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The effect of posterior percutaneous endoscopic cervical discectomy vs. percutaneous nucleoplasty in patients with cervical radicular pain due to a single-level contained soft-disc herniation: *a retrospective cohort study*

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Abstract

Introduction Cervical radicular pain (CRP) is a common disorder among adults. Minimally invasive surgical techniques, such as posterior percutaneous endoscopic cervical discectomy (PPECD) and percutaneous cervical nucleoplasty (PCN) are considered when conservative treatment fails to contain severe persistent pain. Our retrospective study evaluated the clinical outcomes of CRP in patients treated with PPECD and PCN.

Methods Between May 2019 and June 2021, 67 patients with CRP, due to single-level contained soft-disc herniation, were treated with either PPECD or PCN. Clinical outcomes were assessed by the numerical rating scale (NRS), Neck Disability Index (NDI), and modified Macnab criteria. Pre- and postoperative clinical parameters were also compared.

Results Compared with the preoperative values, the mean NRS scores for radicular arm pain and NDI score improved significantly with both treatments. According to the Macnab criteria, patients with PPECD (82.9%) had a higher clinical success rate than patients with PCN (75.0%), however, this difference was not statistically significant ($P=0.5508$). No major complications were observed in any patients.

Conclusions Both PPECD and PCN are effective and safe options for CRP patients with persistent, and severe pain. Given the absence of superiority in pain relief and clinical outcomes with PPECD, we suggest that the shorter operation time and the less invasive features of PCN is an alternative to PPECD in patients with single-level contained soft-disc herniation.

Clinical trial number Not applicable.

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Key summary points

Cervical radiculopathy with persistent severe pain is amenable to minimally invasive surgery with either posterior percutaneous endoscopic cervical discectomy (PPECD) or percutaneous cervical nucleoplasty (PCN) with equipoise for outcomes. In this retrospective study, we found that both PPECD and PCN are effective and safe options for patients with CRP. Considering the shorter operation time and the minimally invasive features of PCN technique, we argue that PCN can be a good alternative to PPECD in patients with single-level contained soft-disc herniation.

Keywords Posterior percutaneous endoscopic cervical discectomy, Cervical radicular pain, Percutaneous cervical nucleoplasty, Low-temperature plasma radiofrequency ablation, Single-level contained soft-disc hernia

Introduction

Cervical radiculopathy is a prevalent neurologic disorder characterized by chronic pain and sensorimotor deficits resulting from mechanical compression of cervical nerve root caused by either intervertebral disc herniation or foraminal stenosis; furthermore, inflammatory cytokines released from damaged intervertebral disks can contribute to symptoms [1–3]. In most cases, nonoperative interventions such as immobilization, traction, medication, physical therapy, are effective for pain relief; [4, 5] however, according to a population-based study, up to 30% of patients with cervical radiculopathy persist in experiencing symptoms after 8 weeks of nonoperative treatments, indicating the need for surgical intervention [6].

To reduce both pain and structural damage surgical techniques and approaches have evolved to manage patients with cervical radiculopathy including minimally invasive procedures [7–9]. Procedures, such as posterior percutaneous endoscopic cervical discectomy (PPECD), have acceptable outcomes, less injury, and lower complications than fusion surgery [10–13]. In addition, plasma-mediated electrosurgery, which is used in other medical fields [14], has proven useful; two independent outcome studies by Sharps and Isaac [15], and Singh and colleagues [16] have shown statistically significant reduction in pain up to one-year after percutaneous disc decompression using plasma mediated electrosurgery (nucleoplasty) in the lumbar spine. Bonaldi et al. [17] demonstrated that plasma radio-frequency-based discectomy in the cervical spine appears to be a minimally invasive low-risk approach associated with only minimal discomfort to the patient, and effective in the short term. Furthermore, A meta-analysis reported nucleoplasty reduces pain in the long term and increases patients' functional mobility and patients experience more satisfactory pain relief after cervical nucleoplasty than after lumbar nucleoplasty [18]. There is equipoise between PPECD and nucleoplasty in the treatment of cervical radiculopathy. In this retrospective study, we report the clinical outcomes of a series of patients with cervical radiculopathy who were treated with PPECD or nucleoplasty.

