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ORIGINAL ARTICLE

Clinical and radiological outcomes of two-level endoscopic posterior cervical foraminotomy

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Abstract
Purpose The efficacy and safety of endoscopic posterior cervical foraminotomy (EPCF) have been demonstrated for single-level cervical radiculopathy, but no report in the medical literature has described the clinical results of two-level EPCF. The aim of this study was to assess the clinical and radiological outcomes of two-level EPCF performed in patients with cervical radiculopathy.
Methods Twenty-two consecutive patients (9 females and 13 males) that underwent two-level EPCF with cervical radiculopathy from January 2012 to January 2014 were included in this study. Clinical outcomes were assessed before surgery and at 1, 3, 6, 12, and 24 months postoperatively using visual analogue scale for neck and arm, neck pain and disability scale (NPDS), and neck disability index (NDI) scores. Radiological outcomes were assessed by measuring segmental lordosis (SL), C2–7 lordosis, and disc height index (DHI) before surgery and at 12 and 24 months postoperatively.
Results Mean VAS, NPDS, and NDI scores were significant improved at 1 month postoperatively versus preoperative values and these improvements were maintained at 2 years after surgery. SL and C2–7 lordosis were significantly increased after surgery, and no instability in dynamic view was observed during the 2-year follow-up period. Percentage DHIs of operated discs were also maintained without significant change at 2 years after surgery. One patient suffered from transient motor palsy due to root retraction.
Conclusions Two-level EPCF can be safely preformed and should be considered an alternative to two-level anterior cervical discectomy and fusion or open posterior cervical foraminotomy in selected patients.

Keywords Two level · Endoscopic · Posterior cervical foraminotomy

Introduction

Radicular symptoms with arm pain due to degenerative changes of the cervical spine arise typically from lateral disc herniations or osteophytes in an intervertebral foramen. The two main surgical approaches for cervical radiculopathy are anterior cervical discectomy and fusion (ACDF) or posterior cervical foraminotomy (PCF). ACDF is now widely accepted as gold standard surgical treatment and has generally been described as safe and efficacious with good fusion rates [2, 6, 29]. Nonetheless, ACDF has specific potential problems, which include pseudoarthrosis, approach-related complications, and adjacent segment disease [16, 18, 30]. ACDF is certainly preferred over PCF in most patients with a centrally or posterolaterally located disc herniation, but in patients with foraminal stenosis and lateral disc herniation without spinal cord compression, nerve root compression can be treated by PCF, which has some advantages over ACDF. For example, PCF preserves the intervertebral disc and the motion segment, and avoids the need for fusion and the risk of potential adjacent segment disease [13, 24]. PCF can now be performed endoscopically thanks to the continuous development of

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endoscopes and instruments, and endoscopic posterior cervical foraminotomy (EPCF) has been reported to produce good results [20, 31]. In general, endoscopic cervical procedures are classified using two approach categories, that is, anterior discectomy or posterior foraminotomy. The anterior endoscopic approach provides a means of direct decompression and is indicated for central and posterolateral types of cervical disc herniation, but presents the risk of iatrogenic injury to disc contents and, thus, the risk of reduced disc height in the long term [1, 14]. Although EPCF is not indicated for central disc herniation, it has been used to treat lateral disc herniation and foraminal stenosis. Furthermore, because EPCF does not disturb disc contents, it has the advantages of preserving the motion segment and of providing postoperative radiologic stability [31]. Although some have reported favorable outcomes for EPCF for the management of single-level radiculopathy, no such report has been issued on multi-level EPCF. Accordingly, the aim of this study was to evaluate the clinical and radiologic outcomes of two-level EPCF performed through a single stab incision.

Materials and methods

Two-level EPCF was performed in 24 patients between January 2012 and January 2014. Patients underwent relevant clinical and radiological investigations and adequate follow-up was possible in 22 patients; the other 2 patients were excluded. Thus, the medical records of 22 consecutive patients (9 females and 13 males) that underwent two-level EPCF were retrospectively reviewed. The study inclusion was cervical lateral herniated disc or foraminal stenosis without spinal cord compression (Fig. 1). Patients with spinal instability or deformity and those in whom the lower end plate of the C7 body could not be visualized were excluded, as were patients with a centrally located herniated disc, bilateral symptoms, or isolated neck pain. All included patients underwent continuous conservative treatment including medicine, physical therapy, and/or injection therapy for a minimum of 6 weeks before surgery.

