Predictive Factors of Successful Percutaneous Cervical Nucleoplasty for the Treatment of Pain with Cervical Herniated Disk

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■ BACKGROUND: **Percutaneous cervical nucleoplasty (PCN) is an effective treatment for cervical herniated intervertebral disc (C-HIVD). In this retrospective study, we evaluated clinical predictors that affect the successful outcome of PCN.**

■ METHODS: **Fluoroscopically guided PCN was conducted for C-HIVD by one pain physician. Successful outcome was defined as a combination of greater than 50% pain relief on the numerical rating scale pain score, no increase in analgesics, and no cervical epidural steroid injection during the 3-month follow-up period. The relationship between outcomes and independent variables, including patient demographics, comorbid diseases, pain duration, type of disc herniation, presence of spinal stenosis, pain location, analgesics, and shape of the PCN needle tip, were investigated using multivariable analyses.**

■ RESULTS: **Of 201 patients, 134 experienced a successful outcome after PCN. In the positive outcome group, shorter pain durations, rarer central canal stenosis, increased unilateral radiculopathy versus axial pain, and more frequent use of the curved tip technique, were reported. Multivariable analyses revealed that unilateral radiculopathy ($P = 0.013$) and use of the curved-tip technique ($P = 0.027$) were independent positive predictors of successful PCN outcomes; conversely, longer pain duration ($P = 0.014$) and concurrent spinal stenosis ($P < 0.001$) were negative predictors. No serious complications related to PCN occurred.**

■ CONCLUSIONS: **In this study, the success rate of PCN was 66.7% in patients with C-HIVD. Shorter pain duration, the absence of cervical central canal stenosis, pain location (i.e., unilateral radiculopathy vs. axial pain), and the use of the curved-tip technique were positive predictors of successful PCN.**

INTRODUCTION

Cervical pain is a common problem, affecting 1 in 1000 people.[1,2] Of the various cervical pain etiologies, disc pathology is an important risk factor when accompanied by mechanisms such as mechanical compression by disc extrusion, inflammation, and release of chemical mediators.[3] Pain from cervical disc herniation is difficult to manage and costly for healthcare organizations.[4,5]

To manage pain associated with cervical intervertebral disc, a stepladder treatment approach is applied, from conservative management to surgical procedures. Once conservative therapy has failed, minimally invasive techniques using chemical, mechanical, and thermal methods can be considered to avoid surgery. These methods have many advantages compared with open surgery, including less scar formation, reduced trauma to surrounding tissues, application using local anesthesia, and

Key words
- Cervical pain
- Coblation
- Contained disc herniation
- Neck pain
- Nucleoplasty
- Percutaneous nucleoplasty
- Radiculopathy

Abbreviations and Acronyms
C-HIVD: Cervical herniated intervertebral disc
CI: Confidence interval
IRB: Institutional review board
MRI: Magnetic resonance imaging
NRS: Numerical rating scale
OR: Odds ratio
PCN: Percutaneous cervical nucleoplasty

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decreased convalescence time.[6] Such minimally invasive procedures aim to lower disc pressure by removing nuclear material, thereby reducing pain associated with herniated discs; an ablation of 1 mL in disc tissue volume results in a disproportionate disc pressure reduction (approximately 10%–20%) with associated pain relief.[7,8]

Among various percutaneous procedures for cervical disc decompression, percutaneous cervical nucleoplasty (PCN) is a relatively new and popular technique.[9] PCN uses radiofrequency energy with a coblation technique, resulting in ablation of a portion of nucleus tissue with a low temperature plasma field (40°C–70°C) of ionized particles.[4] Coblation technology contributes to the management of pain from cervical disc herniation, not only by disc decompression, but also by inducing neuroimmunologic modification-like reduction of interleukin 1 and promotion of interleukin 8.[10]

Although previous studies have described PCN as both safe and effective, success rates range widely (65%–80%) in the treatment of cervical disc herniation.[11-14] The degree of disc degeneration was suggested as an outcome predictor in PCN, as with the proficient technique, because coblation technology requires water content to transmit energy through an activated plasma field.[15] In addition, strict patient selection may be directly related to successful PCN outcomes; however, clinical predictors, which can affect successful PCN outcomes, have not yet been investigated. In this study, we evaluated various factors associated with the efficacy and patient satisfaction with PCN for the management of pain associated with contained cervical herniated discs.

MATERIALS AND METHODS

Patients

This retrospective study was approved by the institutional review board (IRB) of Seoul National University Hospital (SNUH IRB No. 1708-069-877), a university-based tertiary civilian hospital. The manuscript adheres to the applicable STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.[16] Given the retrospective nature of the study, which used only formal electronic medical records, the need for obtaining informed consent was waived.

