Cite as: Huang JJ, Li L. Research progress on posterior cervical foraminotomy for the treatment of cervical spondylotic radiculopathy [J]. Chin J Clin Res, 2024, 37(5):666-669,673.
DOI: 10.13429/j.cnki.cjcr.2024.05.003

Research progress on posterior cervical foraminotomy for the treatment of cervical spondylotic radiculopathy

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Abstract: The incidence of cervical spondylotic radiculopathy is relatively high among cervical spine diseases. Surgical options for its treatment include anterior cervical discectomy and fusion, disc arthroplasty, and posterior cervical foraminotomy. Posterior cervical foraminotomy, which can avoid problems related to fusion and surgical instruments, as well as the complications associated with anterior approaches, has become a popular alternative to anterior cervical surgery and is now considered a simple and effective surgical method for treating cervical spondylotic radiculopathy. With the continuous development of minimally invasive concepts and the innovation of various auxiliary techniques in spinal surgery, the technique is being continuously improved. It has broad prospects for application in the treatment of cervical spondylotic radiculopathy.

Keywords: Cervical spondylotic radiculopathy; Minimally invasive surgery; Posterior cervical foraminotomy

Fund program: Guangxi Science and Technology Plan Project, Guangxi Science and Technology Base and Talent Special Project (AD20238020); Guangxi Medicine and Healthcare Self-financed Scientific Research Topic (Z20190041); Nanxishan Hospital of Guangxi Zhuang Autonomous Region Hospital-level Scientific Research Topic (NY2019006)

Cervical spondylotic radiculopathy (CSR) is a condition where the nerve roots are compressed due to degenerative changes in the intervertebral discs, leading to a series of neurological dysfunctions, typically manifesting as motor, sensory, and reflex impairments on the side of the compressed nerve root. CSR has a higher incidence rate in cervical spine diseases, accounting for approximately 60%-70% of all cervical spine diseases [1-2]. Conservative treatment is commonly recommended as the first-line therapy for CSR, with surgical intervention being considered when conservative treatment fails [3-4]. Surgical options include anterior cervical decompression and fusion, disc arthroplasty, and posterior cervical foraminotomy. Anterior cervical discectomy and fusion (ACDF) has been recognized as the gold standard for treating CSR [5]. However, literature indicates various complications associated with ACDF, such as adjacent segment disease, pseudoarthrosis, postoperative dysphagia, vascular injury, recurrent laryngeal nerve palsy, cerebrospinal fluid leakage, and hematoma [6]. Posterior cervical foraminotomy (PCF) is a safe and effective treatment for CSR, avoiding the complications associated with anterior approaches, preserving segmental motion, reducing intraoperative bleeding, shortening hospital stays, and decreasing the need for postoperative medication [7]. Microscopic and endoscopic PCF has also gained widespread application, with the former providing enhanced visualization and precision compared to open surgery, resulting in reduced muscle dissection and fewer postoperative complications [8]. Spinal endoscopy, building upon microscopic techniques, directly projects the surgical field onto a monitor through an electronic imaging system, offering greater convenience, clearer visualization, and increased surgical accuracy [9]. In recent years, there has been an increasing number of reports on PCF, and this paper provides a comprehensive review of the research progress on the treatment of CSR through PCF in cases where conservative treatment has failed, aiming to offer clinical reference for treating CSR.

1 Development history

Posterior cervical foraminotomy can be traced back to the 1950s, when Spurling and Scoville first reported successful outcomes of key-hole facet joint excision for treating CSR. Epstein coined the term "foraminotomy" for this procedure in 1953. In 1983, Henderson *et al.* [11] reported favorable outcomes of performing posterolateral foraminotomy in treating CSR based on this procedure. With the rapid advancement of spinal surgery and the extension of various auxiliary techniques such as endoscopy, microscopy, image navigation, and robot-assisted surgery, the technique has evolved. Adamson *et al.* [12] reported good clinical outcomes of microendoscopic PCF in 100 patients. In 2007, Ruetten *et al.* [13] reported outcomes of percutaneous endoscopic PCF in 87 patients, with symptom relief observed in 87.4% of patients and a postoperative recurrence rate of 3.4%. In 2017, Park *et al.* [14] proposed the unilateral biportal endoscopy (UBE) technique based on the experience of a single-channel endoscopic technique.

