Observational Study

Therapeutic Effects and Safety of Percutaneous Disc Decompression with Coblation Nucleoplasty in Cervical Vertigo: A Retrospective Outcome Study with 74 Consecutive Patients and Minimum 1-Year Follow-Up

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Background: Surgical treatment of cervical vertigo has been rarely reported. This is the first retrospective study to evaluate the clinical outcomes of percutaneous disc decompression with coblation nucleoplasty (PDCN) for treatment of cervical vertigo.

Objectives: To assess the clinical outcomes of patients with cervical vertigo who failed to improve with conservative care and who were subsequently treated with PDCN.

Study Design: This study used a retrospective design.

Setting: The research was conducted within an interventional vertigo management and spine practice.

Methods: Seventy-four consecutive patients with cervical vertigo underwent PDCN and were followed for at least one year. Outcome measures included the dizziness intensity Visual Analog Scale (VAS), dizziness frequency, the Dizziness Handicap Inventory (DHI), and neck pain intensity. Clinical efficacy was assessed by rating scale and the modified MacNab evaluation criteria. Surgical complications during the operation and follow-up were also recorded.

Results: The vertigo VAS score, frequency of dizziness, DHI, and neck pain intensity were all decreased significantly from evaluation before surgery to one week after surgery and to the last follow-up, giving a mean effective rate of 94.6% one week after surgery and 90.6% at the last follow-up. Good to excellent results were attained in 85.1% of these patients one week after PDCN and in 75.7% of the sufferers at the last follow-up ($P < 0.001$). There were 5 patients with transient adverse effects (6.25%) reported within the first month after surgery; they all recovered after conservative treatment. No neurological complications were found and no patient went on to spinal fusion surgery thereafter.

Limitations: The rate of follow-up was 70% and a placebo effect cannot be excluded. There is no gold standard for the diagnosis and treatment of cervical vertigo so far.

Conclusion: The clinical outcomes of PDCN for cervical vertigo were satisfactory in both the early and late postoperative period. PDCN is an effective, low-complication, minimally invasive procedure used to treat cervical vertigo. Further prospective randomized controlled trials are essential to verify this conclusion.

Key words: Cervical vertigo, percutaneous disc decompression, coblation nucleoplasty, long-term outcome, dizziness intensity, dizziness frequency, dizziness handicap inventory, clinical efficacy, surgical complication, retrospective study

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Vertigo ranks among the most common complaints in medicine and has a considerable personal impact, affecting 15% to 35% of the general population at some point in their lives (1). The combination of neck disorders with vertigo or dizziness was formally coined "cervical vertigo" by Ryan in 1955 (2). The precise incidence of cervical vertigo is controversial but it is estimated that 20% to 58% of patients who sustain closed-head injuries or whiplash experience late-onset symptoms of dizziness and disequilibrium (3-5).

The treatment options for cervical vertigo are versatile and challenging due to the unclear pathogenesis of this disease. Manual therapy such as spinal manipulation is recommended for treatment of proprioceptive cervical vertigo by restoring normal movement of the zygapophyseal joints, thereby restoring normal proprioceptive and biomechanical functioning of the cervical spine (6). Surgical intervention is recommended when the patient is a good candidate. It is reported that anterior cervical fusion surgery is effective for patients with cervical spondylosis accompanied with Barré-Liéou syndrome, both in short-term (7) and mid-term (8) follow-ups. However, anterior cervical fusion surgery is an open surgery, and long-term follow-up has verified that it is associated with increased adjacent segment disc degeneration (9,10). Therefore, more sophisticated surgical procedures that are less invasive seem likely to eventually offer better results for cervical vertigo. Ren et al reported that percutaneous laser disc decompression (PLDD) exerted good midterm efficacy for treatment of cervical vertigo (11). Nevertheless, the temperature produced by laser vaporization (300°C-600°C) is high enough to possibly damage the adjacent structures and can even cause thermal nerve root damage (12-14). Plasma-mediated ablation using the Coblation Spine-Wand (Arthro-Care, Austin, TX) device has been used for several years to perform spine disc decompression (15-19). The device uses radiofrequency energy to excite electrolytes in a conductive medium to create focused plasma; the energized particles in the plasma have sufficient energy to excise or dissolve soft tissue in a defined area at safe temperatures typically ranging between 40°C and 70°C, finally causing tissue shrinkage or coagulation. However, there is no early or long-term investigation of percutaneous disc decompression with coblation nucleoplasty (PDCN) for treatment of cervical vertigo, and complications observed with this procedure have not been reported yet.