After obtaining IRB approval, we reviewed the medical records of patients with a diagnosis of cervical intervertebral disc herniation and who underwent PCN by a single pain physician (Y.C.K.) between July 1, 2009, and December 31, 2016. The first PCN was performed in March 2008 by the same physician; however, we excluded data (n = 50) from March 2008 to June 2009 to allow for the physician's learning curve. Other patient inclusion criteria were as follows: (1) pain duration >3 months; (2) diagnosis of contained cervical intervertebral disc herniation using magnetic resonance imaging (MRI) examination and patient-reported concordant neck pain or radicular pain in the upper extremity, or both; (3) age 18 years or older; and (4) an 11-point numerical rating-scale (NRS) pain score of 4 or higher after receiving conservative treatment, including oral medication, physical therapy, or less invasive procedures (e.g., peripheral nerve block or epidural steroid injections).

Patient exclusion criteria were as follows: (1) PCN by a practitioner other than Y.C.K.; (2) surgical procedure in the cervical spine before PCN; (3) the absence of cervical spinal MRI 1 month before PCN; (4) poorly controlled coexisting psychiatric diagnosis; (5) carpal tunnel syndrome, postherpetic neuralgia in the cervical spinal nerve, or any other condition potentially accounting for the signs and symptoms of C-HIVD; (6) cervical myelopathy or any evidence of central nervous system injury; (7) the absence of 3-month follow-up data; and (8) pregnancy, coagulation disorder, general infection, fever, or local infection at the puncture site.

To enhance the power to detect differences in outcomes between variables and to strengthen the logistic regression model, all patients treated between July 2009 and December 2012 who met the inclusion criteria were included in our analysis.

Percutaneous Cervical Nucleoplasty

All patients received an intravenous injection of 1 g cefazolin (prophylactic dosage), 1 hour before the PCN but after confirmation of a negative skin test result and administration of 1000 mL of Hartman solution. After entering the operating room, patients were placed in a supine position with a cushion under the lower cervical and upper thoracic spine (to hyperextend the cervical spine), and electrocardiography, heart rate, noninvasive blood pressure, and peripheral oxygen saturation were monitored. All procedures were conducted in a strict, sterile manner using local anesthesia. After confirming the target disc level by initial fluoroscopic imaging, skin preparation (with betadine soap and betadine solution) of the anterior neck (and surrounding skin) was completed, and sterilized drapes were applied to the target area.

Throughout the PCN procedure, C-arm fluoroscopy was used in the anteroposterior and lateral planes to confirm the target disc, align the endplates, and direct needle placement onto the disc surface. First, the physician located the carotid artery pulse, at the level of the target disc, using 2 fingers and pressed the skin against the cervical spine, moving the carotid artery laterally and the larynx and trachea medially. After palpating the anterior cervical spine with the fingertips, a 19-gauge introducer needle was inserted through a right anterolateral oblique approach toward the target disc level, between the 2 fingers using fluoroscopic guidance. A lateral image was then obtained to confirm its final depth. After the introducer needle located the target site, the stylet of the introducer needle was removed. Thereafter, a coblation catheter was inserted into the introducer needle. Two types of coblation bipolar devices were used during the study period. One device was a PERC DC SpineWand connected to an ArthroCare System 2000 (ArthroCare, Sunnyvale, California, USA), and this was considered conventional between July 2009 and December 2012. The other device was a YES C DISC connected to an MK-5000 (Mcarekorea, Seongnam-si, Gyeonggi-do, Republic of Korea), which is considered curved-tip technique and was used between January 2013 and December 2016. Although their mechanism (coblation technology with a 1-mm diameter bipolar instrument) is the same, the tip of the YES C DISC is curved in shape to expand a reduced disc volume, and it is possible to rotate the needle 360° while performing the ablation (Figure 1). After coagulation checks to confirm the absence of movement or paresthesia in the upper extremity, coblation was performed by rotating the tip to create two 360° lesions at different depths. If the patient complained

