

Percutaneous endoscopic cervical foraminotomy as a new treatment for cervical radiculopathy

A systematic review and meta-analysis

Yangyang Zhang, MD, Zhihua Ouyang, PhD, Wenjun Wang, PhD*

Abstract

Background: Anterior cervical discectomy and fusion (ACDF) is the gold standard treatment for this cervical radiculopathy. Posterior endoscopic cervical foraminotomy (PECF), an effective alternative to ACDF, is becoming widely used by an increasing number of surgeons. However, comparisons of the clinical outcomes of ACDF and PECF remain poorly explored. The purpose of this study was to evaluate and compare visual analog scale (VAS)-arm scores, VAS-neck scores, neck disability index (NDI) scores, reoperation, and complications in PECF and ACDF.

Materials and Methods: We comprehensively searched electronic databases or platforms, including PubMed, Web of Science, EMBASE, and the Cochrane Controlled Trial Center, using the PRISMA guidelines. The required information, including VAS-arm scores, VAS-neck scores, NDI scores, reoperation, and complications, was extracted from qualified studies and independently tested and compared by 2 researchers. The methodological index for nonrandomized studies was used to evaluate study quality.

Results: Nine studies consisting of 230 males and 256 females were included. The mean age of the included patients was 49.6 years, and the mean follow-up time was 20.6 months. The VAS-arm scores were significantly higher, and VAS-neck scores and NDI scores of PECF showed greater improvement trends for PECF than ACDF. The complication proportion of patients with PECF was lower, while the proportion of reoperation was similar between PECF and ACDF. ACDF was the most common revision surgery. The most common complication of PECF was transient paresthesia.

Conclusion: Compared with ACDF, PECF is safe and effective in patients with unilateral cervical radiculopathy without myelopathy, and PECF does not increase the probability of reoperation and complications.

Abbreviations: ACDF = anterior cervical discectomy and fusion, MINORS = methodological index for nonrandomized studies, NASS = North American Spine Society, NDI = neck disability index, PCF = percutaneous cervical foraminotomy, PECF = posterior endoscopic cervical foraminotomy, VAS = visual analog scale.

Keywords: anterior cervical discectomy and fusion, cervical radiculopathy, posterior endoscopic cervical foraminotomy

1. Introduction

The radicular symptoms of arm pain caused by cervical degenerative changes are usually caused by lateral disc herniation or osteophyte in the foramen intervertebra.^[1] If conservative

treatment fails or paralysis occurs, surgical decompression may be necessary. Open anterior and open posterior approaches are the traditional surgical techniques for this cervical spondylopathy. Anterior cervical discectomy and fusion (ACDF) was first introduced in 1958 and is an effective technique for cervical radiculopathy.^[2,3] The anterior approach is related to some complications and the risk of neck anatomical injury.^[4] Percutaneous cervical foraminotomy (PCF) is an alternative method for the treatment of cervical spondylosis that avoids many of the complications related to anterior surgery. Further avoidance of fusion can allow the normal movement of the spine to be maintained. However, because subperiosteal dissection is applied to the paravertebral muscle layer in the open posterior approach, it is associated with neck muscle pain and requires a long recovery.^[5,6] The anterior approach has been the gold standard for the treatment of cervical disc herniation and cervical spinal stenosis in recent years, while the posterior approach is becoming increasingly outdated.

However, the ideal surgical method for treating cervical radiculopathy remains uncertain. Due to the development of minimally invasive spine surgery and the spinal endoscopic system, this technology is being used by more surgeons because it can minimize trauma and allows patients to recover faster.^[5,7,8]

Percutaneous endoscopic cervical foraminotomy (PECF), a minimally invasive surgical technique, was first introduced in a study by Ruetten et al^[9] that reported substantially satisfactory

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The authors have no conflicts of interest to disclose.

All data generated or analyzed during this study are included in this published article [and its supplementary information files]; the datasets generated during and/or analyzed during the current study are publicly available.

