Journal of Pain Research

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Which Kind of Prognosis is Better in the Treatment of Cervical and Lumbar Disc Herniation with Coblation Nucleoplasty?

Rongyi Zhang[1,*], Shi Chen[2,*], Liuhu Han[1,3], Bingbing Xu[1], Yuyu Guo[1], Likui Wang[1]

[1]Department of Pain Medicine, the First Affiliated Hospital of AnHui Medical University, HeFei, People's Republic of China; [2]Department of Pain Medicine, Huazhong University of Science and Technology Union Shenzhen Hospital, ShenZhen, People's Republic of China; [3]Anhui Medical University, HeFei, People's Republic of China

*These authors contributed equally to this work

Correspondence: Likui Wang, Department of Pain Medicine, the First Affiliated Hospital of AnHui Medical University, Shushan District, Hefei City, Anhui Province, People's Republic of China, Tel +86 13705690702, Email wlk9560@163.com

Introduction: Coblation nucleoplasty is a minimally invasive procedure developed for the treatment of symptomatic disc herniation.
Methods: We evaluated 118 cases of cervical and lumbar intervertebral discs treated with coblation nucleoplasty. The clinical results were assessed using the visual analogue scale (VAS), modified MacNab criteria, and efficacy. Complications and the re-surgery rate were also evaluated. The procedure was carried out under CT guidance, and the patients were followed up for 1 day, 1 month, 6 months, and 5 years postoperative.
Results: At the 5-year follow-up, the VAS score in the cervical and lumbar groups significantly decreased from 6.20 to 2.43 and 6.11 to 3.29, respectively. While MacNab scores were indistinguishable at the 6-month follow-up, they differed significantly between the cervical (58.2%) and lumbar (34.9%) groups at the 5-year follow-up. At the 5-year follow-up, 6 patients in the cervical group and 11 in the lumbar group underwent conventional operation. The efficacy of coblation nucleoplasty at the 5-year follow-up was higher in cervical group (81.82%) compared with lumbar group (61.90%).
Conclusion: The results of this study suggest that coblation nucleoplasty is a safe and effective treatment option for patients with cervical and lumbar disc herniation. The long-term benefits of this procedure were more pronounced in patients with cervical disc herniation.
Clinical Trial Registration: The trial was registered on ClinicalTrials.gov (ChiCTR2400089145).
Keywords: coblation nucleoplasty, lumbar disc herniation, cervical disc herniation, pain

Introduction

Intervertebral discs are complex joints that consist of fibrous cartilage. Due to their location, they are prone to injury, which can lead to a cascade of painful sequelae, including internal disc disruption, disc degeneration, and disc herniation.[1–4] Disc herniation is the most common disc disease. According to the anatomical location, disc herniation classifies into cervical and lumbar disc herniation (CDH and LDH), which generally leads to neck or back pain and sciatica. Cervical vertebrae are more mobile and have narrower spinal canal and neural foramen than the lumbar ones. The different anatomical structures of cervical and lumbar disc may affect the therapeutic efficacy of disc herniation.[5]

Since symptoms of disc herniation may subside with time, conservative therapy is recommended as the first-line treatment.[6] Physical therapy and local analgesic drug injection are commonly used for this procedure. However, there is a lack of high-quality evidence to define the effectiveness of conservative therapy.[6] Surgical treatment is recommended if conservative care fails. Surgical techniques, such as interbody fusion, entail long-term risks, including stress overload and chronic damage to the neighboring discs, and other complications like infection, bleeding, and risks related to

Received: 11 October 2024
Accepted: 27 January 2025
Published: 20 February 2025

general anesthesia.[7–10] These risks have led to the development of several minimally invasive approaches to the treatment of cervical/lumbar disc herniation.

Coblation nucleoplasty (CN) was initially used to treat symptomatic contained herniation in the spine.[11] This procedure was reported to be safe and was associated with acceptable clinical success.[12,13] It is conducted by using an ablation and coagulation-based device, which performed disc decompression via a plasma-mediated process. The plasma-mediated devices use radiofrequency energy to excite electrolytes in conductive medium, such as normal saline, resulting in the generation of plasma. The plasma consists of charged particles that have sufficient energy to break molecular bonds and remove or dissolve soft tissue through chemical and thermal effects at temperatures ranging from 40 to 70 degrees Celsius.[14,15] The devices have different settings to control the plasma formation and the tissue interaction. The plasma-forming settings are used for tissue ablation, while the non-plasma-forming settings are used for tissue coagulation.

Coblation nucleoplasty has shown effectiveness in both cervical and lumbar herniation.[16,17] However, the comparative long-term clinical outcomes of this technique for the two spinal regions remain unclear. In this study, we conducted a five-year retrospective follow-up study to evaluate the clinical outcomes of patients with cervical and lumbar disc herniation who received coblation nucleoplasty.

