Int J Clin Exp Med 2017;10(2):3147-3154
www.ijcem.com /ISSN:1940-5901/IJCEM0021665

Original Article

Efficacy of coblation annuloplasty combined with nucleoplasty in cervical discogenic and radicular pain

Liangliang He*, Liqiang Yang*, Baishan Wu, Jianning Yue, Yuna Guo, Guanghui Lai, Yuanzhang Tang, Jiaxiang Ni

*Department of Pain Management, Xuanwu Hospital, Capital Medical University, Beijing, China. *Equal contributors and co-first authors.*

Received December 8, 2015; Accepted June 12, 2016; Epub February 15, 2017; Published February 28, 2017

Abstract: Background: Cervical discogenic pain and radicular pain often appear concurrently. Discogenic pain can be treated with thermal annular procedures that interrupt annular nociceptors, and radicular pain can be treated by decompression of nerve roots; however, there are no effective therapeutic approaches for treating patients with concurrent discogenic pain and radicular pain. Objective: This study aimed to evaluate the efficacy of coblation annuloplasty combined with nucleoplasty in treating cervical discogenic pain with concurrent radicular pain. Methods: This was a prospective, clinical, observational study of 20 patients with cervical discogenic and radicular pain related to contained disc herniation. Patients received coblation annuloplasty combined with nucleoplasty. Pain was assessed via the visual analogue scale (VAS) (significant pain relief was defined as VAS improvement ≥ 50%), and functional outcome was assessed using the modified MacNab criteria. All patients had 12 months of follow-up. Results: General, discogenic and radicular VAS scores significantly decreased from respective preoperative values of 7.9 ± 0.7, 6.2 ± 1.0 and 7.7 ± 0.9 to 3.1 ± 1.1, 2.6 ± 1.5 and 2.5 ± 2.0, respectively at 12 months postoperatively. Significant relief of general, discogenic and radicular pain at 12 months postoperatively was reported in 15 (75%), 17 (85%) and 15 (75%) patients, respectively. At postoperative 1, 3, 6 and 12 months, an "excellent" or "good" functional outcome was reported in 16 (80%), 16 (80%), 15 (75%) and 15 (75%) patients, respectively. Conclusions: Coblation annuloplasty combined with nucleoplasty effectively treated patients with cervical discogenic pain and concurrent radicular pain.

Keywords: Cervical disc herniation, discogenic pain, radicular pain, coblation, nucleoplasty, annuloplasty, thermal annular therapy

Introduction

Cervical discogenic pain and radicular pain are the most common ailments related to degenerative cervical disc disease in modern industrial society; both conditions seriously reduce quality of life and bring about enormous socioeconomic burden [1, 2]. Pain related to degenerative disc disease is generally managed using the stepladder treatment approach from conservative therapy to minimally invasive techniques to spinal fusion [3]. Among the various minimally invasive techniques, thermal annular procedures treat discogenic pain through interruption of nociceptors in the annulus [4, 5], and disc decompression treats radicular pain through decompression of nerve roots [6-8]. However, there is no one standard effective therapeutic approach to treat patients with discogenic pain and concurrent radicular pain.

To treat patients with discogenic pain and concurrent radicular pain, a therapeutic approach combining a thermal annular procedure and disc decompression was proposed in 2002 [9]. Patients with lumbar discogenic pain and concurrent radicular pain were treated by intradiscal electrothermal therapy (IDET) combined with coblation nucleoplasty, but no additional benefit was observed in clinical efficacy compared with IDET alone [9]. Another study using IDET plus coblation nucleoplasty to treat this type of pain had a similar clinical outcome [10]; the IDET alone was far superior to the combination of the two techniques [10]. Therefore, IDET and coblation nucleoplasty are potentially incompatible.

