Eur Spine J (2008) 17:1664–1669
DOI 10.1007/s00586-008-0786-7

ORIGINAL ARTICLE

Percutaneous cervical nucleoplasty in the treatment of cervical disc herniation

Jian Li · Deng-lu Yan · Zai-Heng Zhang

Received: 6 February 2008 / Revised: 31 August 2008 / Accepted: 12 September 2008 / Published online: 1 October 2008

Abstract Percutaneous disc decompression procedures have been performed in the past. Various percutaneous techniques such as percutaneous discectomy, laser discectomy, and nucleoplasty have been successful. Our prospective study was directly to evaluate the results of percutaneous cervical nucleoplasty (PCN) surgery for cervical disc herniation, and illustrate the effectiveness of PCN in symptomatic patients who had cervical herniated discs. From July of 2002 to June of 2005, 126 consecutive patients with contained cervical disc herniations have presented at the authors' clinic and treated by PCN. The patients' gender distribution for PCN was 65 male, 61 female. The age of patients ranged from 34 to 66 years (mean 51.9 ± 10.2 years). The levels of involvement were 21 cases at C3–4, 30 cases at C4–5, 40 cases at C5–6, and 35 cases at C6–7. The clinical outcomes, pain reduction and the segment stability were all recorded during this study. A clinical outcome was quantified by the Macnab standard and using VAS. The angular displacement (AD) ≥11° or horizontal displacement (HD) ≥3 mm was considered to be radiographically unstable. In the results of this study, puncture of the needle into the disc space was accurately performed under X-ray guidance in all cases. There was one case where the Perc-D Spine Wand had broken in the disc space during the procedure. The partial Perc-D Spine Wand, which had broken in the disc space could not be removed by the percutaneous cervical discectomy and thus remained there. There were no recurrent cases or complications in our series. Macnab standard results were excellent in 62 cases, good in 41 cases and fair in 23 cases. The rate of excellent and good was 83.73%. The VAS scores demonstrated statistically significant improvement in PCN at the 2-week, 1, 3, 6, and 12-month follow-up visits when compared to preoperational values ($P < 0.01$). There were no cases of instability following the PCN procedure. There was no significant difference in stability either preoperatively or postoperatively ($P > 0.05$). Our findings confirm that PCN for the treatment of cervical disc herniation results in a good outcome without any tampering of the stability of the cervical spine. Hence, PCN as a procedure is safe, minimally invasive, less traumatic, requiring less time with an excellent clinical outcome. PCN should be performed for those patients who fail conservative medical management including medication, physical therapy, behavioral management, psychotherapy, and who are unwilling to undergo a more invasive technique such as spinal surgery.

Keywords Nucleoplasty · Disc herniation coblation · Cervical · Discectomy

J. Li · D.-l. Yan (✉)
Orthopedic Department, The Third Affiliated Hospital of Guangzhou Medical College, 510150 Guangzhou, People's Republic of China
e-mail: spineyan@hotmail.com

J. Li
e-mail: spineyy@hotmail.com

Z.-H. Zhang
The Spinal Column Mini-Trauma Cure Center, Peking Zhongguancun Hospital, 100080 Beijing, People's Republic of China

Introduction

The current trend of evolution of all spinal surgery has been toward less-invasive techniques. Stookey [23] described the clinical symptoms and anatomic location of cervical disc herniation in 1928. Subsequently, the landmark paper by

Mixter and Barr [16] clearly established the relationship between herniated discs and sciatica, and provided evidence that laminectomy and disc excision could successfully relieve pain associated with radiculopathy. Bailey and Badgley [2], Cloward [7], and Robinson and Smith [20] popularized the anterior approach with interbody fusion in the 1950s. Hirsch [11], Robertson [19] recommended cervical discectomy without fusion. Fukushima [9] introduced the ventriculofiber in 1973 and further enhanced the foundation for percutaneous endoscopic cervical discectomy [12].

Minimally invasive treatments aimed at removing nuclear material and lowering intradiscal pressure through devices inserted percutaneously into intervertebral discs. A number of techniques have recently been developed that are applicable in the treatment of disc herniation. Smith [21, 22] introduced chymopapain chemonucleolysis to treat herniated nucleus pulposus. Hijikata [10] described percutaneous lumbar discectomy. Ascher [1] 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. [3] 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 a moderate or good clinical result. To date, no study has been published in which investigators examine the therapeutic effect of PCN for the treatment of cervical disc herniation. The aim of this paper is to present the clinical outcomes of cervical disc herniation treated by PCN.