All 22 patients had radicular symptoms at the time of the preoperative examination (Table 1). Radicular arm pain was the most common presenting symptom, and was present in all patients. Seven patients complained of numbness or paresthesia in the upper extremities, five patients had grip weakness or exhibited deltoid atrophy. Hoffmann's reflex or any other sign of upper motor neuron disease was not noted.

All patients were assessed before surgery and at 1, 3, 6, 12, and 24 months after surgery. The study was approved by the Clinical Research Ethics Committee of our institute.

Surgical technique

All EPCF were performed using the TESSYS^{TM} system (joimax GmbH, Germany). Under general anesthesia, a

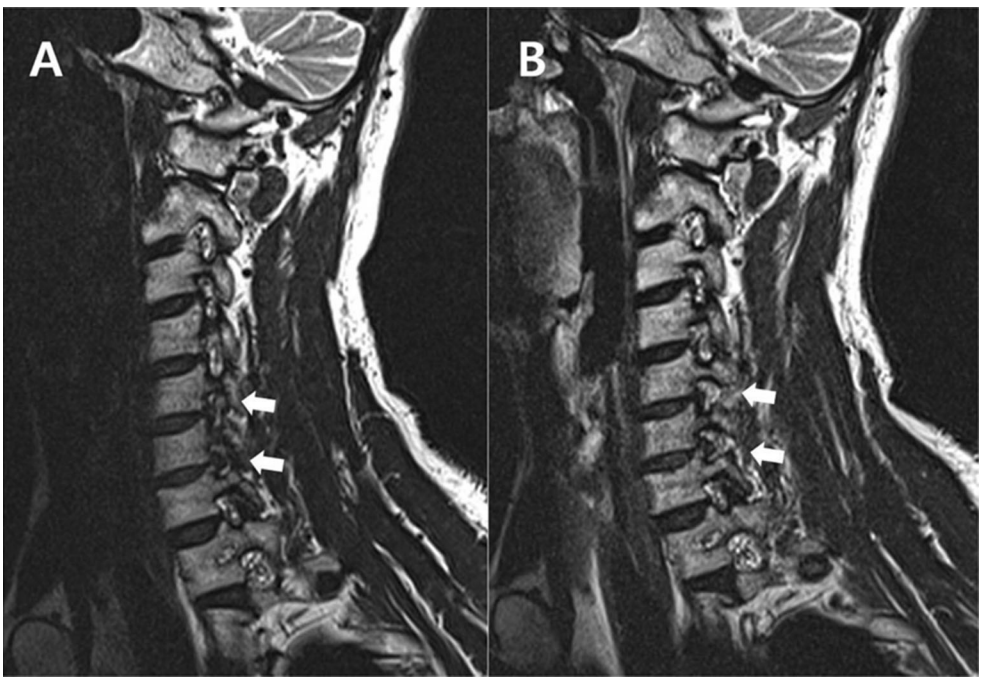

Fig. 1 Preoperative (**a**) and postoperative (**b**) oblique T2-weighted magnetic resonance images of a 49-year-old male demonstrating C5/6, C6/7 left-sided foraminal stenosis (*white arrows*)

Table 1 Clinical characteristics, and pre- and postoperative physical findings associated with cervical radiculopathy of patients