There is still a need to determine one effective therapeutic approach to treat patients with concurrent discogenic and radicular pain, especial-

Table 1. Demographic characteristic

Gender N (%)		Male	7 (35)
		Female	13 (65)
Age (years)		Mean ± SD	50 ± 8
		Range	33-63
Pain VAS score	General	Mean ± SD	7.9 ± 0.7
		Range	6-9
	Discogenic	Mean ± SD	6.2 ± 1.0
		Range	5-9
	Radicular	Mean ± SD	7.7 ± 0.9
		Range	7-9
Duration of pain (years)		Mean ± SD	4 ± 2
		Range	1-10
Treated Level N (%)		C4/5	4 (20)
		C5/6	16 (80)

ly for cervical degenerative disc disease as the cervical anatomy limits the application of IDET. Coblation technology is currently used to perform nucleoplasty, but coblation technology has rarely been used to perform annuloplasty [11-21]. Coblation nucleoplasty combined with coblation annuloplasty can avoid the poor clinical outcomes that resulted from the potential incompatibility of IDET and coblation nucleoplasty. The purpose of this study was to evaluate the efficacy of coblation annuloplasty combined with nucleoplasty to treat patients with cervical discogenic and concurrent radicular pain secondary to cervical contained disc herniation.

Patients and methods

After the institution's Ethics Examining Committee of Human Research's approval and written informed patient consent, 20 patients complained of cervical discogenic pain with radicular pain related to contained disc herniation scheduled to receive coblation annuloplasty combined with coblation nucleoplasty between September 2013 and February 2014.

Inclusion criteria

Inclusion criteria for the coblation technology were as follows: unilateral cervical discogenic pain with radicular pain, the pain VAS ≥ 4, the duration of pain ≥ 3 months, contained herniated disc ≤ 6 mm and not compromising more than 1/3 of the central spinal canal according to magnetic resonance imaging (MRI), no neurological deficits, such as loss of sensory, motor or reflex, unresponse to conservative management including medication, physical therapy and epidural injection therapies, and a positive one-level provocation discography, revealed at least 7 of 10 concordant pain at the abnormal disc along with a normal adjacent control disc.

Exclusion criteria

Patients affected by coagulopathy, disc herniation with sequestration, infection, spinal instability, spinal fractures, tumor, advanced spondylosis resulting on osseous foraminal stenosis or disc space collapse, previous spinal surgery on the same level, uncontrolled psychological disorders.

Coblation procedure

The procedure was performed in an operating room using sterile technique. The patient was placed in supine position on the operation table, a 10 cm cushion was placed under the shoulder to keep neck slightly hyperextended and received the vital sign monitoring. Before procedure, an intravenous injection etimicin 1.0 g was administered as a prophylactic antibiotic. Patients received intravenous injection fentanil 50 μg and able to respond if a nerve root was irritated by thermal or mechanical stimulation. Then, all procedures were performed under local anesthesia.

First, the puncture angle was confirmed under fluoroscopic guidance with anterior-posterior (AP) and lateral view. Second, an 18-gauge, 8-cm introducer needle was advanced via a left or right anterior approach to the target disc. During the puncture process, introducer needle was inserted slowly and the advancement was stopped immediately when movement or paresthesia was occurred in patient's upper limb. Once the introducer needle entered into the cervical disc, the advancement should be slowly until the tip reached to the opposite posterior annulus/nucleus junction and the position of tip should be checked carefully in AP and lateral view. Third, the coblation wand (UNITEC, China America United Technology (Beijing) Co. Ltd, China) was inserted into the introducer needle until the its tip was extended approximately 5 mm beyond the tip of the needle in order to ensure that the active portion of wand