Department of Spinal Surgery, the First Affiliated Hospital of University of South China, Hengyang, Hunan, People's Republic of China.

* Correspondence: Wenjun Wang, Department of Spinal Surgery, the First Affiliated Hospital of University of South China, 69 Chuanshan Road, Hengyang, Hunan 421001, People's Republic of China (e-mail: wwj19641202@163.com).

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results. PECF has many advantages, including preserving discs and motion, avoiding graft-related complications and reducing adjacent segmental disease. Recently, Sahai et al^[10] conducted a meta-analysis that compared minimally invasive PCF (PECF included) and ACDF, and the results showed that compared with ACDF, minimally invasive PCF may be effective and safe. To our knowledge, no meta-analysis study has previously been performed to compare outcomes between ACDF and PECF. Therefore, this study was conducted to compare the efficacy and harm of PECF and ACDF in cervical discectomy, and the evaluating indicators included visual analog scale (VAS) arm scores, VAS-neck scores, neck disability index (NDI) scores, reoperation, and complications.

2. Materials and methods

2.1. Literature search

According to PRISMA guidelines, 2 independent authors searched electronic databases, including the PubMed, EMBASE, Cochrane Controlled Trial Center Registration, and Web of Science. The results were last updated to May 2, 2020. Boolean search expressions were used as follows: (cervical or radiculopathy) and (foraminotomy or laminoforaminotomy or discectomy) and (endoscopic or full-endoscopic). Two reviewers respectively evaluated the potentially included articles. A senior author evaluated studies if consensus was not reached. The review protocol has been registered on PROSPERO (CRD42020170413). The study was approved by the ethics committee of the clinical research institute of the first affiliated hospital of university of south China.

2.2. Inclusion criteria

The following studies were included: prospective or retrospective studies, patients over 18 years old, cervical radiculopathy caused by foraminal stenosis and/or lateral disc herniation, and clinical outcomes, the proportion of cases with reoperation and complications were available.

2.3. Exclusion criteria

The following studies were excluded: central stenosis or myelopathy, and animal or cadaver studies.

2.4. Data extraction

Data were extracted from qualified studies and independently tested in detail by the 2 researchers. The data included the following: author; publication year; patient's age and sex; follow-up time; type of study design; sample size; methodology index of nonrandomized research scores (MINORS); evidence of level and grades of recommendation; VAS-arm scores, VAS-neck scores, NDI, reoperations, and complications.

2.5. Quality assessment

The full text of all selected articles was obtained. Standard MINORS is an effective tool to evaluate the quality of studies. It is used to each included article to evaluate the quality of research. A MINORS score of greater than 10 for noncomparative studies and greater than 16 for comparative studies are the standard for high-quality studies. Levels of evidence and grades of

recommendation were based on the Evidence-Based Guidelines of the North American Spine Society (NASS).

2.6. Data analysis

An Excel Spreadsheet was used to record all data and outcome measures. Software R version 3.6.1 was used for statistical analyses. The heterogeneity of the relevant studies was tested using I^2 statistics. We adopted the random-effects model if $I^2 > 50\%$. Otherwise, a fixed-effects model was adopted. The results of our statistical analysis were compared with those of previously published ACDF cohorts. The pre- and postop clinical outcome scores were compared with the data of ACDF from Schroeder's study.^[11] Reoperation and complication proportions were compared with the data of ACDF presented in Liu's study.^[12] These 2 references were used to compare the results for MI-PCF reported in Sahai's study.^[10] The overlap in the 95% CIs of the 2 cohorts indicated there was no significant difference at the $P < .05$ level.

3. Results

3.1. Characteristics of the included studies

A total of 635 articles were collected, and duplicated studies were removed. Next, the title, abstract, and full text of each article were carefully read to select eligible research content. Nine studies met the inclusion criteria. The filtration process is shown in Figure 1. In this study, PECF data reported in 9 published studies were analyzed (Table 1).^[13–21] Two of these 9 studies were prospective, while the other 7 studies were retrospective. A total of 486 patients (male:female=230:256) were included in the study. The mean age of the study population was 49.5 years, and the mean follow-up was 20.6 months.