2 Indications and contraindications

Indications: (1) The major part of the disc herniation located on the lateral edge of the spinal cord on MRI and CT scans; (2) Compression of unilateral nerve root; (3) Typical symptoms of CSR; (4) Ineffective conservative treatment.

Contraindications: (1) Lumbar spinal stenosis; (2) Disc herniation on the medial side of the spinal cord; (3) Definite segmental instability or cervical deformity; (4) Neurological or vascular lesions resembling disc herniation; (5) Poor cardiopulmonary function, making the patient unfit for surgery.

3 Preoperative "V" point localization

Preoperative and intraoperative localization is particularly crucial in PCF. Currently, the handling of the surgical V point (intersection of the upper and lower vertebral plates with the intervertebral disc) is critical during surgery. The methods and accuracy of localization are key issues in this surgical research. Due to the smaller size of the vertebral plates in the cervical spine compared to the thoracolumbar spine, the intervertebral space decreases with age, and the lateral edge of the spinal cord is positioned more laterally at the C4-5, C5-6, and C6-7 levels than the V point. Therefore, understanding the clinical anatomical relationship of the V point can help reduce surgical time and complications. Traditional X-ray fluoroscopy requires repeated fluoroscopy, increasing radiation exposure, and is limited in clarity for some patients with small cervical intervertebral spaces or obesity. Loss of the V point during surgery can also affect the surgical process, leading to more postoperative complications. Cao *et al.* [15] determined a safe range of 1.2-5.0 mm for grinding the V point based on 20 adult cervical spine specimens. Zhang *et al.* [16] reported improved accuracy of V point localization using O-arm navigation systems to create 3D images in 36 patients, resulting in significant improvements in VAS scores for radicular arm pain, neck pain, and neck disability index (NDI) scores for all patients. However, the high cost and radiation exposure of the O-arm navigation system limit its application. Liao *et al.* [17] used vertical anchoring techniques to localize the V point, resulting in significantly shorter surgical rime, intraoperative fluoroscopy times and fewer repetitions compared to patients undergoing conventional posterior percutaneous endoscopic cervical discectomy (PECD). Ning *et al.* [18] utilized CT-guided and ring saw anchoring methods to accurately localize, making a postoperative 88.2% rate of excellent outcomes according to the modified MacNab criteria and decreases in VAS and NDI scores in CSR patients at 6 months postoperatively. Zhong *et al.* [19] reported a new image-assisted V point localization technique, inserting K wires under A/P X-ray fluoroscopy and fixing them to the vertebral arch, then rapidly establishing a working channel, resulting in shorter surgical times and significant improvements in postoperative VAS scores for neck and arm pain, NDI scores, and cervical range of motion in 34 patients. Wang *et al.* [20] achieved satisfactory results by directly anchoring the upper edge of the vertebral arch under endoscopic visualization for V point localization. In recent years, the utilization rate of robot-assisted and computer-assisted navigation systems has rapidly increased. Lebl *et al.* [21] showed a good outcome of robot and computer-assisted navigation in cervical spine surgery, but extensive clinical experiments are still needed to confirm these results. With the continuous development of assistive technologies, such as 3D printing and robot-assisted applications, V-point positioning has become more efficient.

4 Surgical methods and clinical efficacy

4.1 PCF via open approach

Surgical method: After general anesthesia, the patient is positioned prone with the head fixed, and the neck slightly flexed to increase the intervertebral space of the target segment and reduce joint overlap. C-arm fluoroscopy is used to determine the surgical segment gap. A puncture needle is placed, and a 2.5-3 cm skin incision is made around the puncture needle. The skin, fascia, and muscles are sequentially dissected, and the facet joints and lamina are exposed. The intervertebral foramen is opened using a tube retractor system, ensuring at least 50% of the facet joints are preserved for cervical stability [22]. The nerve root is decompressed, and disc fragments are removed, if necessary, followed by hemostasis and wound closure.

PCF provides direct decompression of the nerve root and can be an alternative for patients who have failed ACDF, especially at the C7-T1 level [23]. Fang *et al.* [24] reported comparable effectiveness and complication rates between PCF and ACDF, with shorter surgical and hospitalization times and lower total hospitalization costs for PCF in CSR patients. Padhye et al. [25] showed that compared with ACDF, PCF treated CSR without fusion, avoiding the risk of related complications such as pseudo joint disease and graft, and its operation time was significantly shortened. Broekema *et al.* [26] demonstrated comparable success rates (88% in the PCF group and 76% in the anterior surgery group) and arm pain relief between PCF and anterior approaches in patients with neural foraminal stenosis.

