

APPLICATION PROGRESS OF MINIMALLY INVASIVE INTERVERTEBRAL FORAMEN INCISION IN THE TREATMENT OF CERVICAL SPONDYLOTIC RADICULOPATHY

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Abstract: Cervical spondylotic radiculopathy (CSR) is a common degenerative disease in spinal surgery, which is mainly caused by intervertebral disc degeneration and its secondary pathological changes, resulting in nerve root compression at the same stage, resulting in pain, numbness, weakness and other root symptoms in the corresponding nerve distribution area. Cervical spondylotic radiculopathy is mainly treated by conservative treatment, but ineffective by regular conservative treatment needs surgical treatment. At present, the traditional anterior fusion and internal fixation is still the "gold standard" for the treatment of cervical spondylotic radiculopathy. However, this operation has some shortcomings such as greater surgical trauma and more postoperative complications. With the rapid development of minimally invasive techniques such as channel dilator, microscope and endoscopic system in recent years, posterior minimally invasive intervertebral foramen decompression has been paid more and more attention because of its advantages such as less trauma, rapid recovery and less complications. According to the literature reports at home and abroad, this paper summarizes and introduces several surgical methods for the treatment of cervical spondylotic radiculopathy by posterior minimally invasive approach.

Keywords: Cervical spondylotic radiculopathy; key-hole; posterior approach; minimally invasive.

Cervical spondylotic radiculopathy (cervical spondylotic radiculopathy, CSR) is a common degenerative disease in spinal surgery. Degenerative changes are often accompanied by cervical disc herniation. Nerve root compression at the same stage is often caused by nerve root canal stenosis, resulting in typical symptoms such as root pain, numbness and weakness. Cervical spondylotic radiculopathy is mainly treated by non-operative treatment, which can be cured by strict and regular conservative treatment, and only a few patients who are ineffective by conservative treatment need surgical treatment (1).

In 1958, Smith et al. (2) reported that anterior cervical fusion and fixation (anterior cervical discectomy and fusion, ACDF) yielded excellent clinical results, so this procedure was called the "gold standard" for surgical treatment of cervical spondylotic radiculopathy (3). However,

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anterior surgery can lead to hoarseness, dysphagia, esophageal and cervical vascular injury, airway obstruction caused by hematoma, adjacent segmental degeneration and other related complications(4-6).

With the rapid development of minimally invasive techniques such as channel dilation system, microscope and endoscopic system in recent years, minimally invasive cervical intervertebral foramen incision and decompression and discectomy have been improved and improved. Posterior keyhole decompression of the cervical spine has gradually become a hot spot because of its advantages such as less trauma, rapid recovery, good function retention and so on. In this paper, the application progress of minimally invasive posterior cervical foramen decompression in the treatment of cervical spondylotic radiculopathy is reviewed as follows:

1. Open posterior cervical foramen incision and decompression

Zeidman (7) reviewed the application of posterior cervical foramen incision and decompression in the treatment of cervical spondylotic radiculopathy in 1993. for the first time, posterior cervical foramen incision decompression was called posterior "keyhole" incision decompression. Root pain was relieved in 167 patients (97%) who underwent keyhole incision decompression, but only 5 patients (3%) were not relieved. Surgical methods: prone position, tracheal intubation under general anesthesia, head on Mayfield head frame, neck flexion, pulling shoulders and back downward with wide adhesive tape, fluoroscopy marking responsible segment, incision 3cm in posterior median spinous process line, peeling paraspinal muscle under periosteum under microscope to expose vertebral lamina on the affected side. To remove the medial part of the cervical facet joint, the decompression range is from the upper pedicle to the lower pedicle, from the inside to the outside, the resection of the articular process should be less than 50%, to prevent joint instability (8), gradually remove the ligamentum flavum, release the nerve root, remove the compression herniation, and focus on exploring the course of the nerve root head, tail, ventral and axillary, to ensure the removal of all protruding disc fragments. Nerve probe hook was used to explore the patency of intervertebral foramen and complete decompression.