Materials and methods

This study was approved by the Ethics Committee of the First Affiliated Hospital of Anhui Medical University and were in accordance with the 1964 Declaration of Helsinki and its later amendments. Informed consent of the procedures was obtained from all patients included in the study and every participant could provide their consent. Patients were eligible for inclusion if they presented with radicular pain originating from a single-level contained soft-disc herniation at the C3–C7 level, accompanied by arm or neck pain, and had not achieved sufficient symptom relief after at least eight weeks of conservative management. Conservative treatments included nonsteroidal anti-inflammatory drugs (NSAIDs), cervical immobilization, and epidural steroid injections. Symptom severity was assessed using the Numerical Rating Scale (NRS), with inclusion requiring a minimum score of 5 (0 = no pain, 10 = worst pain imaginable). Patients were excluded if they have previous cervical spine surgery, cervical instability or imaging studies that revealed (i) extruded disc fragment, (ii) bony spur, calcified disc, cervical instability [19] or severe degenerative disc disease with more than 50% loss of disc height. Needle electromyography (EMG) was performed to evaluate nerve root function and exclude alternative neurological etiologies, such as ulnar neuropathy, median nerve entrapment, or peripheral neuropathy. Using retrospective analysis of medical records, consecutive patients that underwent PPECD or PCN between May 2019 and June 2021 and had ≥ 1 year follow-up were identified. Both PPECD and PCN are feasible therapeutic approaches for single-level contained soft disc herniation. After presenting the advantages and disadvantages of each procedure, the choice of surgical approach was ultimately made by the patients and their families.

The PPECD process was consistent with the previous reports [20]. Briefly, the patients were placed in the prone position with the head and arm fixed in place using tape. The neck was adjusted on a radiolucent table in a slightly flexed and high-low position to reduce the overlap of the facet joints and lower the pressure of the venous plexus. The surgical area was prepared and draped in a sterile, standard manner. After thorough local anesthesia, an 8G,

10-cm needle was first used to identify the target segment with the C-arm in the anteroposterior (AP) and lateral views. After confirming the right entry point, a 9-mm skin incision was made and an obturator (6.9-mm outer diameter) was introduced. The tip of the obturator was placed at the V-point under fluoroscopic guidance and the boundaries of the inferior lamina, superior lamina, and medial margin of the facet joint were palpated with the obturator. An oblique-type working channel was introduced via the obturator and an endoscope was introduced. The surgery was performed under visual control with continuous irrigation with a 0.9% saline solution from a bag positioned 1 m above the patient. After clearing out the soft tissue around the V point, a high-speed drill was used to polish the lateral part of the inferior lamina, the medial part of the facet joint (no more than 50%), and the lateral part of the superior lamina. The thin bone was then removed using a rongeur. The ligamentum flavum was removed, and the vessels were coagulated using a bipolar radiofrequency coagulator to expose the lateral edge of the dural sac and the exiting nerve root. Herniation was identified from the axillary or shoulder of the nerve root and was removed using a pituitary rongeur (Figures. 1a and b). Decompression of the nerve root is considered appropriate if the pulsations are visible. When the intervertebral foramen was enlarged and the nerve root was decompressed, the endoscope and the working channel were carefully removed. The skin was closed with a single stitch. Preoperative and postoperative (3 months) MRI scans demonstrated that the herniation had been removed at the C5/6 level (Figures. 1c and d).

