

Application Progress of Spinal Endoscopy in the Treatment of Lumbar Disc Herniation: A Literature Review

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Abstract: Lumbar disc herniation (LDH) is one of the most common spinal diseases. The surgical options can be open or minimally invasive which is adopted according to the condition of patient. With the development of minimally invasive technology, spinal endoscopic therapy has gradually become the main surgical option to treat LDH. According to the situation of patients with lumbar disc herniation and its influence on peripheral nerves and other tissues, combined with the advantages of different endoscopic spinal surgical options, choosing the most suitable surgical option can improve the surgical effect, reduce the occurrence of complications and accelerate the postoperative rehabilitation. This article reviews the progress of endoscopic treatment of lumbar disc herniation.

Keywords: Spinal endoscopy, Progress, Review.

1. Introduction

Lumbar disc herniation (LDH) is a common spine-related disease in clinic. With the development of minimally invasive surgery, especially the continuous innovation and progress of spinal endoscopy, it has provided a better surgical treatment for patients with LDH. Minimally invasive spinal surgery has the advantages of small impact on normal anatomical structure, small incision compared with open surgery, and rapid recovery after surgery. Based on the relevant clinical literature, the advances in surgical techniques of spinal endoscopy for the treatment of LDH are summarized as follows.

2. Spinal Endoscopy and Its Application

1. Transintervertebral foramen approach (percutaneous transluminal endoscopic disc surgery, PTED) In 2003, Thomas Hoogland of Germany invented the transintervertebral foramen endoscope Tessys (Transluminal Endoscopic Spine System) technology, which means that the herniated intervertebral disc is removed from the outside to the inside by entering the epidural space through the intervertebral foramen, and the indications of the intervertebral foramen endoscope are further expanded. The nucleus pulposus tissue protruding into and free from the spinal canal can be effectively excised. The hyperosteoegeny at the posterior edge of the vertebral body, the hyperplastic zygapophyseal joints, and the ligamentum flavum can also be removed, and the spinal canal volume can be restored. It can be use for treating intervertebral foramen stenosis, lateral recess stenosis, spinal canal stenosis, prolapse of intervertebral disc, and prolapse of spinal canal. Bai Yibing et al. [1] adopted the Maxmorespine intervertebral foramen endoscopy device made in Germany for 57 patients with lumbar nerve root canal stenosis with an average age of 68 years. The operation method adopted the modified Tessys (Transferring Endoscopic Spine System) technology. All

patients were assessed preoperatively, at discharge, 3 months postoperatively, and at the last follow-up using Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI). The improvement rate was excellent in 100%-75%, good in 74%-50%, and poor in < 24% in 49%-25%. Improvement rate > 25% is effective. The results showed that the curative effects were excellent in 43 cases (75.4%), good in 7 cases (12.3%), moderate in 4 cases (7%), and poor in 3 cases (5.3%). The excellent and good rates were 87.7%, and the effective rate was 97%. Compared with the traditional posterior fenestration surgery, the technique has the advantages of small incision, less bleeding, small trauma, short operation time and fast recovery time, does not damage the physiological structure of the spine, and preserves the laminae ligamentum flavum, thereby keeping the stability of the spine and reducing postoperative adhesion. All patients were evaluated by Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI) before operation, at discharge, 3 months after operation and at the last follow-up. The improvement rate was 100% ~ 75% excellent, 74% ~ 50% good, and 49% ~ 25%, < 24. Improvement rate > 25% is effective. Results The results showed that the curative effect was excellent in 43 cases (75.4%), good in 7 cases (12.3%), fair in 4 cases (7%) and poor in 3 cases (5.3%). The excellent and good rate was 87.7% and the effective rate was 97%. Compared with the traditional posterior fenestration surgery, this technique has the advantages of small incision, less bleeding, less trauma, short operation time, fast recovery time, no damage to the physiological structure of the spine, and preservation of the ligamentum flavum of the lamina, which can maintain the stability of the spine and reduce postoperative adhesion.