This is the first retrospective outcome study with minimum one-year follow-up conducted to evaluate the therapeutic effect and safety of PDCN in cervical vertigo in consecutive cases.

Methods

Study Design and Patient Follow-up

This retrospective study was conducted in a single-center, interventional vertigo management and spine practice group in the Third Affiliated Hospital of Sun Yat-sen University. All patients had a recurring symptom of dizziness over 3 months and conservative treatment applied for at least 3 weeks that had failed. The diagnosis of cervical vertigo is dependent upon correlating symptoms of imbalance and vertigo with neck pain, previous neck injury such as whiplash injury, or pathology. There are a number of different causes of vertigo that are essential to eliminate, including those arising from disturbances of the ear, nose, and throat, central nervous system, and cardiovascular system (20); therefore, we first held consultations for the suspected patients with an otorhinolaryngologist, neurologist, and cardiologist after admission, and the diagnosis of cervical vertigo was finally confirmed by the spine surgeons. Initially, 107 consecutive patients with cervical vertigo who underwent PDCN for more than one year were followed up by using retrospective analysis of medical records, outpatient reviews, and telephone calls. We excluded 33 patients: 31 who could not be contacted and 2 who died. Finally, 74 patients entered the study and underwent full clinical assessment using a detailed questionnaire. All follow-up assessments and data analysis were conducted by researchers blinded to the patients' information.

Percutaneous Disc Decompression with Coblation Nucleoplasty

The basis for choosing which level to treat is mainly based on the magnetic resonance imaging (MRI) findings (21). The most degenerated disc with or without disc bulge, but no herniation, is the target. Because it is reported that nucleoplasty has a negligible effect on highly degenerative discs (22), the black discs of Pfirrmann Grade IV and Grade V should be avoided (21). Moreover, when several degenerated disc exist, we prefer to choose the disc above C4/5 because most sympathetic nerve fibers are presented in the upper cervical spine (23,24). PDCN was performed using the COBLATION Perc-DC SpineWand surgical device (ArthroCare

System 2000, Arthrocare Costa Rica, Heredia, Costa Rica). Three spine surgeons with postgraduate qualifications and a minimum of 5 years' experience in the field of spine surgery performed all the interventions during the study. The PDCN procedure took about 30 minutes and was performed under local anesthesia (0.5% lidocaine) according to the manufacturer's instructions. Patients were allowed to lie in the supine position with neck set at a backward extension position (Fig. 1.A-B). After detecting the intervertebral space under a fluoroscopic view, the introducer cannula (19-gauge, 7.6 cm) was pierced into the target intervertebral disc through an anterior lateral approach, and stopped when the annulus/nucleus junction was reached. The tip of the cannula stylet was then aimed at the center of the nucleus and confirmed precisely in both the anteroposterior and lateral x-ray monitoring views (Fig. 1.C-D). The stylet was withdrawn from the introducer cannula and replaced with the Perc-DC SpineWand. The wand was advanced until its tip extended approximately 5 mm beyond the tip of the cannula. As the wand was drawn back out through the disc, ablation energy was set to level 3, and 2 ablation cycles of 25 to 30 seconds each were performed, rotating the wand tip 180 degrees each time to form 3 consecutive pockets within the disc. Patients were immediately mobilized following the procedure and discharged 24 hours after surgery. No antibiotic prophylaxis was given in all cases. Patients were assigned additional conservative therapies (such as halo drugs, nonsteroidal anti-inflammatory drugs [NSAIDs], or muscle relaxant) following PDCN if necessary. Collars were applied for 2 weeks post operation.