Materials and methods

Patient population

A prospective study of 126 consecutive patients with 126 contained cervical disc herniations had presented at the authors' clinic and treated by PCN was had from July of 2002 to June of 2005. Patients had to satisfy specific inclusion and exclusion criteria to be enrolled. All patients had the radiographically determined contained disc herniation on CT and MRI. Inclusion criteria were contained disc herniation complaints of radicular pain with or without neck pain, and no improvement 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. Patients' gender distribution for PCN was 65 male, 61 female. The age of patients ranged from 34 to 66 years (mean 51.9 $\pm$ 10.2 years). The levels of involvement were 21 cases at C3–4, 30 cases at C4–5, 40 cases at C5–6, and 35 cases at C6–7.

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 adjacent to the medial border of the right sternocleidomastoid muscle, firm pressure was applied digitally 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 of the neck and passed into the disc space. The position was confirmed fluoroscopically.

The fiber of the Perc-D SpineWand was inserted through the 18-gauge needle. The wand was connected to the standard Arthrocare power generator. The power of nucleoplasty ablation was 3 W with 1 s coagulation. If any syndrome of pain were to be elicited, the Perc-D Spine Wand would be replaced in the right place on the disc. When there was no pain during the coagulation then coblation for 15 s, while the Perc-D Spine Wand would move around on the monitor of C X-ray. When the Perc-D Spine Wand had return to annulus, coagulation for 1 s to shrink the surrounding collagen and widen the channel. This process was redone four to six times during the surgical procedure. The procedure shows in Fig. 1.

The 1-mm skin incision was then closed with Steri-Strips, and the patients were discharged home within 1 h following the procedure. The patients received periprocedural and after-operation oral every 8 h for 48 h. Postoperatively, patients were allowed unlimited walking, standing and sitting. Return to sedentary or light work was permitted at 3–4 days following the surgery.

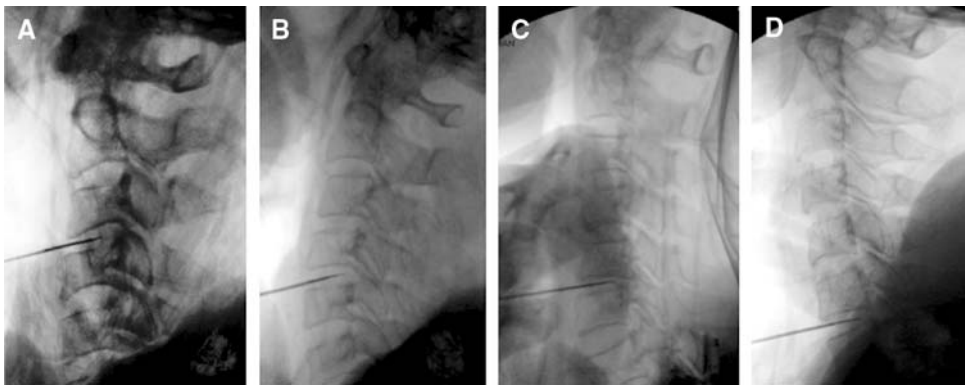

Fig. 1 Shows the PCN one level procedure at C3–4 (**a**), C4–5 (**b**), C5–6 (**c**) and C6–7 (**d**) in different patient

Radiographic assessment

The radiographic assessment of the segment stability was determined by two independent radiologists, blinded to the assigned treatment group of the patients. The radiologists studied anteroposterior, lateral, and flexion–extension lateral radiographs. The radiographical stability been considered less than 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 to extension lateral radiographic views. The AD $\geq$ 11° or HD $\geq$ 3 mm was consider radio graphically instability.

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 software. The treatment effect was evaluated by the Macnab standard [14] and by using the 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 success based on demographic variables. Results were considered statistically significant if the *P* value was equal to or less than 0.05 for continuous variables.