3.2. Quality assessment

The mean MINORS score of these 9 studies was 12.9 (from 10 to 20). For the 5 studies that included VAS-arm scores, the mean MINORS score was 12.0 (from 10 to 17). The mean MINORS score of the 5 studies with VAS-neck results was 12.0 (from 10 to 17). For the 3 studies used to assess NDI, the mean MINORS score was 13.5 (from 10 to 17). Eight studies evaluated reoperation, and these patients had a mean MINORS score of 12.4 (from 10 to 20). Finally, 9 studies evaluated complications, and these patients had a mean MINORS score of 12.9 (from 10 to 20). On the basis of Evidence-Based Guidelines of NASS, 2 of 9 studies were Level II and the rest of other studies were Level III. For grades of recommendation, 6 of 9 were B and 3 were C.

3.3. Clinical outcomes

Five retrospective studies reported VAS-arm scores, and VAS-neck scores, while 3 of the 5 studies referred to NDI scores. The mean VAS-arm improvement of PCDF was 5.71 (95% CI, 5.20–6.23) (Fig. 2A), which was higher than that reported for ACDF (2.27, 95% CI, 1.82–2.70). The mean VAS-neck improvement was 3.55 (95% CI, 2.42–4.68) (Fig. 2B) for PCDF, which is higher than that reported for ACDF (2.47, 95% CI, 2.09–2.84). The mean NDI improvement of 22.54 for PCDF (95% CI, 18.77–26.32) (Fig. 2C) was higher than that reported for ACDF (16.85, 95% CI, 14.96–19.10). Compared with VAS-arm scores reported for ACDF, those reported in PECF patients were significantly better (Table 2). There was no significant difference