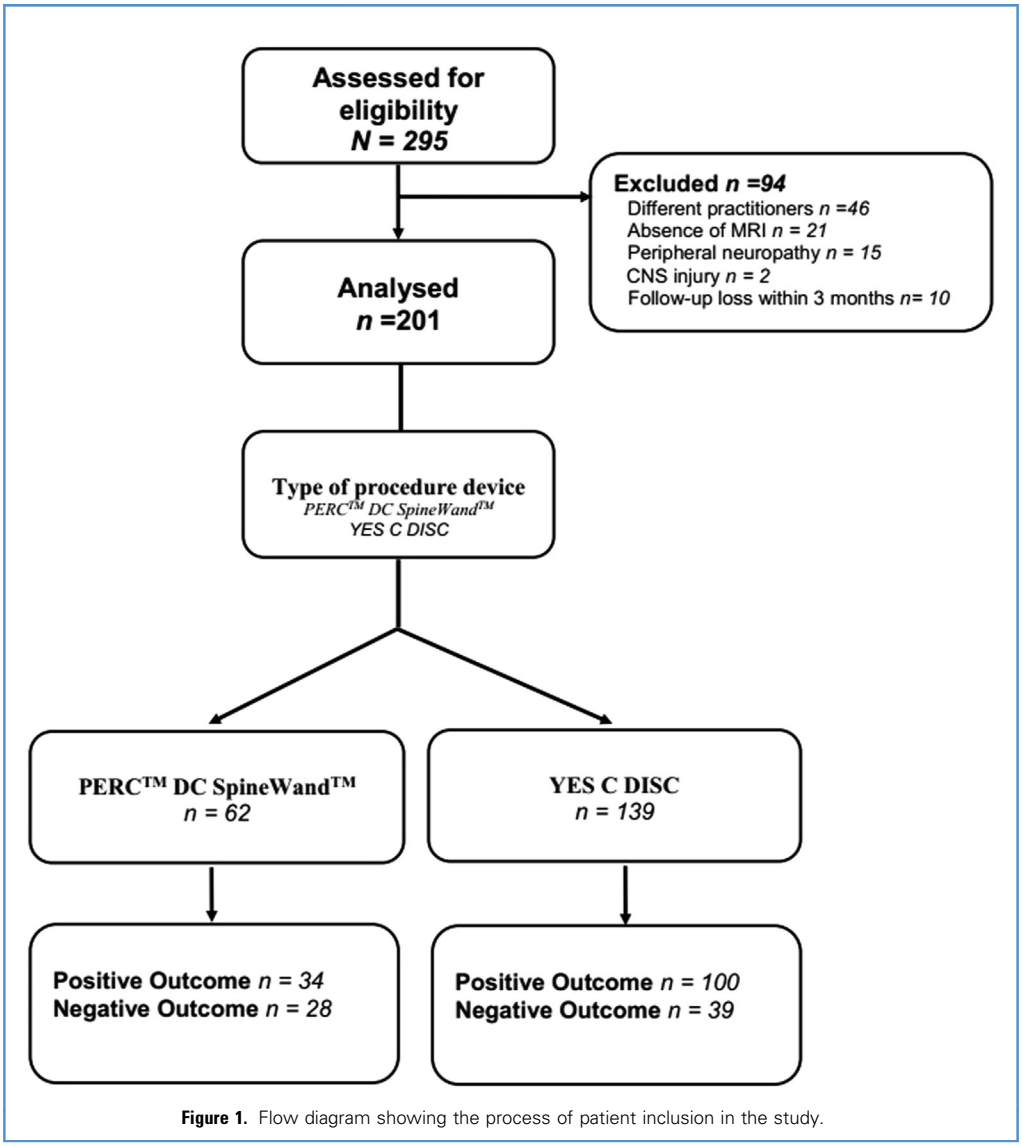

Figure 1. Flow diagram showing the process of patient inclusion in the study.

of abnormal pain during the ablation, the needle tip was slightly withdrawn, and the coagulation stage was repeated. Void number, duration, and ablation intensity were all adjusted according to the size and hardness of the protruded disc material.

After the procedure, patients were observed for 4 hours for any complications related to the PCN; they also were confined to bed rest in the supine position for 24 hours. Patients were advised to apply a soft collar for 2 weeks and to avoid vigorous activities for 1 month. Patients were discharged 1 day after the procedure, and they visited the outpatient clinic after 1 and 3 months for evaluation.

Data Collection

Patient demographic data and clinical findings, including age, sex, height, weight, smoking history, comorbid psychiatric conditions (depression and anxiety disorders), litigation status, illness duration, type of cervical disc herniation on MRI (disc bulge and protrusion or contained extrusion),[17] spinal stenosis at the target cervical level (defined as a true canal diameter less than 12 mm),[18] pain location dominance (axial or radiculopathy pain dominant, or both), location of radiculopathy (unilateral vs. bilateral), and current analgesic intake (none, nonsteroidal anti-inflammatory drugs, and weak or strong opioids), were recorded. Procedure-related variables, including curved-tip versus conventional technique and number of treatment levels, along with postprocedural variables, including any changes in analgesics and incidence of additional cervical epidural injections for 3 months after PCN, were also recorded.