Table 2. Location of pain and quality of pain before operation for 20 patients

Subject	Gender	Pre-VAS	Location of pain (quality of pain)						
			Neck	Shoulder	Scapular	Chest	Upperarm	Forearm	Finger
1	M	6	N	Y (A\D)	Y (A\D)	N	Y (A\D)	Y (D\L)	N
2	M	7	Y (A)	Y (A)	Y (A\L)	N	Y (A\S)	Y (L)	Y (L)
3	F	9	N	Y (A\S)	Y (L)	N	Y (L)	Y (L)	Y (L)
4	F	8	N	Y (A)	Y (D)	N	Y (S)	Y (S\L)	Y (S\L)
5	F	7	Y (A\D)	Y (A\D)	Y (A\D)	N	Y (A\S)	Y (A\S)	N
6	F	9	N	Y (L)	Y (L)	Y (L)	Y (S)	Y (L)	Y (L)
7	M	9	N	N	Y (L)	N	Y (L)	Y (L)	Y (L)
8	F	7	Y (A)	Y (A\D)	Y (D)	N	Y (D\S)	Y (S)	Y (S)
9	M	8	N	N	Y (D\L)	N	Y (S)	Y (S\L)	Y (S\L)
10	M	6	Y (A\D)	Y (A\D)	Y (A\D)	N	Y (A\D)	Y (A\D)	N
11	F	7	Y (A)	Y (A\D)	Y (L)	Y (D\S)	Y (S)	Y (S)	Y (S)
12	M	8	Y (A)	Y (A)	Y (B)	N	Y (B)	Y (B)	Y (B)
13	F	8	N	N	Y (L)	N	Y (S)	Y (L)	Y (L)
14	M	8	N	N	Y (D)	N	Y (D)	Y (D\L)	Y (D\L)
15	F	7	Y (A\D)	Y (A\D)	Y (A\D)	N	Y (A\D)	Y (S)	N
16	F	7	Y (A)	Y (A)	Y (A)	N	Y (S)	Y (S)	Y (S)
17	F	9	Y (A)	Y (A)	Y (A\D)	N	Y (L)	Y (L)	Y (L)
18	M	8	N	N	Y (B)	N	Y (B)	Y (B)	Y (B)
19	F	7	Y (D)	Y (D)	Y (D)	N	Y (D\S)	Y (D\S)	Y (S)
20	F	8	Y (A\D)	Y (A\D)	Y (L)	N	Y (L)	Y (L)	Y (L)

Y: Yes; N: No. Quality of pain: A: Ache; D: Dull pain; S: Swelling pain; L: Lancinating pain; B: Beyond description.

was deployed into the annulus [16], and the position of wand tip was checked in AP and lateral view again. Fourth, coagulation was tested with the radio-frequency controller set at 2' for 1/2-1 second to check that there was no movement or paresthesia in the patient's upper limbs. Fifth, coablation mode was carried out with the radio-frequency controller set at 2' of intensity for 1-10 seconds to ablate disc materials by rotating the wand 360°. Then, coagulation mode was carried out with controller set at 2' of intensity for 1-2 seconds to denature adjacent materials and seal channel. After this, the tip of introducer needle was retreated to the anterior annulus/nucleus junction center of disc and the active portion of wand was inserted into the nucleus, and the position of tip is checked carefully again in AP and lateral view. The coablation and coagulation modes were performed again following the above steps if no movement or paresthesia in the patient's upper extremities was reported. After withdraw of the wand, 2 ml of 0.5% lidocaine was injected into the introducer needle tract. All patients took the bed rest in the supine position for 48 hours. After discharged from hospital, patients were advised to avoid strenuous activities.

Therapeutic efficacy assessment

Clinical improvement of pain after coblation technology, as the primary outcome, was assessed with pain VAS score (ranging from 0 to 10) at 1 week, and 1, 3, 6, 12 months postoperatively. The following variables were recorded as the secondary outcomes: significant (≥ 50%) pain relief was recorded at 1 week, and 1, 3, 6, 12 months postoperatively; patient's function status was evaluated with "excellent", "good", "fair" and "poor" according to the Modified MacNab criteria at 1, 3, 6 and 12 months postoperatively; pain medication intake was assessed at 1, 3, 6 and 12 months postoperatively. Finally, complications such as hemorrhages, paresthesia or infection were recorded.

