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Percutaneous cervical nucleoplasty and percutaneous cervical discectomy treatments of the contained cervical disc herniation

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Abstract
Background There were no studies in literature to compare the clinical outcomes of percutaneous nucleoplasty (PCN) and percutaneous cervical discectomy (PCD) in contained cervical disc herniation.
Methods A retrospective of patients with symptomatic contained cervical disc herniated were operated on with PCN and PCD from June 2003 to July 2005. Two-hundred and four patients initially fulfilled the study criteria, and 28 patients were lost in follow-up. The patients were categorized into different groups depending on the procedure by PCN (81 cases) or PCD (95 cases).
Results The clinical outcomes, pain reduction, and segment stability were recorded during this study. Puncture of the needle into the disc space was accurately performed under C-arm fluoroscopy guidance in all cases and no intraoperative deaths were reported in our study. At the end, 176 cases had follow-up and 28 cases were lost, and the follow-up rate was 88.0% (81/92) in the PCN group and 84.8% (95/112) in the PCD group. The follow-up time ranged from 16 to 48 months (average 29 months), and on an average of 28.86 ± 4.52 months on PCN and 8.42 ± 3.21 months on PCD ($t = -0.24$, $P = 0.81$, >0.05). The operation time averages of PCN and PCD are 4.67 ± 1.16 and 11.95 ± 1.80, respectively ($P < 0.01$). The pain index improved from 7.12 ± 1.13 to 2.74 ± 0.89 ($t = 27.03$, $P = 0.0000$, <0.001) in PCN patients and from 7.18 ± 1.09 to 2.71 ± 0.91 ($t = 29.57$, $P = 0.0000$, <0.001) in PCD patients. Clinical results of PCN were excellent in 31 cases, good 32 cases, fair 13 cases, and poor 5 cases; for PCD, the results were 33, 42, 12, and 7 cases, respectively, and 1 in discitis. Good and excellent was 78.4% (77.8% in PCN and 79.5% in PCD, $P > 0.05$). There was one case of PCN that had the partial Perc-D SpineWand broken in the disc space, cannot be moved by the percutaneous cervical discectomy, and remained there itself. One of the cases had discitis in this study after PCD. Patient presented with neck pain and associated radicular pain and numbness in the left upper-limb after 8 days of PCD. There were no instable cases after procedures of PCN and PCD. There were no significant difference in stability of preoperatively and postoperatively between PCN and PCD ($P > 0.05$).
Conclusions PCN and PCD treatments of contained cervical disc herniation show good outcomes and there was no difference in the stability of cervical spine. PCN and PCD are safe, minimally invasive, and no differences were observed between the methods in clinical outcome.

Keywords Nucleoplasty · Disc herniation · Coblation · Cervical · Diskectomy

Introduction

The current trend of evolution of all spinal surgery has been toward less-invasive techniques. Stookey [1] described the clinical symptoms and anatomic location of cervical disc herniation in 1928. Subsequently, the landmark paper by Mixter and Barr [2] clearly established the relationship between herniated discs and sciatica, and provided evidence that laminectomy and disc excision could successfully relieve

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the pain associated with radiculopathy. Bailey and Badgley [3], Cloward [4], and Robinson and Smith [5] popularized the anterior approach with interbody fusion in the 1950s. Hirsch [6] and Robertson [7] recommended cervical discectomy without fusion. Fukushima et al. [8] introduced the ventriculofiberscope in 1973 and further enhanced the foundation for percutaneous endoscopic cervical discectomy [9].

Minimally invasive treatments aimed at removing nuclear material and lowering intradiscal pressure through devices were inserted percutaneously into intervertebral discs. A number of techniques have recently been developed that are applicable in the treatment of disc herniation. Smith et al. [10, 11] introduced chymopapain chemonucleolysis to treat herniated nucleus pulposus. Hijikata [12] described percutaneous lumbar discectomy. Ascher [13] then reported laser discectomy.

