Background: The biportal endoscopic technique (BE) is a fast-growing surgical modality that can be applied to posterior cervical foraminotomy (PCF), as well as lumbar discectomy and decompressive laminectomy. It has several technical differences from the percutaneous full-endoscopic technique (PE), which has been standardized as the representative endoscopic spinal surgery technique. The purpose of this study was to compare the short-term clinical outcomes between BE-PCF and PE-PCF.

Methods: A retrospective review was conducted on 66 patients who had single-level unilateral cervical foraminal disc disease (UCFD). All patients underwent PE- or BE-PCF. Clinical outcomes including visual analog scale (VAS)-arm, VAS-neck, and Neck Disability Index (NDI) were evaluated. Perioperative data including operation time, length of hospital stay (LOS), amount of surgical drain, postoperative complications, and reoperation were collected. Serum creatine phosphokinase (CPK) and C-reactive protein (CRP) levels were recorded.

Results: A total of 65 patients were included in the final analysis: 32 with PE-PCF and 33 with BE-PCF. There was no statistically significant difference in demographic and preoperative data between the two groups. All patients had significant improvement in VAS-arm, VAS-neck, and NDI compared to the baseline value. The improvement of all parameters was comparable between the two groups at each point for 1 year after surgery (p > 0.05), except for the significantly lower VAS-neck at postoperative 2 days in PE-PCF (p = 0.005). The total operation time was significantly shorter in BE-PCF (p = 0.036). There were no statistically significant differences between the two groups in regard to LOS, amount of surgical drain, and serum CPK and CRP levels (p > 0.05). Reoperation and complications between the two groups were comparable (p > 0.05).

Conclusions: The 1-year postoperative clinical outcomes of PE-PCF and BE-PCF for cervical pain and disability caused by UCFD were good and comparable. PE-PCF resulted in significantly less immediate postoperative neck pain, but BE-PCF required shorter total operation time.

Keywords: Cervical radiculopathy, Unilateral cervical foraminal disc disease, Posterior cervical foraminotomy, Percutaneous full-endoscopy, Biportal endoscopy
The radicular symptoms of arm pain caused by cervical degenerative disc disease is often caused by lateral cervical disc herniation or osteophytes in the neural foramen.\(^1,2\) Posterior cervical foraminotomy (PCF) provides direct nerve root decompression and preserves intersegmental motion, allowing it to be free from adjacent segment degeneration. In addition, PCF has the advantage of avoiding anterior cervical approach-related complications, such as dysphonia and dysphagia, but has the disadvantage of causing intersegmental instability and progressive cervical kyphosis due to cervical paravertebral muscles and facet joint injury.\(^3-6\)

Percutaneous full-endoscopy for PCF using an endoscopic instrument equipped with the rod-lens optics with separated working canal is attracting attention as it can reduce paravertebral muscle injury, perioperative blood loss, postoperative pain and disability, and opioid consumption, while maintaining the clinical results of microscopic PCF.\(^6,7\) The biportal endoscopic technique (BE) is a fast-growing surgical modality that can be applied to PCF, as well as lumbar discectomy and decompressive laminectomy.\(^8-10\) Additionally, it has several technical differences from the uniportal full-endoscopic technique in spinal surgery. This technique creates a workspace over the junction between the vertebral lamina and lateral mass through two separated viewing and working channels at the top and bottom and allows cervical foraminotomy very similar to microscopic PCF.\(^11,12\) However, there is still a lack of clinical evidence for BE-PCF. This study aimed to compare clinical outcomes of percutaneous full-endoscopic technique (PE)- and BE-PCF 1 year postoperatively.

**METHODS**

**Study Design and Patient Population**

This study was a retrospective review, approved by the Institutional Review Board of Hallym University Kangnam Sacred Heart Hospital (No. 2021-12-012) and was conducted in accordance with the Declaration of Helsinki. Informed consent was obtained from all participants, including photographs of patients.

A retrospective review was conducted on 65 consecutive patients who had cervical spondylotic radiculopathy (CSR) with unilateral cervical foraminal disc disease (UCFD). All patients underwent the PE- or BE-PCF between September 2018 and January 2020. Inclusion criteria were as follows: (1) age 20 to 80 years; (2) clinical manifestations and physical examinations consistent with a single-level, unilateral CSR, which was refractory to more than 6 weeks of conservative treatment; and (3) lateral and/or foraminal cervical disc herniation or stenosis confirmed in magnetic resonance imaging (MRI). Exclusion criteria were as follows: (1) patients with cervical myelopathy with cord signal change upon MRI, segmental instability, presence of hypoplasia of lateral mass, and cervical deformities; (2) patients with central localization of the disc herniation or multi-level cervical spinal stenosis; (3) patients with prior surgery on the same level; and (4) those who had not been followed up for more than 1 year.

