

Retrospective Case Series

Efficacy of Nucleoplasty for Radiculopathy Caused by Foraminal Cervical Disc Herniation: Clinical Results of Case Series and Technical Note

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Background: Percutaneous cervical nucleoplasty (PCN) is a minimally invasive technique used for the treatment of cervical disc herniation. However, if the lesion is located at the neural foramen, complete access and effective neural decompression are often challenging because of the special anatomical condition of the uncovertebral joint, osteophyte, and facet joint of the cervical foraminal space.

Objectives: To investigate the effect of PCN on radiculopathy caused by foraminal cervical disc herniation (FCDH).

Study Design: Retrospective case series.

Setting: Single-center tertiary hospital.

Methods: This study included 44 patients with radiculopathy caused by FCDH who were treated with PCN. Visual analog scale (VAS) scores, preoperative, 1 week, and 3 months postoperatively, and at the last follow-up, as well as the Macnab criteria, were used to evaluate clinical outcomes. A paired t-test was used to compare the preoperative and follow-up VAS scores. The percentage of patients with VAS scores ≤ 3 at each follow-up time point was also investigated. Statistical significance was set at $P < 0.05$.

Results: Twenty-seven men (62.4%) and 17 women (38.6%) were enrolled in this study. The mean age was 54.5 years (range 31-81). The average follow-up period after the operation was 15.4 months (range 3.7-30.8). The mean preoperative VAS was 7.50 ± 1.21 . The VAS scores at 1 week, 3 months, and the last follow-up were 4.36 ± 2.46 , 3.20 ± 2.58 , and 2.91 ± 2.74 , respectively, showing a significant improvement in pain compared to before the operation ($P < 0.001$ for all). The number of patients (percentage) with a VAS score of ≤ 3 was 20 (45.5%), 28 (63.6%), and 31 (70.5%) of 44 patients at 1 week, 3 months, and the last follow-up, respectively. The number of patients (percentage) with excellent, good, fair, or poor satisfaction according to the Macnab criteria was 17 (38.6%), 9 (20.5%), 8 (18.2%), and 10 (22.7%) of 44, respectively. No patients experienced postoperative complications.

Limitations: This study was retrospective and included a small number of patients from a single center.

Conclusions: Although PCN for radiculopathy caused by FCDH is thought to have limitations because of the surrounding bony structure, the clinical outcome seemed favorable. If PCN is not contraindicated, it may be a viable treatment option for CR due to FCDH.

Key words: Cervical radiculopathy, cervical foraminal disc herniation, percutaneous cervical nucleoplasty, radiofrequency, clinical outcome, minimally invasive, case series, Macnab criteria

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Cervical radiculopathy (CR) is a pathological condition in which radiating pain in the upper extremity occurs due to compression of the

cervical nerve roots. It is one of the most common conditions in the spine clinic (1,2). Anterior cervical discectomy and fusion (ACDF) or posterior cervical

foraminotomy are conventional methods of treatment and are proven standard surgical techniques that can be implemented if clinical improvement is not achieved even with sufficient conservative treatment for CR (3-5). However, in recent years, there have been several reports on the simple, safe, and excellent therapeutic effectiveness of percutaneous cervical nucleoplasty (PCN) for CR, which is minimally invasive and avoids the risk of complications associated with open surgery (6-8). In PCN, an introducer needle passes through the skin and intervertebral disc in front of the neck under fluoroscopic guidance, through which a radiofrequency (RF) probe reaches the lesion and generates a plasma field to relieve neural compression.

If CR arises purely from a foraminal cervical disc herniation (FCDH), the special anatomical condition of the cervical foraminal space consisting of the uncovertebral joint (UVJ), osteophyte, and facet joint should be considered when performing PCN. This is because this condition can result in significant limitations in performing PCN. However, no author has described in detail the PCN treatment strategies related to this condition. Therefore, this study described the anatomical factors that should be specially considered when performing PCN in patients with radiculopathy caused by FCDH and analyzed the clinical results of treatment with this technique to determine the therapeutic effect.

METHOD

This retrospective study was approved by the institutional review board. Among the patients diagnosed with radiculopathy caused by FCDH at a single institute, 76 patients who underwent PCN for intractable pain that could not be controlled even with medication, physical therapy, or nerve block were identified between June 2018 and May 2021. Preoperative plain radiographs, computed tomography (CT) images, and magnetic resonance images of the cervical spine were reviewed, and only patients with radiculopathy due to FCDH were selected as subjects in this study. Intractable pain cannot be controlled with medication, physical therapy, or block treatment.

