European Review for Medical and Pharmacological Sciences 2024; 28: 3982-3992

Minimally invasive posterior cervical foraminotomy *vs.* anterior cervical discectomy and fusion in the treatment of patients with single-level unilateral cervical radiculopathy

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Abstract. – OBJECTIVE: The aim of this study was to observe the clinical efficacy and safety of minimally invasive posterior cervical foraminotomy (MI-PCF) and anterior cervical discectomy and fusion (ACDF) in the treatment of single-level unilateral cervical radiculopathy (SLUCR).

PATIENTS AND METHODS: We retrospectively analyzed 81 patients with SLUCR in two hospitals from February 2020 to February 2022, including the MI-PCF group (n=40) and the ACDF group (n=41). The differences in neck and shoulder pain, visual analog score (VAS), upper limb radiating pain (VAS), and neck disability index (NDI) were compared. Operative time, intraoperative bleeding, hospital stay, and complications were also compared between the two groups.

RESULTS: The degree of neck and shoulder pain relief at 1 day postoperatively was better in the ACDF group than in the MI-PCF group ($p<0.05$), while there were no significant differences between the two groups in terms of neck and shoulder pain relief at 1 month, 3 months, 6 months, and 12 months postoperatively, ($p>0.05$). There were no significant differences in the relief of upper limb radiating pain and the decrease of NDI scores between the two groups at 1 day, 1 month, 3 months, 6 months, and 12 months after surgery ($p>0.05$). The patients in MI-PCF group had shorter operative time, less bleeding, and shorter hospital stay, which were statistically different ($p<0.05$). There was no statistical difference in the complication rate between the two groups, ($p>0.05$).

CONCLUSIONS: The clinical efficacy and safety of MI-PCF and ACDF in the treatment of SLUCR are satisfactory, meanwhile, MI-PCF has shorter operative time, less bleeding and shorter hospital stay than ACDF, which is worthy of clinical promotion.

Key Words:
Anterior cervical discectomy and fusion, Cervical radiculopathy, Minimally invasive technique, Minimally invasive posterior cervical foraminotomy.

Introduction

Cervical radiculopathy is a common disorder involving dysfunction of the cervical nerve roots, and most cases can be cured with conservative treatment[1]. Only a small number of patients who fail to regular conservative treatment require surgical treatment[2]. The anterior cervical discectomy and fusion (ACDF) is currently the gold standard for the treatment of cervical radiculopathy, which not only can directly relieve the compression of nerve roots and obtain good bony fusion, resulting in effectively relieving clinical symptoms but also can maintain the stability of the spinal alignment[3,4]. However, long-term postoperative follow-up reveals that after spinal fusion, new neurological symptoms appear due to biomechanical changes, increased axial stress on adjacent segments, and a compensatory increase in mobility, resulting in accelerated degeneration of adjacent segments[5,6]. In recent years, with the development

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of minimally invasive spine techniques, minimally invasive posterior cervical foraminotomy (MI-PCF) has become more and more popular among spine surgeons as the most representative posterior cervical non-fusion minimally invasive technique[7-9]. It has the advantages of minimal trauma, adequate decompression, and few complications while preserving the mobility of the operated segment, maintaining the stability of the spinal alignment, and providing definitive results[10]. However, there were rare comparative studies investigating the efficacy of these two surgical approaches[11-13], so this study retrospectively analyzed 81 patients with SLUCR treated by MI-PCF and ACDF from two hospitals to evaluate the clinical efficacy and safety of these two surgical interventions.

Patients and Methods

General Information

From February 2020 to February 2022, 81 patients with SLUCR treated in two hospitals were selected, including 40 patients in the MI-PCF group, with an average age of 51.25±5.01, lesion segments: C4/5, 10, C5/6, 18, and C6/7, 12, among them, there were 23 cases complaining of left upper limb radiating pain and 17 cases complaining of right upper limb radiating pain. 41 patients in the ACDF group, with an average age of 51.44±4.55, lesion segments: C4/5, 13, C5/6, 16, and C6/7, 12 cases, among them, 25 cases complaining of left upper limb radiating pain and 16 cases complaining of right upper limb radiating pain. This study was conducted in accordance with the principles of the Declaration of Helsinki, and the study protocol was approved by the ethics committee of Dalian Municipal Central Hospital Affiliated with Dalian Medical University (No. YN2022-032-01) and the First Affiliated Hospital of Dalian Medical University (No. PJ-KS-KY-2023-76).