Statistics

Statistical analyses were performed by using GraphPad Prism version 5.0 (GraphPad Software Inc, San Diego, CA). Patient's demographic and baseline clinical data were analyzed descriptively. The pain VAS score between the preoperative and postoperative time points

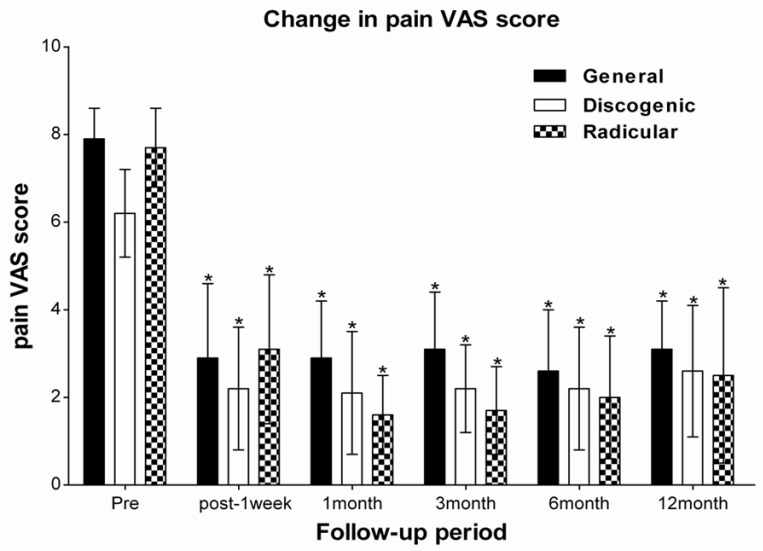

Figure 1. General, discogenic and radicular pain VAS score at pre-operation and post-operative 1 week and 1, 3, 6 and 12 months. Values are shown as means (error bars: 95% CI for mean). *Indicates significant difference with pre-operation.

was compared using repeated measures analysis of variance (ANOVA) test. The clinical results of significant pain relief, patients satisfaction and pain medicine intake were evaluated with the Wilcoxon sign rank test. A value of $P < 0.05$ was considered statistically significant in all analyses.

Results

Demographic characteristic

20 patients suffering from cervical discogenic pain and radicular pain received coblation annuloplasty and coblation nucleoplasty, male 7 and female 13. The mean pain VAS score was 7.7 ± 0.9 (ranging from 5-9), mean age was 50 ± 8 year-old (ranging from 33-63 year-old), and average duration of pain was 4 ± 2 years (ranging from 1-10 years). The C4/5 disc level was treated in 4 cases (20%), C5/6 in 16 cases (80%) with coblation technology (**Table 1**). The detailed information of location and quality of pain before operation was showed in **Table 2**.

Compared with 7.9 ± 0.7 of pre-operation, the general pain VAS score significantly decreased to 2.9 ± 1.7 (P < 0.05), 2.9 ± 1.3 (P < 0.05), 3.1 ± 1.3 (P < 0.05), 2.6 ± 1.4 (P < 0.05) and 3.1 ± 1.1 (P < 0.05) at post-operative 1 week and 1, 3, 6 and 12 months, respectively (**Figure 1**). And 17 (85%) of patients reported significant (≥ 50%) pain relief at post-operative 1 week and 1 month, 16 (80%) at 3 and 6 months, and 15 (75%) at 12 months (**Figure 2**).

Compared with 6.2±1.0 of pre-operation, the discogenic pain VAS score significantly decreased to 2.2 ± 1.4 (P < 0.05), 2.1 ± 1.4 (P < 0.05), 2.2 ± 1.0 (P < 0.05), 2.2 ± 1.4 (P < 0.05) and 2.6 ± 1.5 (P < 0.05) at post-operative 1 week and 1, 3, 6 and 12 months, respectively (**Figure 1**). And 18 (90%) of patients reported significant (≥ 50%) pain relief at post-operative 1 week, 17 (85%) at 1 and 3 month, and 16 (80%) at 6 and 12 months (**Figure 2**).