Inclusion Criteria

The study included patients with 1) a diagnosis of FCDH at a single level, 2) clearly corresponding radiating pain in the upper extremity, 3) no other lesion with the potential to cause radiating pain in the cervical spine, 4) no lesion in any other body part with the potential to cause arm pain other than the cervical

spine, 5) a follow-up period of at least 3 months after the procedure, 6) complete access to the herniated disc and sufficient plasma application during the PCN, and 7) no acute fracture, infectious disease, or tumor in the cervical spine.

Visual analog scale (VAS) data, preoperatively, 1-week postoperatively, and 3-months postoperatively, were collected from the medical records of the subjects. VAS data at the last follow-up and details on satisfaction with surgery (Macnab criteria) were also collected. Other treatments received after the operation were also evaluated. Patients whose medical records did not contain the information needed for the study or who did not undergo telephone interviews were excluded. To assess how much clinical improvement was achieved via the operation, a paired t-test was performed between the preoperative VAS score levels and each follow-up time point. The percentage of patients with a VAS score of ≤ 3 at each time point was also investigated. Frequency analysis was performed on the degree of satisfaction collected using the Macnab criteria. SPSS version 26 (IBM, Armonk, NY) was used for the statistical analysis. Statistical significance was set at $P < 0.05$.

Description of Implemented PCN Technique

General Process

Preventive antibiotic therapy was administered an hour before the procedure. The patient was placed in the supine position on the surgical table. A soft pillow was placed under the upper back to slightly extend the cervical spine. Sterilization of the skin on the anterior side of the neck was performed with povidone-iodine solution, and sterilized drapes were used to cover the operating area. Using the index and middle fingers of the surgeon's hand, the patient's trachea and esophagus complex were pushed from the opposite side of the lesion toward the lesion, and the skin entry of the introducer needle was made between the index and middle finger. The skin was pushed downward to the spine with the 2 fingers to minimize the distance between the anterior surface of the disc with the lesion and the skin entry. Under fluoroscopic guidance, an introducer needle pierced the skin between the two fingers that pressed the skin and entered the disc. The needle approached the lesion on the contralateral foraminal side. The inner stylet in the introducer needle was removed, the YES DISC-C® (Mcare, Seongnam-si, Gyeonggi-do, South Korea) was passed through the

introducer needle, and the RF probe was used to approach the cervical foramen. The plasma energy around the probe was applied to the target site and nearby area for 5 minutes. Thereafter, the RF probe and introducer needle were removed, and the operation was completed. This method is not notably different from the methods of other surgeons (9-12).