Inclusion Criteria

1. Unilateral cervical radiculopathy in single segment; 2. presence of radicular symptoms, with progressive or sudden aggravation, and no relief after 6 weeks of non-surgical treatment; 3. cervical dynamic radiographs suggest good stability of the cervical spine; 4. CT or MRI suggests unilateral cervical disc herniation and single foraminal stenosis; 5. all surgeries were performed by the same experienced surgeon.

Exclusion Criteria

1. Unilateral cervical radiculopathy with multiple segments or bilateral nerve root compression; 2. patients with spinal stenosis and axial pain; 3. patients with multiple medical conditions that cannot tolerate surgery; 4. patients with previous cervical spine surgery; 5. patients with incomplete medical records (Figure 1).

All cases were deemed suitable candidates for the two procedures following a comprehensive evaluation of their radiology reports, medical histories, and physical examination reports by experienced spinal surgeons in our team. Patients selected for these procedures were provided with detailed information regarding the respective advantages and disadvantages of both MI-PCF and ACDF approaches. This informed consent process enabled patients to make autonomous decisions about choosing either MI-PCF or ACDF.

Surgical Procedures

MI-PCF group

Surgeries were performed using a total spinal endoscopic system (CESSYS® Dorsal, Joimax, Germany). The patients were placed in a prone position after general anesthesia, with a head-high, foot-low position, and the puncture site was identified and marked under the C-arm machine at the posterior aspect of the affected facet joint. A puncture needle is placed at the marked site, and the needle is gradually advanced to the facet joint under the C-arm machine. An incision of about 8 mm is made at the center of the guide needle, and the endoscopic system with the temperature controlled-radiofrequency ablation system was inserted. Intraoperatively, saline was used for continuous flushing. The medial edge of the facet joint and the ligamentum flavum were bitten; after taking care of the facet joint medial edge, the intervertebral foramen was enlarged to achieve a complete release of the nerve root. Later, the nerve root was retracted, and the compressed nucleus pulposus or disc tissue was clamped out. Again, the nerve root was meticulously explored and freed to ensure a complete decompression. After hemostasis, the incision was closed with 1 stitch (Figure 2).

ACDF Group

After successful general anesthesia with tracheal intubation, the patient was placed in a supine, head-neutral, posteriorly extended cervical position with a soft cushion placed on the shoul-