Compared with 7.7±0.9 of pre-operation, the radicular pain VAS score significantly decreased to 3.1 ± 1.7 (P < 0.05), 1.6 ± 0.9 (P < 0.05), 1.7 ± 1.0 (P < 0.05), 2.0 ± 1.4 (P < 0.05) and 2.5 ± 2.0 (P < 0.05) at post-operative 1 week and 1, 3, 6 and 12 months, respectively (**Figure 1**). And 14 (60%) of patients reported significant (≥ 50%) pain relief at post-operative 1 week, 15 (80%) at 1 month, 16 (85%) at 3 months, 17 (80%) at 6 months, and 15 (75%) at 12 months (**Figure 2**).

In according to the Modified MacNab criteria, no difference was found in the portion of "excellent" or "good". At post-operative 1, 3, 6 and 12 months, the proportion of "excellent" or "good" was 16 (80%), 16 (80%), 15 (75%), and 15 (75%), the proportion of "fair" was 2 (10%), 1 (5%), 2 (10%), 2 (10%), and the proportion of "poor" was 2 (10%), 3 (15%), 3 (15%) and 3 (15%), respectively (**Figure 3**).

16 (80%) patients reported a significant reduction (≥ 50%) in pain medicine intake at post-operative 1 and 3 months, 15 (75%) patients at 6 and 12 months (**Figure 3**). 16 (80%) patients didn't take pain medicine at post-operative 1 month, 15 (75%) patients at 3 and 6 months, and 14 (60%) patients at 12 months.

6 (30%) patients reported soreness and 3 (15%) patients experienced ecchymoma at the

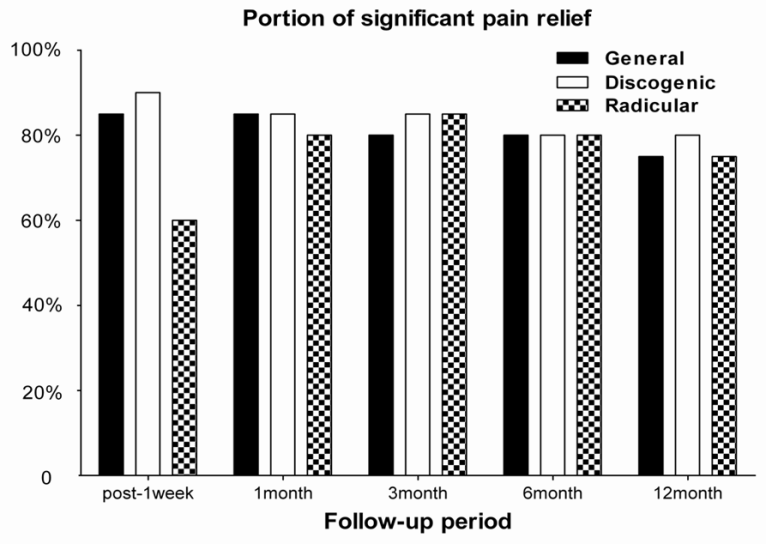

Figure 2. Proportion of patients expressed significant (≥ 50%) relief in general, discogenic and radicular pain at post-operative 1 week, and 1, 3, 6 and 12 months.

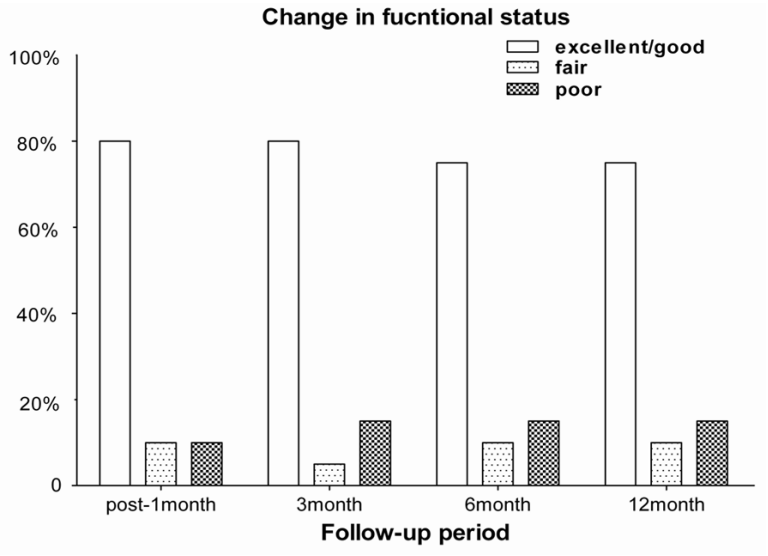

Figure 3. Proportion of patients expressed "excellent" or "good", "fair" and "poor" at post-operative 1, 3, 6 and 12 months.

needle insertion site, but the symptoms completely disappeared in two weeks after operation. No hemorrhages, paresthesia or infection were observed.