All operations were performed by two spine surgeons (MSK and HJP) with more than 1 year of experience with endoscopic spine surgery. The decision of two techniques was determined by surgeon’s preference and experience. There was no specific contraindication or exclusion criteria in selecting either surgical option.

**Fig. 1.** Patient positioning. The patient was placed in a modified prone position on a radiolucent frame with slight reverse Trendelenburg inclination that accommodates fluoroscopy. Compression-free eyeball and intubation tube devices were placed on the face, and slight neck flexion and traction were performed with surgical plaster tape to reduce cervical venous pressure and to increase the interlaminar space.
Surgical Procedure

Patient positioning was performed according to a previous study conducted by the authors of the current study (Fig. 1). Endoscopic PCF was performed under general anesthesia with the patient placed in a modified prone position on a radiolucent frame with slight reverse Trendelenburg inclination to accommodate fluoroscopy. Compression-free eyeball and intubation tube devices were placed on the face, and slight neck flexion and traction were performed to increase the interlaminar space using surgical plaster tape. The patients were then prepared and draped using a Suez pouch, which ensures that the water from the outflow does not contaminate the operating room in a sterile fashion. PE-PCF was performed using the H-View Endoscopic System (8.4-mm outer diameter, 5.7-mm working channel, and 12° field of view; H-View, Daejeon, Korea). On the other hand, BE-PCF was performed using a general arthroscopic surgical system (4-mm diameter, and 0° or 30° field of view; ConMed Linvatec, Largo, FL, USA). In addition, continuous fluid irrigation was maintained throughout the operation using an automated pressure-controlled pump system (10K Fluid System, ConMed Linvatec). Water pressure was set within the range known to be safe in a previous study. It was limited to 30–40 mmHg before exposure of the epidural space and 30 mmHg after exposure of the epidural space. There were no signs of increased intracranial pressure such as postoperative headache, nausea, and vomiting in any of the patients.

The target segment was confirmed under the guidance of C-arm fluoroscopy. In PE-PCF, a 1-cm vertical skin incision was made at the medial border where the superior and inferior articular process meet, known as V-point. In BE-PCF, two 0.7-cm vertical skin incisions were made at an interval of 2 cm around this V-point (Fig. 2). After performing muscle splitting using a sequential dilator onto the facet joint, the endoscopic sheath containing an endoscope was inserted, then the proper endoscopic visualization was obtained through tissue cauterization using a bipolar radiofrequency ablator (Ellman Surgitron; Ellman International, NY, USA or Quantum 2; Arthro-Care, CA, USA). In BE-PCF, sufficient fasciotomy and muscular release was performed using an arthroscopic tissue shaver (Ergo Shaver handpiece; Conmed Linvatec) at this stage. Both PE-PCF and BE-PCF were performed in the same process as conventional microscopic PCF, as described below after obtaining adequate endoscopic visualization.

Once the V-point where the superior and inferior articular processes meet and the ligamentum flavum located inside them were identified, the inferolateral border of the upper lamina, superolateral portion of the lower lamina, and medial portion of facet joint were drilled out with a 3.5-mm endoscopic drill (Primado II high-speed drill system; NSK, Osaka, Japan) until the attachment of the ligamentum flavum was exposed. After circumferential foraminotomy along the pathway of the exiting nerve root, further decompression for the lateral portion of nerve root was implemented with the 1-mm Kerrison punch and small-head curved curettes. Subsequently, piecemeal removal of the lateral extension of the ligamentum flavum was commenced. During this process, a vascular complex surrounding the nerve root requires keen attention for possible bleeding; a bipolar radiofrequency ablator was useful for vascular coagulation without nerve injury. Sufficient neural decompression was ensured by identifying the whole nerve root exit route and the disc pathology while gently manipulating the nerve root at its exit. With the use of a nerve root retractor, if needed, enough space for discectomy was secured while protecting the spinal cord and exiting nerve root; limited discectomy was performed.