Methods

The research was approved by the Ethics Committee of the First Affiliated Hospital of Anhui Medical University (Ethical Application Reference: PJ 2024–02-52) and was registered at the Clinical Trial Registry (ChiCTR2400089145). This study was conducted in accordance with the Declaration of Helsinki and clinical practice guidelines. All patients had previously signed informed consent for the procedure. Consecutive patients who suffered from CDH or LDH between May 2016 and June 2017 were included in this single-center retrospective cohort study.

Inclusion Criteria

(1) The diagnosis of a single segmental cervical/lumbar disc herniation was confirmed by clinical manifestations and CT/MRI examination. (CDH: Pain in the shoulder and neck region or radicular upper limb pain; LDH: Low back pain or radicular lower limb pain) (2) The patients had failed to respond to previous medical or physical treatment for at least three months. (3) There was no evidence of severe spinal cord compression or obvious changes in spinal cord signals. (4) The protruded nucleus pulposus was enclosed by annulus fibrosus or posterior longitudinal ligament and did not form free fragments in the spinal canal.

Exclusion Criteria

The study excluded patients who had a history of cervical/lumbar surgery or significant spinal stenosis, motor weakness, fracture, cervical or lumbar instability, suspected infection tumor or spondylolisthesis. Patients who had more than two symptomatic discs were also excluded.

Surgical Procedure

Patients with CDH lay in supine position on the CT scan bed, with vein administration and ECG monitoring. Patients with LDH were in prone position. CN was performed after local anesthesia. A 17-gauge needle was advanced slowly according to the preoperative design approach to the position of the protruding target with the guidance of CT. After injecting 0.5 mL normal saline, the Spine wand was inserted into the disc through the needle after being well tested. The proximal and distal limits for intradiscal movement of the wand were identified. Two channels for patients with CDH and three channels for patients with LDH were used. Every channel was created by advancement of the wand in ablation mode and by its retraction in coagulation mode for 10–15 seconds. The ablation pedal was gently touched at each gear and released quickly. The operation should be stopped immediately, and the depth of the wand should be adjusted when patients felt pain in the neck, arms or legs. The procedure could not continue until patients felt painless (Figures 1, and 2). After the surgery, the wand and needle were withdrawn carefully. All patients were required to lie in bed for six hours after treatment. A neck or lumbar collar support was essential when patients moved.

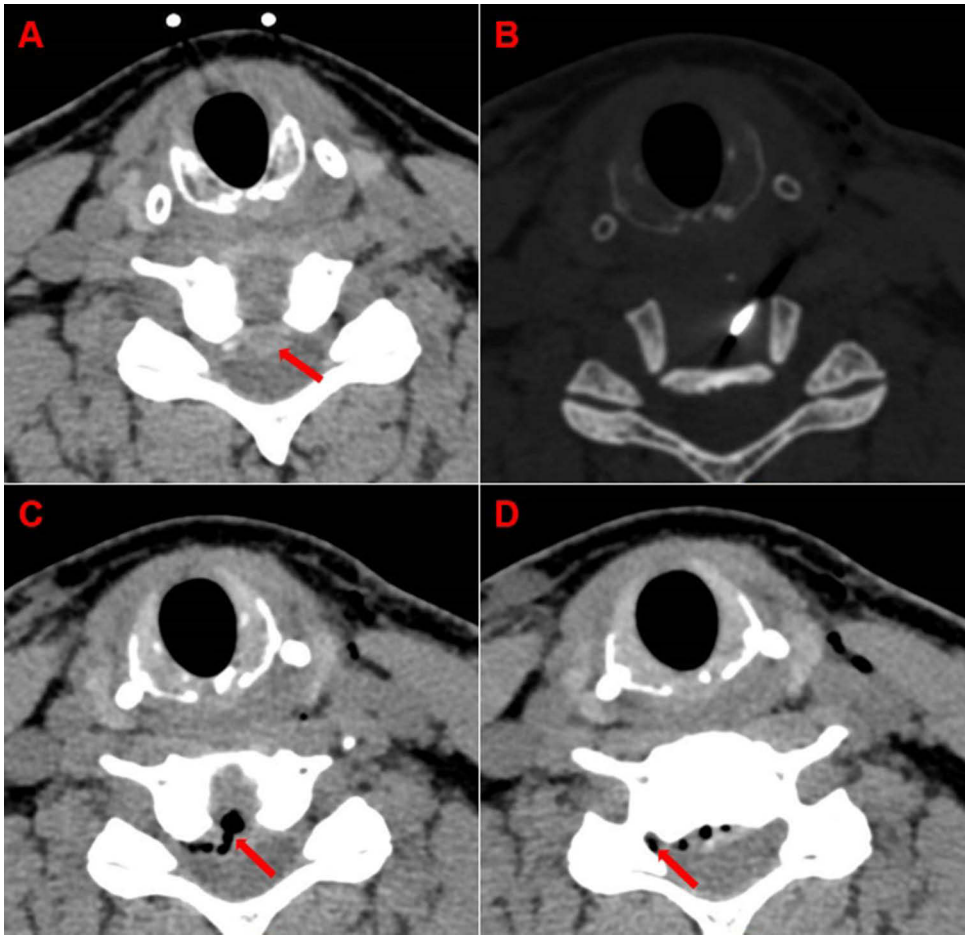

Figure 1 Preoperative localization, intraoperative manipulation and postoperative decompression in C group.
Notes: (**A**) preoperative localization, red arrow: protrusion; (**B**) Intraoperative puncture to the target; (**C and D**), red arrow: decompression of spinal canal, intervertebral disc and lateral recess.