Discussion

Coblation annuloplasty combined with coblation nucleoplasty significantly decreased pain intensity, significantly improved functional status, and markedly reduced pain medication intake in patients with cervical discogenic pain and concurrent radicular pain after 12 months of follow-up.

Coblation nucleoplasty has been performed to treat pain related to degenerative cervical disc disease for over a decade [21]. This technique ablates nucleus material and decompresses nerve roots, resulting in significant improvement in cervical radicular pain [18, 20]; a 2006 study investigating the feasibility, safety and efficacy of coblation nucleoplasty in 55 patients with radicular pain related to contained disc herniation reported a significant improvement in pain VAS score and functional status over a 29-month period [20], and a 2010 study investigating coblation nucleoplasty in 47 patients with radicular pain related to contained disc herniation reported that VAS score and neck disability index were significantly improved after 24 months of follow-up [18]. However, clinical efficacy data of coblation nucleoplasty in treating cervical discogenic pain are limited.

To date, cervical discogenic pain has only been considered as a secondary symptom to be evaluated after coblation nucleoplasty treatment [15, 16, 19]; this has made it difficult to confirm the therapeutic role of coblation nucleoplasty in treating cervical discogenic pain. Because the major origin of discogenic pain has been confirmed as the innervated outer annulus, not the nerves growing into the nucleus along annular tears [22], the therapeutic role of coblation nucleoplasty in treating discogenic pain is uncertain.

Two previous studies investigated the use of coblation nucleoplasty combined with IDET to

alleviate radicular pain and discogenic pain simultaneously [9, 10]; however, this approach was only assessed in lumbar degenerative diseases. This may be because the relatively narrow anatomic structure of the cervical spine compared with the lumbar spine can lead to technical difficulties and potential heat injury to cervical nerve roots during IDET [5, 23]. Unlike IDET, coblation technology is not a heat-driven process. A thermal mapping study in the porcine model showed that the subject's skin temperature during coblation decreased from 20°C to 0°C when the distance from the tip of the wand was increased from 1 mm to 5 mm [24]; the radius of the thermal zone of coagulation is approximately 1 mm when the wand is moved at a speed of 0.5 cm/s [25]. These temperature properties indicate that coblation annuloplasty should be a reasonable complementary treatment for cervical discogenic pain.

In the present study, concordant pain during coblation annuloplasty or nucleoplasty was reported by eight and five patients respectively. The concordant pain was located mainly in the neck, back, scapular and shoulder, but not over the elbow joint; this is similar to the characteristics of cervical discogenic pain described in a previous study [26]. The provocation of concordant pain may be owing to interruption of nerves in the nucleolus or annulus during ablation and coagulation, indicating that coblation annuloplasty and nucleoplasty are complementary approaches that interrupt the nerves involved in cervical discogenic pain. In the present study, 80% of patients reported significant relief of discogenic pain at 12 months postoperatively. These encouraging clinical outcomes are potentially the result of the combination of coblation annuloplasty and nucleoplasty.

Unlike discogenic pain, radicular pain was not provoked during coblation annuloplasty or nucleoplasty in the present study. If radicular pain (radiation of electric shock-type pain into the fingers [26]) was experienced during the procedure, the procedure would have been stopped. This is because the principle in treating radicular pain is to depress, but not irritate, the nerve root [7]. In the present study, 75% of patients reported significant relief of radicular pain at the 12-month follow-up. Although similar positive clinical outcomes using coblation nucleoplasty to treat cervical radicular pain have been published [18, 20], it is hard to determine whether the clinical efficacy originated from coblation nucleoplasty in the present study. The significant pain relief could potentially be owing to coblation annuloplasty alone or to the combination of annuloplasty with nucleoplasty; further research is needed to investigate this.