Patient	Age	Sex	Side	Level	OP time (min)	Weakness		Sensory change		nVAS		aVAS	
						PreOP	POP 2 years	PreOP	POP 2 years	PreOP	POP 2 years	PreOP	POP 2 years
1	68	M	Rt.	C5/6/7	85	–	–	–	–	40	20	60	10
2	55	M	Rt.	C5/6/7	100	Deltoid	–	–	–	40	20	60	10
3	61	M	Lt.	C6/7/T1	90	–	–	–	+	30	30	60	50
4	55	M	Rt.	C6/7/T1	65	–	–	–	–	40	30	60	10
5	53	F	Rt.	C4/5/6	90	Finger	–	+	–	60	30	70	10
6	49	F	Rt.	C4/5/6	70	–	–	–	–	40	20	60	10
7	40	M	Rt.	C4/5/6	70	–	–	–	–	20	20	70	10
8	71	M	Rt.	C4/5/6	80	Deltoid	–	+	–	30	10	70	20
9	46	M	Rt.	C5/6/7	95	Finger	–	+	–	50	30	90	0
10	49	M	Lt.	C5/6/7	65	–	–	–	–	50	30	70	20
11	58	F	Lt.	C5/6/7	70	–	–	–	–	30	20	90	20
12	59	F	Lt.	C5/6/7	75	–	–	+	–	30	20	70	20
13	58	M	Rt.	C4/5/6	60	–	–	–	–	50	30	50	10
14	62	M	Rt.	C4/5/6	70	–	–	+	–	70	10	90	0
15	52	F	Rt.	C5/6/7	75	–	–	–	–	50	30	80	30
16	63	F	Lt.	C5/6/7	70	–	–	–	–	50	20	80	10
17	46	F	Rt.	C5/6/7	90	–	–	+	–	50	20	70	20
18	58	M	Lt.	C4/5/6	75	–	–	–	–	50	10	60	20
19	53	M	Lt.	C5/6/7	80	–	–	–	–	60	20	60	10
20	59	F	Lt.	C5/6/7	60	–	–	–	–	60	0	70	20
21	73	F	Rt.	C5/6/7	65	–	–	+	–	40	20	80	20
22	44	M	Rt.	C4/5/6	70	Deltoid	–	–	–	40	20	80	10

aVAS arm VAS, *nVAS* neck VAS, *OP* operation, *PreOP* preoperative, *POP* postoperative

patient was placed prone with the neck slightly flexed by tape. Correct incision positioning was verified using C-arm fluoroscopy. A 1-cm longitudinal skin incision was made 1.5-cm lateral from midline (inner border of the lateral mass) at midpoint between two-level lesion sites. For the determination of the lesion, blunt insertion of an unbeveled dilator sheath was performed under lateral fluoroscopic control. After identifying two adjacent vertebral laminae and the ipsilateral facet joint by endoscope of 6.3 mm outer diameter, an interlaminar window above the lesion was opened using a burr from its medial to lateral margin. Having identified the dural sac by partial resection of the ligamentum flavum, coagulation of the epidural venous plexus was performed using low-energy bipolar radiofrequency to maintain a clear visual field and to identify the spinal nerve root precisely. Depending on the pathology, foraminotomy can be extended in the lateral direction using an endoscopic punch and a powered resector (Shrill®, joimax GmbH). Decompression was performed until proximal and distal pedicles were confirmed longitudinally, a probe was then easily inserted through the foramen to confirm adequate neural decompression (Fig. 2). In ruptured disc cases, free moving ruptured discs were removed; however, routine discectomy of contained discs was not performed. After the cephalad nerve root had been decompressed satisfactorily, focus was shift toward the caudal level. Blunt insertion of an unbeveled dilator sheath to a caudal lesion was performed under lateral fluoroscopic control, using the procedure described above through the same skin incision (Fig. 3). Direct skin closure was done, after removing all instruments. Because bleeding was minimal in all cases, no drainage was required. All 22 patients were discharged within 2 days of surgery and given a soft cervical brace to wear for 7 days.

Measurements of clinical and radiological outcomes

At each visit, patients were asked to complete an outcome questionnaire and plain radiographs were obtained. Clinical outcomes were evaluated using visual analogue scale for neck (nVAS) and arm (aVAS), neck pain and disability scale (NPDS), and neck disability index (NDI) scores at 1, 3, 6, 12, and 24 months postoperatively [15, 25]. Radiological parameters were measured preoperatively and at 1 and 2 years postoperatively. Radiological outcomes were evaluated using segmental lordosis (SL), C2–7 lordosis,