Clinical Outcomes Assessment

We used the Visual Analogue Scale (VAS) and the modified MacNab criteria to assess the pain intensity and the clinical outcomes of the patients who underwent CN. Prior to surgery as well as one day, one month, six months, and five years postoperative, the VAS score was evaluated. VAS scores range from 0 (no pain) to 10 (most severe pain).[18,19] The modified MacNab criteria was performed at six months and five years postoperative and classified into four categories: excellent (no pain, no restriction of activity), good (occasional back or leg pain, sufficient relief for normal activity), fair (improved functional capacity but handicapped by intermittent pain), and poor (no improvement or worse than before surgery).[20] The efficacy of the surgery was evaluated according to VAS scores. The VAS score is less than 4, indicating a good clinical outcome, otherwise, meaning a poor outcome.

Statistical Analysis

The quantitative data were presented as the mean ± standard deviation (SD). For VAS scores analysis, repeated one-way or two-way analysis of variance (ANOVA) followed by Tukey post-hoc tests were used. The patients without complete VAS scores due to re-surgery were excluded. The MacNab criteria and effective rate were analyzed using chi-square tests. Two-tailed statistical significance tests were used, and $P<0.05$ was considered statistically significant.

https://doi.org/10.2147/JPR.S500287

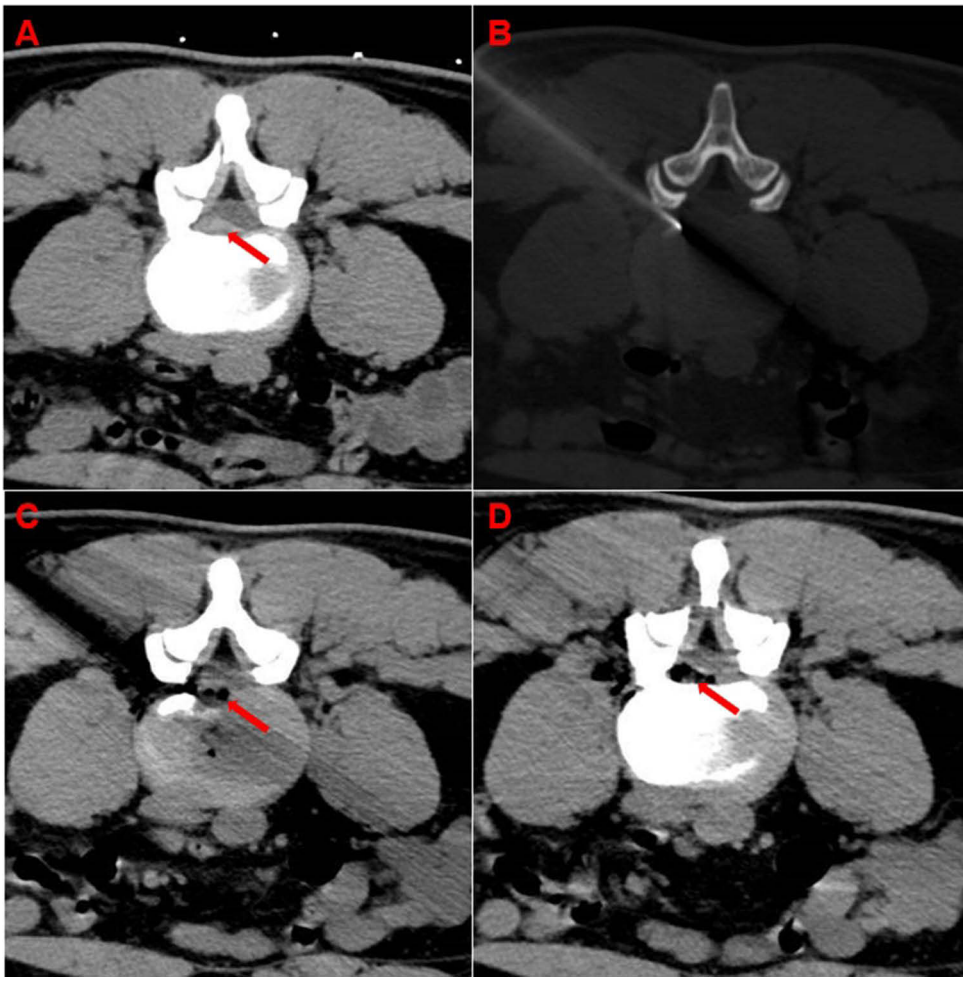

Figure 2 Preoperative localization, intraoperative manipulation and postoperative decompression in L group.
Notes: (**A**) preoperative localization, red arrow: protrusion; (**B**) intraoperative puncture to the target; (**C and D**), red arrow: decompression of spinal canal, intervertebral disc and lateral recess.