4.2 Microscopic PCF (MI-PCF)

Surgical method: Similar to PCF, MI-PCF is performed with the patient under general anesthesia in a prone position with the head fixed and the neck slightly flexed. A 2 cm incision is made at the center of the spinous process, and a working channel is established under fluoroscopic guidance. A microscope is connected for better visualization during the procedure.

The most commonly used system for MI-PCF is the METRx tube assembly, which, unlike other endoscopic systems, is not a water-based procedure and does not use constant saline irrigation. Compared with PCF, MI-PCF can liberate nerve roots more completely and observe the anatomical structure of nerve roots more directly to minimize the risk of nerve injury. In the postoperative follow-up, MI-PCF also achieved good results. Papavero *et al.* [27] reported significant improvement in early postoperative neck/shoulder and arm pain VAS scores in CSR patients treated with MI-PCF. Kerry *et al.* [28] concluded MI-PCF as an effective approach for treating lateral spinal cord compression. We believe that only by mastering the indications and correctly selecting the patients can the best results be obtained. However, the learning curve of micro endoscopic surgery is long, and the surgeon needs to fully grasp the anatomical structure related to the surgery.

4.3 Fully endoscopic PCF (FE-PCF)

Surgical method: After general anesthesia, the patient is placed in the prone position with the head fixed, and the neck is slightly flexed to increase the size of the target segment intervertebral space and reduce joint overlap. C-arm fluoroscopy is used for assistance in positioning. After fluoroscopy, the surgical segment gap is confirmed, and a puncture needle is placed. Using the puncture needle as the center, a 0.5-0.8 cm incision is made in the skin. The working channel is gradually inserted, and the endoscope is connected. Physiological saline is continuously used for irrigation during the procedure to improve intraoperative visualization. Partial ligamentum flavum is removed using a Kerrison punch, and the V point is identified. The intervertebral foramen is enlarged through grinding and laminectomy to expose the nerve root and dura mater. The protruding nucleus pulposus is removed until the nerve root is adequately decompressed. Finally, the annulus fibrosus is thermally ablated or sutured, and the surrounding soft tissue is sutured. Due to the small incision, no drainage tube is required postoperatively.

Recently, spinal endoscopy is gradually being used to treat degenerative disease such as CSR. FE-PCF generally employs Key-hole technology and offers advantages such as shorter hospital stay, faster recovery, and better quality of life compared to open PCF. With an incision of <10 mm, there is less tissue and muscle damage. Zhang *et al.* [29] found that patients undergoing FE-PCF had lower postoperative neck pain scores. Follow-up studies have shown a significant improvement in VAS and NDI scores 6 months after FE-PCF surgery [30]. Shi *et al.* [31] demonstrated that VAS and Japanese Orthopedic Association (JOA) scores were significantly lower at different time points postoperatively, and the intervertebral foramen height, anteroposterior diameter, and area were significantly increased postoperatively compared to preoperative measurements.

4.4 UBE-PCF

Surgical method: After general anesthesia, the patient is placed in the prone position with the head fixed, and the neck is slightly flexed to increase the size of the target segment intervertebral space and reduce joint overlap. C-arm fluoroscopy is used for assistance in positioning. Under C-arm fluoroscopy guidance, the surgical segment gap is confirmed. Two 6 mm incisions in the skin and fascia are made beside the midline of the lesion gap to create observation and working channels, with a distance of approximately 1.2-2 cm between the two incisions. Physiological saline is continuously used for irrigation during the procedure. Space is created through sequential dilation and bone surface dissection, and peripheral tissues and muscles are managed through the working channel. The V point is exposed, and the lamina and articular processes are treated with a burr and osteotome. Partial ligamentum flavum is removed with a Kerrison punch, and the nerve root is dissected. The protruding nucleus pulposus is removed to ensure the nerve root's free movement. Instruments are removed, and a drainage tube is placed, followed by wound closure.