In 1998, Kumar et al. (9) performed posterior cervical foramen incision in 89 patients with CSR caused by simple cervical osteophyte. The excellent and good rate of follow-up was 95.5%. Only 6.7% of the patients needed further surgical treatment of recurrent root symptoms because of incomplete decompression in the previous operation, and the therapeutic effect was satisfactory. It is considered that although most of the osteophytes leading to nerve root compression are located in front of the nerve root, posterior foraminotomy is still an effective and safe treatment, especially for CSR secondary to single segment due to osteophyte compression. Nancy (10) in the review of the application of intervertebral foramen incision in the treatment of lateral and intervertebral foramen cervical disc herniation or bone spur, it is pointed out that posterior cervical foramen incision and decompression is suitable for lateral and intervertebral foramen disc herniation and bony cervical spondylotic radiculopathy. During the 10-year follow-up of 338 patients undergoing this procedure in 2014, Church (11) pointed out that 90% of the patients had improved their symptoms such as pain and numbness, and about 93% of the patients returned to work or engaged in normal daily activities shortly after operation. the overall complication rate was only 3%, and the recurrence rate was 6.2%. The recurrence and reoperation rate after posterior cervical intervertebral foramen incision is about 6%, 6.7%. The main reasons include misdiagnosis, wrong location of protruding position and segment, inappropriate condition of patients, improper selection of surgeons and incomplete decompression (10).

Therefore, for cervical spondylotic radiculopathy caused by disc herniation and osteophyte compression, the clinical effect of posterior cervical foramen incision and decompression is satisfactory.

2. Minimally invasive dilation channel assisted posterior cervical foramen incision and decompression.

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In 1999, Foley (12) first reported microendoscopic discectomy (microendoscopic discectomy, MED) for the clinical treatment of lumbar disc herniation with good results. Roh (13) performed cervical discectomy with MED at multiple levels in cadavers, and the

decompression effect was the same as that of open surgery. It is suggested that microendoscopic discectomy is feasible in posterior cervical discectomy. In 2001, Adamson (14) was the first to treat patients with posterior cervical endoscope-assisted intervertebral foramen incision and decompression (cervical microendoscopic laminoforaminotomy, CMEF), and achieved good results. The method of operation: anesthesia and posture are the same as open posterior cervical foramen incision and decompression. About 1.5cm beside the posterior median line of the diseased segment, a 2cm longitudinal incision was made under the guidance of the puncture needle, and a dilatation cannula was placed to dilate the surrounding soft tissue step by step. The microendoscope was connected to expose the upper and lower lamina and facet joint of the diseased intervertebral space, and the other steps were the same as those of open posterior cervical foramen incision and decompression (15). In the comparative study of CMEF and open posterior cervical foramen incision decompression, Kim (16) pointed out that in the channel-assisted operation group, the length of stay and analgesia time of skin incision were significantly reduced, the extensive peeling of paraspinal muscles during operation was avoided, and the incidence of neck and shoulder pain, muscle motor dysfunction and neurological impairment was greatly reduced. Long-term follow-up showed that the curative effect of the two methods was the same, and there was no significant difference in operation results. The same good clinical effect was achieved. Fessler (17) and Oshima (18) compared this operation with open operation, and obtained similar results. It is concluded that transchannel endoscope-assisted surgery can more clearly observe the involved nerve roots and herniated intervertebral discs, remove the herniated disc more thoroughly and release the involved nerve roots, and the patients' satisfaction is higher.

In 2003, Boehm (19) first reported the treatment of cervical spondylotic radiculopathy with transforaminal incision and decompression of intervertebral foramen under channel microscope (minimally invasive posterior cervical foraminotomy, MI-PCF). The postoperative clinical effect was excellent, with less blood loss, lower anesthesia requirements, faster postoperative recovery and shorter hospital stay (17). Byron (20) reviewed and studied 463 patients who underwent MI-PCF, 98.2% of the patients' symptoms were improved before operation, 92.2% of the patients' symptoms were completely relieved,

and the incidence of complications was only 2.2%. It was considered that the posterior minimally invasive approach compared with the open approach, the incidence of complications was lower and the prognosis of the patients was better. Papavero (21) follow-up (32 months) of 103 patients with cervical spondylotic radiculopathy treated with MI-PCF showed that within 3 months after operation, the VAS pain score of the neck and shoulder was significantly lower than that of the open operation group, and the cervical disability index NDI was significantly improved and tended to decrease during the follow-up period.

