the lack of imaging studies [2]. However, in the latter half of the 20th century, advancements in diagnostic imaging and surgical techniques significantly improved the diagnosis and prognosis of TDH. Thoracic disc excision surgery constitutes approximately 0.15% to 4% of all disc surgeries performed [3]. Symptoms of TDH may manifest as thoracic or back pain (localized, axial, or radicular), sensory disturbances, myelopathy, reflex hyperactivity/spasms, and urinary or fecal incontinence, depending on the location of the herniated disc, and typically exhibit a progressive course [4]. With the widespread use and increased frequency of imaging studies, TDH is often an incidental finding.

Conservative treatment, including activity modification, nonsteroidal anti-inflammatory drugs, and rehabilitation exercises or physical therapy, is appropriate for most asymptomatic patients [5]. However, surgical intervention should be considered for symptomatic patients with myelopathy or refractory radicular pain. Vertebrectomy and fusion were among the initial surgical approaches for TDH treatment; however, due to severe complications such as spinal cord ischemia and high mortality rates, they are now prohibited [6, 7]. With the growing popularity of minimally invasive techniques and advancements in endoscopic spinal surgery, surgical interventions for TDH have become increasingly minimally invasive and safer. Minimally invasive surgeries offer advantages such as reduced trauma, less postoperative pain, minimal blood loss, shorter hospital stays, faster recovery, and satisfactory clinical outcomes [8-10]. Currently, minimally invasive thoracic disc excision surgeries include thoracoscopic thoracic disc excision, mini-open thoracic disc excision, microscopic thoracic disc excision, endoscopic thoracic disc excision, percutaneous endoscopic thoracic discectomy, and unilateral bilateral channels spinal endoscopy for thoracic disc excision. Each approach has its own advantages and characteristics. This review article summarizes the research progress on these minimally invasive thoracic disc excision surgeries.

2. Thoracoscopic Surgery for Thoracic Disc Herniation

Thoracoscopic surgery serves as an alternative approach to traditional open thoracotomy for the treatment of thoracic disc herniation (TDH), offering significant advantages through an anterior

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approach [11]. The origins of thoracoscopic technology date back to the early 20th century, with the first clinical application of thoracoscopy introduced by Jacobaeus in 1910, marking a century-long history of thoracoscopic surgery. In the early 1990s, thoracic surgeons discovered that video-assisted thoracic surgery (VATS) could effectively improve pulmonary function and alleviate post-thoracotomy pain. Following traditional open thoracic surgeries, up to 50% of patients experienced post-thoracotomy intercostal neuralgia, a chronic condition where 30% of patients continued to experience pain for 4 to 5 years postoperatively, leading to a portion of patients becoming occupationally disabled due to severe pain [12, 13]. Landreneau et al. [14], through comparative studies of thoracoscopic surgery, open surgery, and posterior rib resection, concluded that thoracoscopic surgery significantly reduced the incidence of intercostal neuralgia and favored patients' return to normal life postoperatively. The effectiveness of the surgery can also be reflected by the thoroughness of disc removal. Rosenthal et al. [15] demonstrated the efficacy and sufficiency of thoracoscopic disc excision by examining the rate of residual disc fragments in patients undergoing thoracoscopic, open, and rib resection surgeries. Through relevant prospective studies, it was found that thoracoscopic management of TDH resulted in significant improvements in postoperative pain symptoms, satisfactory recovery of neurological and motor functions, high patient satisfaction with the surgery, and significantly reduced surgical complications compared to open surgery [16].

However, thoracoscopic treatment of TDH also has certain limitations. Firstly, the greatest challenge of thoracoscopic technology in minimally invasive spinal surgery lies in its steep learning curve [17]. Most spinal surgeons are unfamiliar with thoracoscopic techniques, and the low incidence of thoracic spine disorders, difficulty in physician training, and the high cost of instrumentation significantly limit the development of thoracoscopic technology in treating spine-related diseases. Additionally, establishing thoracoscopic channels requires single-lung ventilation, posing anesthesia risks associated with lung collapse, making respiratory system-related complications more significant with this technique. The incidence of complications following anterior approach treatment of TDH ranges from 11% to 27% [18], with complications such as pleural effusion, atelectasis, pneumonia, and pneumothorax, which also considerably hinder the development of thoracoscopic technology in minimally invasive spinal surgery.

3. Thoracic Microscopic Discectomy (TMD)

Bartels and Peul [19] reviewed cases of thoracic disc herniation (TDH) treated with their thoracoscopic and microscopic minimally invasive techniques and found that thoracic microscopic discectomy is equally effective for decompression of the spinal canal while avoiding the steep learning curve associated with thoracoscopic inspection. The microscope used in this procedure provides an excellent field of view, with virtually no learning curve.