UBE technology evolved from arthroscopic techniques and offers advantages such as a wide field of view and flexible operation. Compared to FE-PCF, UBE-PCF has two channels: one for observation and the other for working with surgical instruments commonly used in cervical spine microsurgery. Both channels are independent and unaffected by each other, providing clear and precise visualization of anatomical structures through continuous saline flow. A retrospective study by Zhong et al. [32] showed that the surgical time for the UBE-PCF group was significantly shorter than that for the FE-PCF group [(59.47±3.71) min vs (73.36±6.98) min, P<0.01]. With continuous visualization, UBE-PCF can achieve thorough decompression in a shorter surgical time. Wang *et al.* [33] found that compared to FE-PCF surgery, UBE surgery had shorter fluoroscopy and surgical times, and both VAS and NDI scores were significantly improved postoperatively in the UBE and PE groups. Zhang *et al.* [34] found significant improvement in neck and arm VAS scores and NDI scores after UBE-PCF surgery, and postoperative CT scans showed adequate decompression of the nerve roots. These results indicate that UBE-PCF has broad prospects in CSR and is a feasible minimally invasive approach for decompressing existing nerve roots in the cervical intervertebral foramen. However, there are still relatively few clinical reports on its use in treating CSR, and further clinical studies are needed to demonstrate its efficacy.

Although minimally invasive techniques can result in smaller traumas, they still have some unique drawbacks, including a steep learning curve, incomplete decompression, and increased radiation exposure. Therefore, surgeons should be proficient in open surgery to adequately address these issues or complications. However, each surgical approach has its pros and cons. It is essential to understand the indications for each surgical method and select the appropriate one for each patient to achieve the best outcomes and minimize the risk of complications.

5 Complications and prevention

Although PCF surgery does not damage cervical structures as much as anterior surgery does, such as the esophagus, trachea, thyroid gland, and cervical blood vessels damage, a key issue of PCF is the instability resulting from the small joint excision, which can lead to cervical segmental hypermobility. There are also studies indicating that the neck and shoulder pain and spasms are related to damage to the paraspinal muscles after PCF [35]. In terms of infection, a retrospective analysis concluded that the superficial and deep infection rates of PCF were higher than ACDF [36]. However, the emergence and increased use of minimally invasive and spinal endoscopic methods can reduce the future rates of infection and reoperation by minimizing tissue exposure, contamination, and destruction. In minimally invasive PCF, due to the small incision, most operations are conducted in a limited space, making incomplete decompression and incomplete removal of expected intervertebral disc fragments. Even though PCF, whether open or minimally invasive, does not always provide direct and complete visualization of the surgical area and its adjacent structures. Accidental dural tears and nerve root injuries are also common complications [37]. Choi *et al.* [38] found that out of 133 patients undergoing PCF, 2 cases (3.5%) experienced motor nerve paralysis, with 2 involving the C6 nerve root and 1 involving the C5 nerve root. The management of nerve root injury has been a hot topic of research, and the only condition that cannot be monitored is when the patient is awake under local anesthesia, because the patient can provide direct feedback on any unexpected neurological changes. However, the operation is usually performed under general anesthesia, and the addition of electrophysiological monitoring during the operation can avoid effective nerve damage.

6 Conclusion

PCF, also known as the "keyhole technique", has the advantages of expanding the field of view, maintaining mobility and stability, reducing surgical trauma, and no risk of anterior-related complications, and achieving satisfactory results in the treatment of CSR. For patients with unilateral CSR who have disc herniation or degenerative spinal foraminal stenosis that is refractory to conservative treatment, PCF may be preferred.

Conflict of Interest None

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Submission received: 2023-10-09 / **Revised**:2023-11-18

· 研究进展 ·

颈椎后路椎间孔切开减压术治疗神经根型颈椎病的研究进展

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摘要：神经根型颈椎病在颈椎病中发病率较高，其手术方式包括颈前路减压和融合、椎间盘关节置换术和颈椎后路椎间孔切开术，颈椎后路椎间孔切开减压术既可避免与融合和手术器械相关的问题，又避免了前路手术带来的并发症，如今已经成为治疗神经根型颈椎病的一种简单有效的手术方法。随着微创理念在脊柱外科中的不断发展，各种辅助技术的创新，颈椎后路椎间孔切开减压术也在不断被完善，在治疗神经根型颈椎病上拥有广阔的应用前景。