Results

Patients

From May 2016 to June 2017, 118 patients suffered from CDH or LDH were selected from the pain department of our hospital. Figure 3 gives a graphical overview of the follow-up of the enrolled patients. This study included 55 patients with cervical disc herniation (CDH group) and 63 patients with lumbar disc herniation (LDH group). There was no significant difference of gender, age and preoperative VAS scores between two groups. The most common segments for cervical disc herniation were C4/5 (5.45%), C5/6 (52.73%) and C6/7 (41.82%), whereas the most common segments for lumbar disc herniation were L3/4 (6.35%), L4/5 (50.79%) and L5/S1 (42.86%). After CN, six patients (10.91%) in CDH group and 11 patients (17.46%) in LDH group suffered second decompression surgery during 5-years follow-up (Figure 3). The occurrence of re-surgery was lower in the CDH group. The detail information of patients was summarized in Table 1.

Coblation Nucleoplasty Shows Better Clinical Outcomes in Cervical Disc Herniation

The clinical outcome of CN for CDH and LDH was evaluated by VAS before and after the operation. The VAS score was significantly reduced at 1 day, 1 month, 6 months and 5 years postoperative in both CDH and LDH group (Table 2, Figure 4). However, the VAS score increased at 5 years compared with 6 months after surgery in the LDH group rather than the CDH group, suggesting that the CN had a better long-term performance in CDH. It was supported by that the

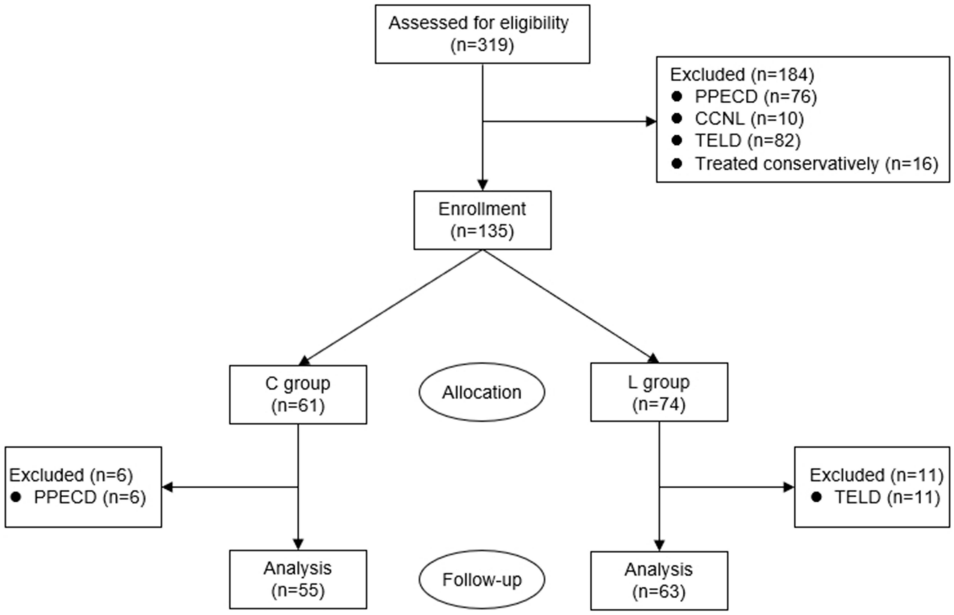

Figure 3 Graphical overview of the study procedures and the treatment protocols performed.
Abbreviations: PPECD, posterior percutaneous endoscopic cervical discectomy; CCNL, collagenase chemonucleolysis; TELD, transforaminal endoscopic lumbar discectomy.

VAS score did not differ significantly between CDH and LDH group at preoperative and 1 day, 1 month, 6 months postoperative but was considerably increased in the LDH group at 5 years postoperative (Table 2, Figure 4).

According to the modified MacNab criteria, the percentage of patients with excellent and good outcome was 70.91% at 6 months and 58.18% at 5 years postoperative in the CDH group, whereas it was 55.56% at 6 months and 34.92% at 5 years postoperative in the LDH group (Table 3). When compared with the LDH group, the clinical result in the CDH group was slightly better at 6 months (P = 0.091) postoperative and considerably better at 5 years postoperative (P = 0.016). We then compared the efficacy of operation between CDH and LDH. There was no significant difference at 6 months (89.09% in CDH group and 84.13% in LDH group, Table 4). Of note, the efficacy of operation was remarkable higher at 5 years postoperative in CDH group (81.82% in CDH group and 61.90% in LDH group, P = 0.024, Table 4).