However, the endoscopic system has the following shortcomings: 1) it presents two-dimensional images, lacks three-dimensional sense, and the surgical field is limited, so it is difficult to accurately grasp the scope and depth of the operation. 2) the space in the working sleeve is limited and the operation is limited. 3) there are many restrictions on operation, and the preparation of preoperative and instrument is relatively tedious. 4) it is difficult to remove bony stricture. 5) Endoscope and instrument operation should be used alternately, which may increase the probability of nerve injury and iatrogenic infection (27 ~ 28). However, the endoscopic system has the following shortcomings: 1) it presents two-dimensional images, lacks three-dimensional sense, and the surgical field is limited, so it is difficult to accurately grasp the scope and depth of the operation. 2) the space in the working sleeve is limited and the operation is limited. 3) there are many restrictions on operation, and the preparation of preoperative and instrument is relatively tedious. 4) it is difficult to remove bony stricture. 5) Endoscope and instrument operation should be used alternately, which may increase the probability of nerve injury and iatrogenic infection (22).

The operating microscope can accurately identify the fine structures such as nerve root, intervertebral disc and tiny bleeding point by three-dimensional imaging, improve the precision of operation, reduce nerve traction, excessive irritation and accessory injury of operation, and reduce the incidence of postoperative bleeding, epidural hematoma and other complications (23-26). Compared with the endoscopic system, it presents two-dimensional images, which is more in line with the visual habits of the operator. the operator and the assistant cooperate with each other face to face with the same field of vision, the safety of the

operation is higher, and the learning curve is smoother (27). Therefore, many surgeons think that the surgical microscope is a more ideal method of minimally invasive surgery with simple operation and less complications, and has gradually become the mainstream.

3. Percutaneous total endoscopic posterior cervical foramen incision and decompression

Thanks to the popularity of minimally invasive concept in spinal surgery, cervical total endoscopic surgery has gradually been widely used in clinical practice. In 1997, Yeung (28) invented the coaxial spinal endoscopic operating system (Yeung Endoscopic Spine System, YESS) on the basis of posterolateral arthroscopic lumbar discectomy, which opened up a precedent for minimally invasive endoscopic surgery for lumbar vertebrae. In recent years, percutaneous total endoscopy in the treatment of lumbar disc herniation is becoming more and more mature, and it is gradually used in the treatment of CSR.

Routine surgical field disinfection, using local or general anesthesia, fluoroscopy to locate the medial edge of the facet joint of the diseased segment, the guide needle was punctured to the posterior edge of the articular process, with the guide needle as the center, the skin was cut open for about 7mm, and the working cannula was inserted into the endoscopic operating system. continuous saline irrigation of the operating area, endoscopic radiofrequency hemostasis, high-speed grinding to remove the lamina and part of the articular process, lamina rongeur to treat the ligamentum flavum and enter the spinal canal. The intervertebral foramen was enlarged in the posterior wall of the nerve root canal, and the compressed nucleus pulposus tissue was removed for nerve root decompression.

In 2007, Ruetten (29) first reported that 87 patients with unilateral cervical spondylotic radiculopathy were treated by percutaneous endoscopic posterior cervical discectomy (posterior percutaneous endoscopic cervical discectomy, PPECD) with diameter 6.9mm endoscope. the excellent and good rate of 2-year follow-up was as high as 93%. The following year, the team conducted a comparative study of PPECD and ACDF in the treatment of unilateral cervical spondylotic radiculopathy. It was found that PPECD was significantly superior to ACDF in surgical trauma, intraoperative bleeding, hospital stay, postoperative rehabilitation and motor segment preservation, but there was no significant difference in surgical efficacy, recurrence rate and complication rate between the two

methods (30). Kim (31) compared the clinical efficacy of patients with PPECD and MI-PCF, there was no significant difference, and both achieved satisfactory results. His team followed up patients with PPECD in 2015 and 2017, and observed the changes of cervical curvature, segmental Cobb angle and anterior / posterior height of surgical segmental space. It was concluded that PPECD retained more than 50% of the facet process did not affect cervical curvature (32, 33). Zheng et al. (34) 252 patients with CSR were followed up by PPECD, for 2 years, 86.7% of the patients' symptoms were completely relieved, only 2 patients complained of postoperative neurosensory hypoesthesia and recovered after 1 week. Wu et al. (35) previous studies also reported that the application of PPECD in the treatment of cervical disc herniation has the advantages of less trauma, less bleeding and reducing the days of hospitalization.