关键词：神经根型颈椎病；微创手术；颈椎后路椎间孔切开减压术；定位；颈椎活动度
中图分类号：R614.2　**文献标识码**：A　**文章编号**：1674-8182(2024)05-0666-05

Research progress on posterior cervical foraminotomy for the treatment of cervical spondylotic radiculopathy

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Abstract: The incidence of cervical spondylotic radiculopathy is relatively high among cervical spine diseases. Surgical options for its treatment include anterior cervical discectomy and fusion, disc arthroplasty, and posterior cervical foraminotomy. Posterior cervical foraminotomy, which can avoid problems related to fusion and surgical instruments, as well as the complications associated with anterior approaches, has become a popular alternative to anterior cervical surgery and is now considered a simple and effective surgical method for treating cervical spondylotic radiculopathy. With the continuous development of minimally invasive concepts and the innovation of various auxiliary techniques in spinal surgery, the technique is being continuously improved. It has broad prospects for application in the treatment of cervical spondylotic radiculopathy.

Keywords: Cervical spondylotic radiculopathy; Minimally invasive surgery; Posterior cervical foraminotomy; Location; Cervical range of motion
Fund program: Guangxi Science and Technology Plan Project, Guangxi Science and Technology Base and Talent Special Project (AD20238020); Guangxi Medicine and Healthcare Self-financed Scientific Research Topic (Z20190041); Nanxishan Hospital of Guangxi Zhuang Autonomous Region Hospital-level Scientific Research Topic (NY2019006); Guangxi Medical and Health Key Cultivation Discipline Construction Project (Guiweikejiaofa〔2022〕No.4)

神经根型颈椎病(cervical spondylotic radiculopathy, CSR)是在椎间盘退行性病变的基础上压迫神经根，从而引发一系列神经功能障碍，通常表现为与受压神经根一侧的运动、感觉和反射功能障碍。CSR 在颈椎病中的发病率较高，占所有颈椎病的 60%～70%[1-2]。多数研究推荐保守治疗作为 CSR 的一线治疗，当 CSR 保守治疗无效时，可采取手术治疗[3-4]。手术方式包括颈前路减压和融合、椎间盘关节置换术和后路颈椎间孔切开术。既往颈前路椎间盘切除融合术(ACDF)被公认是治疗 CSR 的金标准[5]，但文献显示该术式存在多种并发症，包括邻近节段疾病、假性关节病、术后吞咽

DOI：10.13429/j.cnki.cjcr.2024.05.003
基金项目：广西科技计划项目，广西科技基地与人才专项（AD20238020）；广西医药卫生自筹经费科研课题（Z20190041）；广西壮族自治区南溪山医院院级科研课题（NY2019006）；广西医疗卫生重点培育学科建设项目（桂卫科教发〔2022〕4 号）
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出版日期：2024-05-20

QR code for English version

困难、血管损伤、喉返神经麻痹、脑脊液渗漏和血肿等[6]。颈椎后路椎间孔切开减压术(PCF)治疗 CSR 安全、有效[7]。它可避免前路手术的相关并发症,并保留手术节段的活动性,减少术中出血,缩短住院时间,减少术后使用药物的需求。显微内镜和脊柱内镜下行椎间孔切开减压术同样得到了广泛的应用。显微内镜可利用显微镜放大术野,使术中更加准确精确,相比于开放式手术,肌肉剥离减少,术后并发症少[8]。脊柱内镜则在显微内镜的基础下,通过电子成像系统将术野直接投射至显示屏上,更加便捷,术野更加清晰,术中更加准确[9]。近年来,关于 PCF 的报道越来越多,现本文将对保守治疗失败的情况下,治疗 CSR 的研究进展进行综述,为治疗 CSR 提供参考。

1　发展历程

颈椎后路椎间孔切开减压术可以追溯到上世纪 50 年代,Spuring 和 Scoville 首次报道了锁孔性关节面切除术治疗 CSR 并取得不错的临床疗效[10]。Epstein 在 1953 年将此手术称为椎间孔切开减压术。1983 年,Henderson 等[11]报道通过在此手术基础上开展后外侧孔切开术治疗 CSR 取得良好效果。伴随着脊柱外科手术的快速发展,内镜、显微镜、影像导航及机器人等各种辅助技术的延伸,该技术不断发展。Adamson[12]报道显微内镜下 PCF 在 100 例患者中取得良好的临床效果。2007 年,Ruetten 等[13]报道了行单通道下经皮全脊柱内镜下 PCF 的 87 例患者,随访 2 年,有 87.4%的患者症状缓解,术后复发率为 3.4%。2017 年 Park 等[14]在单通道的经验上提出了经皮脊柱内镜单纯双通道脊柱内镜(UBE)技术。