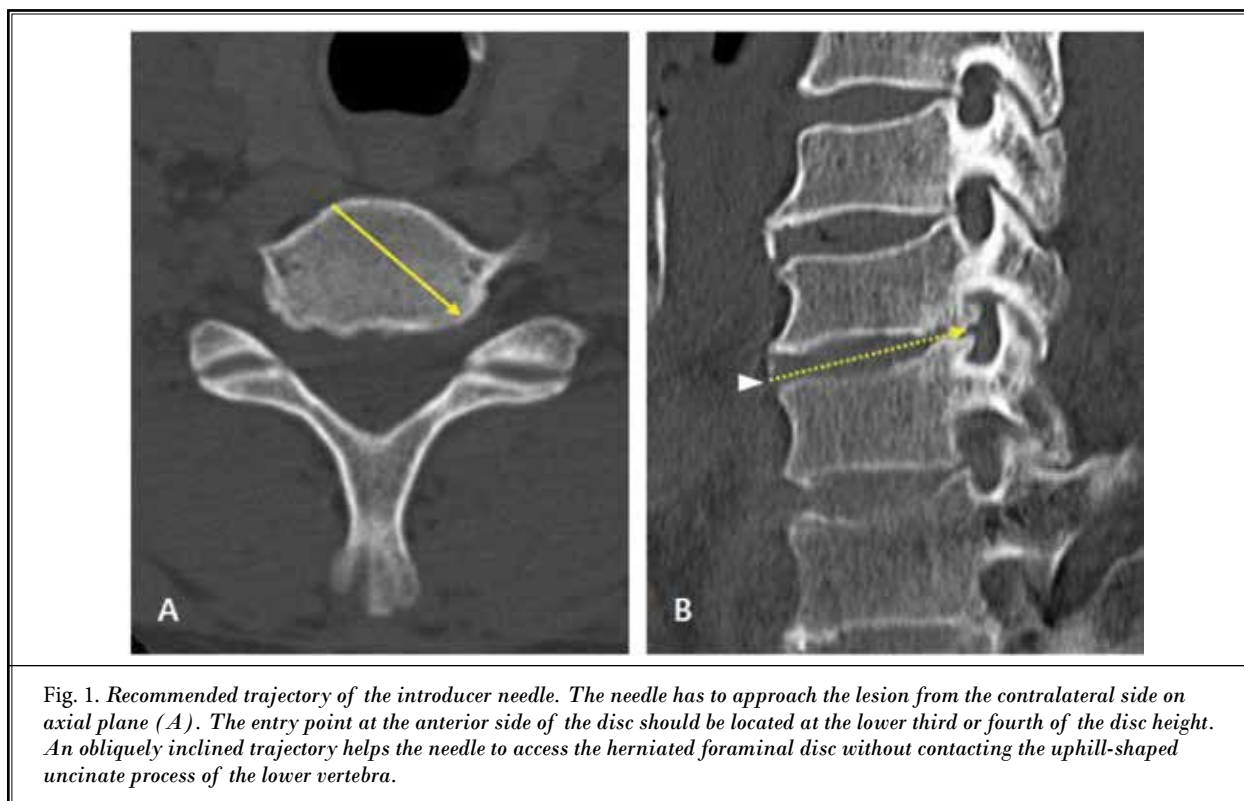
Special Tips for Accessing the Intervertebral Foramen and Prevention of Thermal Injury:

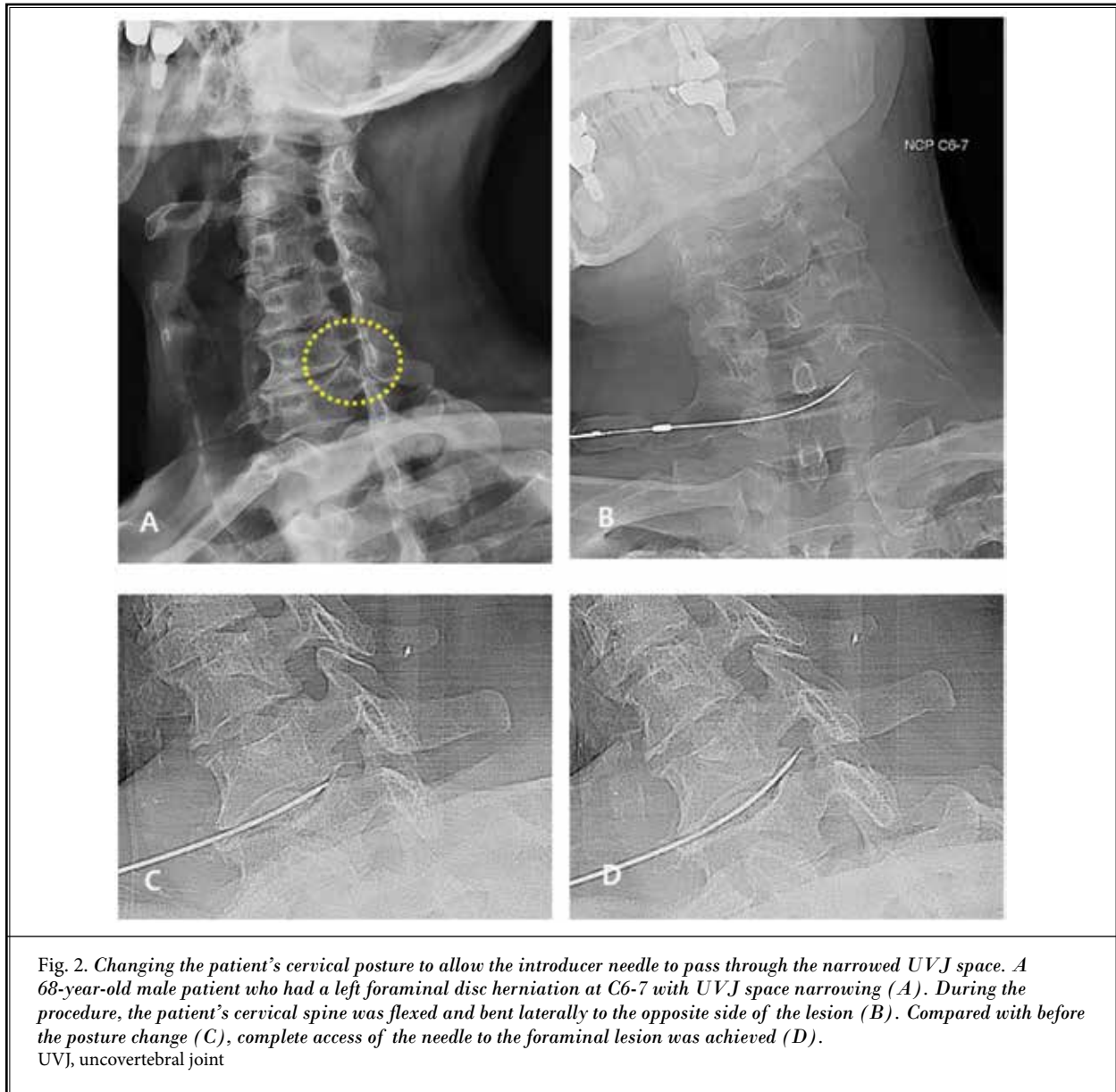
When the introducer needle enters the disc on the anterior side, the entry point should be located at the lower third of the disc height. At the same time, the trajectory of the needle should be obliquely inclined rather than parallel to the disc space (Fig. 1). This is to avoid contact until the needle reaches the herniated foraminal disc from the disc entry to the uphill-shaped uncinete process of the lower vertebrae. Occasionally, for C6-7 in a patient with a short neck, it is not possible to form this inclined trajectory because of the patient's clavicle. In this situation, it may be helpful to intentionally shape the introducer needle to be slightly curved at 1 cm from the distal end.