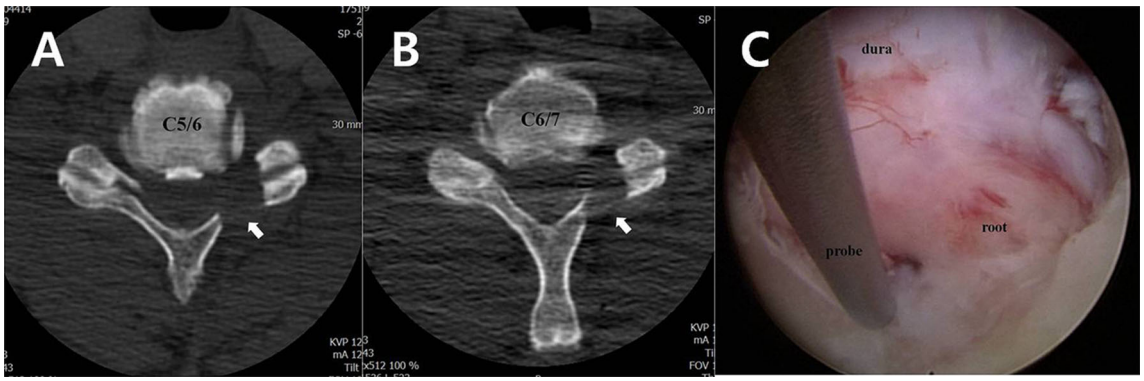

Fig. 2 **a**, **b** Axial computed tomographic images after EPCF demonstrating the partial laminectomy and foraminotomy (*white arrows*) performed in a 49-year-old male with C5/6, C6/7 left-sided foraminal stenosis. **c** Intraoperative endoscopic view of the final phase of the EPCF procedure, showing an well-decompressed root after foraminotomy

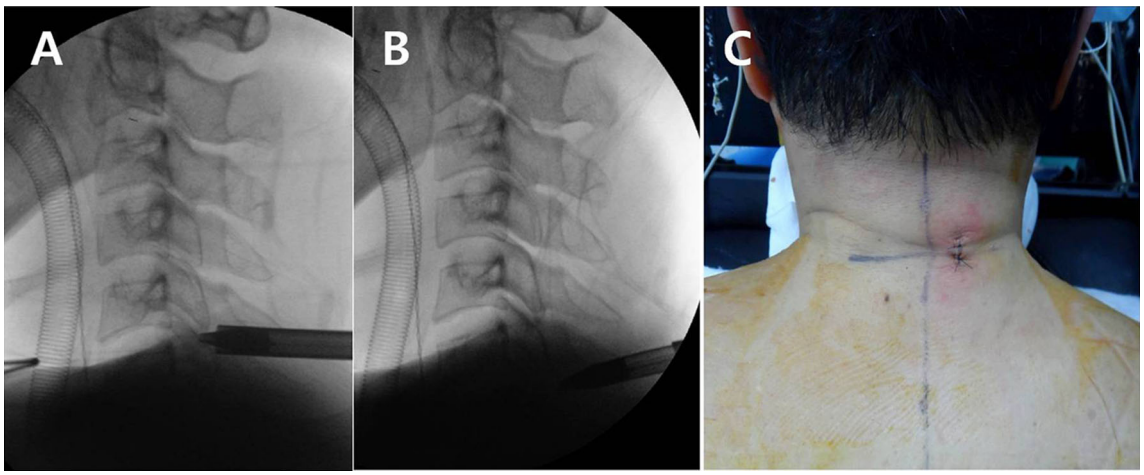

Fig. 3 **a**, **b** Lateral fluoroscopic images demonstrating a dilator sheath localized over the C5/6 and C6/7 levels in a 46-year-old male subject. **c** EPCF for the surgical treatment of C5/6/7 right-sided foraminal stenosis was performed through a common skin incision

and disc height index (DHI) as observed in plain radiographs obtained in neutral standing position with a 4-kg dumbbell in each hand (Figs. 4, 5) [27]. Radiological instability was defined as translation in the sagittal plane exceeding 3.5 mm (20% of vertebral body anterior–posterior diameter) or a sagittal plane rotation of >20° in dynamic flexion and extension postures [28]. SL was quantified using Cobb's angle, which was defined as the angle between lines drawn at the superior margin of the superior vertebra and the inferior margin of the inferior vertebra of the two operated level on a straight lateral radiograph. C2–7 lordosis was defined as Cobb's angle formed by lines between the inferior margin of C2 and the lower end plate of C7. Disc height index (DHI) was defined as the ratio of mean six-point disc height (three-point disc heights at each operated level) to mean sagittal diameter of the three consecutive vertebra, and was calculated from the midvertebral level using a modification of the Inoue method [10]. All measurements were performed twice independently by three spine surgeons with an interval of 2 weeks between measurements to decrease intraobserver (Pearson correlation coefficient = 0.921, range 0.888–0.945) and interobserver errors (Pearson correlation coefficient = 0.911, range 0.875–0.931).