Chi et al. [20] emphasized the importance of minimizing damage to muscles and ligaments in alleviating postoperative pain. They treated 7 patients with TDH using a posterior approach under microscopic guidance and compared them with 4 patients undergoing traditional open surgery. The microscopic group exhibited significantly lower muscle and ligament damage and intraoperative bleeding compared to the open group, with the former showing significant improvement in Prolo scores compared to the latter. Khoo et al. [21] first achieved thoracic disc excision, spinal canal decompression, and interbody fusion through a posterior approach with a microscopic minimally invasive technique, treating 13 symptomatic TDH patients. All cases achieved complete decompression without fusion device displacement, and patients in the TMD group showed better clinical scores than those in the traditional thoracic surgery group. Kasliwal et al. [22] developed a lateral thoracic membrane posterior approach under microscopic guidance for the treatment of TDH. They reported treating 7 cases of central TDH with this technique, with an average hospital stay of 2.6 days and no postoperative surgical complications, yielding good clinical outcomes. Cerillo et al. [23] considered the lateral thoracic membrane posterior approach under microscopic guidance to be an effective method for treating TDH, reporting satisfactory clinical outcomes in 20 out of 23 patients treated with this method. Cho et al. [24] reported treating TDH through a microscopic oblique paravertebral approach using 3D navigation and tubular retraction system, providing a new surgical strategy for minimally invasive TDH treatment. Regev et al. [25] reported treating TDH through a microscopic intervertebral foramen approach. They treated 12 TDH patients with this technique, with a median operative time of 128 minutes, median blood loss of 100ml, median hospital stay of 2 days, and significant improvement in all patients' symptoms postoperatively, with the average pain VAS score decreasing from 4.5 to 2.

Advantages and disadvantages of thoracic microscopic discectomy: (1) Three-dimensional imaging

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provides a surgical field similar to open surgery, with a short learning curve, making it easier for surgeons to master and teach. (2) Compared to endoscopy, surgeons can use both hands freely for operation, with a large operating space, and assistants can stand on the opposite side to assist in the same field of view. (3) Compared to traditional open surgery, TMD causes less damage to muscles and ligaments and less bleeding during surgery, alleviating postoperative pain symptoms. (4) However, this method requires a long operative channel, usually exceeding 13 centimeters, and may require longer instruments. The narrow channel also makes it difficult to address bleeding and other complications, possibly requiring conversion to open surgery.

4. Thoracic Microendoscopic Discectomy (TMED)

Perz-Cruet et al. [26] developed a new minimally invasive technique for the treatment of thoracic disc herniation—thoracic microendoscopic discectomy (TMED)—in 2004. This technique is an improvement upon lumbar microendoscopic discectomy (MED), which has been successfully used to treat various lumbar spine conditions including stenosis, disc herniation, and instability. They reported on 7 patients, with an average single-level surgical time of 1.7 hours, average intraoperative blood loss of 111ml, average follow-up of 9 months, and a success rate of 85.7% according to the modified Prolo scoring criteria. No postoperative complications were observed, and most patients resumed normal activities and work within three weeks postoperatively. Isaacs et al. [27] treated 9 TDH patients with TMED, with an average surgical time of 60 minutes, an average lateral facet joint violation rate of 35.4% (±17.5%), and an average spinal canal decompression rate of 73.5% (±7.9%). Smith et al. [28] treated 16 TDH patients using TMED technique, with an average single-level surgical time of 153 minutes, average hospital stay of 21 hours, no perioperative complications, and an average follow-up of two years, with a success rate of 81.2%. Benzel et al. [29] suggested that treatment plans vary depending on the severity of TDH symptoms, and TMED is a safe and effective method for non-calcified lateral disc herniation.

Advantages and disadvantages of TMED: (1) Minimal damage to the facet joints and avoidance of entering the thoracic cavity and associated complications; (2) Establishment of a stable channel through a series of dilation tubes, reducing damage to surrounding soft tissues and alleviating postoperative pain; (3) Clear intraoperative visualization and exposure of structures. Disadvantages: (1) Long learning curve, requiring thorough mastery of lumbar MED techniques before performing TMED surgery proficiently; (2) Limited operating space.