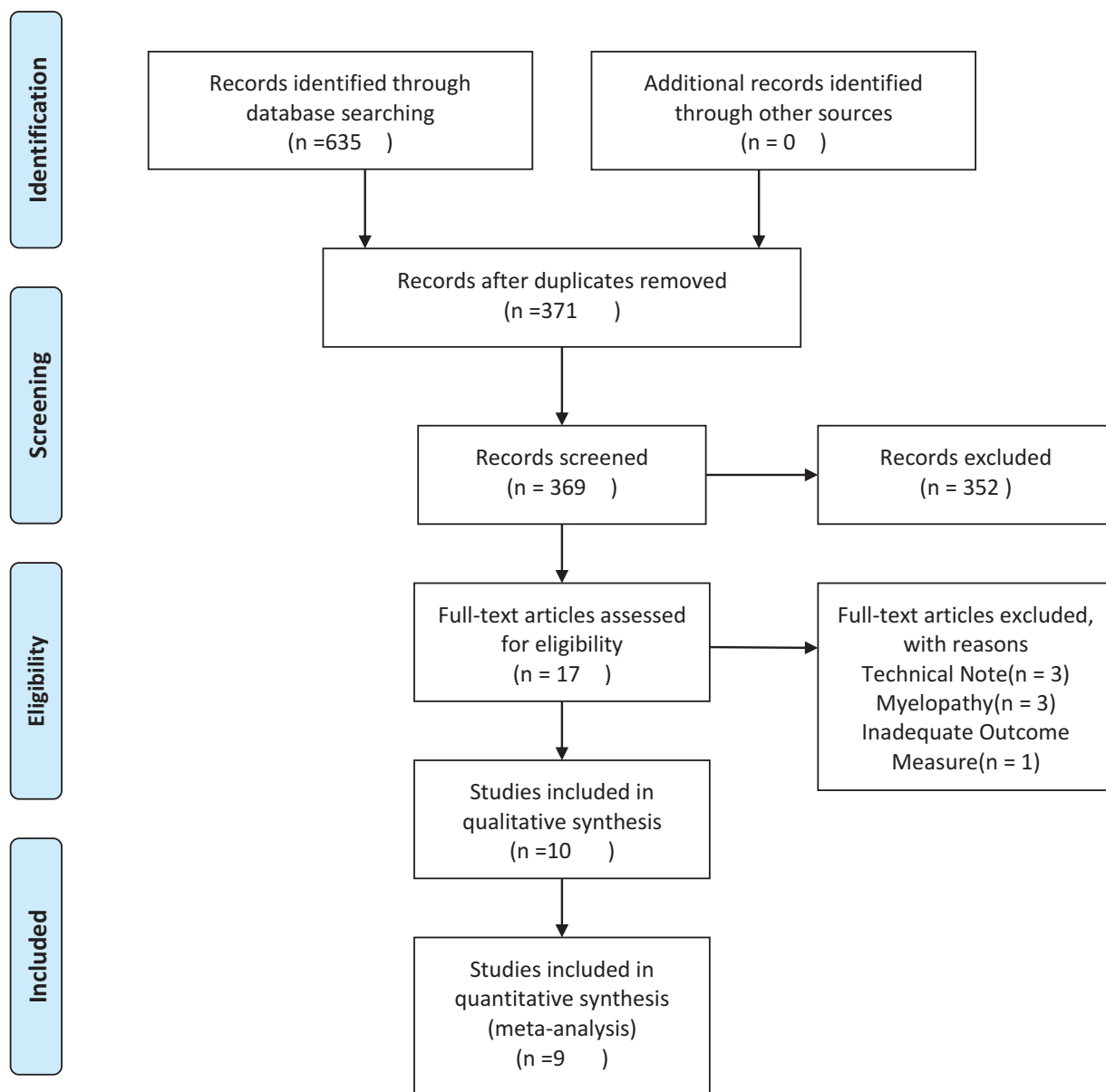


Figure 1. Flow chart showing the search strategy used in the selection of publications for inclusion in this meta-analysis.

Table 1

Characteristics of included studies.

Author	Publication year	Mean age	Male/female	Follow-up (mo)	Type of study design	Sample size	MINOR score	Level of evidence	Grade of recommendation
Ruetten et al	2008	43.0	68/132	24.0	Prospective	200	20	II	B
Kim et al	2015	48.3	15/7	24.0	Retrospective	44	17	III	C
Oertel et al	2016	55.3	27/16	28.8	Retrospective	43	11	III	B
Chen et al	2017	49.5	17/6	23.5	Retrospective	23	13	III	B
Park et al	2017	47.1	5/8	14.8	Retrospective	13	10	III	C
Youn et al	2017	56.2	13/9	24.0	Retrospective	22	10	III	C
Lee et al	2018	49.2	68/38	22.4	Retrospective	106	10	III	B
Wan et al	2018	38.0	14/11	12.0	Prospective	25	15	II	B
Shu et al	2019	63.0	14/18	12.0	Retrospective	32	10	III	B