Pain from C-HIVD was recorded preoperatively and again 1 and 3 months postoperatively, using the NRS pain score[19,20] by asking the patient, "What was your average pain score over the past week, on a scale of 1 to 10, with 0 being no pain and 10 being the worst

pain imaginable?" A successful outcome was predefined as a combination of greater than 50% pain relief (according to the NRS pain score) at the patient's 3-month follow-up visit, no increase in analgesics, and no cervical epidural steroid injection over the 3-month follow-up period. In addition, patient satisfaction was evaluated using the Modified MacNab criteria (response options include excellent, good, fair, poor, or worse) 3 months postoperatively.

Any complications that occurred after the procedure (e.g. upper extremity motor weakness, sensory changes, cervical discitis, hematoma, infection) were reviewed within the 3 months following the procedure.

Statistical Analysis

Patients were classified into either the negative or positive outcome group, according to the predefined success criteria. Between-group comparisons of patients' characteristics were made using Student t tests (continuous variables) and χ^2 or Fisher exact tests (descriptive variables). P values less than 0.05 were considered statistically significant. For multiple comparison between pain location, type of radiculopathy, analgesic use, and NRS pain scores, Bonferroni corrections were applied to minimize the chance of a type 1 errors ($P < 0.017$ was accepted as statistically significant).

To quantify the relationship between successful outcomes and patients' clinical and demographic characteristics, binary logistic regression techniques were used. To determine independent positive prognostic factors of PCN, multivariate logistic regression analyses were performed with variables showing a statistical significance ($P < 0.2$) via univariate analyses, using a backward stepwise conditional method. Baseline reference characteristics were male sex, no smoking, no litigation status, no concurrent stenosis, cervical intervertebral disc bulging only, axial located pain only, absence of radiculopathy, use of curved-tip technique, and no analgesic use.

All parametric data are presented as means ± standard deviations (SDs) and nonparametric data as numbers and proportions (%). Odds ratios (ORs) and 95% confidence intervals (CIs) were also calculated as required. All statistical analyses were performed using SPSS Statistics version 22.0 (IBM, Armonk, New York, USA) for Windows.

RESULTS

We reviewed the medical records of 295 consecutive patients who underwent PCN between July 1, 2009, and December 31, 2016. Of these, 91 patients were excluded from our analyses for the following reasons: (1) underwent PCN by a different practitioner (n = 46); (2) absence of cervical spinal MRI 1 month before the PCN procedure (n = 21); (3) peripheral neuropathy in the upper extremity (n = 15); (4) cervical myelopathy or evidence of central nervous system injury (n = 2); and (5) absence of 3-month follow-up data (n = 10). Therefore, 201 patients were included in our analyses (Figure 2).

Patient demographics and characteristics are given in Table 1. In the cervical MRI, disc protrusions or contained extrusions were more frequent than bulging discs. Concurrent cervical spinal canal stenosis was found in 46 patients (19.6%). Half of the patients complained of dominant radiculopathy, and unilateral radiculopathy was more frequent than bilateral radiculopathy or absence of radiculopathy.

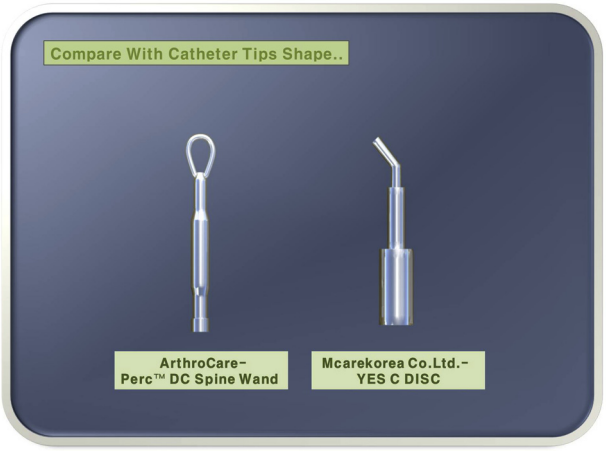

Figure 2. Conventional and curved tips for coblation technique of percutaneous cervical nucleoplasty.

Table 1 shows a comparison between the demographic and clinical variables of the positive versus negative outcome groups (based on the predefined success criteria). Among the entire cohort (n = 201), 134 patients (66.7%) experienced a successful outcome after PCN. Disease duration was significantly shorter in the positive versus negative outcome group (27.2 ± 26.2 vs. 43.4 ± 42.6 weeks; $P = 0.001$). Cervical central canal stenosis was more common in the negative (n = 34; 50.7%) versus the positive (n = 12; 9.0%) outcome group. Patients with unilateral radiculopathy were more frequent in the positive outcome group than those with axial pain only ($P = 0.007$, Bonferroni correction) or bilateral radiculopathy ($P = 0.001$, Bonferroni correction). The curved-tip technique was more frequent in the positive versus the negative outcome group ($P = 0.023$).