Table 1 Baseline Demographic Information of Patients

Characteristics	C group (n=55)	L group (n=63)	*P* value
Age, yr	52.36±13.13	55.95±13.72	0.151
Sex			0.563
Male, %	25 (45.45%)	32 (50.79%)	
Female, %	30 (54.55%)	31 (49.21%)	
Surgical segment			
C4/5, %	3 (5.45%)		
C5/6, %	29 (52.73%)		
C6/7, %	23 (41.82%)		
L3/4, %		4 (6.35%)	
L4/5, %		32 (50.79%)	
L5/S1, %		27 (42.86%)	
Postoperative duration of hospitalization, days	3.98±1.68	4.27±1.79	0.372

Abbreviations: C, cervical; L, lumbar; S, sacral.

https://doi.org/10.2147/JPR.S500287

Table 2 Comparison of Visual Analogue Scale Between the Two Groups

Time Point	C group	L group	*P* value
Preoperative	6.20±1.19	6.11±0.97	0.656
1 Days PO	2.62±1.19[a]	3.19±1.32[b]	0.015
1 Months PO	2.27±1.06[a]	2.78±1.11[b]	0.013
6 Months PO	2.15±1.16[a]	2.50±1.32[b]	0.127
5 Tears PO	2.38±1.28[a]	3.06±1.49[b]	0.009
P value	<0.001	<0.001	

Note: compared with Preoperative, [a]$P<0.05$, [b]$P<0.05$; C, cervical; L, lumbar; PO, postoperative.

Above findings suggests that CN is an effective therapeutic strategy for both CDH and LDH, with superior long-term performance for CDH patients.

Discussion

Cervical or lumbar discogenic pain affects more than 50% of patients, which severely impair quality of life and impose a huge socioeconomic burden.[5,21,22] Various treatments are available for discogenic pain, such as medication, physical therapy, nerve block, behavior management, psychotherapy, minimally invasive interventions, and fusion or non-fusion surgery.[22–26] However, these treatments have obvious limitations and complications, and do not always yield satisfactory results.[27]

In CDH and LDH, the discs in the spine bulge or protrude from their normal positions, which can cause pain or numbness in the corresponding region. Disc herniation is primarily occurring at levels of C6/7, L4/5 and L5/S1.[28] In consistent with this finding, our results showed that CDH was mostly observed at the levels of C5/6 (52.73%) and C6/7

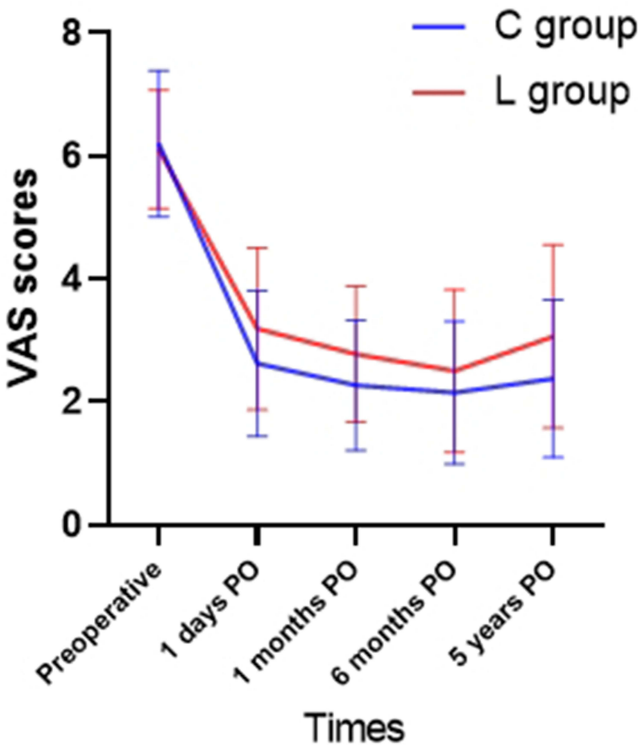

Figure 4 Trends in VAS between the two groups.
Abbreviations: C, cervical; L, lumbar; PO, postoperative.

Table 3 Outcomes as Measured by Modified MacNab Criteria

Parameters	C group (6M / 5Y)	L group (6M / 5Y)	*P* value
Excellent	13 (23.64%)/9 (16.36%)	12 (19.05%)/7 (11.11%)	0.091/0.016
Good	26 (47.27%)/23 (41.82%)	23 (36.51%)/15 (23.81%)	
Fair	10(18.18%)/13 (23.64%)	18 (28.57%)/17 (26.98%)	
Poor	6 (10.91%)/10 (18.18%)	10 (15.87%)/24 (38.10%)	

Abbreviations: C, cervical; L, lumbar.

Table 4 Compared the Efficacy of Operation Between Two Groups

Parameters	C group (6M / 5Y)	L group (6M / 5Y)	*P* value
Efficient	49 (89.09%)/45 (81.82%)	53 (84.13%)/39 (61.90%)	0.781/0.024
Inefficiency	6 (10.91%)/10 (18.18%)	10 (15.87%)/24 (38.10%)	

Abbreviations: C, cervical; L, lumbar.