Percutaneous disc decompression, regardless of technique, has been based on the principle that a small reduction of volume in a closed hydraulic space, like an intact disc, results in a disproportionately large fall of pressure. Case et al. [14] studied showing that a large rise in pressure will regularly result from a small increase in volume, confirming the biochemical basis for the benefits obtained from interventions designed for disc decompression. Percutaneous cervical discectomy (PCD) has been developed as an effective treatment option for soft cervical disc herniation. Percutaneous nucleoplasty (PCN) is a new minimally invasive technique which uses radiofrequency energy to ablate the nucleus pulposus in a controlled manner for disc decompression.

In general, all these have shown moderate or good clinical results of PCN and PCD. To date, no study has been published in which investigators examine the therapeutic effects of PCN and PCD for the treatment of cervical disc herniation. The aim of this paper was to compare the clinical outcomes of PCN and PCD in contained cervical disc herniation.

Materials and methods

Patient population

A retrospective study on patients with contained cervical disc herniations from June 2003 to July 2005 had procedures of PCD or PCN. Patients had to satisfy specific inclusion and exclusion criteria to be enrolled. All patients had the radiographically determined contained disc herniation on magnetic resonance imaging (MRI). Inclusion criteria were contained disc hemiation (diagnosed by MRI) complaints of radicular pain with or without neck pain, and no improvement was observed for at least 6 weeks of conservative therapy (i.e., physical therapy together with use of anti-inflammatory medications and muscle relaxants at the manufacturer's recommended therapeutic dose). Exclusion criteria were extruded disc fragment, hemorrhagic diasthesis, spondylolisthesis, spinal canal stenosis, ossification of longitudinal ligament (OPLL), previous surgery at the indicated level, and cases of myelopathy. Initially, 204 patients fulfilled the study criteria and 28 were lost in follow-up. Of the remaining 176 patients available for analysis, 81 had PCN (group 1, 43 men and 38 women with an average age 50.73 ± 11.61 years), and 95 had PCD (group 2, 49 men and 46 women with an average age 51.51 ± 11.17 years). Both groups had similar age and sex distribution, level of involvement, and the pain history as shown in Table 1, and there were no significant differences between the groups ($P > 0.05$).

Surgical technique

Under local anesthesia, the patient was placed in a supine position with the neck extended by placing a rolled towel under the shoulders. A soft strap was placed over the forehead for stabilization. The shoulders were gently distracted downward with tape. C-arm fluoroscopy was used in anteroposterior and lateral planes to direct the placement of a spinal needle onto the disc surface. Initially, at the point of entry which is adjacent to the medial border of the right sternocleidomastoid muscle, firm pressure was digitally applied in the space between the muscle and the trachea and pointed toward the vertebral surface. The larynx and trachea were displaced medially and the carotid artery laterally. The anterior cervical spine was palpated with the fingertips, and a spinal needle was used to puncture the right-side skin of the neck and passed into the disc space. The position was confirmed by C-arm fluoroscopy.

The fiber of the Perc-D Spine Wand was inserted through the 18-gauge needle. The wand was connected to a

Table 1 Comparison of the general data between PCN and PCD groups ($x \pm s$)

Group	Y/A (years of age)	Sex		Level				Syndrome time (months)	Symptom (pain)	
		Male	Female	C3-4	C4-5	C5-6	C6-7		Ridiculer	Ridiculer with neck
PCN ($n = 81$)	50.73 ± 11.61	41	40	6	11	30	34	6.47 ± 3.25	62	19
PCD ($n = 95$)*	51.51 ± 11.17	49	46	5	14	37	39	6.54 ± 3.47	73	22