Percutaneous cervical nucleoplasty was performed with low-temperature plasma radiofrequency ablation (coblation) technology [21]. Briefly, the patient was placed in a supine position and the procedure performed with CT guided puncture positioning technology. The shoulders of patient were stabilized to achieve better visualization of the lower cervical disk. To facilitate access to the intervertebral disk space, head and neck were slightly hyperextended during surgery. The surgical procedure was performed under local anesthesia with a solution of 1% lidocaine infiltration into the skin and subcutaneous tissue. The introducer cannula (19-G, 7.6 cm) is then inserted under CT guidance and is angled medially to the sternocleidomastoid muscle and vessels through an antero-lateral approach with CT guided. The tip of the cannula stylet is aimed for the center of the nucleus. The stylet is withdrawn from the introducer cannula and replaced with the Spine Wand coblation needle. This device is advanced until its tip extends approximately 5 mm beyond the tip of the cannula, in order to ensure that the active portion of the wand is deployed in the center or posterior third of the nucleus pulposus. A short initial motoric stimulation (0.5 s) was performed upon wand insertion in the most distal position to ensure correct placement. If stimulation or movement was detected, the device was repositioned. As the device was drawn back out through the disk, three ablation cycles of 10 s each were performed, rotating the device tip 360 °each time to form three consecutive pockets within the disk. The first coblation cycle was performed most posteriorly on the disk and confirmed by fluoroscopy; the second and third coblation cycles were performed 3–5 mm more proximally each time,. These three ablation cycles led to a volumetric reduction of the tissue of the nucleus pulposus, resulting in decompression of the herniated disk (Figures. 2a and b). The skin incision edges were approximated with an adhesive. Preoperative and postoperative (three months) MRI scans demonstrated that the herniation had disappeared at the C5/6 level (Figures. 2c and d).

One prophylactic treatment of Cefuroxime was intravenously administered 30 min prior to surgery. A nonsteroidal, anti-inflammatory, analgesic (flurbiprofen 50 mg per day) was intravenously administered for pain control for two days. The patients were instructed to stay in bed for at least two days. To avoid potential damage due to disability of cervical spine, a rigid neck collar was worn for 30 days post-discharge.

The NRS is a valid and reliable Patient Reported Outcome Measure (PROM) in patients with cervical radiculopathy [22]. The Pain was assessed by NRS preoperatively and at postoperative follow-up; contemporaneously functional status was assessed using the Neck Disability Index (NDI) at the same time-point as well as NRS. The global outcome was assessed using the modified Macnab criteria. Excellent and good outcomes were grouped as 'successful,' whereas fair and poor outcomes were grouped as 'failures.' Complications were also recorded.

To assess the post-operative therapeutic effect, according to the local protocol, all patients had a short-term follow-up at the outpatient clinic combined with telephone calls at 1, 3, 6, and 12 months postoperatively. During this phone call, the NRS score for arm pain was evaluated and information regarding the occurrence of reoperations or complications was also collected.

Continuous variables were expressed as mean ± SD for normally distributed data, tested by d' Agostino–Pearson omnibus normality test, and by median and interquartile ranges [IQR] if not normally distributed. Unpaired t-tests or Mann–Whitney U tests were used to determine statistical significance in continuous data as appropriate. Categorical variables were summarized as frequencies and percentages and analyzed using the chi-square or Fisher's exact test. NRS and NDI scores were analyzed using two-way repeated-measures analysis of variance