Figure 3 shows changes over time in NRS pain scores after PCN. Baseline NRS pain scores were not significantly different between the positive and negative outcome groups (6.02 ± 1.96 vs. 6.23 ± 1.66; $P = 0.454$). Overall, NRS pain scores were reduced 1 month from baseline (3.94 ± 2.42; $P < 0.001$ compared with baseline) and further reduced 3 months from baseline (3.04 ± 2.50; $P < 0.001$ compared with baseline, and $P < 0.001$ compared with 1-month follow-up). In the positive outcome group, NRS pain scores were significantly decreased 1 month from baseline (2.96 ± 1.92; $P < 0.001$ compared with baseline), and even more so at 3 months from baseline (1.90 ± 1.49; $P < 0.001$ compared with baseline, and $P < 0.001$ compared with 1-month follow-up). In the negative outcome group, NRS pain scores were significantly decreased 3 months from baseline only (5.30 ± 2.56; $P = 0.001$).

Table 2 shows factors associated with outcome using both univariate and multivariate analyses. Basic demographics and variables showing a trend toward statistical significance ($P < 0.2$) via univariate analyses, including disease duration ($P = 0.029$), coexistence of cervical spinal canal stenosis

Table 1. Comparison of Demographics Between Positive and Negative Outcome Groups

Variable	Total (n = 201)	Positive Outcome (n = 134)	Negative Outcome (n = 67)	*P* Value
Age, years	52.25 (11.32)	52.19 (13.19)	52.28 (10.32)	0.958
Sex (male/female)	108 (57.35%)/93% (46.3%)	73% (54.5%)/61% (45.5%)	35% (52.2%)/32% (47.8%)	0.345
Body mass index (kg/m^2)	24.06 (2.95)	24.11 (3.03)	23.93 (2.82)	0.673
Smoking	28 (13.9%)	19 (14.2%)	9 (13.4%)	1.000
Comorbid psychiatric condition*	15 (6.4%)	8 (6.0%)	7 (10.4%)	0.266
Litigation status	3 (1.5%)	2 (1.5%)	1 (1.5%)	1.000
Pain duration (weeks)	32.59 (33.38)	27.19 (26.22)	43.40 (42.58)	0.001
Central canal stenosis	46 (19.6%)	12 (9.0%)	34 (50.7%)	<0.001
Type of disc herniation				
Disc bulging only	67 (33.3%)	50 (37.3%)	17 (25.4%)	0.113
Disc protrusion or contained extrusion	134 (66.7%)	84 (62.7%)	50 (74.6%)	
Pain location				
Axial pain dominant	60 (29.9%)	37 (27.6%)	23 (34.3%)	0.589
Radiculopathy dominant	100 (49.8%)	68 (50.7%)	32 (47.8%)	
Mixed	41 (20.4%)	29 (21.6%)	12 (17.9%)	
Type of radiculopathy				
None (axial pain only)	19 (9.5%)	11 (57.9%)	8 (42.1%)	<0.001
Unilateral†	99 (49.3%)	77 (77.8%)	22 (22.2%)	
Bilateral	83 (41.3%)	46 (55.4%)	37 (44.6%)	
Number of discs for PCN	1.61 (0.57)	1.61 (0.57)	1.61 (0.58)	1.000
Needle tip technique				
Curved-tip technique	139 (69.2%)	100 (71.9%)	39 (28.1%)	0.023
Conventional technique	62 (30.8%)	34 (54.8%)	28 (45.2%)	
Analgesics use				
None	47 (23.4%)	30 (22.4%)	17 (25.4%)	0.863
NSAIDs	90 (44.8%)	60 (44.8%)	30 (44.8%)	
Weak or strong opioids	64 (31.8%)	44 (32.8%)	20 (29.9%)	
Additional C-ESI	0.62 (0.93)	0.52 (0.84)	0.82 (1.07)	0.032

Data are expressed as means (±SD) or number of patients (%).
PCN, percutaneous cervical nucleoplasty; C-ESI, cervical epidural steroid injection; NSAID, nonsteroidal anti-inflammatory drug.
*Comorbid psychiatric conditions include depression and anxiety disorder.
†Unilateral radiculopathy was significantly frequent in success group than axial pain only ($P = 0.007$, Bonferroni correction) or bilateral radiculopathy ($P = 0.001$, Bonferroni correction).