* Compare PCN, $P > 0.05$

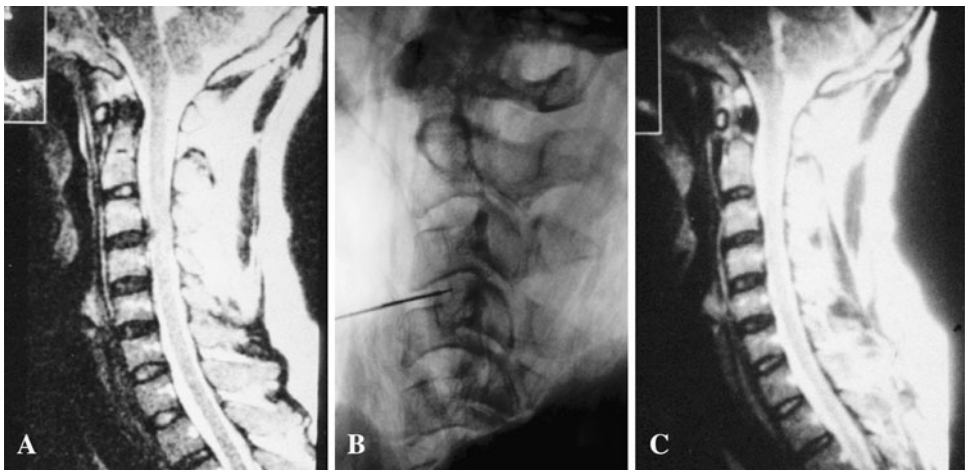

Fig. 1 Pre-, intro-, and post-operative lateral views of radiograph of patient operated on with PCN at C3-4

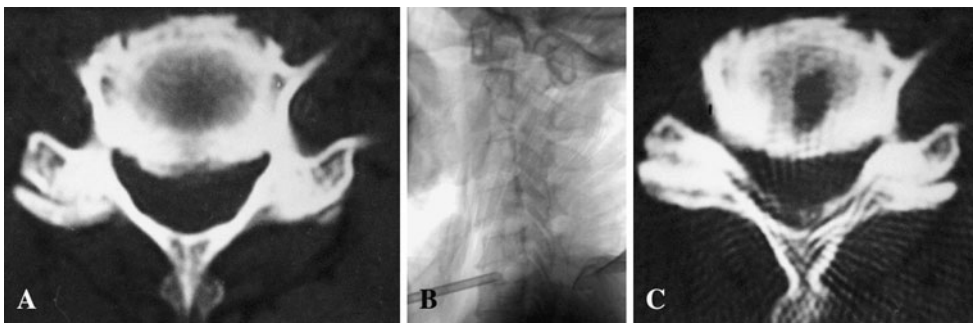

Fig. 2 Pre-, intro-, and post-operative lateral views of radiograph of patient operated on with PCD at C5-6

standard Arthrocare power generator. The power of nucleoplasty ablation was 3 W with 1 s coagulation. If it incites pain syndrome, the Perc-D Spine Wand should be replaced in disc space. No pains during coagulation, had coblation of 15 s while moving the Perc-D Spine Wand on the monitor of C-arm fluoroscopy. When the Perc-D Spine Wand returned to annulus, coagulated 1 s to shrinkage of the surrounding collagen and widening channel. Redo this process for four to six times. The procedure is shown in Fig. 1.

In the PCD procedure, the instrument (rongeur or nucleotome) is then inserted into the disc and the removal of the nucleus pulposus material was estimated to be 1 g. The positioning of instruments is carefully monitored by C-arm fluoroscopy throughout the procedure. The procedure is shown in Fig. 2.

The skin incision (2–3 mm) was then closed with Steri-Strips and the patients were discharged home within a day after the procedure. The operation time of procedures were recorded and compared between PCD and PCN. Patients received periprocedural and after-operation oral antibiotics every 8 h for 48 h. Postoperatively, patients were allowed unlimited walking, standing, and sitting. Return to sedentary or simple work was permitted at 3–4 days following the surgery.

Radiographic assessment

The radiographic assessment of the segment stability was determined by two independent radiologists, who were blinded to the assigned treatment group of the patients. The radiologists studied anteroposterior, lateral, and flexion–extension lateral radiographs. The radiographical stability has been considered $<11°$ of angular displacement (AD), and <3 mm of horizontal displacement (HD) had to be present at the site of the procedure segment when comparing flexion–extension lateral radiographic views. AD $\geq 11°$ or HD ≥ 3 mm was considered radiographically instable.

Statistical analyses

Statistical analyses were performed independently by a non-clinical research assistant and an outside party to ensure objectivity, using SPSS version 11.5. The clinical results of the effect of treatment were evaluated by the Macnab standard [15] as shown in Table 2, and using visual analog pain scale (VAS) for cervical radiculopathy. The Student's *t* test with a two-tailed paired comparison was used to compare the means between visits and to compare the success based on demographic variables.