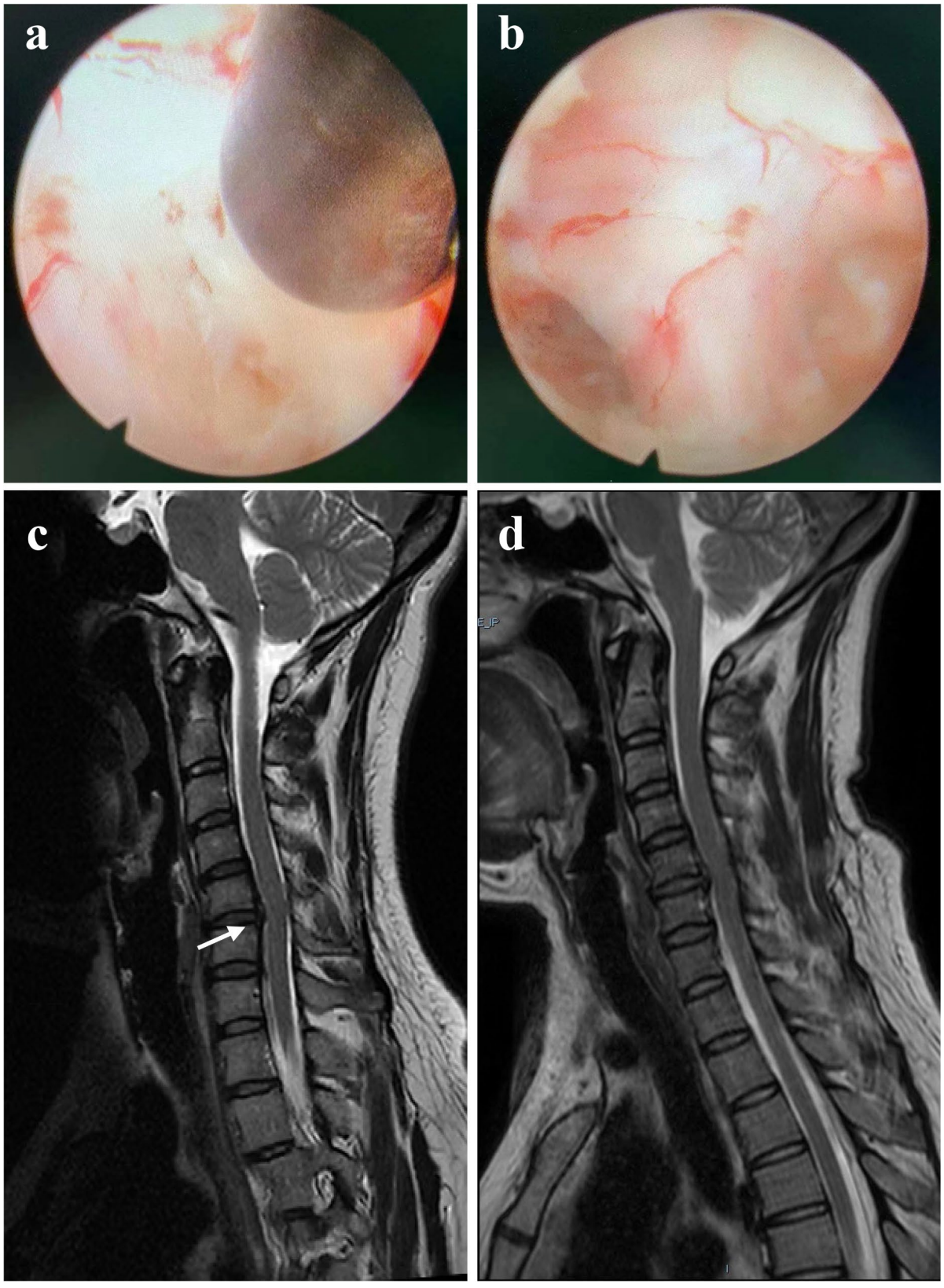

Fig. 1 A 57-year-old female patient presented with neck and left arm pain. Endoscopic image showing a herniation (**a**) and decompression of the nerve root (**b**). Preoperative T2-weighted MRI showed a herniation (white arrow) at the C5/6 level (**c**), and the herniation was removed on postoperative (3 months) MRI scans (**d**)