Fig. 2. Skin incision for percutaneous full-endoscopic technique posterior cervical foraminotomy (PE-PCF) and biportal endoscopic posterior cervical foraminotomy (BE-PCF). (A, B) In PE-PCF, a 1-cm vertical skin incision is made at the medial border where the superior and inferior articular process meet, which is called V-point (yellow circle). (C, D) In BE-PCF, two 0.7-cm skin incisions are made at an interval of 2 cm around the V-point. Blue line: facet joint medial border, red line: incision site.
After meticulous hemostasis, a surgical drain was inserted and the surgical wound was closed (Fig. 3).

Postoperatively, all patients were advised to wear a soft neck collar for 2 weeks. For postoperative pain control, we employed automatic intravenous patient-controlled analgesia with 1 mL of continuous infusion and 1 mL of bolus infusion with a 15-minute lockout interval, combined with 25 μg/kg fentanyl, 0.3 mg Ramosetron, and saline until postoperative day 2. Additional tramadol injection was used for pain control upon request by the patients. After the patient-controlled analgesia was removed, the patients were administered a transdermal 5-mg buprenorphine patch (NORSPAN patch; Mundipharma Korea Ltd., Seoul, Korea).

**Measured Data**

We recorded demographic and past history data, including age, sex, body mass index, and American Society of Anesthesiologists Physical Status Classification System (ASA class). Clinical outcomes were analyzed using a visual analog scale (VAS; a score of 0 indicated no pain and 10 represented the worst pain)-arm, VAS-neck, Neck Disability Index (NDI), and modified MacNab’s criteria. Total operation time (skin to skin), length of hospital stay (LOS; the duration of hospital stay after surgery), amount of surgical drain (mL), and plasma hemoglobin, serum creatine phosphokinase (CPK), and C-reactive protein (CRP) levels were also recorded. The outcomes were assessed preoperatively, 2 days after surgery, and 1, 3, 6, and 12 months after surgery. In addition, reoperation and surgery-related complications were recorded.

**Statistical Analysis**

All data were compared using the chi-square test, and independent t-tests were performed for comparison of continuous variables between the two groups. Analyses of perioperative data, modified Macnab’s criteria, and surgery-related complications were performed using Fish-
er’s exact test. A $p$-value of less than or equal to 0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS ver. 26.0 (IBM Corp., Armonk, NY, USA).

RESULTS

A total of 65 patients were included in the final analysis: 32 with PE-PCF (mean age, 53.74 ± 8.50 years) and 33 with BE-PCF (mean age, 52.68 ± 9.56 years). One patient with PE-PCF was excluded due to insufficient medical records. The demographic and preoperative data did not differ significantly between the two groups ($p > 0.05$) (Table 1).

All patients had significant improvement in VAS-arm, VAS-neck, and NDI compared to the baseline values from 2 days after surgery, which lasted until the final follow-up. There was also no statistically significant difference in incremental improvement for VAS-arm and NDI between both groups ($p > 0.05$). However, VAS-neck at 2 days after surgery was statistically significantly lower among those who underwent PE-PCF (2.55 ± 0.96 vs. 3.04 ± 0.79; $p = 0.005$) and was comparable between the two groups at each point from 1 month after surgery ($p > 0.05$) (Fig. 4). According to the modified Macnab criteria, at the final follow-up, 91.7% of the patients in the PE-PCF group and 87.9% of the patients in the BE-PCF group had excellent or good levels of satisfaction.

The mean total operation time was 70.97 ± 12.00 minutes in BE-PCF, which was statistically significantly shorter than 78.61 ± 14.47 minutes required in PE-PCF ($p = 0.036$). However, there were no significant differences between the two groups in regard to LOS (2.16 ± 1.14 days vs. 2.48 ± 1.23 days; $p = 0.347$) and the amount of surgical drain (48.84 ± 7.73 mL vs. 53.88 ± 23.71 mL; $p = 0.416$) (Table 2). Serum CRP and CPK levels showed an increase-decrease pattern, which rose to the highest value 1 day after surgery and recovered to normal ranges 2 days postoperatively. The patterns showed no statistically significant difference between the two groups ($p > 0.05$) (Table 3).