2　适应证及禁忌证

适应证:(1) 椎间盘突出部位的主要部分在 MRI 和 CT 扫描中位于脊髓外侧边缘的外侧;(2) 只有单侧神经根受压;(3) 具有典型的 CSR 症状;(4) 保守治疗无效。禁忌证:(1) 椎管内狭窄;(2) 椎间盘突出在脊髓内侧边;(3) 明确的节段不稳定或颈椎畸形;(4) 类似于椎间盘突出的神经或血管性病变;(5) 心肺功能较差,不能耐受手术者。

3　术前“V”点定位的应用

术前术中的定位在各种 PCF 中尤为重要,目前手术 V 点(上、下椎板与椎间盘交汇处)的处理是手术的关键,关于如何定位、定位准确是该手术研究的热点问题。由于颈椎两椎板间相对于胸腰椎要小的多,椎间隙高度随年龄而减小,脊髓外侧缘在 $C_{4\sim5}$、$C_{5\sim6}$ 和 $C_{6\sim7}$ 水平上比 V 点更横向定位。因此认识 V 点的临床解剖关系可以帮助缩短手术时间,减少并发症。在传统的 X 线透视下,需要反复透视,从而增加了辐射量,对于一些颈椎椎间隙小或肥胖的患者来说,X 线在清晰度上有一定局限性。在术中 V 点的丢失,同样会影响手术过程,引起更多的术后并发症。曹禹文等[15]利用 20 例成人颈椎标本得出磨除 V 点手术的安全范围应在 1.2~5.0 mm。Zhang 等[16]报道了在 36 例患者中利用 O 臂导航系统形成 3D 图像精准定位 V 点,提高了手术的精准度,所有患者的神经根性手臂疼痛和颈部疼痛的视觉模拟评分(VAS 评分)以及颈椎功能障碍指数(NDI)评分均显著改善。但 O 臂导航系统费用高且辐射量大,使其应用受到了限制。Liao 等[17]则通过垂直锚固技术定位 V 点,结果显示术中透视时间、次数和手术时间明显少于接受常规后路经皮脊柱内镜下颈椎间盘摘除术(PECD)的患者。宁本翔等[18]通过 CT 引导结合环锯锚定法精准定位,术后 6 个月,CSR 患者改良 MacNab 评估优良率为 88.2%,VAS 和 NDI 评分均下降。Zhong 等[19]报道一种新的图像辅助 V 点定位技术,在 A/P X 线透视下插入 K 线并固定在椎弓根眼上,然后迅速建立工作通道,使 34 例患者的手术时间缩短,术后颈臂疼痛 VAS 评分和 NDI 评分、颈椎活动度显著改善。王凯等[20]直接在内镜直视下椎弓根内上缘投影点垂直锚定方法定位 V 点,同样取得了不错的效果。近年来,机器人辅助和计算机辅助导航系统的利用率迅速增加。Lebl 等[21]分析机器人和计算机辅助导航在颈椎手术定位中取得的良好成效,但仍需要大量临床试验去证实。随着辅助技术的不断发展,3D 打印技术及机器人辅助应用的开发,V 点定位更加高效。