It is common to encounter cases in which the UVJ

space is narrowed due to severe arthrosis of the uncinete process. At this time, the pillow placed on the upper back should be moved to the head vertex, resulting in a flexed posture of the cervical spine. The patient's neck should be laterally bent to the opposite side of the lesion. This makes the joint space temporarily wider, which can help the needle pass through the narrowed UVJ space (Fig. 2).

The "stepping back technique" described below was used to prevent thermal damage to the nerves by plasma generated at the RF probe. When the plasma energy fired by the RF probe gets close to the nerve root, the patient feels radiating numbness, a burning sensation, or involuntary movement in the affected upper extremity. However, these sensations are temporary, and if the RF delivery is stopped within 1-2 seconds or the RF probe is retracted slightly in the opposite direction of the nerve, it does not cause any damage to the nerve structure. In this case series, plasma energy was applied close to the nerve root first, and the RF probe was gradually retreated as the patient complained. When the disc material was contracted by the plasma, the nerve root became closer to the RF probe by itself, and the patient may have had these sensations again.





After retreating and repeating the application of plasma continuously, the neural decompression effect could be maximized.

RESULTS

Patient Characteristics

Forty-four patients who met the inclusion criteria for this study were selected as subjects. The treated cervical levels were C4-5 in 2 cases (4.5%), C5-6 in 18 cases (40.9%), and C6-7 in 24 cases (54.5%). There were

27 men (62.4%) and 17 women (38.6%). The mean age was 54.5 years (range 31-81), and the average follow-up period after the operation was 15.4 months (range 3.7-30.8) (Table 1).

Clinical Outcome

The mean VAS score for radiating pain due to CR before the procedure was 7.50 ± 1.21 . At 1 week postoperatively, 3 months postoperatively, and the last follow-up, the VAS scores were 4.36 ± 2.46 , 3.20 ± 2.58 , and 2.91 ± 2.74 , respectively. There was a significant im-

provement in the degree of pain compared to before the operation in all the follow-up times ($P < 0.001$ for all) (Table 2). The number of patients (percentage) who had a VAS score of ≤ 3 was 20 (45.5%), 28 (63.6%), and 31 (70.5%) of 44 patients at one week postoperatively, 3 months postoperatively, and at the last follow-up, respectively (Fig. 3). Seventeen (38.6%), 9 (20.5%), 8 (18.2%), and 10 (22.7%) patients out of 44 rated their satisfaction as excellent, good, fair, and poor, respectively, according to the Macnab criteria (Table 3 and Fig. 4). Therefore, 26 patients (59.1%) were considered to have good satisfaction. No patient experienced postoperative complications. One patient underwent ACDF at the same institute because of symptoms that persisted after the operation, and 2 patients stated that they underwent surgery because of persistent pain at another institution.