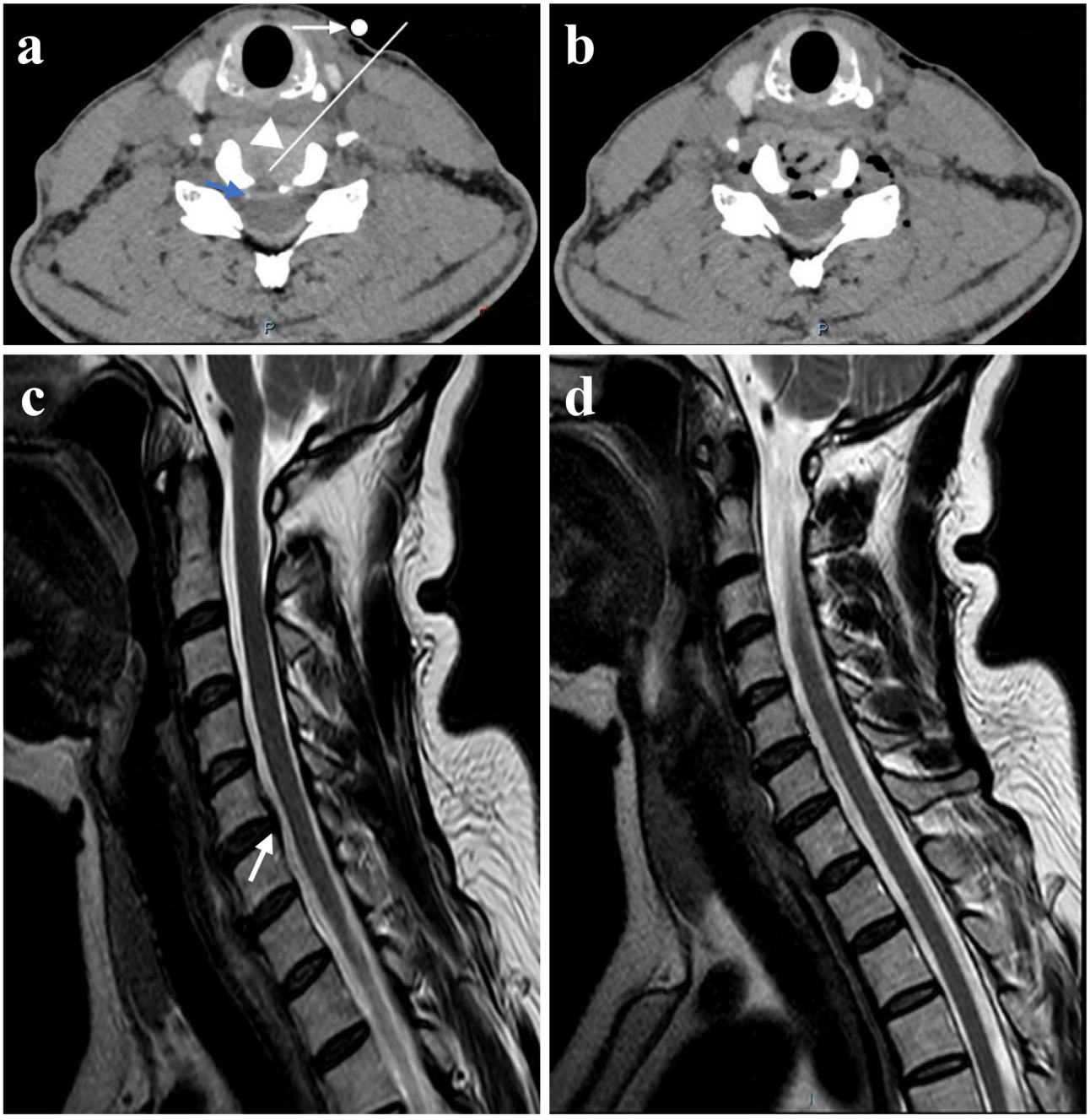

Fig. 2 A 63-year-old female patient presented with right arm pain. Intraoperative CT scans showing a herniation (blue arrow) on the right side, surface markers (white arrow), and the designed needle route (white triangle and line) (**a**). Intraoperative CT scans showing volumetric reduction of the tissue of the nucleus pulposus after coalition (**b**). Preoperative T2-weighted MRI showed a herniation (white arrow) at the C5/6 level (**c**), and the herniation was disappeared oin postoperative (3 months) MRI scans (**d**)

with Bonferroni correction for both within-group and between-group comparisons. *P* values less than 0.05 were considered statistically significant. Calculations and statistical analyses were performed using GraphPad Prism version 5.03 (GraphPad Software, San Diego, California, USA).

Results

Between May 2019 and June 2021, 67 consecutive patients with a single-level contained soft-disc hernia and arm pain at least 5 on the NRS underwent PCN ($n = 32$) or PPECD ($n = 35$). The age of the 67 patients ranged from 29 to 72 years (mean 53.8 years). The duration of the symptoms ranged from 6 to 24 months (mean 11.2 months). Twenty operations were performed at C4/5

Table 1 Patient characteristics and operation time

	PEECD Mean (SD)/ Median [IQR]/*n* (%)	PCN Mean (SD)/ Median [IQR]/*n* (%)	*P*-value
Number	35	32	
Ages	53.1 ± 9.4	54.5 ± 7.4	0.4922
Gender (Female)	15 (42.9%)	23 (71.9%)	0.0166
Duration of symptoms (mo)	10.0 [8.0–13.0]	10.5 [8.3–14.8]	0.6816
Affected level			
C4/5	7	13	0.1491
C5/6	15	12	
C6/7	13	7	
Surgical side			
Right	26	21	0.5938
Left	9	11	
Operation time (min)	49.7 ± 6.3	32.0 ± 6.4	< 0.0001