(41.82%), whereas LDH was mainly detected at the levels of L4/5 (50.79%) and L5/S1 (42.86%). Conservative treatment is the first choice for most patients with disc herniation, including physical therapy, anti-inflammatory and epidural steroid injection.[29,30] Decompression surgery may be considered when the conservative treatment fails to improve the condition, including discectomy for radiculopathy from herniated intervertebral disc, decompressive laminectomy for symptomatic spinal stenosis with or without degenerative spondylolisthesis, and fusion for nonradicular pain with degenerative changes.[22,31,32]

Microdiscectomy and interbody fusion can effectively relieve pain in the short term; however, the long-term outcomes are less satisfactory.[33–36] Nucleoplasty has been proven to provide simple and efficient disc decompression in cervical and lumbar disc herniations cases by creating a controlled and localized ablation that minimizes damage to the surrounding healthy tissue.[37] Unlike fusion procedures, CN does not involve the removal of disc material or fusion of adjacent vertebrae, which preserves spinal stability and potentially reduces the risk of complications associated with fusion surgery.[37,38]

In this study, we evaluated the long-term efficacy (up to five years) of CN in cervical disc herniation (CDH) and lumbar disc herniation (LDH). Our results demonstrated that CN is a safe and efficient therapeutic strategy in treating both CDH and LDH patients. Although the VAS score demonstrated time-dependent decreasing in the LDH group within six months postoperative, the VAS score increased at five years postoperative, indicating that the CN exhibits a short-term benefit in LDH patients. It is worth noting that the VAS score was significantly decreased in CDH patients and kept stable even at five years postoperative. Furthermore, the therapeutic effectiveness in CDH was also better than LDH in the long-term follow-up (five years). This findings were consistent with previous study that percutaneous plasma disc coagulation therapy has better performance in cervical disc herniation patients.[5]

In addition, in order to achieve better curative effect of CN in LDH patients, surgeons often adopt combined treatment. For example, after ablation of a portion of the nucleus pulposus, the puncture needle is withdrawn to the intervertebral foramen, and then ozone and anti-inflammatory analgesic solution (mixture of lidocaine and compound betamethasone) are injected. In contrast, patients with CDH were treated with a single CN.

The intervertebral discs in the cervical and lumbar spine are subjected to high levels of pressure and tension due to flexion/extension and torsion movements, which increase their vulnerability to damage.[39] Although the cross-sectional areas and thickness of lumbar discs are greater than cervical discs, the intervertebral nerves in the lumbar region are vulnerable to compression and damage due to the combined effects of axial loading, torsional stress and flexion-extension movements.[39,40] Those extra pressure in the lumbar intervertebral discs may affect the long-term therapeutic effectiveness for lumbar disc herniation. In addition, we noted that the decrease in VAS score was more pronounced in patients with CDH than LDH at all time points after surgery. This may be attributed to that the volume of the cervical vertebral canal is smaller than the lumbar vertebral canal, and the degree of pressure release in the cervical vertebral

canal after surgery is greater than that in the lumbar vertebral canal, which further indicates that CN is more suitable for patients with CDH.

In conclusion, the current study provides evidence supporting the safety and effectiveness of CN as a therapeutic strategy for patients with cervical and lumbar disc herniation. Furthermore, the long-term benefits of this procedure appear to be more significant in patients with CDH compared to those with LDH. These findings contribute to our understanding of CN for treating disc herniation as a valuable minimally invasive intervention, especially for CDH. Of note, in the present study, we only enrolled 118 patients, and large-sample, multicenter studies are needed to validate these results and refine the selection criteria for optimal patient outcomes.

Conclusion

In summary, the treatment of cervical and lumbar disc herniation with coblation nucleoplasty is effective and safe, and the long-term benefits of this operation are more obvious in patients with cervical disc herniation.

Data Sharing Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical Approval

The study was approved by the Ethics Committee of the First Affiliated Hospital of Anhui Medical University (Ethical Application Reference: PJ 2024-02-52 Anhui, China) and was registered at the Clinical Trial Registry (ChiCTR2400089145). The research was conducted in accordance with the Declaration of Helsinki, and all patients provided informed consent.

Acknowledgments

We thank all those who supported and participated in the study, including our staff, the patients and their family members.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This research was supported by the Research Fund of Anhui Institute of Translational Medicine (No.2023zhyx-C45) and Anhui Provincial Natural Science Foundation (No.1808085MH310).

Disclosure

The authors declare no conflicts of interest in this work.

