Eklem Hastalıkları ve Cerrahisi
Joint Diseases and Related Surgery

Original Article / *Çalışma - Araştırma*

Joint Dis Rel Surg
2005;16(2):102-110

New surgical techniques of percutaneous endoscopic lumbar discectomy for migrated disc herniation

Migrasyonlu disk herniasyonunun perkütan endoskopik lomber diskektomi ile tedavisinde yeni cerrahi teknikler

Seungcheol Lee, M.D., Seok-Kang Kim, M.D., Sang-Ho Lee, M.D., PhD., Song-Woo Shin, PhD.

Department of Neurosurgery, Wooridul Spine Hospital, Seoul, Korea

Objectives: Although percutaneous endoscopic lumbar discectomy (PELD) offers a favorable outcome for protruded discs, there have been difficulties for migrated discs. The purpose of this study was to present new surgical techniques of PELD for migrated disc herniation.

Patients and methods: From April 2002 to March 2003, 116 patients (73 males, 43 females; mean age 35.5 years; range 16 to 68 years) underwent PELD for radiculopathy due to migrated discs. According to preoperative MRI findings, disc migration was classified into four zones based on the direction and distance from the disc space. Two surgical techniques were used according to this classification. Far-migrated discs (zone 1 and 4) were treated with the "epiduroscopic" technique, which involved introducing the endoscope into the epidural space directly. Near-migrated discs (zone 2 and 3) were treated with the "half-and-half" technique, which involved positioning a beveled working sheath across the disc space to the epidural space. The clinical outcome was evaluated according to the modified Macnab criteria,. The intensity of pain was measured by a visual analogue scale (VAS). The mean follow-up period was 14.5 months (range 9 to 20 months).

Results: According to the modified Macnab criteria, satisfactory (excellent or good) results were distributed as follows: 91.6% (98/107) in the down-migrated discs, 88.9% (8/9) in the up-migrated discs; 97.4% (76/78) in the near-migrated discs, and 78.9% (30/38) in the far-migrated discs. The mean VAS score significantly decreased from 7.5 preoperatively to 2.6 at the final follow-up ($p<0.0001$). The mean time to return to work was 12.5 days. There were no approach-related complications.

Conclusion: Using the classification proposed, the two techniques of PELD can be safely employed in the treatment of migrated disc herniation.

Key words: Diskectomy, percutaneous/methods; intervertebral disk displacement/surgery/radiography; lumbar vertebrae/surgery.

Amaç: Perkütan endoskopik lomber diskektomi (PELD) protrude diskler için iyi sonuçlar sağlasa da, migrasyonlu disklerde çeşitli sorunlar ortaya çıkmaktadır. Bu çalışmada, migrasyonlu diskler için geliştirilen iki yeni PELD tekniği sonuçlarıyla birlikte sunuldu.

Hastalar ve yöntemler: Nisan 2002-Mart 2003 arasında 116 hastaya (73 erkek, 43 kadın; ort. yaş 35.5; dağılım 16-68) migrasyonlu disklere bağlı gelişen radikülopati nedeniyle PELD uygulandı. Disk migrasyonu, ameliyat öncesi manyetik rezonans bulgularına göre, disk boşluğuna göre gösterdiği yön ve mesafeye bağlı olarak dört bölge şeklinde sınıflandırıldı. Bu sınıflandırmaya dayanarak iki cerrahi teknik kullanıldı. Uzağa migrasyon gösteren diskler (bölge 1 ve 4), endoskobun epidural boşluğa doğrudan gönderilmesini içeren "epiduroskopik" teknikle tedavi edildi. Yakına migrasyon gösteren diskler (bölge 2 ve 3) ise, "half-and-half" olarak adlandırılan ve disk boşluğu ile epidural boşluk arasına açılı bir koruyucu tabaka yerleştirilmesini içeren teknikle tedavi edildi. Klinik sonuçlar modifiye Macnab ölçütlerine göre, ağrı görsel analog skala (GAS) ile değerlendirildi. Ortalama izlem süresi 14.5 ay (dağılım 9-20 ay) idi.

Bulgular: Modifiye Macnab ölçütlerine göre, aşağıya migrasyonlu disklerin %91.6'sında (98/107); yukarıya migrasyonlu disklerin %88.9'unda (8/9); yakına migrasyonlu disklerin %97.4'ünde (76/78); uzağa migrasyonlu disklerin %78.9'unda (30/38) tatmin edici (mükemmel ve iyi) sonuç alındı. Ameliyat öncesinde 7.5 olan ortalama GAS skoru son kontrolde 2.6 bulundu ($p<0.0001$). İşe dönüş süresi ortalaması 12.5 gün idi. Her iki teknikle ilgili komplikasyon görülmedi.

Sonuç: Migrasyonlu disklerin tedavisi, önerilen sınırlandırmadan sonra belirlenecek iki PELD tekniği ile güvenle yapılabilir.

Anahtar sözcükler: Diskektomi, perkütan/yöntem; intervertebral disk deplasmanı/cerrahi/radyografi; lomber vertebra/cerrahi.