Statistical analysis was performed using SPSS ver. 21 for Windows (SPSS, Chicago, IL, USA). Results are presented as means ± SEs. Clinical and radiological outcomes were compared by the ANOVA test, and the posttest was used to analyze individual differences. P values of <0.05 were considered statistically significant.

Results

Twenty-two (9 females and 13 males) of the originally considered Twenty-four patients had adequate clinical and radiological follow-ups and constituted the study cohort. Average age at surgery was 56.2 (40–73) years. Eight patients had surgery at C4/5/6, 12 at C5/6/7, and 2 at C6/7/T1. Eight cases were left-sided and 14 right-sided.

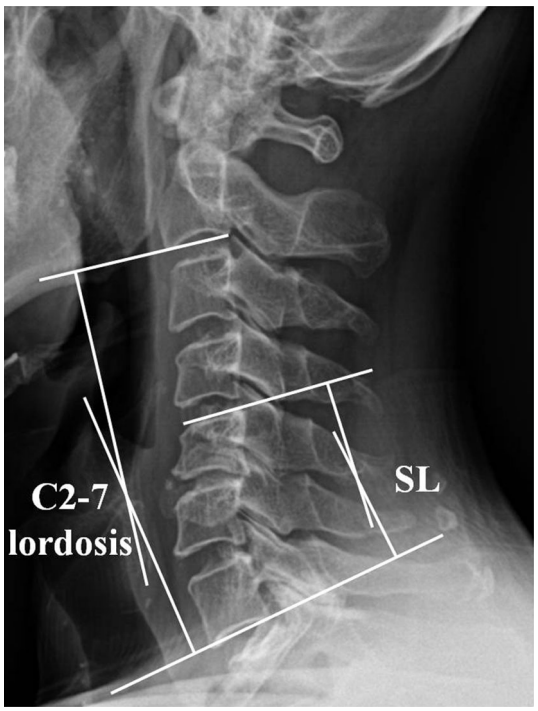

Fig. 4 Radiological measurements: segmental lordosis and C2–7 lordosis. Segmental lordosis (SL) was quantified using Cobb's angle, which was formed by *lines* drawn at the superior margin of the superior vertebra and the inferior margin of the inferior vertebra of the two operated level on a straight lateral radiograph. C2–7 lordosis defined a Cobb's angle formed by *lines* between C2 and C7

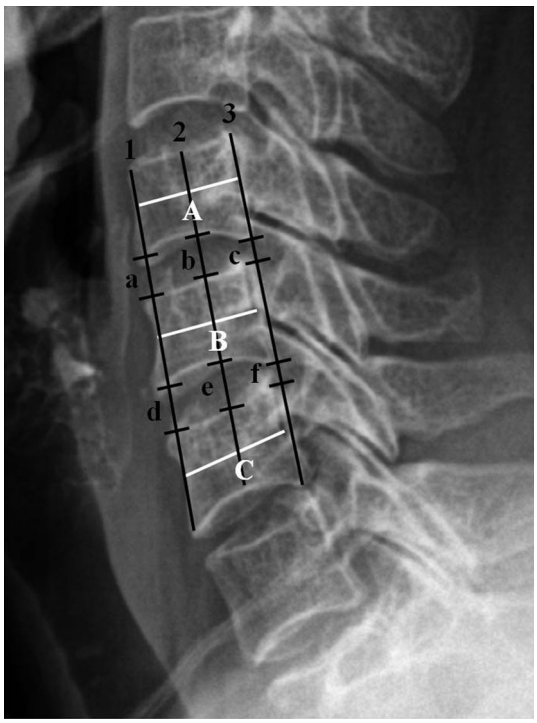

Fig. 5 Radiological measurement: DHI. *A–C* (*white lines*) Sagittal diameters of the midvertebral levels of three consecutive vertebrae. *1 line* (*black line*) The *line* between the anterior/superior corner of the uppermost vertebra and the anterior/inferior corner of the lowermost vertebra. *2 line* (*black line*) The *line* between the middle/superior point of the uppermost vertebra and the middle/inferior point of the lowermost vertebra. *3 line* (*black line*) The *line* between the posterior/superior corner of the uppermost vertebra and the posterior/inferior corner of the lowermost vertebra. *a–f* Measured disc heights on *lines 1*, *2*, and *3*. Disc height index (DHI) was calculated using a modification of the Inoue method with the following formula. $\text{DHI} = [(a + b + c + d + e + f)/6]/[(A + B + C)/3] \times 100$