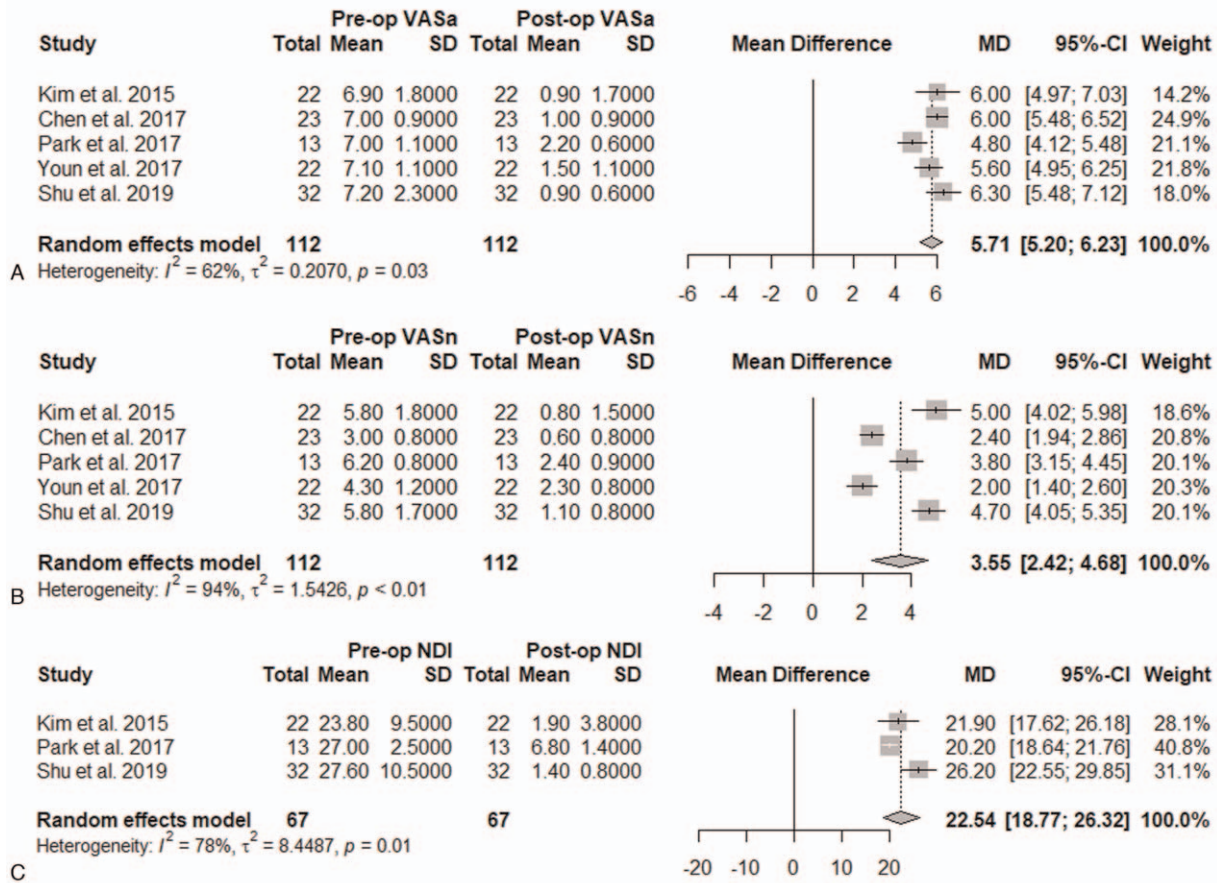


Figure 2. Forest plot of the mean improvement scores of the clinical outcomes in the PECF cohort: (A) VAS-arm, (B) VAS-neck, and (C) NDI. CI=confidence interval, MD=mean difference, NDI=neck disability index, VAS=visual analogue scale, PECF=posterior endoscopic cervical foraminotomy.

in the improvement in VAS-neck scores and NDI scores between the 2 groups (Table 2). However, compared with the ACDF group, in the PECF group, the VAS-neck scores and NDI scores showed a greater tendency to improve.

3.4. Reoperation

There were 12 reoperations among all of the included studies. Two prospective studies and 6 retrospective studies reported on these reoperations. Of the patients who underwent initial PECF, 7 of 12 proceeded to have ACDF, 4 of 12 proceeded to undergo PECF again, and 1 of 12 underwent anterior cervical corpectomy and fusion. Of the patients who underwent PECF,

the proportion with reoperation was 1% (95% CI, 0%–4%) (Fig. 3A), which was lower than the 3.90% (95% CI, 2.77%–5.46%) of ACDF patients who had reoperation. However, there was no significant difference between the 2 groups (Table 2).