In the present study, six patients experienced soreness and three patients experienced ecchymoma at the needle insertion site, but the symptoms had completely disappeared by 2 weeks after surgery. Soreness and ecchymoma are the most commonly reported side effects of coblation technology [27]. No haemorrhage, paraesthesia or infection were observed in our study.

There were some limitations to the present study. First, there was no control or placebo; this was because conducting a blinded, randomised, placebo-controlled study was prohibitively expensive and logistically difficult in a practice setting. The efficacy of coblation annuloplasty or nucleoplasty in treating cervical discogenic and radicular pain should be evaluated separately in future research. Second, the sample size was small and may not be generalisable to all patient populations; however, our study will help to provide a preliminary framework for the planning of future prospective, randomised, controlled studies. Third, coblation annuloplasty or nucleoplasty itself is a blind technique, so it was difficult for the physician to completely deploy the tip of the wand in the annulus or nucleolus; the phrase "coblation annuloplasty" or "coblation nucleoplasty" was a more accurate description of the procedure used in this study.

Conclusion

The approach of coblation annuloplasty combined with nucleoplasty significantly improve pain intensity and functional status in patients with cervical discogenic and radicualr pain, which is an effective, safe, minimally-invasive and less uncomfortable procedure.

Acknowledgements

Funding: Beijing Municipal Administration of Hospitals Clinical Medicine Development of Special Funding Support, code: ZYLX201507.

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Jiaxiang Ni, Department of Pain Management, Xuanwu Hospital, Capital Medical University, 45 Changchun Street, Xicheng District, Beijing 100053, China. Tel: +86-13910743476; Fax: 086-010-83198161; E-mail: nijiaxiang@263.net

References

[1] Malik KM, Cohen SP, Walega DR, Benzon HT. Diagnostic criteria and treatment of discogenic pain: a systematic review of recent clinical literature. Spine J 2013; 13: 1675-1689.

[2] Yin W, Bogduk N. The nature of neck pain in a private pain clinic in the United States. Pain Med 2008; 9: 196-203.

[3] Kumar NS, Shah SM, Tan BW, Juned S, Yao K. Discogenic axial back pain: is there a role for nucleoplasty? Asian Spine J 2013; 7: 314-421.

[4] Helm S, Hayek SM, Benyamin RM, Manchikanti L. Systematic review of the effectiveness of thermal annular procedures in treating discogenic low back pain. Pain Physician 2009; 12: 207-232.

[5] Helm S, Deer TR, Manchikanti L, Datta S, Chopra P, Singh V, Hirsch JA. Effectiveness of thermal annular procedures in treating discogenic low back pain. Pain Physician 2012; 15: E279-304.

[6] Keren A, Berkovich Y, Merom L. Lumbar nucleoplasty. Harefuah 2014; 153: 407-410.

[7] Wullems JA, Halim W, van der Weegen W. Current evidence of percutaneous nucleoplasty for the cervical herniated disk: a systematic review. Pain Pract 2014; 14: 559-569.

[8] Eichen PM, Achilles N, Konig V, Mosges R, Hellmich M, Himpe B, Kirchner R. Nucleoplasty, a minimally invasive procedure for disc decompression: a systematic review and meta-analysis of published clinical studies. Pain Physician 2014; 17: E149-173.

[9] Derby R. Outcome comparison between IDET, combined IDET-nucleoplasty and biochemical injection treatment. Abstract presentation from the International Spinal Injection Society 10th Annual Scientific Meeting Syllabus, Austin, TX, September 2002; 93-94.

[10] Cohen SP, Williams S, Kurihara C, Griffith S, Larkin TM. Nucleoplasty with or without intradiscal electrothermal therapy (IDET) as a treatment for lumbar herniated disc. J Spianl Disord Tech 2005; 18: S119-124.