Clinical outcomes were evaluated using nVAS, aVAS, NPDS, and NDI scores 1, 3, 6, 12, and 24 months postoperatively [15, 24]. Baseline (preoperative) mean values of nVAS, aVAS, NPDS, and NDI were 42.5, 70.6, 38.8, and 29.5, respectively (Table 2), and corresponding values at 1-month follow-ups showed significant improvements (27.5, 21.9, 19.5, and 12.4, respectively). Furthermore, similar results were observed at 2-year follow-ups (23.1, 15, 16.6, and 10.8, respectively; Fig. 6). Three of five patients with grip weakness or deltoid muscle atrophy preoperatively improved within 6 months of surgery.

Radiological parameters were measured preoperatively and at 1 and 2 years postoperatively. For all study subjects, preoperative mean SL was 4.2° and mean C2–7 lordosis was 9.3°. At 1 year postoperatively, these values were significantly higher at 6.5° and 14.2°, respectively, and were maintained at 2 years (6.3° and 14.3°, respectively). Mean DHI values were effectively unchanged at 1 and 2 years postoperatively (23.7% at baseline, 23.5% at 1 year, and 23.8% at 2 years; Table 3).

Postoperative complications were encountered in 4 patients. Two patients had transient root injury due to significant root retraction, which improved during follow-up. One of these patients suffered from transient motor palsy on the fourth and fifth digits of the left hand due to intraoperative C7 root retraction. However, finger strength recovered at 6 months after surgery and residual paresthesia was well controlled by epidural injection and medications. In the other patient, dermatome-related paresthesia was improved by medications at 3 months after surgery. Two patients experienced a superficial wound infection, which responded successfully to dressing changes. No other serious complication like postoperative bleeding, dural tear, or injury to the cord with hemi/paraplegia or paralysis occurred, and no recurrence or deep infection like spondylodiscitis or meningitis was encountered. All patients experienced some incisional pain that lasted at most 3 days. Follow-up images on dynamic radiograph showed no evidence of instability at operated or any adjacent segments.

Discussion

Posterior cervical foraminotomy is widely used for the surgical treatment of lateral cervical disc herniation or foraminal stenosis, and is well described in the literature

Table 2 Clinical outcomes

	Preoperative	1 month	3 months	6 months	12 months	24 months	*P* value
nVAS	42.5	27.5	27.5	25.0	21.9	23.1	<0.001
aVAS	70.6	21.9	19.4	16.3	13.8	15.0	<0.001
NPDS	38.8	19.5	16.8	16.3	15.8	16.6	<0.001
NDI	29.5	12.4	11.3	10.4	10.6	10.8	<0.001

VAS scores were calculated with sum of 100 points

nVAS neck VAS, *aVAS* arm VAS, *NPDS* neck pain and disability scale, *NDI* neck disability index