Results

The puncture of the needle into the disc space was accurately performed under X-ray guidance in all cases. There was one case where the Perc-D SpineWand had broken in the disc space during the procedure (Fig. 2). The partial Perc-D SpineWand that was broken in the disc space could not be removed by the percutaneous cervical discectomy and thus remained there. All patients received follow-ups. The follow-up averaged 2 years, with a range of 14–36 months. Macnab standard results were excellent in 62 cases, good in 41 cases and fair in 23 cases. The rate of excellent and good was 83.7%.

Preprocedure and the postprocedure VAS scores are illustrated in Table 1. The VAS scores demonstrated statistically significant improvement in PCN at the 2-week, 1, 3, 6, and 12-month follow-up visits when compared to the preoperational values. There were significant differences in VAS scores in the preoperatively and postoperatively ($P < 0.01$).

The procedure segment stability of preprocedure and postprocedure are illustrated in Table 2. There were no instability cases after procedure of PCN. There were no significant difference stability in the preoperatively and postoperatively ($P > 0.05$).

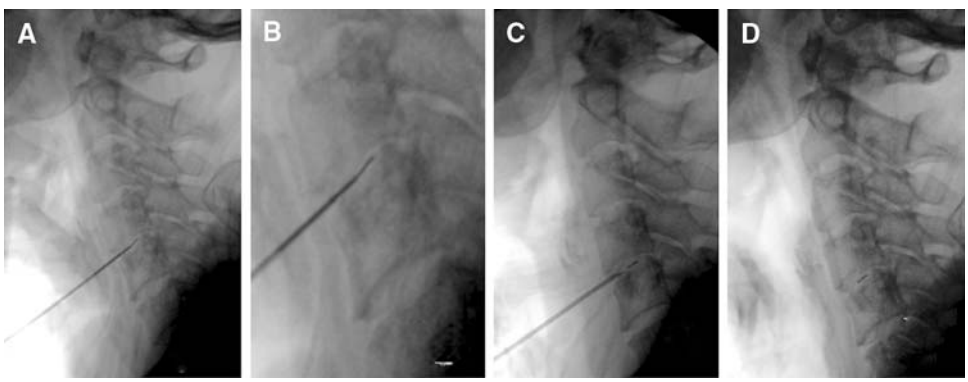

Fig. 2 Shows the case had the Perc-D SpineWand broken in C4–5 space when procedure. The partial Perc-D SpineWand to bend (**a**; **b** an enlargement in the radiograph showed it) and broken in C4–5 space can not been moved by the percutaneous cervical discectomy (**c**) and remain in there (**d**). The clinical outcome of this case is good, and no complication

Table 1 The outcomes of PCN ($\bar{x} \pm S$)

Time	VAS	*T* value	*P* value
Pre-PCN	7.25 ± 0.44		
Aft-PCN 2 weeks	2.42 ± 0.71	63.77	0.000
Aft-PCN 1 month	2.43 ± 0.71	66.12	0.000
Aft-PCN 3 month	2.43 ± 0.72	66.04	0.000
Aft-PCN 6 month	2.44 ± 0.71	65.73	0.000
Aft-PCN 12 month	2.42 ± 0.72	66.06	0.000

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 open surgery was the only remaining option available. Conventional open cervical discectomy, with or without bony fusion, is considered the standard treatment for cervical disc protrusion[10]. More over, 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 alternative ways of decompressing a pathological disc. In our series, we selected patients without myelopathy. The VAS score was decreased after 2-week and 1, 3, 6, and 12-month follow-up. The rate of excellent and good was 83.7%. Therefore, myelopathy is considered outside the indication of PCN for cervical disk hernia.

Internal disc disruption and disc herniations are 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 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 [18]. 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 patients [8]. 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, estimated 1 g is vaporized during PCN, and the clinical out is very good. There were excellent in 62 cases, good in 41 cases and fair in 23 cases. The rate of excellent and good was 83.7%. There were significant difference on VAS sores in the preoperatively and postoperatively in PCN ($P < 0.01$).

It was in 1989 that Hijikata 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 [10]. Increasing nuclear pressure 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 [13, 15]. 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. [4] showed that for every gram of nucleus removed, the disc space narrows 1.42 mm and the disc bulge increases 0.45 mm. In this study, 1 g is removed with the PCN procedures; there were no instability change of the operation segment.