4　手术方法及临床疗效

4.1　开放性 PCF　手术方法:全身麻醉后,患者处于俯卧位并头夹固定,颈部略微屈曲,以增大目标节段的椎间隙大小,减少关节重叠,使用 C 臂肌辅助定位,在 C 臂透视的引导下确定手术节段间隙,放置穿刺针,以穿刺针为中心,切开皮肤 2.5~3 cm,逐层切开皮肤、筋膜、肌肉,沿着椎旁肌肉剥离,直至暴露小关节和椎板,可用管状撑开器系统扩大视野,使用磨钻去除小关节内侧及上下椎板,正确进行椎间孔切开术必须保留至少 50%的小关节以保持颈椎稳定性[22]。暴露神经根的中外侧,通过神经根的轻微回缩去除破裂的椎间盘,在突出的椎间盘难以去除的情况下,小心地对近端根部进行减压,摘除突出的髓核直至充分松解神经根,使用神经探钩探查神经根是否充分的减压,可用凝胶泡沫海绵等止血剂适当止血,最后缝合伤口。值得注意的是,PCF 提供神经根的直接减压,可作为 ACDF 手术失败的患者群体的另一种选择,但直接神经椎间孔减压,PCF 同样也可以在 $C_7 \sim T_1$ 时减压,因为此时颈前通路受到锁骨和胸骨的限制[23]。Fang 等[24]在一项 Mata 分析中表示 PCF 的有效性和并发症发生率与 ACDF 相当,但 PCF 的手术时间及住院时间更短,治疗 CSR 的总住院费用更低。Padhye 等[25]回顾性比较 CSR 患者的不同治疗方法,PCF 相对于 ACDF 无需融合,避免了假关节病、移植物等相关并发症的风险,其手术时间明显缩短,收益更高。Broekema 等[26]研究显示,265 例神经根椎间孔病患者术后 1 年后路手术的成功率(PCF 手术组为 88%,前路手术组为 76%)和手臂疼痛均不劣于前路手术。

4.2　显微镜通道下 PCF(MI-PCF)　手术方法:全身麻醉后,患者处于俯卧位并头夹固定,颈部略微屈曲,以增大目标节段的椎间隙大小,减少关节重叠,使用 C 臂肌辅助定位,待透视后确定手术节段间隙,棘突中心切开皮肤做 2 cm 切口,利用

扩张器逐层扩张,安置工作通道,透视待达到椎板间隙,连接显微镜,其余步骤同开放 PCF。MI-PCF 最常用的系统是 METRx 管组件,与其他内镜系统不同,该系统不是基于水的程序,并且不使用恒定盐水冲洗。相比于 PCF,MI-PCF 术中能更加彻底地解放神经根,更直观地观察神经根等解剖结构,避免损伤神经。在术后随访中,MI-PCF 同样取得了不错的效果。Papavero 等[27]治疗单侧 CSR103 例,患者术后早期(3 个月)颈部/肩部和手臂的疼痛 VAS 评分显著改善。Kerry 等[28]研究认为 MI-PCF 为治疗脊髓根部外侧压迫的有效手术方式。笔者认为掌握适应证,正确选择患者才能获得最佳效果,但显微内镜下手术操作学习曲线长,且需要术者充分掌握与手术有关的解剖结构。

4.3　单通道经皮脊柱内镜下 PCF(FE-PCF)　手术方法:全身麻醉后,患者处于俯卧位并头夹固定,颈部略微屈曲,以增大目标节段的椎间隙大小,减少关节重叠,使用 C 臂肌辅助定位,待透视后确定手术节段间隙,放置穿刺针,以穿刺针为中心,切开皮肤做 0.5~0.8 cm 切口,逐步置入工作通道,连接内镜。术中不断采用生理盐水冲洗,提高术中术野清晰度,通过蓝钳剔除部分黄韧带,找到 V 点,通过磨削和椎板切除术扩大椎间孔,暴露神经根和硬脊膜,摘除突出的髓核直至充分松解神经根。最后用射频消融纤维环或缝合纤维环及周围软组织,撤出工作通道及缝合伤口。由于伤口小,术后无需放置引流管。近年来,脊柱内镜逐渐被用于治疗 CSR 等退行性疾病。FE-PCF 一般采用 Key-hole 技术,与开放式 PCF 相比,FE-PCF 具有住院时间短,恢复快,生活质量更好等优点。切口<10 mm,对组织和肌肉的损伤也明显减少。Zhang 等[29]研究发现 FE-PCF 患者的术后颈部疼痛值较低。随访研究发现,FE-PCF 手术后 6 个月 VAS 和 NDI 评分显著提高[30]。Shi 等[31]研究显示,术后不同时间点的 VAS 和 JOA 均比术前显著降低,术后椎间孔高度、前后径和面积均较术前显著增加。