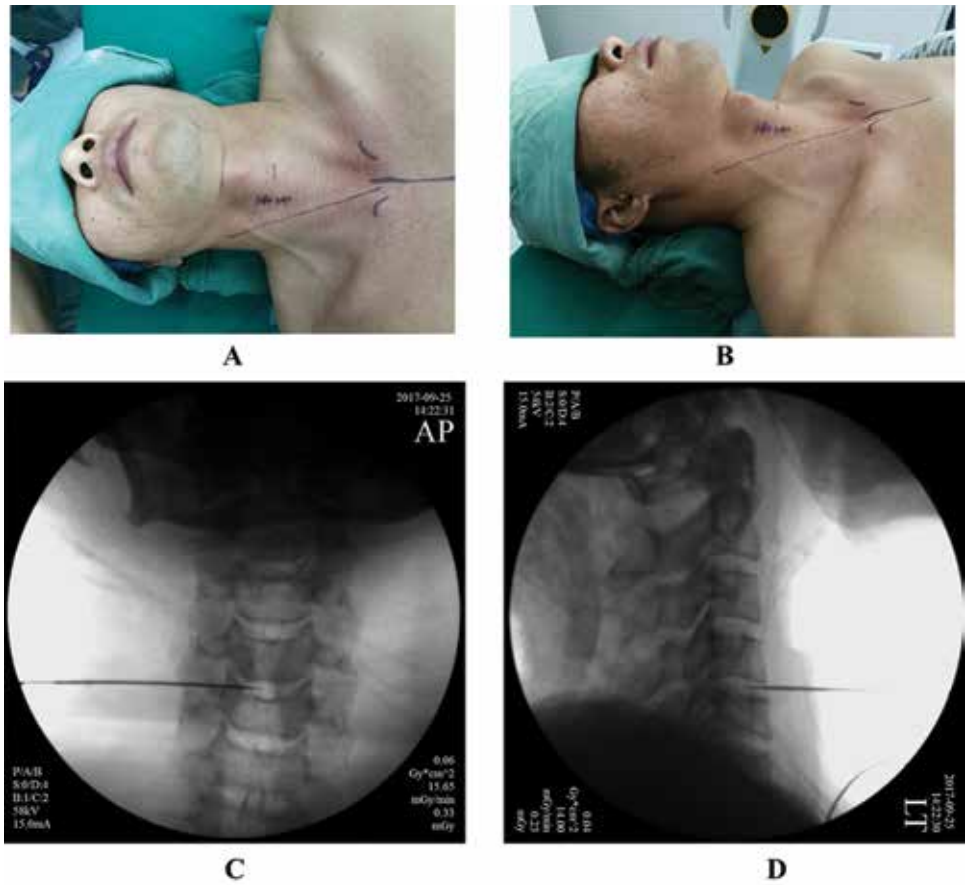

Fig. 1. *Patient position during operation (A, B) and the position of the puncture needle confirmed by the anteroposterior (C) and lateral (D) x-ray monitoring views.*

Primary Outcome Measures

Severity of dizziness was measured with a 10-cm horizontal Visual Analog Scale (VAS); the VAS has been used successfully to measure dizziness in other studies (25).

Secondary Outcomes Measures

Frequency of dizziness was measured on a 6-point rating scale: 0 = no dizziness, 1 = dizziness less than once per month, 2 = 1 to 4 episodes per month, 3 = 1 to 4 episodes per week, 4 = once daily, 5 = more than once a day or constant. This scoring method has been used by several researchers (25). Disability caused by dizziness was measured specifically with the Dizziness Handicap Inventory (DHI), which has been shown to be a highly reliable tool (26). The DHI assesses quality of life using 3 subscales that evaluate the impacts of dizziness on the functional, emotional, and physical aspects of everyday life. The highest possible score is 100, indicating maximum self-perceived handicap. Severity of neck pain was assessed with a 10-cm VAS. There is much evidence supporting its high validity (27).

Table 1. *Demographics and general characteristics of the patients (n = 74).*

Age (range in yrs, average)	27-81 (55)	
Gender		
Men	25	
Women	49	
Operation Date	May 2009 to August 2016	
Date of Last Follow-up	late August, 2017	
Follow-up Range (yrs/mos)	1/0-8/3	
Median Follow-up (yrs/mos)	5/8	
Number of Surgical Levels	**Levels**	**No. of pts**
Single	C3/4 C4/5 C5/6 C6/7 total	5 10 6 1 22
Double	C3/4 + C4/5 C4/5 + C5/6 C5/6 + C6/7 C3/4 + C5/6 total	24 19 1 1 45
Triple	C3/4 + C4/5 + C5/6 total	7 7
Surgical Disc	**No. of pts**	
C3/4	36	
C4/5	60	
C5/6	33	
C6/7	1	

Clinical Efficacy Evaluation Criteria

Clinical efficacy was assessed one week after surgery and at the last follow-up by using tools as follows. Global perceived effect was measured by self-assessment on a 6-point scale (25): 0 = no benefit, 1 = minimal benefit, 2 = some benefit, 3 = a lot of benefit, 4 = great benefit, 5 = maximal benefit. Modified MacNab evaluation criteria were the following: excellent (A) = dizziness and associated symptoms disappeared completely, and patient resumed normal work and life; good (B) = dizziness and associated symptoms improved significantly, and patient could do former work; acceptable (C) = dizziness and associated symptoms were somewhat improved, and patient could only undertake light work; poor (D) = dizziness and associated symptoms did not improve significantly, and further treatment was required. Fitness rate = A + B; effective rate = A + B + C.