The PCN of cervical disc hernia was safely performed, and the efficacy of this procedure was good in all cases in this study. The advantage of PCN is that it reduces the volume and pressure of the affected disc without damaging other spinal structures. Ablation of a relatively small volume of the nucleus pulposus results in a significant reduction in intradisc pressure. Intradiscal 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 Chen's study in human cadavers [5]. Histologic

Table 2 Comparison of the stability of segment between pre- and after operation ($\bar{x} \pm S$)

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 ± 0.82	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
Aft-PCN*	2.75 ± 0.73	0.96 ± 0.50	5.20 ± 1.18	1.43 ± 0.62	7.77 ± 1.67	1.89 ± 0.54	7.43 ± 1.36	1.63 ± 0.45

* Compare Pre-PCN, $P > 0.05$

examination revealed no evidence of direct mechanical or thermal damage to the surrounding tissues in human cadavers [6]. While given 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 [17]. In this study, the preoperative MRI reveals a bulging herniated disc at C3–4, and 6 months post operation showed the bulging herniated disc disappeared changes in this disc space (Fig. 3).

Technical advances in the use of the mid-sized cannulae approach to decompressing the nucleus have evolved to include newer techniques using even smaller cannulae. 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, monitoring of the needle 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 disc. Vascular injury can occur if the device comes into contact with an artery or a vein. Particular care should be taken to avoid puncture of the anterior annulus. The probe tip can be damaged or broken if it is forced against the vertebral endplates. The patient will feel radicular pain if the surgeon hits the anteriorly traversing nerve with the cannula.

Percutaneous disc decompression has produced a small number of complications. There was one case had the Perc-D SpineWand broken in C4–5 space when procedure (Fig. 2). The partial Perc-D SpineWand that was broken in the C4–5 space could not be removed by the percutaneous cervical discectomy and hence remained there. The clinical outcome of this case was good with no occurrence of any complication. There was no discitis in this study. In our clinical, one patient presented with neck pain and associated radicular pain and numbness in the left upper limb after a PCN in another hospital. The history was negative for fever, night pain or constitutional symptoms. Sagittal and coronal MR images of the spine showing had discitis at C5–6 (Fig. 4**).** There was loss of distinction between the endplates and C5–6 intervertebral disc on T1-weighted images, with decreased signal intensity in the adjacent vertebral bodies on the T1-weighted images and increased signal intensity on T2-weighted images. There were some potential complications of PCN that included infections, bleeding, nerve damage, worsened pain, failure of technique, and recurrence of herniation.

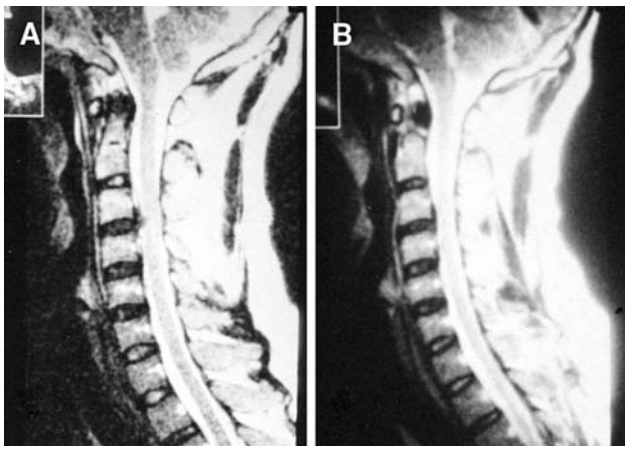

Fig. 3 Preoperative MRI reveals a bulging herniated disc at C3–4 (**a**) and 6 months post operation of PCN showed the bulging disc had disappeared (**b**)

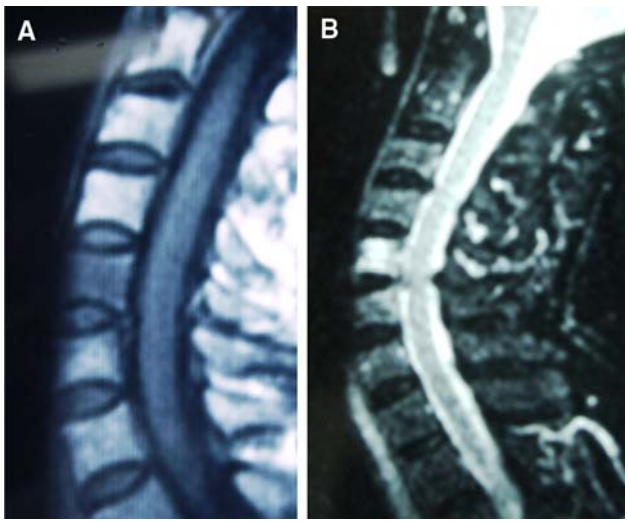

Fig. 4 Sagittal MRIof the spine showing discitis at C5–6. There were decreased signal intensity in the adjacent vertebral bodies on the T1-weighted images (**a**) and increased signal intensity on T2-weighted images (**b**) adjacent disc spaces