Table 2 Clinical results of the Macnab standard

Outcome	Description
Excellent	Disappearance of symptoms
	No restriction of mobility
	Able to return to normal work and activities
Good	Occasional episodes of pain
	No limitation of occupational activities
	No need of drugs to ease pain
Fair	Improvement of symptoms
	Intermittent episodes of pain limiting daily activities
	Require drugs to ease pain
Poor	No improvement of symptoms, medication abuse

Results were considered statistically significant if $P \leq 0.05$ for continuous variables.

Results

Puncture of the needle into the disc space was accurately performed under C-arm fluoroscopy guidance in all cases and there were no intraoperative deaths in our study. At the end, 176 cases had follow-up and 28 were lost with follow-up rate 88.0% (81/92) in the PCN group and 84.8% (95/112) in the PCD group. The follow-up time ranged from 16 to 48 months (average 29 months), and averages of 28.86 ± 4.52 months on PCN and 28.42 ± 3.21 months on PCD ($t = -0.24$, $P = 0.81$, >0.05). The averages of operation time of PCN 4.67 ± 1.16 min and PCD 11.95 ± 1.80 min. There was a significant difference in the operation time between PCN and PCD ($P < 0.01$).

The pain index improved from 7.12 ± 1.13 to 2.74 ± 0.89 ($t = 27.03$, $P = 0.0000$, <0.001) in PCN patients and improved from 7.18 ± 1.09 to 2.71 ± 0.91 ($t = 29.57$, $P = 0.0000$, <0.001) in PCD patients.

The clinical results assessed by Macnab standard of PCN was excellent in 31 cases, good 32 cases, fair 13 cases, and poor 5 cases; and that for PCD 33, 42, 12, and 7 cases, respectively, and 1 in discitis. The good and excellent was 78.4% (77.8% in PCN and 79.5% in PCD, $P > 0.05$).

There was one case of PCN that had the partial Perc-D Spine Wand broken in the disc space and which cannot been moved by the percutaneous cervical discectomy and remained there itself (Fig. 3). The clinical outcome of this case was good and there was no complicated occurrence. There was one case that had discitis in this study after PCD (Fig. 4). The patient presented with neck pain and associated radicular pain and numbness in the left upper-limb after 8 days of PCD. The history was negative for fever, night pain or constitutional symptoms. Cervical X-ray film showing narrowed C5-6 intervertebral space and erosive in the 5-cervical vertebral body wherein 3 months after operation shows narrowed disc space and sclerotic remodeling.

The procedure segment stability of pre- and the post-procedures are illustrated in Table 2. There were no instability cases after procedure of PCN and PCD. There were no significant difference stability in the preoperatively and postoperatively between PCN and PCD ($P > 0.05$).

Discussion

In recent years, the general trend in spinal surgery has been one of reductionism and minimalization. Treatment of cervical disk hernia has been performed under conservative therapy and sometimes under surgical intervention, such as anterior fixation of the cervical spine. At those times, if the patient failed, conservative treatments of open surgery were the only available option. Conventional open cervical discectomy, with or without bony fusion, is considered the standard treatment for cervical disc protrusion [16]. However, some patients were not available for surgery because of their poor general conditions and some refused surgery even though they were good candidates. In an attempt to avoid prolonged suffering from unsuccessful conservative treatment and to minimize the chance of morbidity often associated with open surgery, many surgeons sought