DISCUSSION

Degenerative spondylosis of the cervical spine commonly occurs in the elderly. It includes intervertebral disc herniation, osteophytosis of the vertebral body, and hypertrophy of the intervertebral joints (13,14). The clinical symptoms related to CR may be caused by mechanical compression of the nerve root in the posterolateral or foraminal space due to the degenerative spondylotic pathology mentioned above.

Posterolateral lesions are not difficult to access, and effective neural decompression can be expected only with PCN if osteophytes are not noticeable. However, pure foraminal lesions are surrounded by hard bony structures such as the pedicles superiorly and inferiorly, UVJ anteriorly, and superior articular process posteriorly. Moreover, there is often accompanying hypertrophy of the UVJ or superior articular process, and this point presents the next 2 main challenges in performing PCN for treating CR.

PCN generates plasma in the RF probe within the disc space, thereby evaporating the nucleus as this energy to remove the herniated nucleus or decrease the intradiscal pressure. The energy originating from this plasma mainly affects the nucleus of the disc but never affects the hard bony structure. Therefore, the decompression effect is expected to be limited only to the herniated disc and not to the hypertrophied UVJ and facet. This is the first challenge with PCN for radiculopathy in FCDH.

The UVJ is a unique structure of the cervical spine that exists as a raised posterolateral aspect of the cervical vertebrae, and it is responsible for stability

Table 1. Patient characteristics.

Characteristics		Value
Age (yrs)		54.5 (31-81)
Gender	Male	27
	Female	17
Level	C4-5	2
	C5-6	18
	C6-7	24
Follow-up period (months)		15.4 (3.7-30.8)

Values for age and follow-up period are expressed as mean (range).

Table 2. Visual analog scale (VAS) for pain preoperatively, at one week and 3 months postoperatively, and at the last follow-up. Comparison of VAS pain score between the preoperative and postoperative values.

VAS score			
	Mean	SD	
Preoperative	7.5	1.21	
1 week postoperatively	4.36	2.46	
3 months postoperatively	3.2	2.58	
Last follow-up	2.91	2.74	
Difference in VAS pain score between the preoperative and different follow-up periods*			
	Mean	SD	P value*
Preoperative vs. 1 week	3.136	2.664	< 0.001
Preoperative vs. 3 months	4.295	2.808	< 0.001
Preoperative vs. Last follow-up	4.591	2.991	< 0.001

*The paired t-test was used to assess statistical significance. VAS = Visual analog scale; SD = Standard deviation.

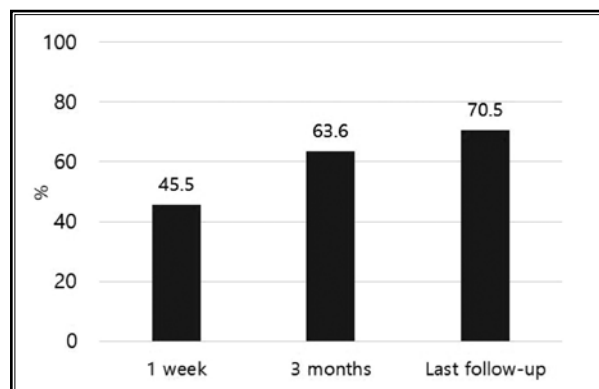


Fig. 3. Percentage of patients whose VAS scores for radicular pain decreased to ≤ 3 at each follow-up time point.

VAS = Visual analog scale

Table 3. Patient satisfaction after PCN according to the Macnab criteria at last follow-up.

	n	%
Excellent	17	38.6
Good	9	20.5
Fair	8	18.2
Poor	10	22.7
Total	44	100

PCN = percutaneous cervical nucleoplasty; n = number

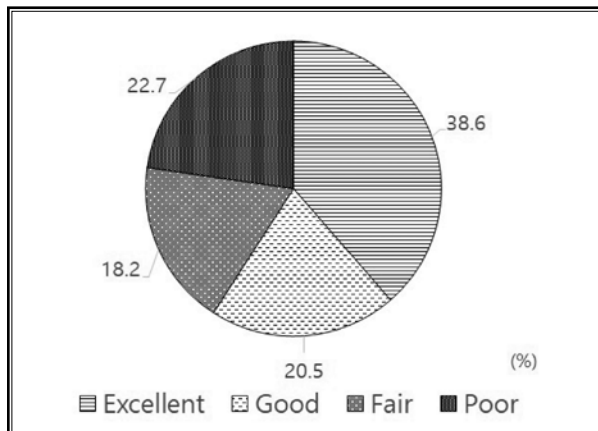


Fig 4. Distribution of patients' satisfaction after PCN according to the Macnab criteria at the last follow-up (percentage).