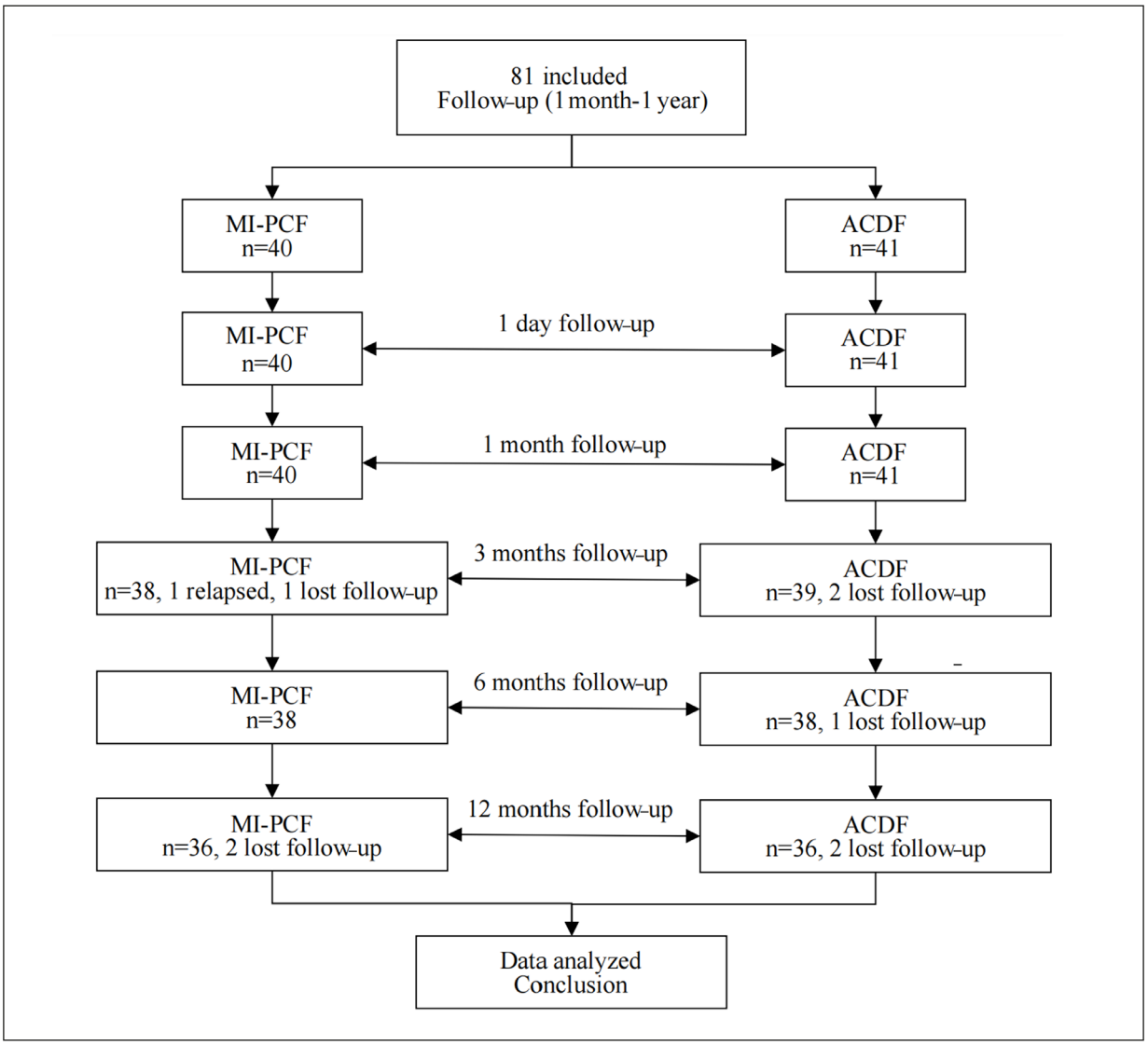

Figure 1. Flow chart of the study. MI-PCF, minimally invasive posterior cervical foraminotomy; ACDF, anterior cervical discectomy and fusion.

der and neck. The right anterior cervical transverse incision was routinely disinfected and laid out. The skin, subcutaneous tissue, and platysma were exposed layer by layer, and later, the internal carotid sheath and carotid sheath were located by blunt separation. Then, the trachea and esophagus were pulled toward the midline with a pulling hook; the carotid sheath was pulled slightly to the right to reveal the vertebral body and gap of the operated segment. After accurate fluoroscopic positioning of the needle, the anterior longitudinal ligament was incised and peeled off to both sides to reveal the cervical vertebral body and the outer layer of the intervertebral disc fibrous ring. The vertebral body spreader is positioned to appropriately dilate the intervertebral space. The fibrous annulus is excised with a scalpel, and the nucleus pulposus is incrementally removed from superficial to deep using a nucleus pulposus forceps. Surgeons would bite off the posterior bones of the Luschka joints on both sides and use a curette to scrape off the residual disc tissue and cartilage when approaching the posterior edge of the vertebral body. The posterior edge of the vertebral body and the epidural space were probed with a neural stripper, and when there was no residual pressure-causing material, the decompression was completed. The cartilage of