Lu [2] selected 108 patients with single-segment LDH and divided them into PTED and MED (Microendoscopic Disease) groups according to the different surgical methods, including 63 patients in the PTED group and 45 patients in the MED group. There was no significant difference in the general information between the two groups ($p > 0.05$). PTED group:

Sixty-three cases were treated by posterior lumbar intervertebral approach, in which the locations of nerve roots were explored and the nerve roots were pushed inward. The denatured nucleus pulposus tissue and hypertrophic yellow ligament were completely removed using nucleus pulposus forceps, and the proliferative articular process and calcified tissue were excised using laminectomy forceps and friction drill. MED group: Under general anesthesia, 45 cases of LDH were treated with posterior lumbar intervertebral disc access, the location of nerve roots was explored and the nerve roots were pushed inwards to protect it, the space was enlarged to fully expose the annulus fibrosus, a sharp knife was used to open the annulus fibrosus, the nucleus pulposus tissue was removed, the lateral recess was enlarged to open the intervertebral foramen, and nerve root decompression was performed. Bone mass at the base of spinous process was removed by grinding drill or bone-biting forceps, and the releasing nerve was enlarged by spinal canal. The results showed that compared with the MED group, the PTED group had shorter operation time and less intraoperative fluoroscopy times, and the difference was statistically significant ($P < 0.05$). The bleeding volume during operation, bed rest time and hospital stay after operation in the PTED group were superior to those in the MED group ($P < 0.05$). The ODI scores of the two groups after surgery were significantly improved as compared with those before surgery ($p < 0.05$).

Ding et al. [3] performed surgical treatment on 89 patients with LDH, including 55 cases using PTED-modified BEIS (broad easy immediate surgery, BEIS) proposed by Bai Yibing and 34 cases using minimally invasive access surgery. The operation time and postoperative complications were compared between the two groups. The severity of lumbocurral pain was assessed preoperatively, 3 days postoperatively, 3 months postoperatively, 1 year postoperatively, and at the last follow-up by VAS score, lumbar function by ODI index, and efficacy by modified MacNab criteria 1 year postoperatively. Lumbar anteroposterior and lateral radiographs as well as dynamic radiographs were used to assess the pre-operative and 1-year post-operative segment disc height and lumbar stability. The excellent and good rates according to the modified MacNab standard in the BEIS group and the minimally invasive access group one year after surgery were 90.9% (50/55) and 88.2% (30/34), respectively, and the differences were not significant ($\chi^2 = 0.002$, $p = 0.964$). The heights of the intervertebral spaces in the two groups one year after surgery were significantly decreased compared with those before surgery ($P < 0.05$), and there was no significant difference in the percentages of decrease between the two groups ($P > 0.05$). In the BEIS group, there were two cases of lumbar instability one year after surgery, of which, one case had lumbago symptoms, and the other one had no obvious clinical symptoms. One case in the minimally invasive access group had lumbar instability and no significant clinical symptoms. There was no significant difference in the incidence of lumbar instability within one year after operation between the two groups ($P > 0.05$). There was no recurrence of LDH in both groups. VAS and ODI of the two groups at each time point after surgery were significantly better than those before surgery ($P < 0.05$). In addition, the score of BEIS group three days after surgery was better than that of the minimally invasive access group. There was no significant difference between the two groups at other time points ($P > 0.05$).

Chen, Zihao et al. [4] evaluated VAS and ODI in a one-year

follow-up study of LDH patients including 153 PTED and MED procedures in a randomized double-blind trial, and indicated that PTED and MED could obtain identical and satisfactory results. The advantages of intervertebral foramen mirror BEIS technology in the treatment of LDH: (1) Local anesthesia is adopted, so the patient can keep awake and communicate at any time; (2) The stability of the intervertebral disc and bony structure is maintained to the maximum extent, the function of spinal motion segments is preserved, and the injury is small, which meets the treatment concept of minimally invasive technology; (3) The visual field under reduced pressure is wider than that with YESS and TESSYS technologies; (5) Manipulation under direct vision, removal of the prominent nucleus pulposus and decompression are needed to avoid the injury of nerve root and dural sac to the maximum extent and the occurrence of adjacent segmental diseases.

3. Transforaminal Approach

Spinal endoscopy via the intervertebral disc approach can be used to treat LDH with central protrusion, lateral protrusion and extreme lateral root pain as main symptoms, as well as LDH with excessive height of iliac spine, hypertrophy of transverse process or huge or even prolapsed intervertebral disc. Yang [5] used endoscopic discectomy to treat 66 patients with LDH. According to the results of preoperative doctor-patient communication, 33 cases adopted the transforaminal approach, and 33 cases adopted the transforaminal approach. There was no significant difference in general conditions between the two groups ($p > 0.05$). Among them, three patients with milder symptoms received conservative rehabilitation therapy, and three patients received reoperation. Over time, VAS and ODI scores of both groups decreased significantly ($P < 0.05$). At the corresponding time point, there was no significant difference in VAS or ODI scores between the two groups ($p > 0.05$). Compared with those before surgery, the occupancy rates of spinal canal in both groups decreased significantly at the last follow-up visit ($P < 0.05$), but there was no significant change in the height of intervertebral space in both groups ($p > 0.05$). At the same time point, there was no significant difference in the space-occupying rate of spinal canal and the height of intervertebral space between the two groups ($p > 0.05$). By the time of the last follow-up, no disc herniation on the obvious image was observed in both groups. The operation time and the times of vertebral fluoroscopy during operation of patients in the intervertebral foramen group were significantly higher than those in the lamina group. The operation space of the transforaminal approach is small, and there is a blind area of the visual field, which limits the operation to a certain extent. During the operation, multiple fluoroscopic examinations are required, so the operation takes a long time and requires multiple fluoroscopic examinations. The transforaminal intervertebral approach can quickly position, has good surgical field of view, large space and convenient operation, can position the lesion without multiple fluoroscopy, and completely removes the nucleus pulposus tissue, and has short operation time and few fluoroscopy times. In addition, there was no statistically significant difference in the incidence of perioperative complications between the two groups, because the minimally invasive surgery for LDH patients had little trauma and less blood loss, and hardly caused any nerve root damage.