Data Analysis

Descriptive statistics included means, standard deviations, medians, lower quartiles (QL) and upper quartiles (QU) for continuous variables, and percentages for categorical variables. Normality of distribution was assessed by the Kolmogorov–Smirnov test. Outcome measures were analyzed using the signed ranks sum test for investigating the differences between groups on a paired basis. All statistical analyses were conducted in SAS Version 9.4 (SAS Institute, Inc., Cary, NC). All statistical tests were 2-sided and values of *P* smaller than .05 were considered significant.

Results

Demographics and General Characteristics of the Patients

Age and gender distribution, the follow-up time details, the number of surgical levels, and the surgical disc distribution are presented in detail in Table 1.

Effects of Intervention

Severity of Dizziness

The severity of dizziness was evaluated by both intensity and frequency of dizziness. The intensity of dizziness was severe for the preoperation group (P group); however, it decreased sharply one week

after surgery (O group), and there was still a significant reduction at the last follow-up (L group) compared to the P group (Table 2 and Fig. 2.A, $P < .001$). There was also statistically significant change between the O group and the L group (Table 2 and Fig. 3.A, $P < .001$), though only small changes occurred in this period. Changes in frequency of dizziness had a trend similar to that of intensity of dizziness (Table 1 and Fig. 2.B).

Dizziness Handicap Intervention

Whitney proposed that a total DHI score of 0 to 30 indicates mild, 31 to 60 moderate, and 61 to 100 severe handicap (28). There were significant reductions in DHI scores in both the O group and the L group compared to baseline in the P group (Table 2 and Fig. 2.C, $P < .001$). Dizziness had a moderate to severe effect on patients' lives before surgery. Scores decreased during follow-up, indicating mild handicap for both the O and L groups and suggesting that PDCN had therapeutic effects of restoring moderate to severe handicaps to mild ones.

Intensity of Cervical Spine Pain

Intensity of cervical spine pain was in the moderate range initially, and its change was also moderate when compared with other parameters. However, there was still a significant decrease one week after surgery and at the last follow-up compared to baseline (Table 2 and Fig. 2.D, $P < .001$), and there was no significant difference between the O group and the L group ($P = .06$). The minimal clinically important change (MCIC) for pain using a VAS has been reported to be 2.0 (29). The MCIC was reduced to 0.5 for the O group with a change of 2.5 from baseline, and the changes also reached the MCIC for the L group.

Clinical Efficacy

The median score was 8.0 for the O group and 7.0 for the L group when evaluated by a self-assessment tool on a 10-point scale (Table 3), indicating great benefit for both groups over the ensuing follow-up period. However, there was a significant decrease in the scores at the last follow-up assessment compared to one week after surgery. Nevertheless, the lower quartile and the upper quartile were 3.0 and 8.0, which were found to have some benefit and great benefit, respectively, in the long term. We further evaluated clinical efficacy under the modified MacNab evaluation criteria (Fig. 3). As clearly demonstrated in the pie chart, most of the patients achieved good results one week after surgery (Fig. 3.A); the fitness rate was 85.1% and the effective rate was 94.6%. Favorable results were also achieved at the last follow-up (Fig. 3.B); the fitness rate was observed in 75.7% of patients while the effective ratewas 90.6%.

Collectively, PDCN significantly reduced cervicogenic dizziness and improved patients' functinal mobility, as indicated by both the short- and long-term satisfactory clinical outcomes.

Surgical Complications

The precise data of patients with postoperative complications is shown in Table 4 and Fig. 4. Discitis was presented in 2 (2.7%) of the patients (Fig. 4) and they both recovered after antibiotics treatment. The discomfort of 3 other patients was temporary and all were relieved after taking NSAIDs and muscle relaxant. There were no neurological complications or vascular injuries during the operation and no severe adverse effects during follow-up after the intervention. No patient went on to spinal fusion surgery thereafter.