PEECD, posterior percutaneous endoscopic cervical discectomy; PCN, percutaneous cervical nucleoplasty; SD, standard deviation; IQR, interquartile range

level, 27 at C5/6, and 20 at C6/7. The imaging results showed that the soft-disc herniations in 29 patients were left-sided and 38 patients were right-sided. No significant differences in baseline characteristics were found between the two treatment groups, except for a higher proportion of female patients in the PCN group. (Table 1). The mean intervention time for PCN was 32.0 ± 6.4 min and 49.7 ± 6.3 min for PPECD ($P < 0.0001$).

Neither the baseline NRS (6.0 ± 0.9 for the PPECD group and 6.1 ± 0.7 for the PCN group), nor the NDI (33.6 ± 1.3 for the PPECD group and 33.1 ± 1.1 for the PCN group) scores were significantly different. All of the 67 patients had follow-up for one year at which time the NRS at decreased significantly compared with the preoperative NRS for both PCN and PPECD treatments ($F_{(2.082,\ 135.3)} = 827.8$, $P < 0.0001$). Furthermore, we found statistically significant group effects ($F_{(1,\ 65)} = 8.775$, $P = 0.0043$) on the primary outcome NRS arm pain in favor of the PPECD group without interaction effects ($F_{(4,\ 260)} = 2.314$, $P = 0.0579$). The NRS values in the PPECD were lower than those in the PCN at 6 ($P = 0.0170$) and 12 ($P = 0.0196$) months postoperatively (Figure. 3a). The NDI values also decreased significantly compared with the preoperative values in both interventions ($F_{(2.587,\ 168.1)} = 13943$, $P < 0.0001$). However, there were no statistically significant group and interaction effects on NDI outcomes. (Figure. 3b). According to the modified Macnab criteria, clinical success was achieved in 29 patients at one-year follow-up, including 19 excellent and 10 good outcomes in the PPECD group. Two patients in the PPECD group had a poor outcome and received conservative treatment which relieved the symptoms after 8 weeks. At the 12-month follow-up, excellent postoperative outcomes were achieved in 15 patients, good outcomes in 9, and a fair outcome was observed in 6 patients and two had a poor outcome in the PCN group. (Table 2).

Complications

There were no severe intra- or post-operative complications such as cervical spinal cord or nerve root injury, dural sac tear, postoperative bleeding, or infection. Three patients in the PPECD group had severe postoperative neck pain and were treated with a stiff neck collar; the neck pain disappeared at discharge. No adverse events occurred in the PCN group. None of the patients