PCN = Percutaneous cervical nucleoplasty

by limiting the horizontal movement of the cervical vertebrae (15). When a degenerative change occurs in this special structure, the process increases in height, inclines toward the intervertebral foramen, and invades the intervertebral foramen, causing stenosis of the intervertebral foramen (16). Simultaneously, the interarticular space of the UVJ narrows. The change in the shape of the UVJ blocks the approach of the PCN device to the foraminal space, making it notably difficult to implement PCN.

Considering the above, PCN for pure foraminal lesions seems like a contraindication. However, the expected limitation was technically overcome in this study. The joint space narrowed by UVJ degeneration was expanded by changing the cervical spine posture to flexed and laterally bent during the procedure. The trajectory of the introducer needle was formed with an uphill-inclined uncovertebral process in the caudal to cranial direction. The device selected for this procedure was designed to be straight, rigid, and sharp, allowing easy penetration of the narrow UVJ space. The RF tip was shaped like a golf iron club, and when the RF

needle was rotated axially while reaching the RF tip in the foraminal space, plasma energy could be effectively delivered to a wider area. This allowed the surgical instrument to pass through the UVJ, and the approach issue was overcome. We found that applying RF only to disc herniation significantly alleviated the symptoms.

However, PCN is not adaptable to all CR conditions originating from the foraminal region. If arthrosis is markedly severe that the uncovertebral process notably increases in height, or the UVJ space on the oblique cross-section is S-shaped, the RF probe cannot pass through the UVJ and enter the foraminal space. In the case of foraminal stenosis caused by the almost total absence of herniated disc material and hard bony structure in the foraminal region, significant neural decompression can hardly be expected, which means that the effect of nucleoplasty cannot be expected (Fig. 5). Therefore, an oblique image from plain radiography or CT is required to ascertain the widening of the UVJ space (even slightly) during flexion, the contralateral bending of the cervical spine, and the severity of osteophytes before deciding on the PCN.

Many authors have demonstrated excellent clinical results of surgical treatment regarding the improvement of radiating pain. Several studies have shown that posterior cervical foraminotomy is a good surgical option for FCDH (17-19). Another surgical treatment, ACDF, has also been severally reported to have excellent therapeutic results for FCDH (20-22). A meta-analysis on the effect of ACDF for CR due to FCDH reported that when the clinical results of 10 studies, including RCT and OS, were combined, the degree of pain reduction on VAS was about 5.54 ± 1.81 (23). This value indicates a larger mean and less variance of pain reduction than the results of our study, suggesting that, currently, PCN cannot replace existing conventional surgical modalities.

However, major complications such as hematoma accumulation, Horner syndrome, swallowing difficulty, vocal cord palsy, dural injury, implant-related complications, pseudoarthrosis, and esophageal injury have also been reported as potential disadvantages of these surgical treatments (5,24-26), but there were no complications in this case series. Additionally, there is no need for general anesthesia, expensive instruments like artificial discs, and graft augmentation such as a demineralized bone matrix. The short hospitalization period, and the fact that it is a minimally invasive method enables patients to return to economic activities faster, which is a great benefit to patients in terms of cost.