(P < 0.001), type of disc herniation (P = 0.092), type of radiculopathy (P = 0.001), and needle tip technique (P = 0.019) were included in multivariate logistic regression analyses. Among the demographics and selected clinical variables, existence of unilateral radiculopathy (adjusted OR = 3.809; P = 0.031) and use of the curved tip technique (adjusted OR = 2.475; P = 0.027) were independent positive predictors of successful PCN, whereas disease duration (adjusted OR = 0.986; P < 0.014) and concurrent central canal stenosis (adjusted OR = 0.095; P < 0.001) were negative predictors of successful PCN.

Regarding patient satisfaction, more than two thirds of patients responded with excellent (28.4%) or good (39.5%), followed by fair (21.4%), poor (8.0%), and worse (3%). Among the patients in the negative outcome group, 34 patients (50.7%) received an epidural injection and 30 patients (44.8%) increased their analgesics in the 3 months after their PCN procedure; nevertheless, a few still reported greater than 50% reduction in pain.

Regarding adverse events related to PCN, 21 patients (10.4%) reported transient neck pain and muscle stiffness, which subsided within 1 month. No postoperative discitis occurred. Six patients

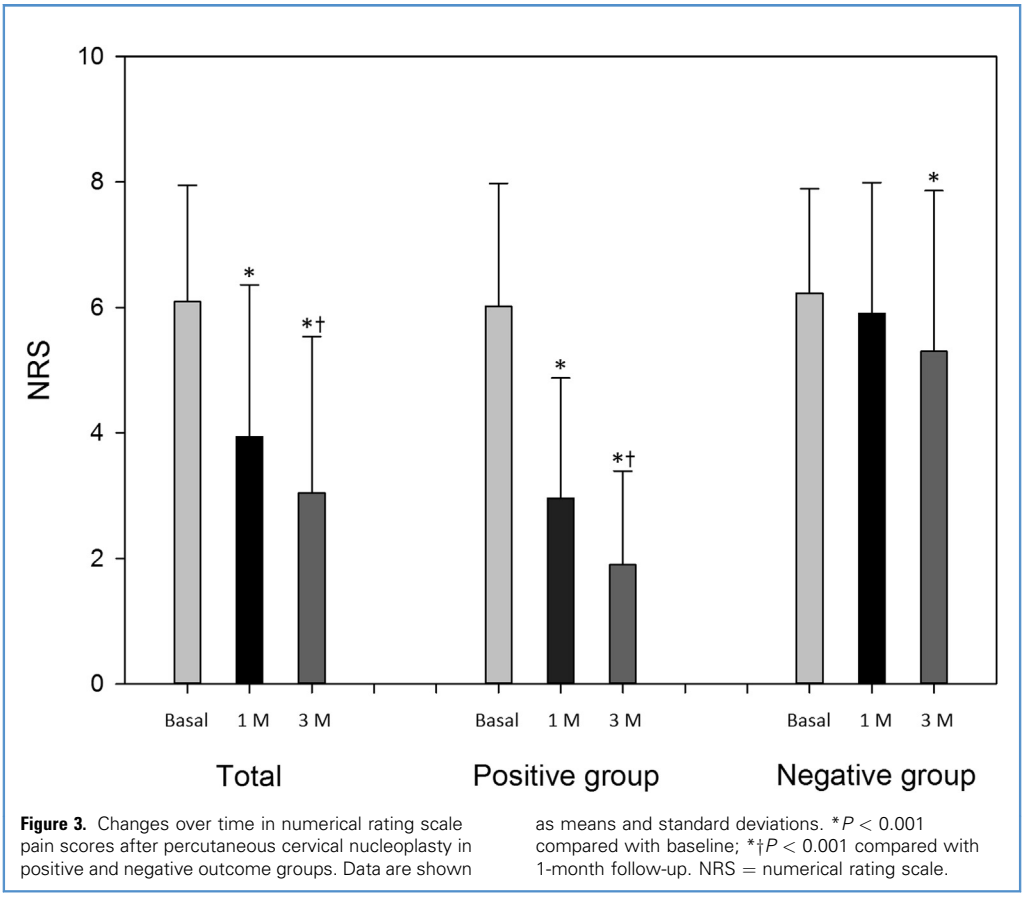

Figure 3. Changes over time in numerical rating scale pain scores after percutaneous cervical nucleoplasty in positive and negative outcome groups. Data are shown as means and standard deviations. *$P < 0.001$ compared with baseline; *†$P < 0.001$ compared with 1-month follow-up. NRS = numerical rating scale.

complained of pain aggravation after PCN, which resolved after 1 month. All complications were mild in severity.