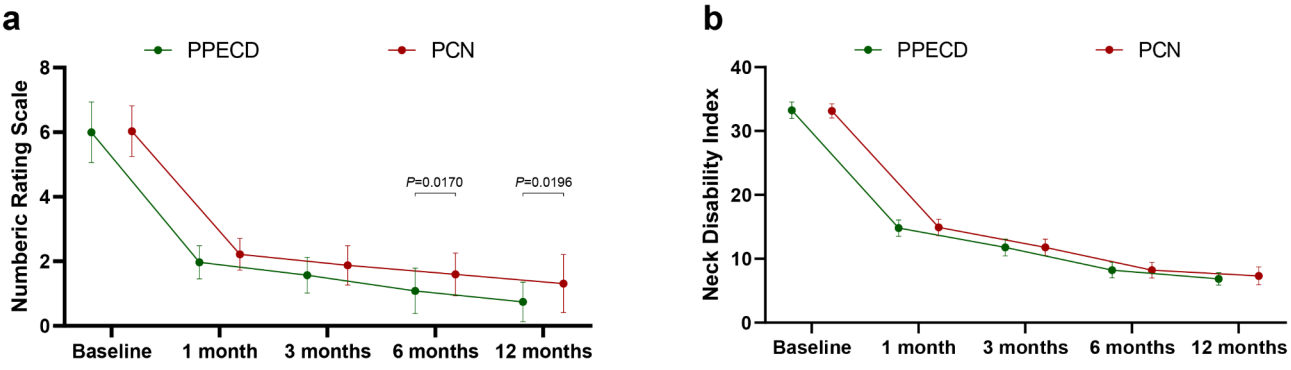

Fig. 3 The intensity of arm pain (**a**) and Neck Disability Index (**b**) between treatment groups at all measurement moments. Data are presented as mean (standard deviation). PEECD, posterior percutaneous endoscopic cervical discectomy; PCN, percutaneous cervical nucleoplasty

Table 2 Clinical outcomes after surgery assessed by the modified Macnab criteria

	Excellent	Good	Fair	Poor	Ratio of clinical success	*P*-value
PEECD	19	10	4	2	82.9%	0.5508
PCN	15	9	6	2	75.0%	

PEECD, posterior percutaneous endoscopic cervical discectomy; PCN, percutaneous cervical nucleoplasty

required additional surgery for sustained or aggravated symptoms during follow-up periods.

Discussion

This study evaluated and compared the clinical outcomes of PCN and PPECD in 67 patients presenting with cervical radicular pain due to a single-level contained soft-disc herniation. Both treatment approaches resulted in significant postoperative pain relief. However, at the 6- and 12-month follow-ups, patients in the PPECD group exhibited lower NRS scores for arm pain compared to those in the PCN group. While the proportion of patients achieving excellent or good outcomes was higher in the PPECD cohort, this difference did not reach statistical significance. No significant differences were found on the NDI during all the entire follow-up period.

Despite the retrospective design of the current study, our data demonstrated success rates similar to those of previous studies [23] with an overall good-to-excellent rate of 82.9% in the PPECD group at the 12-month follow-up, and 75.0% in the PCN group. There are few studies comparing PCN with surgery. Recently Abrishamkar and colleagues [24] performed an RCT reported that performing nucleoplasty treatment in patients suffering from single cervical disc herniation, with an indication for surgery, resulted in a decrease in cervical and radicular pain with no significant difference between cervical and radicular pain changes in two groups at six months postoperatively. Then, in our study, we found the pain is little higher in PCN group. A retrospective study [25] with the average follow-up time nearly 29 months, which compared PCN ($n=81$) to percutaneous cervical discectomy (PCD) ($n=95$) in patients with a contained disc herniation found no difference in pain reduction between PCN and PCD. Meanwhile clinical results, evaluated by Macnab standard, of good and excellent were 77.8% in PCN and 79.5% in PCD respectively, which is comparable with our data. Consistently, the time required for nucleoplasty approach is shorter. Recently, Xueqin et al. conducted a prospective, multicenter, cohort study [26] comparing the effect of percutaneous low-power laser discectomy (PLLD) ($n=30$) and low-temperature plasma radiofrequency ablation (coblation) ($n=28$) to treat degenerative cervical radiculopathy. They reported that the mean good-to-excellent rate at 3-month follow-up was 82.1% in the PLLD group and 66.7% in the coblation group ($P=0.179$). The PLLD group achieved a higher good-to-excellent rate 6 and 12 months after discharge (92.9 vs. 70.0%, $P=0.026$). Radiological data revealed that treatment with PLLD, but not coblation, significantly reduced the disk herniation index. Coblation treatment did not change the Pfirrmann grades of cervical radiculopathy patients ($n=18$), and 7 of 17 (41.2%) patients achieved improvement after PLLD therapy.