3.5. Complications

Seven retrospective studies and 2 prospective studies reported complications. In all, 22 complications were reported among all of the included studies. Nine of 22 were paresthesia, 3 were mild motor weakness, 2 were palsy, 2 were superficial wound infections, 2 were postoperative hematomas, 2 were severe weakness, and 2 were asymptomatic tiny dural tears. The proportion of PECF procedures with complications was 3% (95% CI, 1%–5%) (Fig. 3B), which was lower than that of ACDF (7.79%, 95% CI, 5.54%–10.85%). Moreover, a statistically significant difference existed between the 2 operations (Table 2). Transient paresthesia was the most commonly reported complication, which affected 9 cases, all of which were resolved by the final follow-up time. Nevertheless, none of the complications had a serious effect on the results or recovery at the last follow-up. The most severe complication was motor weakness, which was reported in only 1 article.^[19] In this article, mild motor weakness and severe weakness had normalized by 3 months and 12 months after the operation, respectively.

Table 2

Change of clinical outcomes, reoperation, and complication proportions of ACDF and PECF cohorts.

	ACDF	ACDF 95% CI	PECF	PECF 95% CI
Change of VAS-arm	2.27	[1.82,2.70]	5.71	[5.20,6.23]
Change of VAS-neck	2.47	[2.09, 2.84]	3.55	[2.42,4.68]
Change of NDI	16.85	[14.96, 19.10]	22.54	[18.77,26.32]
Proportion of reoperation (%)	3.90	[2.77,5.46]	1.00	[0.00,4.00]
Proportion of complication (%)	7.79	[5.54,10.85]	3.00	[1.00,5.00]

ACDF=anterior cervical decompression and fusion, NDI=neck disability index, PECF=posterior endoscopic cervical foraminotomy, VAS=visual analog scale.