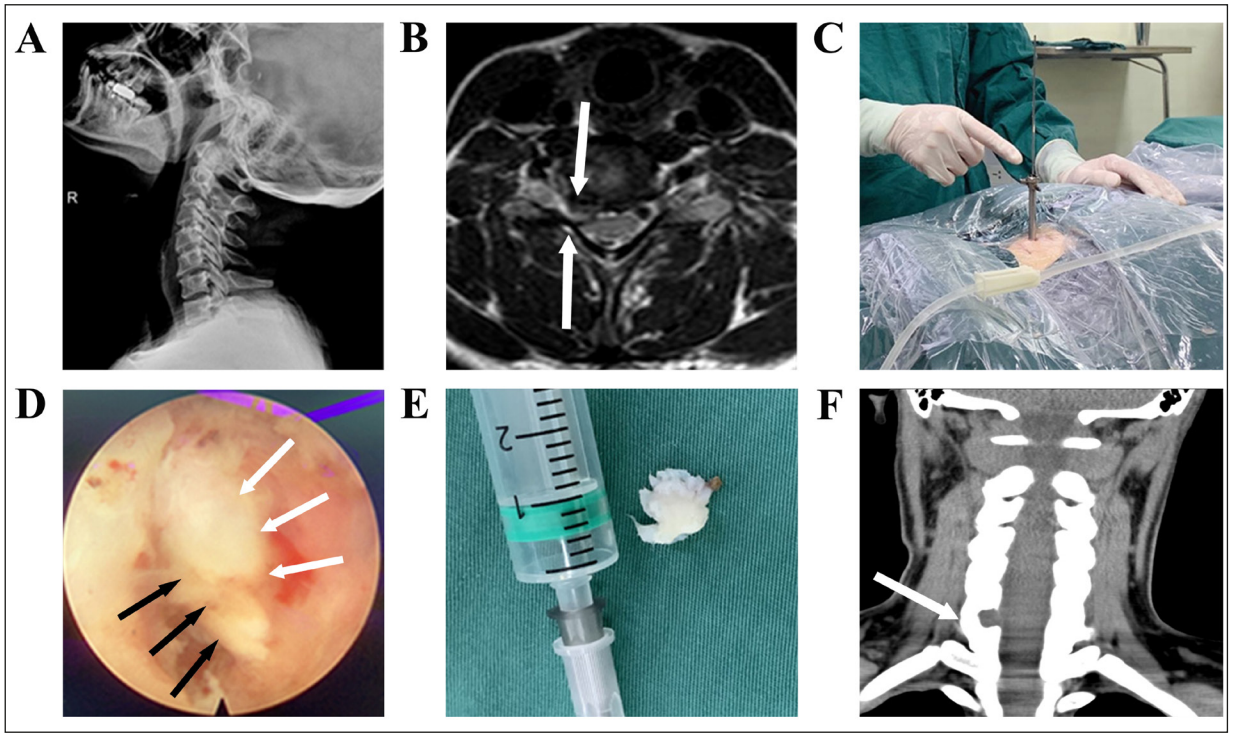

Figure 2. A 48-year-old woman who complained of right limb radiating pain for a year, which was exacerbated during the last two weeks, was admitted. **A**, Dynamic X-ray showed no obvious instability of the affected level (C6/7). **B**, MRI showed a tightly compressed nerve root (white arrows). **C**, The working sleeve was successfully inserted through the guide wire. **D**, Herniated disc of "axillary" type was smoothly clamped out (white arrows), never root was released, a completed decompression was achieved (black arrows). **E**, Specimen of the herniated disc. **F**, Postoperative coronal CT showed the targeted "hole" (white arrow).

the endplate is scraped from above and below the intervertebral space, later an appropriately sized cage (Anatomic Type Cervical Fusion Device, Wego, China) is placed; the intervertebral spacer is loosened, and an anterior cervical titanium plate and screws (Cervilock I, Wego, China) were placed for fixation. After rinsing and hemostasis, a gelatin sponge was covered, drainage was placed, and sutures were finished layer by layer (Figure 3).

Postoperative Management

After the operations, dehydrating agents and dexamethasone were given to prevent nerve root edema and nerve-nourishing drugs were routinely given. The patients were permitted to ambulate while wearing a cervical brace on the first day after surgery. They were advised to wear the cervical brace for 4 weeks.

Evaluation Indexes

Clinical indexes: general information including gender, age, lesion segment, radiating pain direction, operation time, intraoperative bleeding, hospitalization time and complications. The degree of neck and shoulder pain and upper limbs radiating pain: the pain was evaluated before surgery, at 1 day, 1 month, 3 months, 6 months, and 12 months after surgery by VAS, with a maximum score of 10, the higher the score, the more severe the pain. NDI was assessed preoperatively, at 1 day, 1 month, 3 months, 6 months, and 12 months after surgery, with higher scores indicating more severe dysfunction.

Statistical Analysis

Statistical analysis was conducted using SPSS 26.0 (IBM Corp., Armonk, NY, USA). The continuous data with normal distribution were expressed as $\bar{x}\pm s$ by t-test; median (range: min-max) by Mann-Whitney U test was applied when the assumptions of normality were violated. Categorical variables were expressed as a number of patients by χ^2 test, and $p<0.05$ was considered statistically significant.