One case from each group underwent reoperation

| Table 1. Demographic and Preoperative Data |
|--------------------------------------------|
| Variable                                  | PE-PCF (n = 32) | BE-PCF (n = 33) | $p$-value |
| Age (yr)                                  | 53.74 ± 8.50    | 52.68 ± 9.56    | 0.642     |
| Sex (male : female)                       | 10 : 22         | 11 : 22         | 0.783     |
| Height (cm)                               | 166.74 ± 8.52   | 167.65 ± 8.03   | 0.669     |
| Weight (kg)                               | 69.19 ± 8.13    | 68.94 ± 9.38    | 0.908     |
| BMI (kg/m$^2$)                            | 24.87 ± 2.23    | 24.47 ± 2.35    | 0.486     |
| Diagnosis                                 |                |                | 0.556     |
| Foraminal cervical disc herniation, contained lesion | 15 (46.9) | 16 (48.5) |         |
| Foraminal cervical disc herniation, sequestrated lesion | 7 (21.9) | 8 (24.2) |         |
| Foraminal stenosis with osteophyte         | 10 (31.2)       | 9 (27.3)        |           |
| Level                                     |                |                | 0.523     |
| C4–5                                      | 2 (6.3)         | 3 (9.1)         |           |
| C5–6                                      | 11 (34.4)       | 12 (36.4)       |           |
| C6–7                                      | 18 (56.2)       | 14 (42.4)       |           |
| C7–T1                                     | 1 (3.1)         | 4 (12.1)        |           |
| Direction                                 |                |                | 0.220     |
| Right side                                | 17 (53.1)       | 21 (63.6)       |           |
| Left side                                 | 15 (46.9)       | 12 (36.4)       |           |

Values are presented as mean ± standard deviation or number (%). Statistical significance was set at $p < 0.05$.

PE-PCF: percutaneous full-endoscopic posterior cervical foraminotomy, BE-PCF: biportal endoscopic posterior cervical foraminotomy, BMI: body mass index.
Table 3. Laboratory Data

| Variable                  | CRP (mg/dL)                           | CPK (IU)                |
|---------------------------|---------------------------------------|-------------------------|
|                           | PE-PCF  | BE-PCF  | p-value | PE-PCF  | BE-PCF  | p-value  |
| Preoperative              | 0.18 ± 0.39 | 0.04 ± 0.05 | 0.064 | 99.58 ± 33.92 | 102.16 ± 29.14 | 0.758 |
| Postoperative 1 day       | 0.38 ± 0.35 | 0.33 ± 0.24 | 0.507 | 128.65 ± 54.27 | 171.29 ± 105.12 | 0.067 |
| Postoperative 2 day       | 0.19 ± 0.49 | 0.18 ± 0.40 | 0.840 | 107.33 ± 52.74 | 103.71 ± 47.77 | 0.610 |

Values are presented as mean ± standard deviation. Statistical significance was set at p < 0.05. 
CRP: C-reactive protein, CPK: creatinine phosphokinase, PE-PCF: percutaneous full-endoscopic posterior cervical foraminotomy, BE-PCF: biportal endoscopic posterior cervical foraminotomy.
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due to incomplete decompression. The patient who underwent PE-PCF subsequently underwent anterior cervical discectomy and fusion (ACDF), and the patient who underwent BE-PCF had another BE-PCF for revision. Postoperative complications resulted in 1 case of transient C5 nerve root palsy and incidental durotomy in the PE-PCF group and 1 case of epidural hematoma, incidental durotomy, and persistent dysesthesia in the BE-PCF group (Table 4). All patients improved with conservative management.

Table 4. Comparison of Perioperative Complications between the Two Groups

| Variable                        | PE-PCF (n = 32) | BE-PCF (n = 33) |
|---------------------------------|-----------------|-----------------|
| Reoperation                     | 1 (3.1)         | 1 (3.0)         |
| Cause                           | Incomplete      | Incomplete      |
|                                 | decompression   | decompression   |
| Treatment                       | ACDF            | Revisional BE-PCF |
| Complication                    |                 |                 |
| Incomplete decompression        | 1 (3.1)         | 1 (3.0)         |
| Incidental durotomy             | 1 (3.1)         | 1 (3.0)         |
| Transient C5 nerve root palsy   | 1 (3.1)         |                 |
| Epidural hematoma               | 1 (3.0)         |                 |
| Persistent dysesthesia          | 1 (3.0)         |                 |

Values are presented as number (%). PE-PCF: percutaneous full-endoscopic posterior cervical foraminotomy, BE-PCF: biportal endoscopic posterior cervical foraminotomy, ACDF: anterior cervical discectomy and fusion.