For CSR, with osseous cervical intervertebral foramen stenosis, nerve root compression is often caused by osteophyte hyperplasia of unciniate process joint and nerve root canal stenosis (36, 37). According to Wang et al. (38), the osteophyte of the superior articular process is the most important compression factor, which is located at the entrance of the nerve root canal and is most likely to oppress the nerve root. Grinding off part of the upper and lower edge of the lamina and the medial side of the facet joint under the channel can effectively enlarge the intervertebral foramen and fully decompress.

Lin et al. (39) posterior percutaneous endoscopic intervertebral foramen plasty (posterior percutaneous endoscopic cervical foraminotomy, PPECF) was used to treat unilateral cervical intervertebral foramen osseous stenosis. The postoperative pain was significantly relieved in 10 patients, and the excellent and good rate was as high as 90.9%. There were no complications such as spinal cord and nerve root injury during the operation. Oertel (40) 43 cases of osseous intervertebral foramen stenosis were treated with PPECF, 41 patients with postoperative pain were completely relieved, and the excellent and good rate was 90.7%. Only 1 case of postoperative hematoma needed reoperation. It was considered that PPECF was successful in the treatment of bony intervertebral foramen stenosis and had a low risk of complications. The conclusion of the follow-up study of Wang et al. (38) is consistent with that of the previous literature.

There are still some complications in posterior percutaneous endoscopic surgery of cervical spine, such as temporary sensory disturbance associated with hematoma, temporary spinal cord injury, postoperative limb numbness and decreased muscle strength, nerve injury and recurrent reoperation. However, it has the characteristics of good microscopic lighting, continuous water perfusion to control bleeding, clear field of vision in the operative area, reducing the probability of nerve injury (40), avoiding postoperative complications such as neck pain and adjacent vertebral degeneration caused by open surgery, and rapid recovery after operation. it has a good development prospect.

4. Outlook

The evidence-based clinical guidelines of (NASS) multidisciplinary spinal nursing of the North American Spinal Society for the diagnosis and treatment of degenerative cervical spondylotic radiculopathy indicate that posterior foramen incision and decompression is suitable for the clinical symptoms and signs of typical cervical spondylotic radiculopathy and posterolateral or foraminal cervical disc herniation consistent with imaging, and 2 recurrent unilateral upper limb nerve root symptoms are ineffective by systematic conservative treatment. 3) cervical spondylotic radiculopathy with bony stenosis of intervertebral foramen and 4) cervical spondylotic radiculopathy secondary to persistent root symptoms after anterior surgery (29, 41).

With the development of minimally invasive posterior cervical foramen incision, the clinical effect is better, trauma and less impact on cervical motion segments, less postoperative complications, rapid postoperative recovery, and low cost (due to the use of artificial implants, the treatment cost of ADCF is 89% higher than that of most minimally invasive intervertebral foramen incision decompression (42), and has a good clinical application prospect. Nowadays, more and more clinicians prefer posterior "keyhole" intervertebral foramen incision and decompression, but endoscopic cervical surgery has a steep learning curve and high difficulty, which requires long-term and strict training (43), especially with the development of percutaneous spinal endoscopy, the indications of, Li (44) minimally invasive posterior keyhole intervertebral foramen incision and decompression in the treatment of cervical spondylotic myelopathy and other diseases. Liu (45) achieved good

results in the treatment of paracentric cervical disc herniation with posterior percutaneous endoscopic Key-Hole technique, but the long-term effect remains to be observed. Therefore, in the choice of minimally invasive surgery, we should strictly grasp the indications, combined with the patient's condition, do not blindly pursue high difficulty, in order to solve the pain of patients, for the benefit of the majority of patients.

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