DISCUSSION

In this study, the overall NRS pain scores of patients who underwent PCN to manage pain from C-HIVD were significantly reduced at 1- and 3-month follow-up. The reductions in pain were more remarkable at 3 months than at 1 month. Using the predefined successful outcome criteria, the success rate of PCN was 66.7% in patients with C-HIVD. In the positive outcome group, pain duration was shorter, frequency of cervical central canal stenosis was lower, and current unilateral radiculopathy was more frequently observed. Moreover, the curved-tip technique was more commonly used in the positive outcome group. Multivariate analyses identified shorter pain duration, absence of spinal stenosis, current symptoms of unilateral radiculopathy, and use of the curved-tip technique to be significant independent predictors of positive PCN outcome. In terms of patients' satisfaction, "excellent" or "good" was reported in 70% of patients, with no serious adverse events related to PCN.

Previous studies have reported that PCN is safe and effective, with high success rates (>70%).[3,14,21] Although a success rate of 66.7% in our study is not disappointing, it was lower than previously reported. However, although previous studies defined their success rate based only on a reduction in NRS pain score only, we determined a composite successful outcome by combining 3 different clinical variables, including greater than 50% pain relief according to NRS pain score at 3 months, no increase in analgesics, and no cervical epidural steroid injection during the 3-month follow-up period. Among patients in the negative outcome group, 15 reported greater than 50% pain reduction; however, they were included in the negative outcome group as 4 patients received epidural injections and 13 patients increased their analgesics in the 3 months after PCN. If these patients were included in the positive outcome group, based on their reduction in NRS pain score only, the PCN success rate would be 74.2%, which was similar to that found in previous studies.[3,14] However, because of the retrospective nature in this study, we sought a strict way to evaluate success rate. We believe that adopting a composite outcome represents a strength of our study.

Numerous factors can contribute to a positive PCN outcome. An important factor in achieving a successful PCN outcome is operator technique.[9] In addition, our findings suggest that short pain duration, absence of central canal stenosis, current unilateral radicular pain rather than bilateral radicular or axial neck pain only, and the use of the curved-tip technique are associated with a positive PCN outcome. For PCN and other interventional procedures, early treatment is also associated with positive outcomes.[22,23] Moreover, Wullems et al.[9] suggests that appropriate

Table 2. Factors Associated with Treatment Outcome in Multivariate Analysis (Multivariate $r^2 = 0.397$; n = 201)

Variable	Univariable Analysis, OR (95% CI)	*P* Value	Multivariable Analysis, OR (95% CI)	*P* Value
Age, years	1.001 (0.975–1.027)	0.958	1.014 (0.981–1.048)	0.395
Female sex	0.914 (0.508–1.745)	0.914	1.452 (0.691–3.051)	0.325
Body mass index (kg/m^2)	1.022 (0.925–1.129)	0.672	—	—
Smoking	1.065 (0.453–2.500)	0.885	—	—
Comorbid psychiatric condition*	0.544 (0.189–1.571)	0.261	—	—
Litigation status	1.000 (0.089–11.230)	1.000	—	—
Pain duration (months)	0.994 (0.998–0.999)	0.029	0.986 (0.976–0.997)	0.014
Stenosis	0.095 (0.045–0.205)	<0.001	0.095 (0.040–0.228)	<0.001
Type of disc herniation	—	0.092	—	0.415
Disc bulging only	—	—	—	—
Disc protrusion or contained extrusion	0.571 (0.298–1.097)	—	0.707 (0.307–1.628)	—
Pain location	—	0.590	—	—
Axial pain only	—	—	—	—
Radiculopathy only	1.321 (0.677–2.579)	0.415	—	—
Mixed	1.052 (0.642–3.571)	0.348	—	—
Type of radiculopathy	—	0.001	—	0.013
None	—	—	—	—
Unilateral	4.389 (1.574–12.239)	0.005	3.809 (1.130–12.839)	0.031
Bilateral	1.381 (0.509–3.752)	0.526	1.255 (0.395–3.994)	0.700
Number of discs for PCN	1.000 (0.599–1.670)	1.000	—	—
Curved-tip technique	2.112 (1.133–3.934)	0.019	2.475 (1.110–5.522)	0.027
Basal NRS pain score	0.941 (0.803–1.103)	0.452	—	—
Analgesic use		0.863		—
None	—	—	—	—
NSAIDs	1.133 (0.541–2.373)	0.740	—	—
Weak or strong opioids	1.247 (0.562–2.763)	0.587	—	—

OR, odds ratio; CI, confidence interval; PCN, percutaneous cervical nucleoplasty; NSAIDs, nonsteroidal anti-inflammatory drugs; NRS, numerical rating scale.
*Comorbid psychiatric conditions include depression and anxiety disorder.

cases for successful PCN include patients with MRI-confirmed contained herniated and minimally degenerated discs, and those with increased arm versus axial neck pain.[9] Our results may support Wullems' suggestion, as our patients with radicular pain, particularly one-sided, experienced more successful outcomes than those with axial neck pain. Moreover, cervical spinal canal stenosis less than 13 mm in diameter may be associated with an increased risk of pathologic changes in cervical intervertebral discs.[24] Although pain from contained C-HIVD is an appropriate indication for PCN, our results suggest that PCN for patients with C-HIVD combined with spinal stenosis might not guarantee a positive outcome.