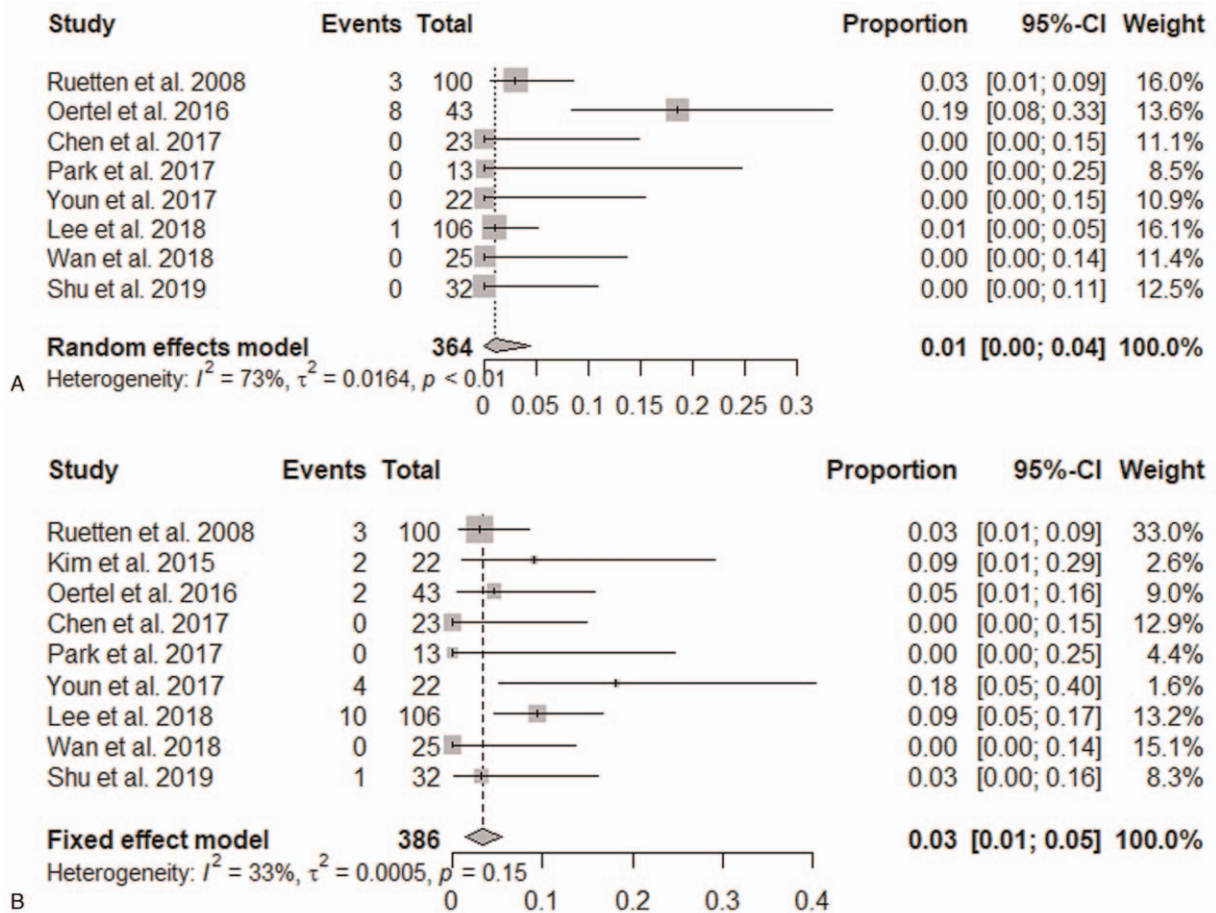


Figure 3. Forest plot of reoperation and complication rates in PECF cohort: (A) reoperation, (B) complications. CI=confidence interval. PECF=posterior endoscopic cervical foraminotomy.

4. Discussion

ACDF was regarded as the gold standard of treatment for patients with cervical radiculopathy. However, it has many non-negligible and even some inevitable complications. Loss of height in the intervertebral space, pseudarthroses, access-related complications, and adjacent segment degeneration due to the loss of mobility have been reported as problems associated with ACDF.^[22–27] PCF has been shown to be a successful option for limiting these complications.^[28,29] However, axial pain, paraspinal spasm, and the loss of normal alignment have often been mentioned in previous studies of PCF.^[6,30] With regard to the symptoms of nerve root compression caused by lateral disc herniation and/or intervertebral foramen stenosis, the goal of the operation should be to fully decompress the tissue under continuous visualization while minimizing the trauma related to the operation and its possible consequences.^[9] PECF was introduced for this reason. PECF has the following advantages: it has an expanded field of vision and good illumination, it allows mobility and stability to be maintained, it reduces operative trauma, and it has no risk of anterior approach-related complications.^[20]

Both ACDF and PECF have been demonstrated to achieve improvements in VAS-arm, VAS-neck, and NDI scores. A comparison of these 2 procedures showed that VAS-arm scores improved more following PECF than ACDF. This may be due to the effectiveness of PECF as an operation, which is applicable to

lateral pathology, rather than central pathology. The extent of improvement in VAS-neck scores and NDI scores were similar between these cohorts, although there were trends toward greater improvement in PECF. Ruetten et al^[13] performed a 2-year prospective, randomized, controlled study in which they examined 100 micro-ACDFs and 100 PECFs performed to treat lateral disc herniation. Their study demonstrated that while there was a significant improvement in VAS-arm scores and VAS-neck scores in both the ACDF and the PECF cohort, there was no difference in the degree of improvement achieved by the 2 clinical outcome measures. In our study, compared with ACDF, PECF showed more beneficial to VAS-arm scores. The improvements observed in VAS-neck scores and NDI scores showed a trend toward more improvement in the PECF group than in the ACDF group. Compared with a historical study, VAS-arm scores were also found to have improved significantly more in patients undergoing MI-PCF than in those with ACDF in Sahai's study, and other outcomes were similar between the 2 groups. Direct and targeted decompression of the cervical nerve is a benefit of both PCF and PECF,^[18] and this may explain why the improvement found in the VAS arm in most PCFs was greater than that found in ACDFs. The lack of implant fixation and the avoidance of fusion effectively maintain the mobility of the cervical segment. However, it can also exacerbate instability in some cases of cervical spondylopathy and cause neck pain,

especially in cases with damage to the posterior cervical muscles. This may be the reason that the improvement in NDI scores and VAS-neck scores was not greater in most PCFs than in ACDF. In contrast to open PCF, PECF does not require the separation of deep muscles by extensive subperiosteal dissection through a long midline incision, which can cause severe pain after posterior cervical surgery.^[6]