4.4　UBE-PCF　手术方法:全身麻醉后,患者处于俯卧位并头夹固定,颈部略微屈曲,以增大目标节段的椎间隙大小,减少关节重叠,使用 C 臂肌辅助定位,在 C 臂透视的引导下, 待透视后确定手术节段间隙,在病变间隙中线旁,行两个皮肤和筋膜 6 mm 切口观察通道和工作通道,两个切口之间的距离为 1.2~2 cm。术中不断采用生理盐水冲洗,通过逐层扩张及骨面的剥离创造空间,通过工作通道处理周边组织及肌肉,显露 V 点,使用磨钻处理椎板及关节突,蓝钳剔除部分黄韧带,剥离部分神经根,髓核钳摘除突出的髓核组织,确保神经根自由活动,取出器械,最后放置引流管,缝合伤口。UBE 技术由关节镜技术演变而来,具有视野宽、操作灵活等优点。与 FE-PCF 相比,UBE-PCF 拥有两个通道,一个为观察通道,另一个为颈椎显微外科手术中常用的手术器械工作通道。两者互相独立且不受影响,通过盐水的连续流动,解剖结构的可视化清晰、精确。Zhong 等[32]回顾性研究显示,UBE-PCF 组的手术时间为(59.47±3.71) min,短于 FE-PCF 组[(73.36 ±6.98)min]($P<0.01$)。在连续可视化下,UBE-PCF 可以在更短的手术时间内实现充分减压。Wang 等[33]研究显示,与 FE-PCF 手术相比,UBE 手术拥有更短的透视时间和手术时间,UBE 组和 PE 组术后 VAS 和 NDI 评分均显著提高。Zhang 等[34]发现,UBE-PCF 术后颈、臂 VAS 评分和 NDI 评分均显著改善,此外,术后 CT 扫描显示神经根充分减压。以上结果表明,UBE-PCF 在 CSR 中拥有广阔的前景,是一种可行的微创方法,用于减压颈椎间孔内的现有神经根,目前其用于治疗 CSR 的相关临床报道仍较少,仍需要大量临床研究来证明疗效。

虽然微创技术可以拥有更小的创伤,但仍然有一些缺点,包括学习曲线长、减压不完全和辐射增加。然而,每种手术方法都各有利弊。有必要了解每种手术方法的适应证,并为每位患者选择正确的手术方法,以达到最佳效果并将并发症风险降至最低。

5　并发症及预防

虽然 PCF 没有像前路手术中对颈部结构的损伤,如对食管、气管、甲状腺、颈部动静脉等损伤,但术后的一个关键问题是小关节切除术的不稳定,易产生脊柱后凸,椎间孔切开术涉及切除超过 50%的小关节,则会导致颈椎节段性过度活动。也有研究表明 PCF 术后颈部和肩部疼痛痉挛与后群肌肉损伤有关[35]。在感染方面,一项回顾性分析中得出 PCF 浅表感染和深度感染率较 ACDF 高[36],但微创和脊柱内镜方法的出现和增加使用,可以通过最大限度地减少组织暴露、污染和破坏来降低未来感染和再次手术的发生率。而在微创 PCF 中,因切口小,大多数在有限的空间内操作,容易切除不彻底,不能完全减压和不能完全切除预期的椎间盘碎片。开放性 PCF 也无法直接和完整地了解手术区域及其相邻结构。意外的硬脑膜撕裂和神经根损伤也是常见的并发症[37]。Choi 等[38]发现接受 PCF 的 133 例患者中有 2 例(3.5%)出现了运动神经麻痹,2 例涉及 C6 神经根,1 例涉及 C5 神经根。对神经根损伤的处理一直是研究的热点问题,唯一可以不监测的情况是手术为局部麻醉下清醒状态,因为患者可以对任何意外的神经系统变化提供直接反馈。但是手术一般在全麻下进行,在术中增加电生理监测,可避免有效的神经的损伤。

6　总　结

PCF 又被称作为“keyhole 技术”,其视野扩大,可以保持活动性和稳定性,减少手术创伤,并且没有前路相关并发症的风险等优势,治疗 CSR 取得较为满意的结果。对于有椎间盘突出或退行性脊柱椎间孔狭窄而保守治疗难治的单侧 CSR 患者,可优先考虑 PCF。

利益冲突　无

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收稿日期:2024-02-06　**修回日期**:2024-03-06　**编辑**:李方

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收稿日期:2023-10-09　**编辑**:王海琴