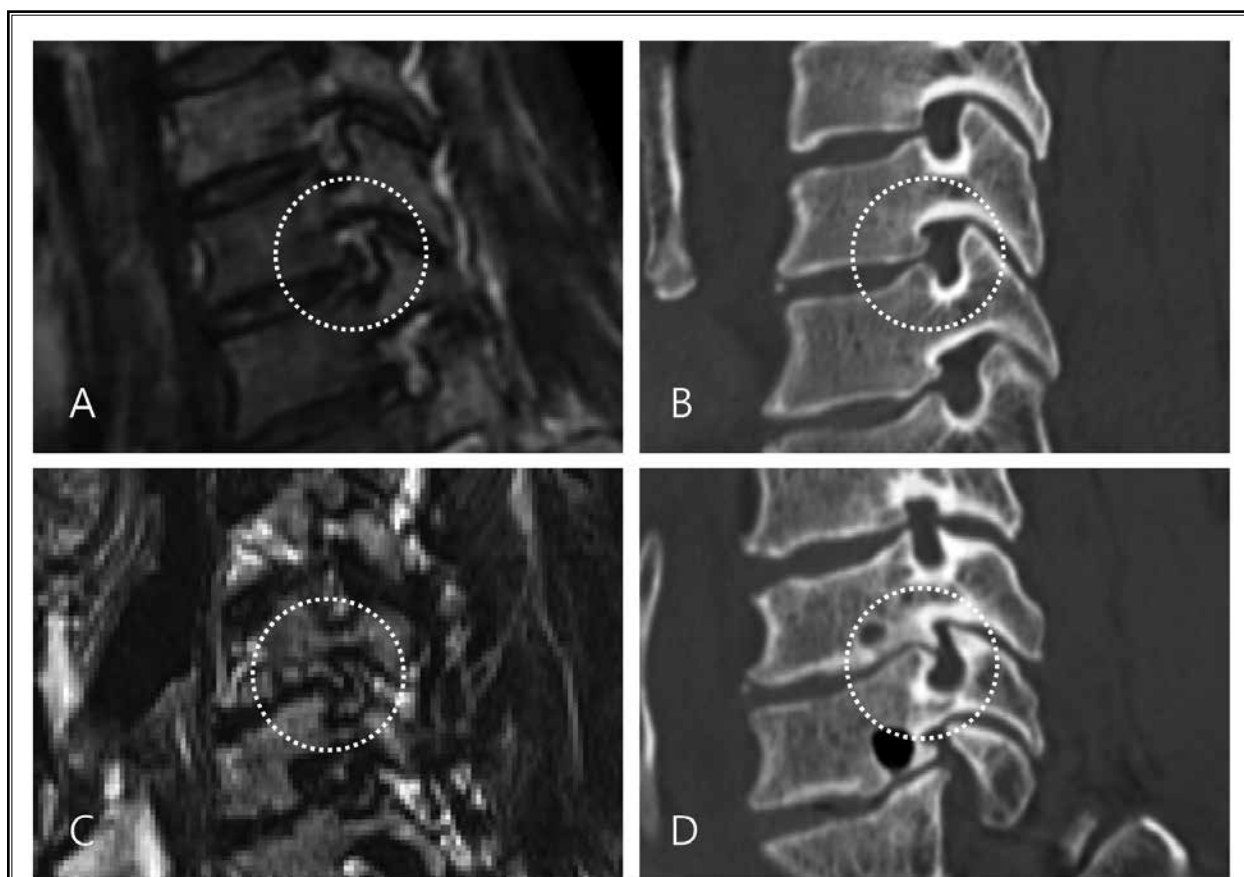


Fig 5. The oblique plane of cervical MRI of a 52-year-old male patient showed a left foraminal disc herniation at C6-7 (A). On the CT scan, the bony spur was not severe due to slight degeneration of UVJ in the same area, and it showed an open lip shape (B). This is an appropriate indication for performing PCN. However, the oblique planes of a cervical MRI and CT scan of a 62-year-old male patient showed right foraminal stenosis at C5-6 with a close lip-shaped bony spur due to severe degeneration of UVJ. Note that the UVJ space is extremely narrow and deformed into an S-shape (C,D). Thus, access of the RF probe is almost impossible. This indicates that caution should be used when deciding on the implementation of PCN. MRI, magnetic resonance image; CT, computed tomography; UVJ, uncovertebral joint; PCN, percutaneous cervical nucleoplasty; RF, radiofrequency.

The efficacy of PCN for cervical disc herniation has been reported by many authors, and this study investigated whether it is particularly effective for FCDH. The clinical outcome was favorable.

Limitations

The limitations of this study include its retrospective nature, the small number of patients recruited from a single center, uncertainty of long-term outcome due to variability in the follow-up period, and the absence of

a control group for comparisons regarding pain relief. Thus, further studies, such as prospective case-control or randomized studies, are needed to verify our results.

CONCLUSION

In conclusion, CR from FCDH may have limitations in treating PCN due to the surrounding bony structure. Our findings indicate that if PCN is not contraindicated, it may be a viable treatment option for CR due to FCDH.

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