No significant difference in reoperation rates was found between these 2 operations, which suggests that spine surgeons can perform PECF without increasing the risk of revision surgery. In previous studies, the reoperation rates of PCF were slightly higher than those of ACDF. Liu et al^[12] reported that the reoperation rate of ACDF was 3.9%. In our analysis, the reoperation rate of PECF was 1%. Most recurrences occurred in early studies, perhaps due to surgical failure or the wrong indication for surgery. Insufficient decompression, and neck pain that may have been caused by facet joint problems were the main reasons for surgical failure.^[15] As the technology matures and experience accumulates, no recurrence was reported on most of the included studies. As with most endoscopic techniques, the learning curve of PECF is steep and requires a certain degree of open surgical experience and peer communication. According to the above analysis, the proportion of cases that required reoperation was low for strict indications and mature surgical techniques.

Finally, a higher complication rate existed in ACDF and there was a statistically significant difference in the complication rate between those 2 procedures. Its lower complication rate indicates that PECF is a safe operation. Unlike the implant-related and ventral approach-related complications of ACDF, the most commonly reported complication of PECF is paresthesia. Youn et al^[18] suggested that the removal of compression, such as in extruded discs or bony spurs, may excessively retract the nerve, causing motor palsy. Lee et al^[19] suggested that excessive traction and mechanical and thermal injury may be causes of weakness or sensory change after PECF. In Youn's study, 2 patients had transient root injury because of root retraction. To decrease the chance of root injury, Ye et al^[31] proposed that surgeons should avoid stretching the root too much during the operation to avoid damaging the nerve. It is necessary to use electrophysiological monitoring during operation.^[31] More types of complications were reported in Lee's study than in other studies. However, unlike in other studies, in Lee's study, cervical radiculopathy presented with motor weakness. Although the types of complications varied among the included studies, no irretrievable complications were reported. Moreover, the complications could be reduced by mastering the corresponding operation techniques, avoiding excessive nerve root operations and coagulation, and following strict indications.^[19] The indications accepted for PECF are as follows: cervical radiculopathy caused by lateral disc herniation and/or foraminal stenosis.^[9]

The limitations of this study include the following: there is a lack of prospective studies and randomized controlled studies; the number of included studies was limited; radiographic outcomes were not included; and the possibility of publication bias exists because of the limited number of studies.

According to our analysis, both ACDF and PECF are safe and efficacious, but PECF has obvious advantages in reducing VAS-arm scores and complication rates. PECF has an efficacy similar to that of ACDF with regard to VAS-neck scores, NDI scores, and reoperation rates. These results suggest that PECF is a safe and validated alternative to ACDF when performed under strict

indications. However, considering the limitations of our study, more large-scale prospective or randomized controlled trials should be performed in the future to compare PECF with ACDF.

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Author contributions

Conceptualization: yangyang Zhang, Wenjun Wang.

Data curation: yangyang Zhang, Zhihua Ouyang.

Formal analysis: yangyang Zhang, Zhihua Ouyang.

Funding acquisition: Wenjun Wang.

Investigation: yangyang Zhang, Zhihua Ouyang.

Methodology: yangyang Zhang.

Project administration: yangyang Zhang.

Resources: Wenjun Wang.

Software: yangyang Zhang.

Supervision: Wenjun Wang, Zhihua Ouyang.

Validation: yangyang Zhang.

Visualization: yangyang Zhang, Wenjun Wang.

Writing – original draft: yangyang Zhang.

Writing – review & editing: Wenjun Wang.

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