References

1. Mirza SK, White AA 3rd. Anatomy of intervertebral disc and pathophysiology of herniated disc disease. *J Clin Laser Med Surg*. 1995;13(3):131–142. doi:10.1089/clm.1995.13.131
2. Manchikanti L, Singh V, Pampati V, et al. Evaluation of the relative contributions of various structures in chronic low back pain. *Pain Physician*. 2001;4(4):308–316. doi:10.36076/ppj.2001/4/308
3. Guiot BH, Fessler RG. Molecular biology of degenerative disc disease. *Neurosurgery*. 2000;47(5):1034–1040. doi:10.1097/00006123-200011000-00003
4. Schwarzer AC, Aprill CN, Derby R, Fortin J, Kine G, Bogduk N. The prevalence and clinical features of internal disc disruption in patients with chronic low back pain. *Spine*. 1995;20(17):1878–1883. doi:10.1097/00007632-199509000-00007

5. Yucetas SC, Gezgin I, Yildirim CH, Ehi Y, Kaya M. Evaluation of long-term clinical results of percutaneous plasma disk coagulation treatment in lumbar and cervical disk herniation. *Neurosurg Quarterly*. 2016;26(3):219–224. doi:10.1097/WNQ.0000000000000178
6. Sakai D. The essence of clinical practice guidelines for lumbar disc herniation, 2021: 4. *Treatment Spine Surg Relat Res*. 2022;6(4):329–332. doi:10.22603/ssrr.2022-0045
7. Bonaldi G, Minonzio G, Belloni G, et al. Percutaneous cervical diskectomy: preliminary experience. *Neuroradiology*. 1994;36(6):483–486. doi:10.1007/BF00593690
8. Harada J, Dohi M, Fukuda K, Nakazaki H, Koyama T, Abe T. CT-guided percutaneous laser disk decompression (PLDD) for cervical disk hernia. *Radiat Med*. 2001;19(5):263–266.
9. Hoogland T, Scheckenbach C. Low-dose chemonucleolysis combined with percutaneous nucleotomy in herniated cervical disks. *J Spinal Disord*. 1995;8(3):228–232. doi:10.1097/00002517-199506000-00009
10. Wilson LA, Fiasconaro M, Liu J, et al. Trends in comorbidities and complications among patients undergoing inpatient spine surgery. *Spine*. 2020;45(18):1299–1308. doi:10.1097/BRS.0000000000003280
11. Bonaldi G, Cianfoni A. *Minimally Invasive Treatment of Herniated Discs: How to Remove the Disc With Physical Tools, in the Disc and Degenerative Disc Disease: Remove or Regenerate?* Manfrè L, Van Goethem J, Editors.. Cham: Springer International Publishing; 2020:185–217.
12. Li S, Chen R, Chen Y, et al. 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. *Pain Physician*. 2019;22(3):E205–E214.
13. Lee JH, Lee SH. Clinical efficacy of percutaneous endoscopic lumbar annuloplasty and nucleoplasty for treatment of patients with discogenic low back pain. *Pain Med*. 2016;17(4):650–657. doi:10.1093/pm/pnv120
14. Kuelling FA, Foley KT, Liu JJ, et al. The anabolic effect of plasma-mediated ablation on the intervertebral disc: stimulation of proteoglycan and interleukin-8 production. *Spine J*. 2014;14(10):2479–2487. doi:10.1016/j.spinee.2014.04.010
15. Marangi GF, Pallara T, Lamberti D, et al. An electrical plasma dissection tool for surgical treatment of chronic ulcers: results of a prospective randomised trial. *Int Wound J*. 2018;15(5):717–721. doi:10.1111/iwj.12915
16. Chen YC, Lee SH, Saenz Y, Lehman NL. Histologic findings of disc, end plate and neural elements after coblation of nucleus pulposus: an experimental nucleoplasty study. *Spine J*. 2003;3(6):466–470. doi:10.1016/S1529-9430(03)00143-8
17. Chen YC, Lee SH, Chen D. Intradiscal pressure study of percutaneous disc decompression with nucleoplasty in human cadavers. *Spine (Phila Pa 1976)*. 2003;28(7):661–665. doi:10.1097/01.BRS.0000051920.45671.88
18. Chiarotto A, Maxwell LJ, Ostelo RW, Boers M, Tugwell P, Terwee CB. Measurement properties of visual analogue scale, numeric rating scale, and pain severity subscale of the brief pain inventory in patients with low back pain: a systematic review. *J Pain*. 2019;20(3):245–263. doi:10.1016/j.jpain.2018.07.009
19. Revill SI, Robinson JO, Rosen M, Hogg MI. The reliability of a linear analogue for evaluating pain. *Anaesthesia*. 1976;31(9):1191–1198. doi:10.1111/j.1365-2044.1976.tb11971.x
20. Macnab I. Negative disc exploration. An analysis of the causes of nerve-root involvement in sixty-eight patients. *J Bone Joint Surg Am*. 1971;53(5):891–903. doi:10.2106/00004623-197153050-00004