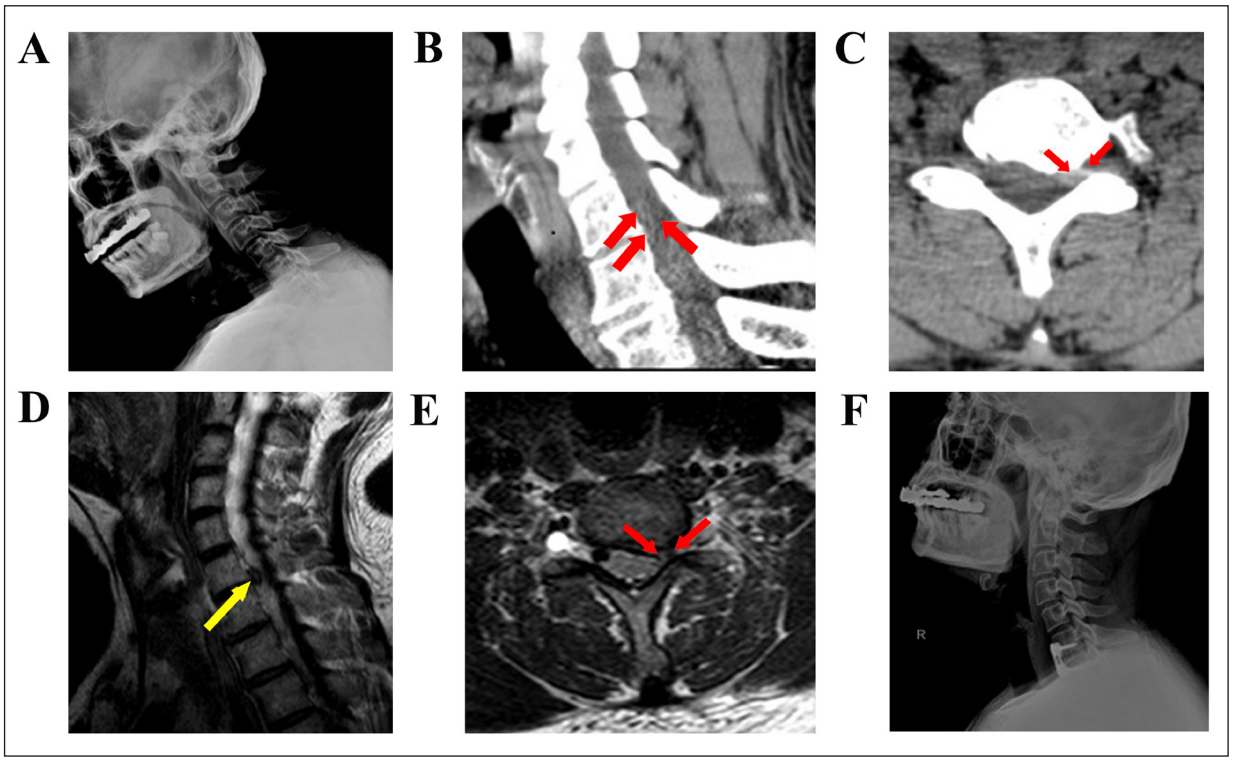

Figure 3. A 55-year-old man complained of left limb radiating pain and numbness for half a year, which debilitated during the current month, was admitted. **A**, Preoperative lateral X-ray showed instability of the cervical spine. **B-C**, Sagittal and axial CT showed a left herniated disc on C6/7 (red arrows). **D-E**, Sagittal (yellow arrow) and axial (red arrows) MRI showed a herniated disc and a tightly compressed nerve root. **F**, Postoperative lateral X-ray showed a sustainable fixation with plate and screws.

Results

Regarding general data such as gender, age, lesion segment, direction of radiating pain, preoperative neck and shoulder pain (VAS), preoperative upper limb radiating pain (VAS), and preoperative NDI, there were no statistically significant differences between the two groups (p>0.05, Table I).

Table I. Comparison of baseline characteristics between the MI-PCF and ACDF groups.

Surgical approach	MI-PCF	ACDF	*p*
Gender	n	n	0.92
Male	18	18	
Female	22	23	
Age	51.25±5.01	51.44±4.55	0.85
Involved segment	n	n	0.78
C4/5	10	13	
C5/6	18	16	
C6/7	12	12	
Involved side	n	n	0.75
Left	23	25	
Right	17	16	
Preoperative VAS			
VAS of NSP	4, (0-8)	4, (0-8)	0.67
VAS of ULRP	8, (6-9)	8, (6-9)	0.88
Pre-operative NDI	53.15±4.63	53.46±4.29	0.75

Data are presented as number of patients or mean ± standard deviation and median (range: min.-max.). MI-PCF, minimally invasive posterior cervical foraminotomy; ACDF, anterior cervical discectomy and fusion; VAS, visual analog score; NDI, neck disability index; NSP, neck and shoulder pain; ULRP, upper limbs radiating pain.

Table II. Comparison of neck and shoulder pain (VAS) between the MI-PCF and ACDF groups.

Surgical approach	VAS of NSP (PO 1 day)	VAS of NSP (PO 1 month)	VAS of NSP (PO 3 months)	VAS of NSP (PO 6 months)	VAS of NSP (PO 12 months)
MI-PCF	4 (0-6) n=40	2 (0-4) n=40	0 (0-2) n=38	0 (0-2) n=38	0 (0-2) n=36
ACDF	2 (0-4) n=41	2 (0-4) n=41	0 (0-2) n=39	0 (0-2) n=38	0 (0-2) n=36
p	0.00*	0.53	0.69	0.85	0.57

Data are presented as number of patients and median (range: min.-max.). *Statistical significance. MI-PCF, minimally invasive posterior cervical foraminotomy; ACDF, anterior cervical discectomy and fusion; VAS, visual analog score; NSP, neck and shoulder pain; PO, postoperative.