Discussion

In this retrospective study, we used the coblation technology for nucleoplasty for the treatment of cervical vertigo. We show for the first time that both early and long-term clinical outcomes are good and that

Table 2. *Severity of dizziness and neck pain one week after surgery and at the end of follow-up.*

	Preoperation (M (QL, QU))	One Week After Surgery (M (QL, QU))	Last Follow-up (M (QL, QU))	*P* Value P vs O	*P* Value P vs L	*P* Value O vs L
Vertigo VAS Score	5.5 (4.0, 8.0)	1.0 (0, 2.0)	1.0 (0, 3.0)	< .001	< .001	< .001
Vertigo Frequency	5.0 (3.0, 5.0)	1.0 (0, 2.0)	1.0 (0, 3.0)	< .001	< .001	< .001
DHI	45.0 (28.0, 62.0)	0 (0, 16.0)	8.0 (0, 24.0)	< .001	< .001	< .001
Neck Pain VAS Score	3.0 (0, 4.0)	0.5 (0, 2.0)	1.0 (0, 3.0)	< .001	< .001	= .06

$P < .05$, significant difference between groups; $P > .05$, no significant difference
Abbreviations: M, median; QL, lower quartile; QU, upper quartile; P, preoperation; O, one week after surgery; L, last follow-up; DHI, Dizziness Handicap Inventory; VAS, Visual Analog Scale.