21. Verrills P, Nowesenitz G, Barnard A. Prevalence and characteristics of discogenic pain in tertiary practice: 223 consecutive cases utilizing lumbar discography. *Pain Med*. 2015;16(8):1490–1499. doi:10.1111/pme.12809
22. Katz JN, Zimmerman ZE, Mass H, Makhni MC. Diagnosis and management of lumbar spinal stenosis: a review. *JAMA*. 2022;327(17):1688–1699. doi:10.1001/jama.2022.5921
23. Mixter WJ. Rupture of the intervertebral disk; a short history of this evolution as a syndrome of importance to the surgeon. *J Am Med Assoc*. 1949;140(3):278–282. doi:10.1001/jama.1949.02900380018005
24. Schneider BJ, Hunt C, Conger A, et al. The effectiveness of intradiscal biologic treatments for discogenic low back pain: a systematic review. *Spine J*. 2022;22(2):226–237. doi:10.1016/j.spinee.2021.07.015
25. Amjad F, Mohseni-Bandpei MA, Amir Gilani S, Ahmad A, Hanif A. Effects of non-surgical decompression therapy in addition to routine physical therapy on pain, range of motion, endurance, functional disability and quality of life versus routine physical therapy alone in patients with lumbar radiculopathy; a randomized controlled trial. *BMC Musculoskelet Disord*. 2022;23(1):255. doi:10.1186/s12891-022-05196-x
26. Zhao L, Manchikanti L, David Kaye A, Abd-Elsayed A. Treatment of discogenic low back pain: current treatment strategies and future options-a literature review. *Curr Pain Headache Rep*. 2019;23(11):86. doi:10.1007/s11916-019-0821-x
27. Zaina F, Tomkins-Lane C, Carragee E, Negrini S. Surgical versus non-surgical treatment for lumbar spinal stenosis. *Cochrane Database Syst Rev*. 2016;2016(1):CD010264. doi:10.1002/14651858.CD010264.pub2
28. Dydyk AM, Ngnitewe Massa R, Mesfin FB, *Herniation D*. StatPearls Publishing; 2023.
29. Woods BI, Hilibrand AS. Cervical radiculopathy: epidemiology, etiology, diagnosis, and treatment. *J Spinal Disord Tech*. 2015;28(5):E251–9. doi:10.1097/BSD.0000000000000284
30. Pengfei Y, Mao F, Chen J, et al. Characteristics and mechanisms of resorption in lumbar disc herniation. *Arthritis Res Ther*. 2022;24(1):205. doi:10.1186/s13075-022-02894-8
31. Suzuki A, Nakamura H. Microendoscopic lumbar posterior decompression surgery for lumbar spinal stenosis: literature review. *Medicina (Kaunas)*. 2022;58(3). doi:10.3390/medicina58030384
32. Scott Kreiner D, Hwang SW, Easa JE, et al. An evidence-based clinical guideline for the diagnosis and treatment of lumbar disc herniation with radiculopathy. *Spine J*. 2014;14(1):180–191. doi:10.1016/j.spinee.2013.08.003
33. Yang Y, Yan X, Li W, Sun W, Wang K. Long-term clinical outcomes and pain assessment after posterior lumbar interbody fusion for recurrent lumbar disc herniation. *Orthop Surg*. 2020;12(3):907–916. doi:10.1111/os.12706
34. Yang LH, Liu W, Li J, et al. Lumbar decompression and lumbar interbody fusion in the treatment of lumbar spinal stenosis: a systematic review and meta-analysis. *Medicine*. 2020;99(27):e20323. doi:10.1097/MD.0000000000020323
35. Xu W, Ran B, Luo W, Li Z, Gu R. Is lumbar fusion necessary for chronic low back pain associated with degenerative disc disease? A meta-analysis. *World Neurosurg*. 2020; 146:298–306. doi:10.1016/j.wneu.2020.11.121
36. Singh V, Piryani C, Liao K, Nieschulz S. Percutaneous disc decompression using coblation (nucleoplasty) in the treatment of chronic discogenic pain. *Pain Physician*. 2002;5(3):250–259. doi:10.36076/ppj.2002/5/250

37. Maximilian eichen P, Achilles N, Konig V, et al. Nucleoplasty, a minimally invasive procedure for disc decompression: a systematic review and meta-analysis of published clinical studies. *Pain Physician*. 2014;17(2):E149–73.
38. Chen B-L, Guo J-B, Zhang H-W, et al. Surgical versus non-operative treatment for lumbar disc herniation: a systematic review and meta-analysis. *Clin Rehabil*. 2018;32(2):146–160. doi:10.1177/0269215517719952
39. Frost BA, Camarero-Espinosa S, Johan Foster E. Materials for the spine: anatomy, problems, and solutions. *Materials (Basel)*. 2019;12(2):253. doi:10.3390/ma12020253
40. Pooni JS, Hukins DW, Harris PF, Hilton RC, Davies KE. Comparison of the structure of human intervertebral discs in the cervical, thoracic and lumbar regions of the spine. *Surg Radiol Anat*. 1986;8(3):175–182. doi:10.1007/BF02427846