The relief of neck and shoulder pain in the ACDF group was better than that in the MI-PCF group at 1 day postoperatively, which was statistically significant ($p<0.05$), while there were no differences in the relief of neck and shoulder pain between the two groups at 1 month, 3 months, 6 months, and 12 months postoperatively, $p>0.005$ (Table II).

There were no significant differences in the relief of upper limb radiating pain between the two groups at 1 day, 1 month, 3 months, 6 months and 12 months postoperatively ($p>0.005$) (Table III).

There were also no significant differences in the decrease of NDI in 1 day, 1 month, 3 months, 6 months and 12 months after surgery between the two groups ($p>0.005$) (Table IV).

MI-PCF group had shorter operative time, less bleeding, and shorter hospital stay, and there were statistically significant differences between the two groups ($p<0.05$). There was 1 case of recurrence in the MI-PCF group and the patient was later cured by compensatory ACDF, while 3 cases developed postoperative dysphagia in the ACDF group, but there was no statistically significant difference between the two groups ($p>0.05$) (Table V).

Discussion

ACDF has been the standard procedure for surgical treatment of cervical radiculopathy, which can completely decompress the cervical nerve root, relieve pain, numbness, and other symptoms, and, at the same time, provide solid fusion and stability for the cervical spine[5,14]. However, there are certain limitations of this procedure: 1. the loss of mobility in fused seg-

Table III. Comparison of upper limb radiating pain (VAS) between the MI-PCF and ACDF groups.

Surgical approach	VAS of ULRP (PO 1 day)	VAS of ULRP (PO 1 month)	VAS of ULRP (PO 3 months)	VAS of ULRP (PO 6 months)	VAS of ULRP (PO 12 months)
MI-PCF	2 (0-4) n=40	1 (0-2) n=40	0.5 (0-2) n=38	0 (0-2) n=38	0 (0-2) n=36
ACDF	2 (0-4) n=41	1 (0-2) n=41	1 (0-2) n=39	0 (0-2) n=38	0 (0-2) n=36
p	0.19	0.60	0.55	0.70	0.29

Data are presented as number of patients and median (range: min.-max.). MI-PCF, minimally invasive posterior cervical foraminotomy; ACDF, anterior cervical discectomy and fusion; VAS, visual analog score; ULRP, upper limbs radiating pain; PO, postoperative.

Table IV. Comparison of NDI scores between the MI-PCF and ACDF groups.

Surgical approach	VAS of NDI (PO 1 day)	VAS of NDI (PO 1 month)	VAS of NDI (PO 3 months)	VAS of NDI (PO 6 months)	VAS of NDI (PO 12 months)
MI-PCF	15 (10-25) n=40	10 (6-20) n=40	8.5 (4-12) n=38	8 (0-12) n=38	7.5 (0-10) n=36
ACDF	15 (10-20) n=41	10 (8-13) n=41	8 (4-11) n=39	8 (0-10) n=38	7 (0-12) n=36
p	0.93	0.71	0.28	0.95	0.85

Data are presented as number of patients and median (range: min.-max.). MI-PCF, minimally invasive posterior cervical foraminotomy; ACDF, anterior cervical discectomy and fusion; NDI, neck disability index; PO, postoperative.

Table V. Comparison of operative parameters between the MI-PCF and ACDF groups.

Surgical approach	Surgical time (min)	Hemorrhage (mL)	Total hospital stay (days)	Complications (n)
MI-PCF	89.90±8.34	8 (3-15)	5 (4-7)	1
ACDF	101.41±8.03	10 (8-20)	7 (6-9)	3
p	0.00*	0.00*	0.00*	0.31

Data are presented as number of patients or mean ± standard deviation and median (range: min.-max.). *Statistical significance. MI-PCF, minimally invasive posterior cervical foraminotomy; ACDF, anterior cervical discectomy and fusion.