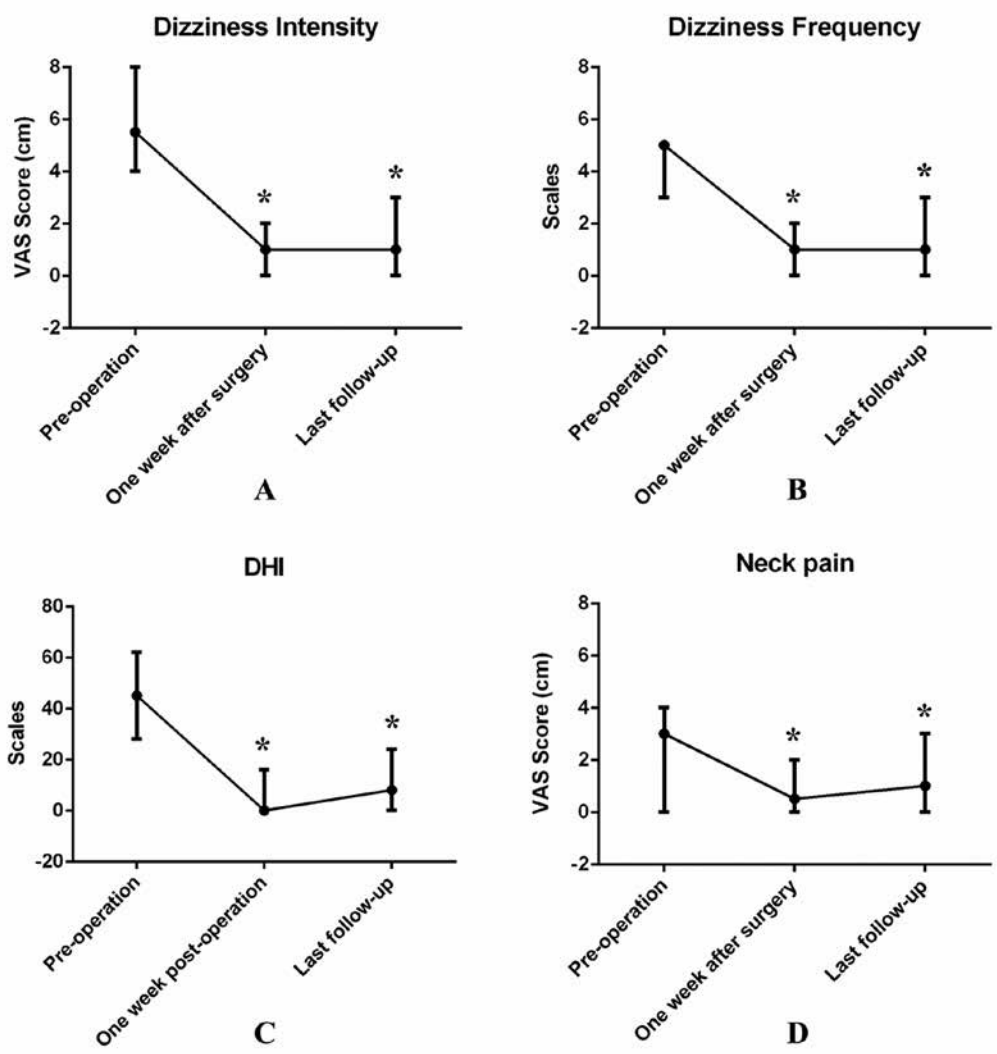

Fig. 2. *Changes in values for dizziness intensity (A), frequency of dizziness (B), Dizziness Handicap Inventory (C), and neck pain (D) over time (preoperation, one week after surgery, last follow-up). * P < .05 vs. preoperation*

Table 3. *Clinical efficacy evaluated by self-assessment tool on a 10-point scale.*

	One Week After Surgery (M (QL, QU))	Last Follow-up (M (QL, QU))	*P* Value
Points	8.0 (6.0, 9.0)	7.0 (3.0, 8.0)	< .001

$P < .05$, significant difference compared to the preoperation group
Abbreviations: M, median; QL, lower quartile; QU, upper quartile.
Values on the 10-point scale: 0 = no benefit; 1-3 points = some benefit; 4-6 points = a lot of benefit; 7-8 points = great benefit; 9-10 points = maximal benefit.

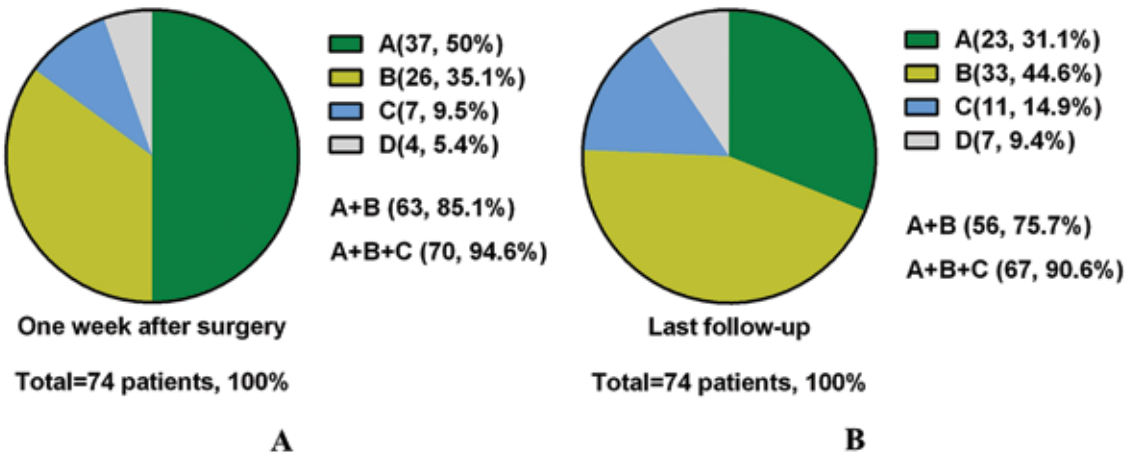

Fig. 3. *Clinical efficacy evaluated by Modified MacNab evaluation criteria one week after surgery (A) and at last follow-up (B). A = excellent, dizziness and associated symptoms disappeared completely, and the patient resumed normal work and life; B = good, dizziness and associated symptoms improved significantly, and the patients could do former work; C = acceptable, dizziness and associated symptoms were somewhat improved, and the patient could only undertake light work; D = poor, dizziness and associated symptoms did not improve significantly, and further treatment was required. Fitness rate = (A + B)/total number of patients × 100%; Effective rate = (A + B + C)/total number of patients × 100%.*

Table 4. *The precise data of patients with postoperative complications.*

No.	Gender	Age	Surgical Disc	Chief Complaint	Physical Examination	Blood Test	MRI Findings	Diagnosis	Treatments
1	male	42	C5/6	immobilizing neck pain, raised body temperature	tenderness and percussion pain	raised CRP and ESR	disc hyperintense signal, bone marrow edema	discitis	antibiotics
2	male	59	C3/4 C5/6	as above	as above	as above	as above	as above	as above
3	female	55	C3/4 C4/5	neck stiffness	tenderness	normal	normal	?	NSAIDs, muscle relaxant
4	male	80	C3/4	pain behind the ear	normal	normal	normal	?	NSAIDs
5	female	64	C4/5 C5/6	pain in the nuchal region	tenderness	normal	normal	?	NSAIDs