DISCUSSION

In the surgical management of UCFD, this retrospective review demonstrated the following results: (1) in both PE-PCF and BE-PCF groups, a significant improvement in VAS-arm, VAS-neck, and NDI scores was observed at each point for 1 year after surgery, compared to preoperative values; (2) except for the significantly lower VAS-neck scores 2 days after PE-PCF, the clinical outcomes of the two endoscopic PCFs were not significantly different; and (3) the operation time was significantly shorter in BE-PCF; however, perioperative results, including complications and reoperation, were comparable between the two groups.

To date, controversy remains over the optimal surgical management of UCFD without myelopathy. In the available literature, ACDF is the most supported surgical technique, and cervical artificial disc replacement (CADR) and minimally invasive PCF can also be considered as motion-preserving techniques. In particular, a prospective randomized control study of lateral cervical disc herniations, treated by either PE-PCF or ACDF, showed that the clinical outcomes including pain improvement and functional recovery were comparable for both groups 2 years postoperatively. In addition, a systemic review and meta-analysis showed that improvement in VAS-arm was significantly higher after PE-PCF, but differences in VAS-neck and NDI were not statistically significant. Still, a greater tendency to improve was noted among those who underwent PE-PCF than those who underwent ACDF. The present study compared PE-PCF, which showed evidence of equivalence with ACDF, with the recently introduced BE-PCF. The findings showed that the clinical outcomes of PE- and BE-PCFs were comparable 1 year postoperatively, and PE-PCF showed the advantage of significantly less immediate postoperative neck pain.

However, the mean total operation time of PE-PCF was 78.61 ± 14.47 minutes, significantly longer than 70.97 ± 12.00 minutes of BE-PCF. There was no significant difference in perioperative data between the two groups, including LOS and the amount of surgical drain. Serum CPK and CRP are useful parameters for evaluating the surgical invasiveness of minimally invasive surgical techniques. In particular, Choi et al. reported that PE techniques were less invasive than the microscopic tubular technique in lumbar discectomy surgery. In the present study, the serum CPK and CRP levels showed a characteristic increase-decrease pattern as previously reported; although CPK levels tended to be higher in BE-PCF (171.29 ± 105.12 IU) than in PE-PCF (128.65 ± 54.27 IU), there was no statistically significant difference between the two groups. Therefore, it can be expected that the surgical invasiveness of BE-PCF is similar to that of PE-PCF.

The incidence of complications following PE-PCF was 3%, including transient paresthesia, motor palsy, surgical site infection, epidural hematoma, and incidental durotomy. Most of these complications have been reported to respond well to conservative treatment, except for severe motor palsy. In the current study, postoperative complications were not different from those of previous reports. In ACDF, however, notable and even some inevitable complications remained a significant challenge such as adjacent segment diseases, pseudoarthrosis, and instrument-related complications. In particular, pseudoarthrosis has been reported to have a prevalence of up to 20% in single-level cases, and it is one of the most common indications for reoperation following ACDF. Pseudo-
arthrosis is implicated in up to 56% of revision cases. PCF also has an advantage of a lower incidence of the same and adjacent-segment disease than ACDF.\textsuperscript{23} In addition, minimally invasive PCF might be associated with lower medical costs than ACDF and CADR.\textsuperscript{20,24-26} Therefore, in single-segment UCFD, where central canal decompression is not required, PCF, which is not implicated in spinal fusion-related problems, may be more suitable than ACDF as first-line treatment.

The shortcomings of this study include the retrospective study design, small sample size, and short follow-up period. In particular, it was difficult to determine how clinically significant the findings was in terms of postoperative complications and reoperation as their incidence was low. In addition, there may be clear limitations in interpreting our results, as most previous studies have compared the clinical outcomes as alternatives of ACDF, such as CADR and PCF, based on ACDF. Nevertheless, endoscopic PCF does not affect the stability of three-joint complexes in the spinal segment in the treatment of cervical lateral disc disease and can lead to favorable clinical outcomes through selective neural decompression without the risk of adjacent segment diseases, pseudoarthrosis, and instrument-related complications. The strength of this study is, to the best of authors’ knowledge, it is the first to compare the short-term clinical outcomes of PE-PCF and BE-PCF for more than 1 year postoperatively. A prospective, randomized controlled study on anterior approaches in microscopic surgery and endoscopic PCF for UCFD without myelopathy are warranted.

In conclusion, our results demonstrated that BE-PCF and PE-PCF can alleviate the associated cervical pain and disability from UCFD without myelopathy. PE-PCF was advantageous for significantly less immediate postoperative neck pain, whereas BE-PCF required a shorter total operation duration.

**CONFLICT OF INTEREST**

No potential conflict of interest relevant to this article was reported.

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