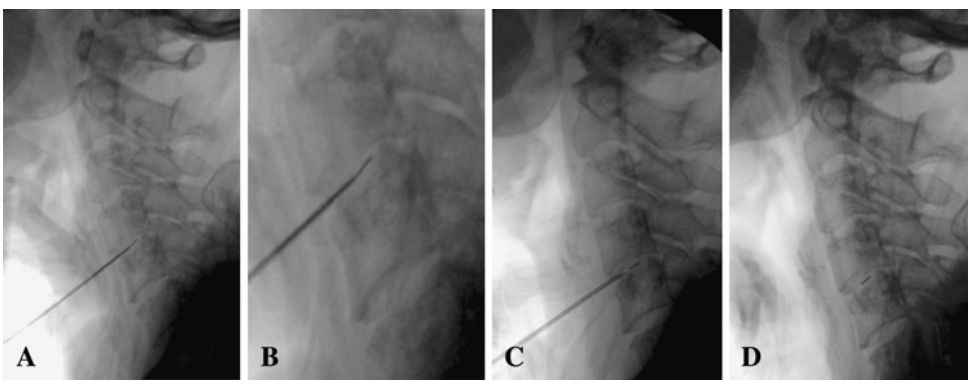

Fig. 3 Shown is the case that had Perc-D SpineWand broken in C4-5 space when procedure. The partial Perc-D SpineWand to bend (**a**; **b**—an enlargement in the radiograph showed it) and broken in C4-5 space cannot be moved by the percutaneous cervical discectomy (**c**) and remain there itself (**d**). The clinical outcome of this case is good with no complications

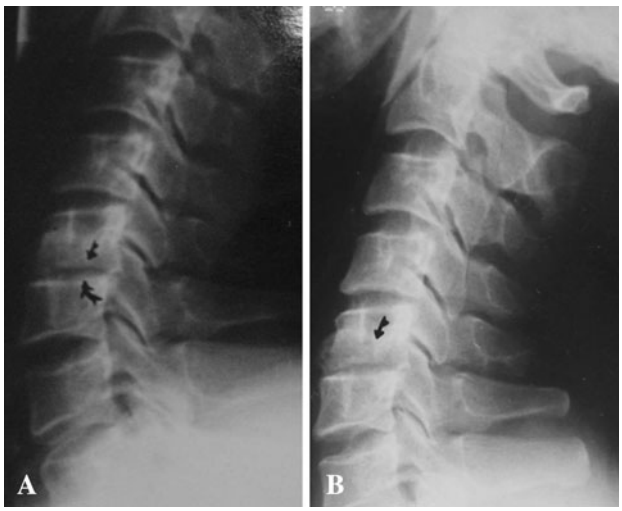

Fig. 4 The C5-6 discitis case after PCD. Cervical X-ray film showing narrowed C5-6 intervertebral space and erosive in the 5-cervical vertebral body (**a**); 3 months after operation shows the disc space narrowed and sclerotic remodeling in the 5-cervical vertebral body (**b**)

alternative ways of decompressing a pathological disc. In our series, we selected patients contained disc herniation complaints of radicular pain with or without neck pain, and no improvement for at least 6 weeks of conservative therapy (i.e., physical therapy together with use of anti-inflammatory medications and muscle relaxants at the manufacturer's recommended therapeutic dose). The pain index improved from 7.12 ± 1.13 to 2.74 ± 0.89 in PCN patients and that for PCD from 7.18 ± 1.09 to 2.71 ± 0.91. Clinical results of good and excellent was 78.4% (77.8% in PCN and 79.5% in PCD, $P > 0.05$). Therefore, myelopathy is considered outside the indication of PCN and PCD for cervical disk hernia.

Internal disc disruption and disc herniations are the common causes of extremity pain which may become chronic if not diagnosed and treated. Annular tears lead to migration of the nuclear material and derange of internal architecture. In the chronically damaged intervertebral disc, leakage of nuclear material from annular tears can initiate, promote, and continue the inflammatory process and delay or stop recovery of vital remaining intradiscal tissue. Inflammatory chemicals from the response to a damaged disc may activate or injure the dorsal root ganglion. Smaller protrusions are postulated to cause referred extremity pain due to neural inflammation and axial pain due to a combination of a sensitized outer annulus and increased outer annular tension [17]. Cervical radiculopathy is due to an abnormal process that involves the nerve root. It is caused mostly by cervical disk herniation or cervical spondylosis. The symptoms of cervical radiculopathy are neck and brachial-radicular pain, with or without motor weakness or paresthesia, in 80–100% of the patients [18]. Partial removal of the nucleus has been shown to decompress herniated discs, relieving pressure on nerve roots, and in some cases, offering relief from disc pain. In this study, puncturing needle into the disc space was accurately performed in all cases and no intraoperative deaths were observed in our study. The operation time of PCN averaged 4.67 ± 1.16 min and that PCD 11.95 ± 1.80 min ($P < 0.01$), and also the clinical outcome was very good (Figs. 1, 2).