Liu [6] selected 98 elderly patients with lumbar spinal

stenosis and divided them into a percutaneous endoscopic group and a microscope group according to the surgical protocol, with 49 cases in each group. The operations were performed through the intervertebral disc space under the guidance of percutaneous total spinal endoscopy and through the intervertebral disc space under the guidance of microscope. Perioperative indicators and complications of the two groups were counted. The inflammatory oxidative stress indicators before and after surgery: oxidized protein product (AOPP), malondialdehyde (MDA), tumor necrosis factor- α (TNF- α) level, visual analogue scale (VAS) score, Japanese Orthopedics Association Evaluation and Treatment (JOA) score were compared between the two groups. The imaging indicators: ISH, DH, ROM and the morphology of paravertebral muscles (functional cross-sectional area of multifidus muscle, relative cross-sectional area of psoas muscle and fatty deposition level of multifidus muscle) were compared. The results suggested that the operation time, bed leaving time and hospital stay in the percutaneous endoscopic group were shorter than those in the microscopic group ($P < 0.05$). The levels of serum AOPP, MDA and TNF- α in the percutaneous endoscopic group were lower than those in the microscopic group 3 d after operation ($P < 0.05$). The VAS score of the percutaneous endoscopic group one week after surgery was lower than that of the microscopic group ($P < 0.05$). There was no significant difference in JOA scores between the two groups before and after the operation ($P > 0.05$). Compared with those before surgery, the ISH and DH of patients in the two groups were smaller three months after surgery ($P < 0.05$), and the ROM was larger ($P < 0.05$). Three months after surgery, the functional cross-sectional area of multifidus muscle in the percutaneous endoscopic group was larger than that in the microscopic group ($P < 0.05$), and the relative cross-sectional area of psoas muscle and fat deposition grade of multifidus muscle were smaller than those in the microscopic group ($P < 0.05$). There was no significant difference in the incidence of complications between the two groups ($P < 0.05$). The results of blood specimen examination in this study showed that compared with the microscope-assisted transphenoidal approach, the inflammatory oxidative stress response in the percutaneous transthoracic approach under the guidance of total spinal endoscopy was milder, which was considered to be related to its short operation time and small trauma. One week after surgery, all inflammatory oxidative stress indicators in the two groups tended to the preoperative level, indicating that inflammatory oxidative stress responses induced by percutaneous whole spinal endoscopy or microscope-assisted trans-laminectomy approach were transient and did not cause long-term effects.

A retrospective study by Sun K et al. [7] showed that the highest incidence rates of LDH were L4/5 and L5/S1, accounting for about 95%. THESSYS technique is still limited in patients with L5-S1 disc herniation with giant or highly displaced disc herniation and high iliac spines. Therefore, Rueten [8] proposed a percutaneous complete endoscopic transforaminal approach with complete visualization of the puncture process. The indications are L5/S1 central type and paracentral type LDH, axillary type and shoulder type LDH, free prolapse type LDH, recurrent LDH, LDH with calcification and hypertrophy of yellow ligament, etc. Choi et al. [9] followed up and reported 65 cases of LDH patients treated via intervertebral disc approach. The patients were followed up for 1.5 years after operation. The VAS score was 7.89 preoperatively and 1.58

postoperatively. The average pre-operative ODI score was 57.43, and the post-operative ODI score was 11.52. The differences were statistically significant. The patient satisfaction rate was 90.8%.