[11] He L, Tang Y, Li X, Li N, Ni J, He L. Efficacy of coblation technology in treating cervical discogenic upper back pain. Medicine (Baltimore) 2015; 94: e858.

[12] Yang B, Xie J, Yin B, Wang L, Fang S, Wan S. Treatment of cervical disc herniation through percutaneous minimally invasive techniques. Eur Spine J 2014; 23: 382-388.

[13] Lim JH, Lee HJ, Lee SH. Application of percutaneous cervical nucleoplasty using the navigable disc decompression device in patient of cervical herniated intervertebral disc: a case report. Ann Rehabil Med 2013; 37: 730-734.

[14] Halim W, Wullems JA, Lim T, Aukes HA, van der Weegen W, Vissers KC, Gültuna I, Chua NH. The long-term efficacy and safety of percutaneous cervical nucleoplasty in patients with a contained herniated disk. Pain Pract 2013; 13: 364-71.

[15] Sim SE, Ko ES, Kim DK, Kim HK, Kim YC, Shin HY. The results of cervical nucleoplasty in patients with cervical disc disorder: a retrospective clinical study of 22 patients. Korean J Pain 2011; 241: 36-43.

[16] Cesaroni A, Nardi PV. Plasma disc decompression for contained cervical disc herniation: a randomized, controlled trial. Eur Spine J 2010; 19: 477-486.

[17] Cesaroni A, Nardi PV. Plasma-mediated disc decompression for contained cervical disc herniation: results through 5 years. Acta Neurochir Suppl 2011; 108: 113-116.

[18] Azzazi A, Elhawary Y. Cervical nucleoplasty using coblation technology: clinical outcome. Neurosurgery Quarterly 2010; 20: 146-150.

[19] Li J, Yan DL, Zhang ZH. Percutaneous cervical nucleoplasty in the treatment of cervical disc herniation. Eur Spine J 2008; 17: 1664-1669.

[20] Bonaldi G, Baruzzi F, Facchinetti A, Fachinetti P, Lunghi S. Plasma radio-frequency-based diskectomy for treatment of cervical herniated nucleus pulposus: feasibility, safety, and preliminary clinical results. AJNR Am J Neuroradiol 2006; 27: 2104-2111.

[21] Singh V. Percutaneous disc decompression for the treatment of chronic atypical cervical discogenic pain. Pain Physician 2004; 7: 115-118.

[22] Moneta GB, Videman T, Kaivanto K, Aprill C, Spivey M, Vanharanta H, Sachs BL, Guyer RD, Hochschuler SH, Raschbaum RF, et al. Reported pain during lumbar discography as a function of annular ruptures and disc degeneration. A re-analysis of 833 discograms. Spine (Phila Pa 1976) 1994; 19: 1968-1974.

[23] Wegener B, Rieskamp K, Büttner A, Habiyambere V, von Schultze-Pellangahr C, Schaffer V, Jansson V, Birkenmaier C. Experimental evaluation of the risk of extradiscal thermal damage in intradiscal electrothermal therapy (IDET). Pain Physician 2012; 15: e99-106.

[24] Chen Y, Lee S, Chen D. Experimental thermomapping study in percutaneous disc decom-

pression, nucleoplasty. In North American Spine Society/South American Spine Society, NASS Meeting of the Americas. New York City: 2001.

[25] Eggers PE, Thapliyal HV, Matthews LS. Coblation: a newly described method for soft tissue surgery. Research Outcomes in Arthroscopic Surgery 1997; 2: 1-4.

[26] Cloward RB. Cervical diskography. A contribution to the etiology and mechanism of neck, shoulder and arm pain. Ann Surg 1959; 150: 1052-1064

[27] Bhagia SM, Slipman CW, Nirschl M, Isaac Z, El-Abd O, Sharps LS, Garvin C. Side effects and complications after percutaneous disc decompression using coblation technology. Am J Phys Med Rehabil 2006; 85: 6-13.