The success rate of PCN depends on strict patient selection. Two retrospective studies evaluated the ideal selection criteria for a successful PCN [27, 28] and reported that the following selection criteria are predictive factors for a positive outcome of PCN: MRI confirmed one-level contained herniated discs, minimally degenerated discs, absence of central canal stenosis, short mean pain duration of 6, 8 [28], and 16 months respectively [27], and unilateral radicular pain rather than bilateral radicular or myelopathic neck pain only [25, 27, 28]. The patients in current study all matched with these criteria with the exception of a shorter pain duration. The mean pain duration of our PCN group was at baseline 11.1 months, which fell within the range of the mean pain duration of patients with a negative outcome of the PCN procedure, respectively 11 [27] to 37 months [26]. This may have had a negative impact on the NRS outcomes of our PCN group. At 6 months, our PPECD patients showed statistically significant reduction in arm pain intensity compared with the PCN patients, an average of 0.5 on a NRS of 10. It is debatable whether or not this difference is of clinical relevance. To further investigate clinical relevance of this difference, we divided the patients into those who showed an improvement in arm pain of ≥ 3 on the NRS at 12 months after treatment and those who did not. A mean reduction in NRS of 3 represents a clinically important difference in pain severity that corresponds to patients' perception of adequate pain control [28]. We found that the proportion of patients who met this criterion did not differ between the two groups ($P=0.6120$, two-sided Fisher's Exact Test 2-sided). Considering this, the absence of a difference in arm pain relief and clinical outcomes between the groups after one year, the smaller number of complications within the PCN group, and the minimally invasive technique of PCN, we argue that PCN can be a good alternative to PPECD from a long-term perspective. Furthermore, three systematic reviews [18, 29, 30] consistently acknowledged the effectiveness of the PCN procedure for discogenic pain (symptomatic contained disc herniation). Interestingly, in our study, female patients showed a preference for choosing PCN treatment due to its minimally invasive nature and shorter operation time.

In addition to investigating pain relief two studies [31, 32] also focused on the patient satisfaction and improvement on PCN treatment. In a prospective RCT trail, the authors compared the effects of PCN and anterior cervical discectomy (ACD) in a group of patients with CRP caused by a single-level contained soft-disc herniation and showed there is no difference in the satisfaction and improvement after the treatment measured with the global perceived effect questionnaire (GPE) between the two interventions. In retrospective study, questions regarding reoperations and occurrence of late

complications and Likert scales on recovery of symptoms and satisfaction with treatment measured with Core Outcomes Measures Index (COMI). At the long-term follow-up, COMI-summary scores showed 67.8% of the patients were fully recovered from all symptoms and 93.3% remained satisfied with the PCN treatment results. In our study, although the overall good to excellent rate at one-year follow up was 75.0%, which was lower than that of PPECD (82.9%), the difference was not statistically significant.

This study has several limitations. First, the sample size was small, and the follow-up period was short. Second, we did not have a comparable radiological measurements. Third, although data regarding the response to arm pain NRS and subsequent complications were collected fully during the follow-up, this study was retrospective in design, which limited the causal inference. Fourth, we must acknowledge that these two types of surgeries were performed by different surgeons. Additionally, the follow-up period was not long enough to derive more rigorous conclusions. There might also be bias because of the lack of blinding of the surgeons to both the initial diagnostic imaging and the patient's symptoms. Futures studies comparing the PCN with other therapeutic options (e.g., fusion surgery) may shed more light on the effect of PCN on the clinical outcomes. Prospective studies with larger sample size and longer duration of follow-up may help to confirm the safety and efficacy of these combined techniques.

Conclusions

Although the PPECD group reported a statistically significant reduction in arm pain compared to the PCN group 6 months after the intervention, the clinical relevance of this difference in treatment effect can be debated. We conclude that at the one-year follow-up PCN can be a good alternative for PPECD. Future studies comparing PCN with other therapeutic options (e.g., fusion surgery) may shed more light on the effects of PCN on clinical outcomes.

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J.H., Z.W., and Y.G. contributed equally to this work.

Author contributions
All authors have made substantial contributions to the conception of the work. J.H., Z.W., and Y.G. performed the research and data analysis. L.H. and L.C. conceived this study. L.W. helped with concept and methodology development and interpretation of data. J.H. and L.W. drafted the manuscript. All authors approved the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Human ethics and consent to participate
Not applicable. Consent to participate is covered by the informed consent. Institutional review boards approved informed consent documentation, study protocols and amendments. The reference number of the ethics approval letter approved by the Ethics Committee of the First Affiliated Hospital of Anhui Medical University is PJ2022-01-26. All investigations were carried out in compliance with the Helsinki Declaration.

Competing interests
The authors declare no competing interests.

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