4. Transpedicular Shoulder Approach

The main difficulties in the treatment of severe distal prolapse of lumbar intervertebral disc by spinal endoscopy are the narrow working channel and short working distance, and the transpedicular shoulder approach is a better choice. Twenty-seven patients (16 males and 11 females) with LDH, with the average age of 40.12 9.66 years old, were treated by transpedicular shoulder approach under the microscope in Aring Zhang [9]. The VAS score of lumbocurral pain, JOA score and ODI index were used to evaluate the clinical effect. The postoperative JOA score was significantly increased and the difference was statistically significant ($P < 0.05$). The ODI index, lumbago and leg pain VAS scores were significantly decreased and the differences were statistically significant ($P < 0.05$). The overall improvement rate of surgery was 94.38%.

Jiao et al. [10] included 14 cases of high-level, distally-directed prolapse of lumbar intervertebral disc, 1 case of protruding segment L2/3 1, 1 case of L3 /4 1, 1 4/5, and 1 5/1 4. One case: recurrent process. A transpedicular over-the-shoulder approach was used to remove part of the pedicle shoulder using a burr and remove the prolapsed nucleus pulposus under direct vision. The VAS score and ODI index of lumbocurral pain before operation, 2 days after operation and at the last follow-up were counted, and the surgical effect was evaluated by MacNab standard. The follow-up time of 14 cases ranged from 11 to 43 months, with an average of 27. 3 months. VAS score and ODI of post-surgery lumbar and leg pain were significantly improved as compared with those before surgery ($P < 0.05$). According to MacNab criteria, on the 2nd day after surgery, there were 12 excellent cases (the symptoms completely disappeared and the original work and life were restored), two good cases (there were slight symptoms, the activity was slightly limited, and there was no impact on work and life); at the last follow-up time, there were 13 excellent cases and one good case. Postoperative imaging showed no residual herniated nucleus pulposus in the spinal canal.

This approach was used for the treatment of severe prolapse of lumbar intervertebral disc. Ying et al. [11] compared the transpedicular shoulder approach with the standard PELD technique for the treatment of distal prolapse of lumbar intervertebral disc. The results showed that the transpedicular shoulder approach had the advantages of shorter operation time, and was equivalent to PELD in safety and efficacy.[11]

5. Unilateral Biportal Endoscopic Technique(UBE)

UBE refers to spinal endoscopic surgery performed unilaterally through two channels. It is suitable for various types of LDH and has unique advantages for spinal canal stenosis. As early as in 1996, De Antoni et al. [12] first proposed and reported the UBE technology. After the development of single-channel spinal endoscopy technology by YESS and TESSYS, UBE once faded out. As shown in the research by Sairyo et al. [13], for patients with severe spinal canal stenosis or requiring bilateral lateral recess decompression, single-channel spinal endoscopic surgery has

difficulties in decompressing the contralateral recess due to limited field of view, incomplete decompression of the contralateral recess stenosis, and poor curative effect. Hwa[14] reported percutaneous dual-channel endoscopic decompression in 2016. In 2017, Heo et al. [15] proposed the concept of unilateral double-hole dual-channel endoscopy (UBE), which has the advantages of wider and clearer view angle of operation field, and wide operation range. It can use the conventional intervertebral foramen endoscopy device and spinal open surgery device, well decompress the lateral recess stenosis, less damage to the paravertebral muscle, and no need of excessive separation of the multifidus muscle. Thus, the stability of the spine and motor system can be well maintained after the operation. The learn curve of that surgeon is shortened; This technique can also be used for the cervical and thoracic segments to reduce the impact on the surgical difficulty due to the patient's condition and device limitations.

Eun et al. [16] performed UBE enucleation of nucleus pulposus in 11 patients with LDH and followed up for 14 months. The pre-operative and post-operative VAS scores and ODI scores were used to analyze the curative effects. The results showed that the intraoperative VAS score decreased from 7.88 1.24 pre-surgery to 0.87 0.64 post-surgery ($P < 0.01$). The ODI index decreased to 9.37 483 from 51.73 18.57 preoperatively ($P < 0.01$). In contrast, Zheng Chao et al. [17] studied 38 cases (40 segments) of simple LDH and randomly divided them into two groups, 18 cases in the UBE group and 20 cases in the MED group. Surgery-related indicators included age, mean hospital stay, mean hospital stay after surgery, and mean follow-up time. Efficacy evaluations included VAS for lower extremity pain, JOA, and angle of lasegue sign (ALS). Complications included dural tear, nerve root injury, zygapophyseal resection, postoperative recurrence, and soft tissue edema. There were 36 cases of single segment protrusion and 2 cases of double segment protrusion, 40 segments in total. There were 18 cases of UBE surgery and 20 cases of MED surgery. Postoperative treatment: The patient was in the supine position after surgery, and began to have isometric muscle contraction of both lower limbs after he was awake. He/she wore his/her waist circumference and got out of bed six hours after surgery to carry out necessary physiological activities. Daily activities resumed on the first postoperative day and he could be discharged after 24 hours. The results of this study showed that at the last follow-up visit, the VAS for lower extremity pain, JOA for lower back pain and the straight leg elevation test angle had the same results, and both of them could achieve satisfactory results. UBE was obviously superior to MED in the degree of pain relief in the lower back and lower limbs as well as in the angle of the straight leg elevation test upon discharge.