Conclusion

The results of this study indicate that PCN was efficacious minimally invasive technique for the treatment of symptoms associated with contained cervical herniated disc. This means that PCN can be used to treat cervical disc herniation.

References

1. Ascher PW (1986) Application of the laser in neurosurgery. Lasers Surg Med 2:91–97
2. Bailey RW, Badgley CE (1960) Stabilization of the cervical spine by anterior fusion. J Bone Joint Surg Am 42A:565–569
3. 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
4. Castro WH, Halm H, Rondhuis J (1992) 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
5. Chen YC, Lee SH, Chen D (2003) Intradiscal pressure study of percutaneous disc decompression with nucleoplasty in human cadavers. Spine 28(7):661–665. doi:10.1097/00007632-200304010-00008
6. Chen YC, Lee SH, Saenz Y et al (2003) Histologic findings of disc, end plate and neural elements after coblation of nucleus pulposus: an experimental nucleoplasty study. Spine J 3(6):466–470. doi:10.1016/S1529-9430(03)00143-8
7. Cloward RB (1958) The anterior approach for removal of ruptured cervical discs. J Neurosurg 15:602–605
8. Ellenberg MR, Honet JC, Treanor WJ (1994) Cervical radiculopathy. Arch Phys Med Rehabil 75:342–352. doi:10.1016/0003-9993(94)90040-X
9. Fukushima T, Ishijima B, Hirakawa K et al (1973) Ventriculofiberscope: a new technique for endoscopic diagnosis and operation. J Neurosurg 38:251–256
10. Hijikata S (1989) Percutaneous nucleotomy. A new concept technique and 12 years' experience. Clin Orthop Relat Res 238:9–23
11. Hirsch D (1960) Cervical disc rupture: diagnosis and therapy. Acta Orthop Scand 30:172–176
12. Kahanovitz N, Viola K, Goldstein T et al (1990) A multicenter analysis of percutaneous discectomy. Spine J 15:713–715. doi:10.1097/00007632-199007000-00017
13. Lee SH, Derby R, Chen Y et al (2004) In vitro measurement of pressure in intervertebral discs and annulus fi brosus with and without annular tears during discography. Spine J 4:614–618. doi:10.1016/j.spinee.2004.03.021
14. Macnab I (1971) Negative disc exploration: an analysis of the causes of nerve-root involvement in 68 patient. J Bone Jt Surg Br 53:891–903
15. Maroon JC (2002) Current concepts in minimally invasive discectomy. Neurosurgery 51:S137–S145. doi:10.1097/00006123-200211002-00019
16. Mixter WJ, Barr JS (1934) Rupture of the intervertebral disc with involvement of the spinal canal. N Engl J Med 211:210–215
17. Nau WH, Diederich CJ (2004) Evaluation of temperature distributions in cadaveric lumbar spine during nucleoplasty. Phys Med Biol 49(8):1583–1594. doi:10.1088/0031-9155/49/8/015
18. O'Neill CW, Kurgansky ME, Derby R et al (2002) Disc stimulation and patterns of referred pain. Spine J 27:2776–2781. doi:10.1097/00007632-200212150-00007
19. Robertson YR (1973) Anterior removal of cervical disc without fusion. Clin Neurosurg 20:259–262
20. Robinson RA, Smith GW (1955) Anterolateral cervical disc removal and interbody fusion for cervical disc syndrome. Bull Johns Hopkins Hosp 96:223–224
21. Smith L (1964) Enzyme dissolution of the nucleus pulposus in humans. JAMA 187:137–140
22. Smith L, Garvin PJ, Jennings RB et al (1963) Enzyme dissolution of the nucleus pulposus. Nature 198:131–132
23. Stookey B (1928) Compression of the spinal cord due to ventral extradural cervical chondromas. Arch Neurol Psychiatry 20:275–278