Abbreviations: CRP, C reactive protein; ESR, erythrocyte sedimentation rate; MRI, magnetic resonance imaging; NSAIDs, nonsteroidal anti-inflammatory drugs

there are few complications observed with this procedure. PDCN meets the principle of modern minimally invasive surgical techniques; it has many advantages such as good preservation of the architecture of the spine with no scarring, short procedure times, fast postoperative recovery, few complications, and no side effects on other treatment even if unsuccessful. Although the study took place only in a single center, the study sample is representative of the wide general population with cervicogenic dizziness in terms of gender, age, duration, and intensity of symptoms. Moreover, the study setting was designed to reflect everyday physical clinical conditions, further enhancing the generalizability of the findings. Therefore, PDCN can be taken as an attractive and effective minimally invasive technique for treating cervical vertigo.

PDCN is a minimally invasive surgical approach for painful disc protrusions and contained herniation in

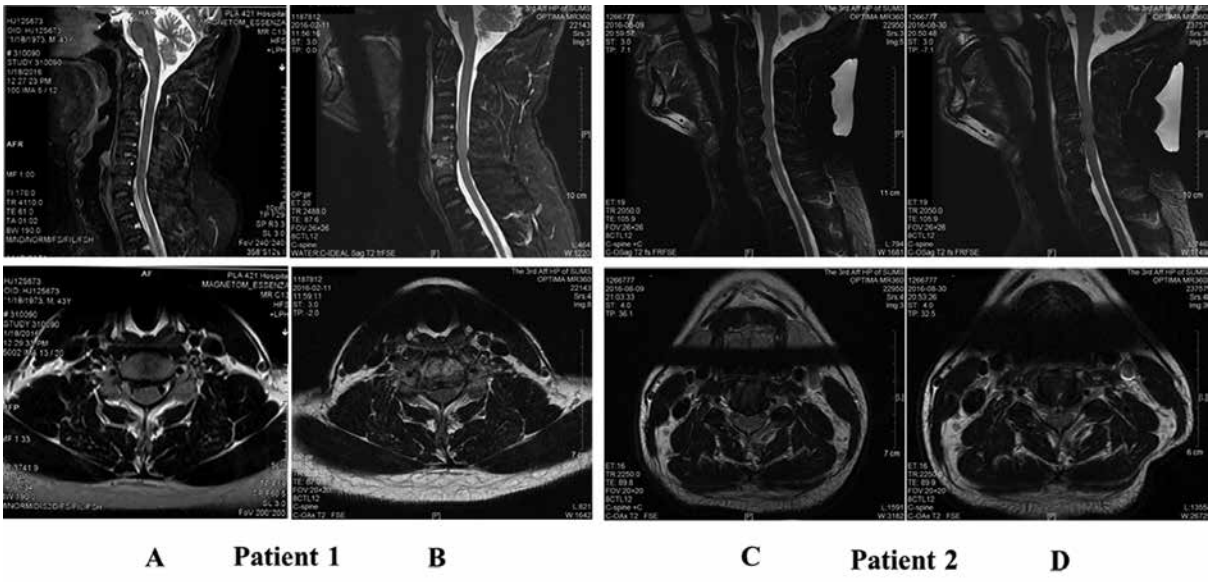

Fig. 4. *Magnetic resonance images (MRI) of patient 1 and patient 2 illustrated in Table 4 with postoperative discitis. Patient 1 and patient 2 were diagnosed with discitis 20 days and 7 days respectively after surgery on the basis of the history and findings displayed in Table 4. A T2 sagittal and coronal MRI of the cervical spine showed endplate and vertebral body hypertension due to edema and inflammation at C5/6 of patient 1 (B) and at C3/4 of patient 2 (D) with spondylodiscitis when compared with MRI images before surgery (A, C), no erosive alteration of end plates, and no epidural or paravertebral abscess formation. Antibiotic treatment was given and further clinical courses were favorable with marked improvement of neck pain and normalization of the systemic inflammatory signs*