Zhang[18]used UBE technology to treat 80 patients with single-segment LDH, all of which had lumbocrural pain and were confirmed as single-segment LDH by CT and MRI examinations. All patients were under general anesthesia. The endoscopic channel and operation channel were established with the assistance of X-ray, and the enucleation was completed through the operation channel under the supervision of endoscope. VAS), ODI index and MacNab score were used to evaluate the efficacy before and after the operation. Man-Kyu Park[19] et al. conducted a follow-up study of 35 patients who received UBE decompression due to

L5/S1 extra-vertebral foraminal stenosis from March 2018 to February 2019, and analyzed the clinical results using the MacNab standard, VAS score and ODI index. Imaging evaluated pseudoarthrosis in the transverse process of L5 and the sacral ala with or without osteophytes, as well as thickened lumbosacral ligaments and extraforaminal ligaments. The VAS pre-surgery value was 3.7 1.8, but it decreased to 2.3 0.8 at the one-year follow-up after surgery ($P < 0.01$). VAS decreased significantly from 7.2 1.1 to 2.3 1.2 one year after surgery ($P < 0.01$). The pre-operative ODI was 61.5 and post-operative 28.6 ($p < 0.01$). A pseudojoint between the transverse process and the sacral ala was found in all 35 cases. UBE decompression has been proved to be effective for the treatment of L5-S1 extra-foraminal stenosis without any complications. Hayati Aygun[20] et al. randomly divided 154 cases of single-segment degenerative lumbar spinal stenosis patients into two groups. Each group consisted of 77 cases: one group received UBE and the other group received MED. Clinical results were evaluated periodically: early postoperatively, 1 month, 3 months, and every 6 months for 2 years. Clinical outcome evaluation procedures included ODI, Zurich Claucaction Questionnaire (ZIQ), and the use of modified Zurich Claucaction Questionnaire (MMC). In addition, hospital admission time, operation time, and estimated blood loss were compared. Studies have shown that UBE is considered an effective alternative to MED with a higher clinical success rate.

For one Meta-analysis, RANATA et al. [21] included 383 LDH surgery patients in five items, which were divided into ULBD and UBE groups. The meta-analysis showed that there was no statistically significant difference in VAS score at the baseline ($p=0.49$), two to three months ($p=0.69$) and the final follow-up ($p=0.26$). There was no significant difference in the ODI index of VAS score of leg pain between the groups before operation ($p=0.76$, $p=0.95$) and between 2 and 3 months ($p=0.46$, $p=0.92$). The mean surgical time was similar between the UBE and ULBD groups ($p=0.36$). Hospitalization was shorter in the UBE group (mean difference -2.60 days [-3.39,-1.81], $p < 0.001$). The complications of the two groups were similar ($p=0.26$).

6. V-Shaped Both Channel Spinal Endoscopy System(VBE)

VBE is a single-hole dual-channel non-coaxial spinal endoscope invented by Chinese scholars and the first spinal endoscope in the world that can be used in both air medium and water medium at the same time. It is designed with a main working channel and an auxiliary working channel. Instruments and the endoscope can cooperate with each other in different channels and common fields of view, thus increasing the scope of direct-view surgery field, operational flexibility and the working space of surgical instruments. At present, it has not been widely promoted, and there are few reports in the literature, which still need further research, summary and improvement.

7. Comment

As a minimally invasive treatment of LDH, spinal endoscopy has experienced decades of development. In particular, the intervertebral foramen endoscopy has attracted widespread attention due to the advantages of small trauma, less bleeding, rapid recovery, and low cost [22]. Studies have shown that the transforaminal approach was the earliest used,

but it is powerless to specific types, such as high iliac spine too high and intervertebral disc prolapse. The transforaminal approach solves a part of the cases of LDH with high iliac spine. For distal severe disc herniation, a transpedicular shoulder approach is more appropriate. The appearance of UBE makes the treatment of intervertebral disc protrusion combined with spinal canal stenosis well resolved and avoids the disadvantages of other approaches. In conclusion, with the development of spinal endoscopy as a modern precise and minimally invasive medicine, and the application of various precise navigation 3D technologies, it will be possible to completely replace the traditional surgical methods.

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