In 1989, Hijikata [12] reported on his series of microdiscectomy patients and reinforced the clinical perception that successful outcome of disc surgery was independent of the amount of disc material excised. Increasing nuclear pressures by injecting the disc with fluid will be reflected as a proportional increase in outer annular pressure when a radial annular tear extends to the outer annulus [19, 20]. This increased pressure is probably analogous to compressing a well-hydrated nucleus and transmitting horizontal forces through the herniated nuclear material to the outer annulus. Castro et al. [21] showed that for each gram of nucleus removed, the disc space narrows to 1.42 mm and the disc bulge decreases to 0.45 mm. The advantage of PCN is that it reduces the volume and pressure of the affected disk without damaging other spinal structures. Ablation of a relatively small volume of the nucleus pulposus results in a significant reduction in intradisk pressure. This pressure was markedly reduced in the younger, healthy disc cadaver. There was an inverse correlation between the degree of disc degeneration and the change in intradiscal pressure in the Chen's study of human cadavers [22]. Histologic examination revealed no evidence of direct mechanical or thermal damage to the surrounding tissues in human cadavers [23], while giving these radial thermal penetrations, high temperatures and lethal thermal doses in small regions outside of the nucleus, or within the bone endplates in human cadavers [24]. In this study, coblation for 15 s and coagulation for 1 s and redoing this process for four to six times were carried out in PCN. While, 1 g is removed by the PCD procedures; there were no instability change of the operation segment (Table 3).

Percutaneous disc decompression has produced less number of complications [25–27]. There was one case that had the Perc-D SpineWand broken in the C4-5 space during PCN procedure (Fig. 3). The partial Perc-D Spine Wand broken in C4-5 space could not be moved by the percutaneous cervical discectomy and remain there itself. The clinical outcome of this case was good, and there were no complication occurrence. There was one case that had discitis in this study after PCD (Fig. 4). The patient presented with neck pain, associated radicular pain, and numbness in the left upper-limb after 8 days of PCD. The history was negative for fever and night pain symptoms. Cervical X-ray film showing narrowed C5-6 intervertebral

Table 3 Comparison of the stability of segment between pre- and post-operation (x ± s)

Group	C3-4		C4-5		C5-6		C6-7	
	AD (°)	HD (mm)	AD (°)	HD (mm)	AD (°)	HD (mm)	AD (°)	HD (mm)
Pre-PCN	2.43 ± 0.32	0.98 ± 0.45	4.94 ± 1.20	1.31 ± 0.48	7.23 ± 1.55	1.79 ± 0.62	7.40 ± 1.04	1.57 ± 0.39
Post-PCN*	2.75 ± 0.73	0.96 ± 0.40	5.20 ± 1.18	1.43 ± 0.62	7.77 ± 1.67	1.89 ± 0.54	7.43 ± 1.36	1.63 ± 0.45
Pre-PCD	2.41 ± 0.86	0.95 ± 0.41	4.96 ± 1.22	1.32 ± 0.46	7.32 ± 1.58	1.88 ± 0.66	7.38 ± 1.12	1.56 ± 0.38
Post-PCD**	2.79 ± 0.54	0.97 ± 0.42	5.22 ± 1.16	1.44 ± 0.65	7.79 ± 1.69	1.92 ± 0.72	7.41 ± 1.38	1.65 ± 0.46

* Compare pre-PCN, $P > 0.05$

** Compare pre-PCD, $P > 0.05$

space and erosive in the 5-cervical vertebral body wherein 3 months postoperatively shows narrowed disc space and sclerotic remodeling. There were some potential complications of PCN and PCD that include infections, bleeding, nerve damage, worsened pain, failure of technique, and recurrence of herniation. With the approach from the anterior neck to disk space, it is important to monitor the distance from the tip of the needle to the spinal canal. Therefore, needle monitoring is essential during this procedure. X-ray fluoroscopy confirmed the correct position of the needle tip during puncture of the needle on axial images, permitting accurate nucleoplasty of the intervertebral disk. The probe tip can be damaged or broken if it is forced against the vertebral endplates.

Conclusions

PCN and PCD treatments of contained cervical disc herniation show good outcomes and no differences on the stability of cervical spine were observed. Both treatments are safe, minimally invasive, and no difference in clinical outcomes.