Fig. 6 Clinical outcomes

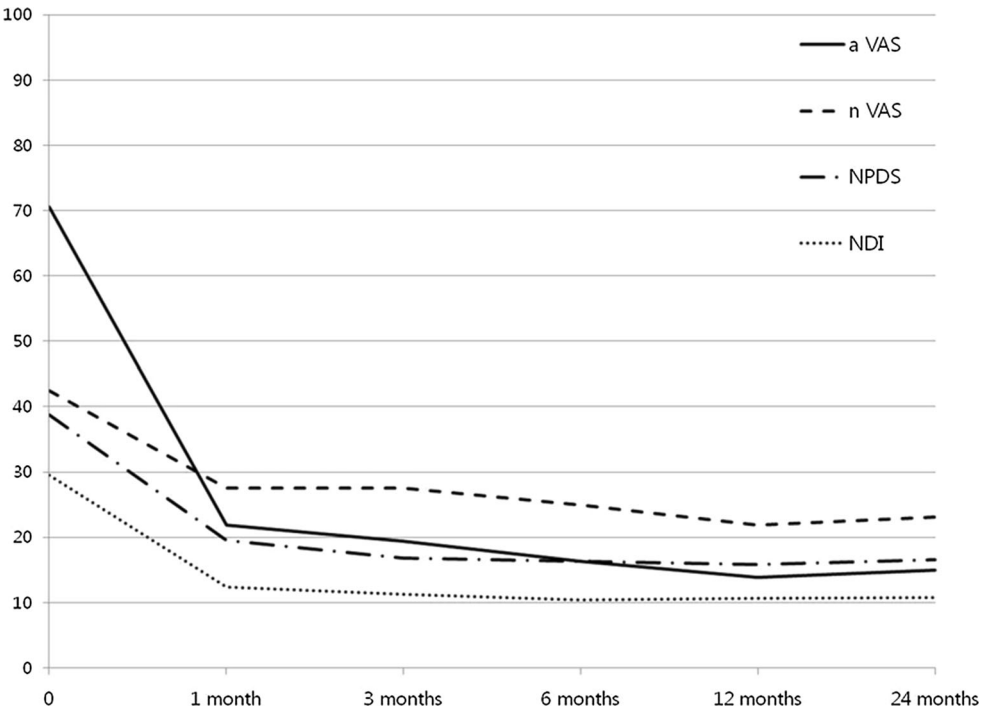

Table 3 Radiological outcomes

	Preoperative	1 year	2 years	*P* value
Segmental lordosis (°)	4.2	6.5	6.3	0.004
C2–7 lordosis (°)	9.3	14.2	14.3	0.008
DHI (%)	23.7	23.5	23.8	0.487

DHI disc height index

[5, 7, 11, 19, 21, 28, 32]. The advantages of this posterior approach include direct and targeted decompression of the involved nerve root under direct visualization, without disruption of the disc space and the avoidance of fusion. Despite these theoretical advantages, open PCF for the treatment of cervical radiculopathy requires a long midline incision with extensive subperiosteal dissection to detach deep muscles, such as the semispinalis and multifidus, which act as dynamic stabilizers of laminae and facet joints. Because the posterior cervical musculature assumes an important role in the maintenance of spinal alignment and neck posture, these muscles can also be a source of severe pain after posterior cervical surgical procedures [9]. Postsurgical neck and shoulder pain have frequently been reported following laminectomy and laminoplasty [5, 9], and thus, several minimally invasive techniques have been devised to reduce postoperative neck pain after PCF [8, 12, 13, 19, 20, 24, 26, 31]. Several studies reported good long-term outcomes of PCF using a tubular retractor or an endoscopic system [13, 20, 24]. Furthermore, new muscle preserving open technique for exposure of posterior cervical spine was introduced and applied to a variety of posterior cervical spine surgeries including PCF, with no adverse effect on cervical mobility or stability [23].

In the present study, at 1-month postoperatively mean VAS, NPDS, and NDI scores were found to be significantly improved versus baseline and these improvements were maintained at 2-year follow-up visits. Furthermore, these results were consistent with the experiences of other authors [12, 13, 20, 24, 31]. In addition, all 22 of our patients had slight incisional pain that lasted for 3 days at

most, which concurs with the previous reports on single-level EPCF [20, 31].

Postoperative kyphosis or instability is one of the most common radiographic complications after PCF [4, 5, 11, 32]. In addition, an age of >60 years at time of surgery and preoperative kyphosis were found to be the risk factors worsening sagittal alignment [11, 12]. In the present study, postoperative follow-up values of SL were increased versus preoperative values, reflecting restoration of cervical lordosis. We believe that these increases were caused by relaxations of neck and shoulder muscles for reasons of pain control. Several authors have reported significant increases in cervical lordosis after endoscopic cervical surgery. Lee et al. reported sagittal alignment and regional Cobb's angle improved significantly after percutaneous endoscopic cervical discectomy [14]. Kim et al. reviewed a series of 44 cervical radiculopathy cases treated by EPCF or tubular retractor assisted PCF with a follow-up of >2 years, and reported segmental angles were more lordotic after EPCF [12], which is comparable with our results. Although we believe that postoperative lordosis could eventually increase after EPCF, additional study is required because of the small number of patients included in this previous study.