ments will inevitably lead to changes in the local biomechanical environment, resulting in a relative concentration of stress in the adjacent segments and an increase in load, which accelerates the degenerative changes in adjacent segments[15,16]; 2. if the intervertebral fusion cage does not completely match the height of the original intervertebral space, it will inevitably change the biomechanical environment of the small intervertebral joint of the fused segment and the discs of the adjacent segments, then the imbalance of compensatory stress distribution in the intervertebral joint causes new clinical symptoms such as loosening and breaking of titanium plate and screws, cage dislodgement, non-fusion of bone graft, and dysphagia, etc.[17,18]. These are all possible problems after ACDF surgery. Ruetten et al[7] first proposed the posterior endoscopic treatment of cervical disc herniation *via* a minimally invasive approach; it was indicated that MI-PCF is a safe and effective minimally invasive technique for cervical radiculopathy, which was then gradually applied in clinical practice. There are certain advantages of MI-PCF for SLUCR, such as 1. less trauma, less bleeding, less stripping of the paraspinal muscles, and avoidance of postoperative neck muscle pain and spasm compared with conventional posterior cervical open surgery. 2. Compared with anterior cervical spine surgery, it can avoid important nerve, blood vessel, and organ damage and reduce the risk of surgery[19]. 3. It can clearly and precisely reveal the operative area and decompress thoroughly, with fewer complications and faster postoperative recovery[20]. 4. Due to its special anatomical characteristics, the cervical spine has a relatively flat plate, which is conducive to the placement and stability of the working channel[21]. 5. Due to the small size of the cervical disc and the low pressure, only the herniated disc tissue needs to be removed and decompressed during surgery, and there is less recurrence after surgery, which can avoid the problem of segment motor loss after anterior fusion treatment[22].

The follow-up results of our study confirmed that both MI-PCF and ACDF techniques were effective in treating SLUCR, and both significantly relieved postoperative neck and shoulder pain, upper limb radiating pain and improved the NDI. Notably, patients in the ACDF group had better relief of neck and shoulder pain than the MI-PCF group on 1 day postoperatively, with a statistically significant difference ($p<0.05$), which may be explained by the fact that the ACDF group provides stronger stability immediately after surgery and reduces provocation of the nerve roots[5]. Patients in the MI-PCF group had shorter operative time, less bleeding, and shorter hospital stays, which were statistically significant ($p<0.05$). In terms of complications, 1 patient in the MI-PCF group had a recurrence of pain on postoperative 3 months follow-up and was successfully cured by later compensatory ACDF, while 3 patients in the ACDF group developed dysphagia, which were all relieved after later follow-up. In the ACDF group, all patients received a plate and screw for fixation, therefore, if the Zero-Profile technique had been used instead, theoretically, it would have significantly reduced the incidence of postoperative dysphagia[23]. In addition, the MI-PCF technique, as a non-fusion minimally invasive technique, basically does not change the dynamic and static stress distribution of the cervical spine structure of the affected segment and has a significant role in protecting the function of the cervical spine structure and the small joints of the degenerated segments[24].

MI-PCF has certain advantages over ACDF, but there are also some shortcomings such as 1. the surgical field of view is limited, and the operation is not under direct vision; 2. intraoperative bleeding or bone chips from the grinding drill may interfere with the clarity of the lens and

affect the surgical process, plus the movement of the working sleeve during decompression might impair the spinal cord or nerve roots; 3. the learning curve is relatively long, and the procedure requires special instruments and equipment, meanwhile, with multiple intraoperative X-ray radiation exposures; 4. the spinal cord is under continuous flushing of saline, and there is a risk of high water pressure inducing spinal hypertension, which may cause irreversible damage to the spinal cord[25].

Compared with ACDF, the indications for surgery are relatively narrow, and it is mostly used for SLUCR; therefore, not all cases achieve favorable outcomes, and the ability to maximize the advantages of MI-PCF while minimizing its drawbacks largely depends on the mastery of indications, of course, surgeon's technique and preference too. MI-PCF is particularly suitable for unilateral cervical radiculopathy without myelopathy caused by unilateral foraminal stenosis due to soft/hard compressive sources, mainly originating from lateral disc herniations, osteophytes, cysts, tumors, etc.[20,26]. MI-PCF involves a non-fusion decompression through a smaller incision, preserving cervical mobility and avoiding a series of complications associated with CAD or traditional open-PCF; however, the indications for MI-PCF are entirely within those for ACDF. Given the limited visibility and surgical field, the following conditions are more suitable for ACDF surgery: 1. paramedian, central, and bilateral disc herniation; 2. the presence of significant instability in the affected cervical spine; 3. cervical kyphosis; 4. cervical spinal stenosis; 5. patients with severe fracture; 6. anterior osteophytes >50% of the diameter of the foramen[27]; 7. abnormalities of the vertebral artery and ossification of the posterior longitudinal ligament etc.[19,28]. For patients who fulfill the indications and whose pathological site morphology is suitable, MIS-PCF stands as an alternative or even the preferred choice[11,29,30].