the lumbar (16,17,30) and cervical (15,31) regions. The clinical data available today validate the benefits of the nucleoplasty procedure (19). Cervical dizziness is pathology difficult to manage by conservative procedures, but we all agree that open surgery should be avoided (32). Consequently, we conceived of PDCN in order to obtain beneficial results in cases of cervical dizziness that have scanty natural tendency to recover (33). To be eligible for this minimally invasive procedure, candidates must complain of symptoms related to a contained herniated disc or focal protrusion in MRI, indicating cervical disc degeneration with vertigo. PDCN does not substitute for conventional discetomy procedures required for extruded discs causing either cervical radiculopathy or myelopathy (34). In our study, 74 consecutive patients presenting with degenerative cervical disc causing cervical vertigo underwent PDCN on the pathological disc. More importantly, we completed the follow-up 1 to 8 years after surgery. We found that complete resolution of symptoms occurred in 75% of cases, and only 10% reported that vertigo had not improved significantly; these patients are still undergoing follow-up with a wait-and-see perspective. Despite its retrospective design and relatively low number of cases, the encouraging results induce us to widely utilize this minimally invasive technique in well-selected cases.

So far, there are 4 different hypotheses explaining the vertigo of cervical origin, including proprioceptive cervical vertigo, Barré-Liéou syndrome, rotational vertebral artery vertigo, and migraine-associated cervicogenic vertigo (24). What are the mechanisms of coblation nucleoplasty in treating cervical vertigo? First, the reason why fusions generally work for cervical vertigo may be due to their effect on restricting neck mobility and resecting posterior longitudinal ligaments (7,8), which contain abundant sympathetic nerve fibers (35). Similarly, PDCN provokes ablation of the nucleus by radiofrequency. In this procedure, 1 to 2 mL of tissue is colliquated, reducing intradiscal pressure as is done in open discectomies. This theoretically redistributes and alleviates the intradiscal forces that cause irritation of the sympathetic nerve (36,37) and the neighboring nerve root (22), finally improving the vertebral-basilar arterial blood supply. Second, vertigo is associated

with advanced degenerative changes in patients with cervical spondylosis (38). Degenerative changes, such as loss of the normal structure and abnormal motion, can provoke mechanical stimulation which generates an amplified response named peripheral sensitization in certain circumstances such as inflammation (39). If the firing characteristics of the mechanoreceptors in the diseased disc are changed, owning to both inflammation and an increase in their number, erroneous signals will be produced and subsequently increase neck deep muscle activity, resulting in cervical vertigo. Positive biochemical changes and alteration in cytokine expression have been observed in vitro as well as in vivo during nucleoplasty (15,40). Therefore, PDCN is posited to down-regulate local inflammatory mediators and reduce algogenic substances, all contributing to alleviation in cervical vertigo and discogenic pain. Third, a recent study revealed an increase in the number and ingrowth of Ruffini corpuscles in the diseased discs of patients with vertigo, suggesting a key role of mechanoreceptors in the pathogenesis of cervical vertigo (41). PDCN might reduce the abnormal neck proprioceptive input integrated from the signals of mechanoreceptors in cervical discs that are transmitted to the central nervous system (33), and prevent further sensory mismatch with vestibular input, resulting in a reduction of the subjective feeling of vertigo. Taken together, the most likely or even most important mechanism of PDCN in curing cervical vertigo might be attributed to its effect on the reduction of intradiscal pressure and improvement of the chemical and physical environments by removing inflammatory mediators and ingrown mechanoreceptors, all contributing to normal proprioception and the improvement of blood supply to the vertebrobasilar artery. The maintenance of long-term clinical efficacy is speculated to be mainly due to the remodeling effect of PDCN on the diseased discs.

The present study has several limitations. First, the rate of follow-up was 70%; we were unable to contact 31 patients, and 2 patients had passed away. A second limitation is the lack of a gold standard for the diagnosis of cervical vertigo. Therefore, differential diagnosis before surgery is of great importance. Third, there is no gold standard for the treatment of cervical vertigo so far. However, a randomized controlled trial (RCT) proved that manual therapy has long-term beneficial effects on chronic cervicogenic dizziness (25). We are thus going to carry out a prospective RCT comparing PDCN with manual therapy to confirm the effectiveness of PDCN in cervical vertigo.

Conclusion

In summary, our data clearly demonstrated and validated for the first time that PDCN is an effective and safe surgical intervention in both the short and long-term for patients experiencing refractory cervical vertigo. Since cervicogenic dizziness is a relatively common problem, the findings of this study have the potential to benefit many patients. A high-quality RCT with sufficiently large sample sizes is urgently needed to further verify this conclusion.

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