5. Transforaminal Endoscopic Thoracic Discectomy (TETD)

Since the 1980s, endoscopic spine surgery for lumbar disc herniation has seen expanding indications and has been utilized for treating cervical spinal stenosis, cervical disc herniation, and thoracic disc herniation [30]. The foraminal approach provides a safe surgical corridor for accessing the thoracic spinal canal, and transforaminal endoscopic thoracic discectomy (TETD) under local anesthesia has emerged as an effective method for treating TDH. Choi et al. [31] treated 14 cases of soft lateral or central TDH using TETD, all surgeries were performed under local anesthesia, with an average surgical time of 61 minutes. Twelve patients were discharged on the day of surgery or the following day, and patients expressed overall satisfaction with the procedure. Hong-Fei Nie et al. [32] treated 13 TDH patients with TETD under local anesthesia, with an average surgical time of 50 minutes and minimal intraoperative bleeding. One patient experienced positional headache postoperatively, and one patient had recurrence at 8 months postoperatively. With an average follow-up of 6 months, the success rate was 76.9%. Junseok Bae et al. [33] reported treating 92 TDH patients with TETD, with an average follow-up of 38 months. The VAS score decreased from an average of 7.6 preoperatively to 1.6 at the last follow-up, and the ODI score improved from 68.2% to 13.2%. All patients experienced significant improvement in pain symptoms postoperatively, with only one case of transient motor weakness and three cases of limb sensory abnormalities. According to the modified Macnab score, the success rate reached 90.2%. Junseok Bae et al. [34] later compared the clinical efficacy of TETD and MD for TDH treatment, with 39 patients in the TETD group and 38 patients in the MD group. TETD showed significant advantages in terms of awake anesthesia, less blood loss, shorter surgical time, and shorter hospital stay. Consequently, patients undergoing TETD tended to be more satisfied with the modified Macnab score results than those undergoing MD. Albert E. et al. [35] provided detailed reports on two cases treated with TETD technique. Through a step-by-step technique and illustrative videos, the authors concluded that TETD is a safe and effective minimally invasive surgical method for treating

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TDH. However, the time and cost required to master this technique often discourage most surgeons.

Advantages of transforaminal endoscopic thoracic discectomy include: (1) Minimal incision and minimal bone removal maintain spinal stability and reduce postoperative pain; (2) Minimal traction on nerves can reduce nerve edema and minimize postoperative nerve adhesion; (3) Minimal soft tissue dissection reduces surgical blood loss and postoperative pain; (4) Surgery under local anesthesia is safe and allows for same-day discharge, significantly reducing treatment costs. Limitations include: (1) Limited operating space, inability to completely remove the disc, and potential for recurrence; (2) Due to the high risk of thoracic spine surgery, this technique requires surgeons to have extensive endoscopic surgical experience; (3) Difficulty in handling central and calcified protrusions.

6. Unilateral Biportal Endoscopic Thoracic Discectomy (UBE)

Unilateral biportal endoscopic (UBE) technology, an emerging minimally invasive spinal endoscopic technique, originated in Argentina and developed in South Korea. In recent years, it has experienced rapid growth and widespread adoption in China. By establishing two portals (one for observation and one for instrumentation, with incisions of 0.8 cm and 1.0 cm, respectively), this technique is safer than open surgery and more efficient than traditional minimally invasive procedures. UBE has been widely used for treating degenerative lumbar diseases such as lumbar spinal stenosis and disc herniation. With continuous advancements, it has also made breakthroughs in the treatment of degenerative cervical and thoracic diseases [36, 37]. However, reports on UBE for thoracic disc herniation (TDH) are still relatively scarce. Due to the unique sensitivity of the thoracic spinal cord to traction, treating TDH with UBE poses challenges. Ideally, decompression and disc removal should be performed without traction on the spinal cord while avoiding excessive damage to the paraspinal muscles and facet joints. Given the fragility of the thoracic spinal cord, electrophysiological monitoring is essential to prevent cord injury. Through a lateral approach under UBE, with a tilted view and layer-by-layer imaging, bone destruction and traction on the spinal cord can be minimized, ensuring safe and effective removal of the herniated disc.

Advantages of unilateral biportal endoscopic thoracic discectomy include: (1) Clear visualization and layer-by-layer imaging in a watery medium, enhancing safety; (2) Minimal damage to paraspinal muscles and bony structures, reducing postoperative pain; (3) Utilization of traditional spinal surgical instruments, leading to higher efficiency in handling hypertrophic and degenerative tissues, resulting in shorter surgical times; (4) Broad applicability, capable of addressing complex cases involving fusion, cervical, thoracic, and lumbar spine pathologies. Limitations include: (1) Requirement of a certain level of endoscopic expertise and familiarity with thoracic anatomy; UBE procedures for thoracic disc herniation should be performed only after mastering UBE for lumbar and cervical degenerative diseases; (2) Limited reports on UBE for thoracic disc herniation.

7. Conclusion

Thoracic disc herniation has always been a significant challenge for spinal surgeons. The aforementioned minimally invasive surgical techniques are all effective in performing disc removal, thereby improving patients' clinical symptoms. With the increasingly widespread application and development of minimally invasive techniques, spinal surgeons can now safely and reliably perform thoracic disc discectomy through various minimally invasive surgical approaches. In recent years, the unilateral biportal endoscopic (UBE) technique has continued to develop, and the number of reports on treating thoracic disc herniation with UBE in China has also been increasing. Minimally invasive thoracic disc discectomy offers advantages such as reduced trauma, decreased blood loss, alleviation of patient pain, and accelerated recovery. Each minimally invasive surgical approach for thoracic disc herniation has its own advantages and limitations. When patients have clear indications for surgery, the optimal surgical treatment approach should be selected based on the patient's symptoms, physical signs, imaging findings, and individual circumstances.

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