References

1. Stookey B (1928) Compression of the spinal cord due to ventral extradural cervical chondromas. Arch Neurol Psych 20:275–278
2. Mixter WJ, Barr JS (1934) Rupture of the intervertebral disc with involvement of the spinal canal. N Engl J Med 211:210–215
3. Bailey RW, Badgley CE (1960) Stabilization of the cervical spine by anterior fusion. J Bone Joint Surg Am 42A:565–569
4. Cloward RB (1983) The treatment of ruptured lumbar intervertebral discs by vertebral body fusion. J Neurosurg 10:15–19
5. Robinson RA, Smith GW (1955) Anterolateral cervical disc removal and interbody fusion for cervical disc syndrome. Bull Johns Hopkins Hosp 96:223–224
6. Hirsch D (1960) Cervical disc rupture: diagnosis and therapy. Acta Orthop Scand 30:172–176
7. Robertson YR (1973) Anterior removal of cervical disc without fusion. Clin Neurosurg 20:259–262
8. Fukushima T, Ishijima B, Hirakawa K (1973) Ventriculofiberscope: a new technique for endoscopic diagnosis and operation. J Neurosurg 38:251–256
9. Kahanovitz N, Viola K, Goldstein T, Dawson E (1990) A multicenter analysis of percutaneous discectomy. Spine 15:713–715
10. Smith L (1964) Enzyme dissolution of the nucleus pulposus in humans. JAMA 187:137–140
11. Smith L, Garvin PJ, Jennings RB (1963) Enzyme dissolution of the nucleus pulposus. Nature 198:1311–1312
12. Hijikata S (1989) Percutaneous nucleotomy. A new concept technique and 12 years' experience. Clin Orthop 238:9–23
13. Ascher PW (1986) Application of the laser in neurosurgery. Lasers Surg Med 2:91–97
14. Case RB, Choy DS, Altman P (1985) Intervertebral disc pressure as a function of fluid volume infused. J Clin Laser Med Surg 13:143–147
15. Macnab I (1971) Negative disc exploration: an analysis of the causes of nerve-root involvement in 68 patient. J Bone Joint Surg Br 53:891–903
16. Cloward RB (1958) The anterior approach for removal of ruptured cervical discs. J Neurosurg 15:602–605
17. O'Neill CW, Kurgansky ME, Derby R, Ryan DP (2002) Disc stimulation and patterns of referred pain. Spine 27:2776–2781
18. Ellenberg MR, Honet JC, Treanor WJ (1994) Cervical radiculopathy. Arch Phys Med Rehabil 75:342–352
19. Maroon JC (2002) Current concepts in minimally invasive discectomy. Neurosurgery 51:S137–S145
20. Lee SH, Derby R, Chen Y, Seo KS, Kim MJ (2004) In vitro measurement of pressure in intervertebral discs and annulus fibrous with and without annular tears during discography. Spine 4:614–618
21. Castro WH, Halm H, Rondhuis J (2002) The influence of automated percutaneous lumbar discectomy (APLD) on the biomechanics of the lumbar intervertebral disc. An experimental study. Acta Orthop Belg 58:400–405
22. Chen YC, Lee SH, Chen D (2003) Intradiscal pressure study of percutaneous disc decompression with nucleoplasty in human cadavers. Spine 28:661–665
23. Chen YC, Lee SH, Saenz Y, Lehman NL (2003) Histologic findings of disc, end plate and neural elements after coblation of nucleus pulposus: an experimental nucleoplasty study. Spine 3:466–470
24. Nau WH, Diederich CJ (2004) Evaluation of temperature distributions in cadaveric lumbar spine during nucleoplasty. Phys Med Biol 49:1583–1594
25. Slipman C, Frey M, Bhargava A, et al. (2004) P86. Outcomes and side effects following percutaneous cervical disc decompression using coblation technology: a pilot study. Spine J 4(5 Suppl 1):S71–S72
26. Li J, Yan DL, Zhang ZH (2008) Percutaneous cervical nucleoplasty in the treatment of cervical disc herniation. Eur Spine J 17(12):1664–1669
27. Knight K, Woods DM, McHaourab A (2009) Nucleoplasty for disc protrusion: a novel percutaneous decompression technique. Tech Reg Anesth Pain Manag 13(2):93–101