In comparison with other surgical treatments for Single Level Cervical Radiculopathy, such as ACDF, cervical disk arthroplasty, and open-PCF, MI-PCF is associated with less blood loss, shorter operative time and total hospital stay, and reduced medication use and costs[26,31]. The limited exposure and tissue damage, along with the clinical benefits of maintaining cervical mobility, are also reflected in more pronounced early symptom relief and shorter postoperative recovery times. Compared to ACDF, MI-PCF results in more score change in VAS-arm, VAS-neck, and NDI, allowing patients to return to work earlier, with an average time of 1.9 weeks needed to return to full baseline activities[20,22].

Scholz et al[11] reported that patients in the posterior foraminotomy group tended to have more late reoperations. However, studies by Ruetten et al[7] and Emami et al[13], among others, showed no significant differences in complication rates and revision rates between MI-PCF and ACDF during follow-ups[20], which is consistent with the conclusions of this study.

During the MI-PCF surgery, we would like to share some insights and recommendations. It is crucial to thoroughly review the patient's cervical CT and MRI prior to surgery to accurately assess the nature of the nerve root compression. This allows for comprehensive preoperative planning. In case of soft compression, intraoperative removal of the compression with a microscopic nucleus pulposus forceps is necessary to achieve adequate decompression, while in the case of hard compression (e.g., calcification of the nucleus pulposus, hyperplastic sclerosis of facet joints, etc.), a power grinding drill and a bone rongeur were used to grind and bite away the compression to achieve decompression instead of forcible resection or pulling which might cause injury to the spinal cord and nerve roots. Our intraoperative findings were similar to the results reported by Tanaka et al[32], which showed that the herniated nucleus pulposus was predominant in the "supra-shoulder" type of C5 nerve root, while the herniated nucleus pulposus was predominant in the "axillary" type of C6 and C7 nerve roots. Some scholars[33,34] have found that resection of less than 50% of the facet joints can expose 3-5 mm of the nerve roots without affecting the stability of the cervical spine, whereas resection of more than 50% of the facet synovial joints can expose the nerve roots more clearly but can easily affect the stability of the patient's cervical segments after surgery. Similarly, we recommend that the resection of facet joints should be less than 50%. We believe that patients would have a better surgical experience if surgery were performed under general anesthesia. Meanwhile, it is highly recommended that intraoperative neurophysiological monitoring be implemented during surgery. Furthermore, it is recommended that the patient's cervical spine better be fixed in flexion at approximately 15° intraoperatively to ensure maximum lamina clearance and facilitate the microscopic search for the Y-shaped joint complex

(i.e., the "V" point) formed by the inferior margin of the superior lamina and the superior margin of the inferior lamina at the medial junction of the facet joints[35,36].

Limitations

The number of patients in the two groups is small, and the follow-up period is relatively short, so there are limitations in evaluating the clinical efficacy of these two surgical methods in the short term, and the long-term effects need to be further consolidated in clinical practice. Additionally, the precise blood loss resulting from continuous saline flushing introduced a potential bias in estimating the total blood loss during MI-PCF. Advanced techniques and equipment are anticipated to assess the total blood loss during MI-PCF more accurately.

Conclusions

The clinical efficacy and safety of MI-PCF and ACDF in treating SLUCR are satisfactory. MI-PCF has a shorter operative time, less bleeding, and a shorter hospital stay than ACDF. Meanwhile, it can effectively preserve cervical mobility and reduce the degeneration of adjacent segments.

Authors' Contributions

H. Wang and Y.-X. Hu designed the study. R. Yang, J. Huang, and X.-F. Liu were responsible for data collection and analysis and manuscript writing. R. Yang, J. Huang, X.-F. Liu and S.-M. Liu were responsible for the follow-up. All authors read and approved the final manuscript.

Ethics Approval

This study was approved by the ethics committee of Dalian Municipal Central Hospital Affiliated of Dalian Medical University (No. YN2022-032-01) and the First Affiliated Hospital of Dalian Medical University (No. PJ-KS-KY-2023-76).

Informed Consent

The participants enrolled in the study agreed to the use of data for research. Informed consent was obtained from all individual participants included in the study.

Funding

This project was supported by the National Natural Science Foundation of China (grant No. 31971275).

Acknowledgments

We highly appreciate Prof. Hong Wang for his erudite guidance and persistent encouragement.

Availability of Data and Materials

For further information or to request additional data, please contact the corresponding author.

Conflict of Interest

The authors declare no competing interests.

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