Even in the endoscopic field, loss of disc height and degeneration are significantly related to the anterior approach [1, 14]. On the other hand, PCF may be associated with a low rate of operated or adjacent segment disease [5, 31]. In the present study, DHI at operated levels was well maintained postoperatively, and during follow-up, although a slight increase in DHI was observed in some cases. We suppose that a slight increase in SL promotes an increase in anterior disc height at the operated level. However, additional follow-up examinations are required because of the small number of patients recruited.

Zdeblick et al. reported foraminotomy involving resection of more than 50% of a facet results in segmental hypermobility of the cervical spine, but resection of 25 or 50% of a facet did not appear to lead to acute hypermobility [32]. We were cautious of preserving more than 50% of the facet joint during foraminotomy, and no patient demonstrated kyphosis or instability on dynamic views at operated or adjacent segments during the study period. However, due to the 2-year follow-up adopted, we cannot comment on long-term outcome after two-level EPCF.

In the present study, affected levels were determined using a combination of neurological examinations, such as sensory disturbance, muscle weakness and tendon reflex examinations, and radiological imaging modalities. Oblique MRI views were mainly employed to determine operative levels. In general, the diagnosis of cervical foraminal stenosis is difficult, and the conventional MRI series typically use only axial and sagittal views. Due to anatomic features of the cervical foramen and limitations of the conventional MR techniques, it is difficult to identify disease in lateral aspects of the spinal canal and foramen [22]. Oblique view MRI has better confidence rates for determining the presence of foraminal stenosis and better intraobserver agreements [17], and thus, we assessed lesion sites and severities using oblique MRI views preoperatively. Electromyography might be helpful for identifying responsible levels, but it is less than perfect, because each muscle is often controlled by a number of nerves. Accordingly, we used preoperative serial (minimum 1-week interval) selective nerve root block to identify operative levels.

The EPCF method has some inherent limitations of technology. First, because the EPCF is the method of inducing indirect decompression through posterior decompression without removing the protruding disc in the anterior part of the spinal cord, the disc protruding centrally is not operable with this technique. Second, at the stage of inserting a dilator sheath, when the sheath extends beyond the medial border of the facet joint and is biased toward the midline, it enters the interlaminar space and can cause a spinal cord injury. Accordingly, an initial guide wire insertion is not recommended for EPCF unlike lumbar procedures. Insertion of a dilator sheath with hand manipulation and gentle use of a hammer under lateral fluoroscopic control was found to be sufficient. The extent of foraminotomy was not limited by the small size of the skin incision for two-level EPCF due to the pivoting ability of the endoscope and the working channel [12]. Furthermore, routine discectomy of the contained disc was not performed, because the pathology of cervical radiculopathy concerns impingement, which can be released by removing counterparts of herniation or bony spurs [26]. In our opinion, removal of an extruded disc or bony spur introduces the potential risk of excessive retraction-induced motor palsy. In the present study, two patients had transient root injury due to root retraction without discectomy, although these symptoms improved during the follow-up. We also believe that routine discectomy may accelerate postoperative instability. A number of studies demonstrated reoperation rates for PCF of 5–9.9% [3, 30]. Bydon et al. reported that reoperation after PCF was 9.9% at an average 2.4 years after the initial surgery [3]. However, in the present study, no reoperation was performed after EPCF, but the short follow-up study period (24 months), precludes our statements regarding long-term outcomes after two-level EPCF.

This study has several limitations that require consideration. First, the number of patients included was relatively small (due to the rarity of two-level lesions in cervical radiculopathy) and no control group was used, which diminished the statistical power of the study. Second,

radiological outcomes were examined in stress view, and although shoulder traction devices would have improved visibility of the lower cervical spine, radiological measurements, such as SL and C2–7 lordosis, may have been disturbed. Third, because of relative short follow-up, we cannot comment on long-term outcomes after two-level EPCF.

Due to continuous development of endoscopes and instruments, several authors have reported good results for the surgical treatment of single-level pathologies by EPCF [12, 20, 31]. Recently, some authors have been described favorable results for two-level open PCF [8, 26], but open PCF has major drawbacks, as described above. Thus, in our opinion, EPCF is a better option than ACDF or open PCF for the surgical treatment of multi-level radiculopathies. This study is the first to address the clinical and radiologic outcomes of two-level EPCF, and shows that it can be safely preformed and should be considered an alternative to two-level ACDF or open PCF in selected patients.

Compliance with ethical standards

Conflict of interest This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2015R1D1A1A01059035).

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