In our study, multivariate analyses revealed that the curved-tip technique was associated with positive PCN outcomes. It is assumed that the curved tip creates a wider treatment lesion than conventional tips do, by rotating the needle 360° while performing the ablation. This curved-tip technique has been used widely for radiofrequency ablation in patients with cervical or lumbar facet and sacroiliac joint pain.[25-27] In addition to creating a wide ablation, the curved tip can provide better control over the direction of the needle to target the ablation site during PCN (**Figure 4**). As an ablation of only 1 mL of small disc volume results in a disproportionately large fall in pressure,[15,28] we infer that the curved-tip technique, which can create a wider ablation than the straight-tip technique can, resulted in a trend toward positive PCN outcomes. However, in vivo and in vitro studies are required to investigate whether needle tip shape has an effect on lesion size and the degree of pressure decrease in PCN.

This study had several limitations. Although we thoroughly reviewed electric medical records and selected patients with C-HIVD diagnosed with MRI taken 1 month before PCN, this retrospective analysis lacked a control group and did not include

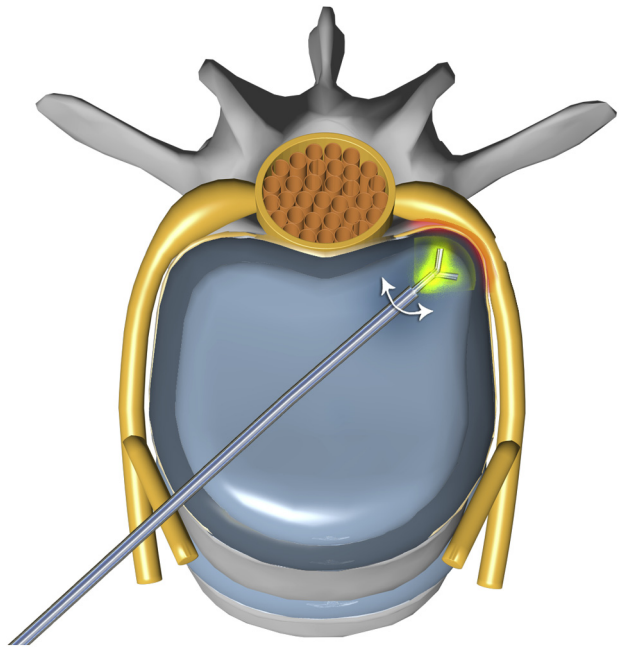

Figure 4. Lesions created by the curved-tip technique during percutaneous cervical nucleoplasty.

functional assessment using a validated questionnaire, such as the neck pain disability index. Furthermore, the 2 different devices used in the study were sequentially applied (PERC DC SpineWand for PCN from July 2009 to December 2012 and YES C DISC from January 2013 to December 2016), which could be a major confounding factor. In addition, although our study aimed to find predictive factors for successful PCN outcome, a 3-month follow-up period might not have been long enough to assess full procedural efficacy. Nonetheless, as we included only patients whose C-HIVD was refractory to conservative management, including cervical epidural injections, our results could provide positive evidence as to the clinical usefulness of PCN procedures in patients with contained cervical disc herniation. If conservative management fails, physicians can strongly consider PCN as the next treatment method to avoid invasive surgery. Importantly, no previous study has investigated the predictive clinical and radiologic findings of successful PCN. Therefore, our study, including a relatively large cohort (n = 201), may provide clinically useful information. Appropriate prospective clinical trials with extended follow-up are warranted to verify our results.

CONCLUSION

In this study, PCN was found to be safe and effective for the management of pain from C-HIVD. Two thirds of the included patients showed greater than 50% pain reduction, without any additive interventional procedures or increases in analgesics during the 3-month follow-up period. Shorter pain duration, an absence of cervical central canal stenosis, pain location (i.e., unilateral radiculopathy vs. axial pain), and the use of the curved-tip technique were positive predictors for successful PCN. Overall, 70% of patients were fairly satisfied with the result of their PCN.

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