- *Correspondence: Sang-Ho Lee, MD, PhD. Department of Neurosurgery, Wooridul Spine Hospital, 47-4 Chungdam-Dong Gangnam-Gu, Seoul 135-100, Korea. Tel: +00 - 82 - 2 - 513 8151 Fax: +00 - 82 - 2 - 513 8146 e-mail: swshin@wooridul.co.kr*
- *This work was supported by a grant from the Wooridul Spine Foundation.*

Beginning in 1973, Kambin introduced the concept of indirect decompression of the spinal canal via a posterolateral approach using a Craig cannula for evacuation of a protruded disc.[1] Hijikata in 1975, described the first percutaneous discectomy.[2] Since then, many surgeons have developed new techniques for percutaneous endoscopic discectomy.[2-5] Currently, percutaneous endoscopic lumbar discectomy (PELD) is growing in popularity in the treatment of disc herniation.

Over the past several decades, minimally invasive spinal surgery has been developed to satisfy two aims in a simultaneous manner, that is, removing the pathologic lesion more effectively and minimizing the incidence of neural and musculoskeletal injuries. With advances in instrumentation including endoscopes and Ho:YAG laser, several percutaneous endoscopic techniques have developed for the treatment of soft disc herniation. Among these, PELD has received considerable attention.

Percutaneous endoscopic lumbar discectomy minimizes epidural scar formation which is associated with postoperative paresthesia, and also reduces the risk of injuries to both the epidural venous system and nerve roots.[6-8] In addition, postoperative spinal instability and facet arthropathy can be avoided because the percutaneous endoscopic technique does not compromise normal anatomical structures, such as ligaments, muscles, bone, and facet joints.[9-11] The procedure is performed under local anesthesia as one-day surgery. Therefore, it is associated with significantly less operation-related pain and the patient can resume work within a very short time.

Although many authors have described various types of percutaneous endoscopic techniques, an illustrative technical explanation of the removal of a migrated fragment of soft disc is lacking.[12-16] Even, there is still doubt among surgeons as to whether PELD can serve to remove migrated disc fragments effectively, because the procedure is performed through a small working space and its learning curve is extremely stiff. In this study, the authors present a new surgical technique for PELD in the treatment of migrated disc herniations.

PATIENTS AND METHODS

Patient population

From April 2002 to March 2003, 116 patients underwent PELD for radiculopathy due to migrated discs. There were 73 males and 43 females, with a mean age of 35.5 years (range 16 to 68 years). The inclusion criteria were as follows: *(i)* neurological signs including radiculopathy, sensory changes, motor weakness, and the presence of abnormal reflex due to more than one of the above-mentioned signs; *(ii)* symptoms corresponding with preoperative magnetic resonance (MR) images and computed tomography (CT) scans; *(iii)* unsuccessful conservative treatment including root blocks and analgesics for at least four weeks; *(iv)* no past history of back surgery. Patients with *(i)* central stenosis (<10 mm) or lateral recess stenosis (<3 mm) confirmed by MR images and CT scans; *(ii)* a narrowing foramen (<7 mm); *(iii)* a combined end plate fracture; *(iv)* sequestered disc below the center of the lower pedicle; and *(v)* segmental instability confirmed by dynamic radiographs were excluded.

Preoperative and postoperative MR images were obtained in all the patients. Postoperative MR images were taken immediately after surgery to ensure adequate removal of the migrated disc. Clinical follow-ups were undertaken at the end of a week, a month, three months, six months, and a year. Final clinical assessments were made with the use of the cross-sectional outcome analysis. Clinical outcome was defined as excellent, good, fair and poor according to the modified Macnab criteria.[17] Excellent and good outcomes were rated as clinical success. The intensity of pain was mea-

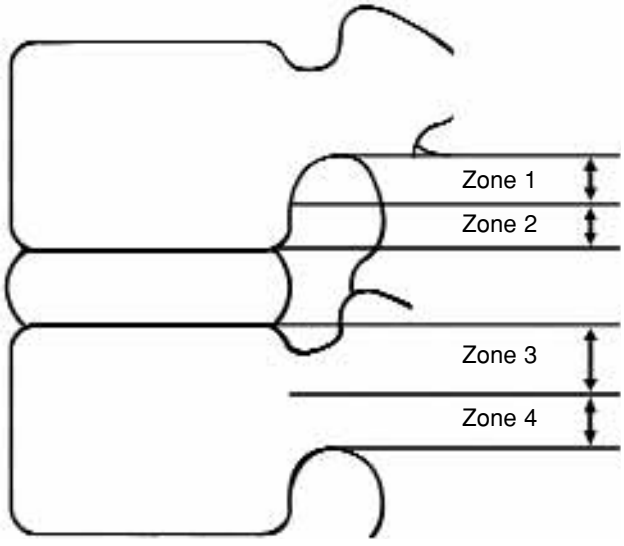

Fig. 1. Schematic illustration of the four anatomic zones and levels of disc herniation.

TABLE I

Radiologic classification of migrated disc herniations according to direction and distance

Zones	Direction	Distance	Definition
1	Up	Far	From the inferior margin of the upper pedicle to 3 mm below the inferior margin thereof
2	Up	Near	From 3 mm below the inferior margin of the upper pedicle to the inferior margin of the upper vertebral body
3	Down	Near	From the superior margin of the lower vertebral body to the center of the lower pedicle
4	Down	Far	From the center to the inferior margin of the lower pedicle

*: The center of direction and distance is the disc space.

sured by a visual analogue scale (VAS). Preoperative and postoperative VAS scores were compared according to gender, level, and zone. The mean follow-up period was 14.5 months (range 9 to 20 months). Statistical analyses were made using the Fisher's exact test.

Radiologic classification

Based on preoperative MRI findings, disc migration was classified into four zones depending on the direction and distance from the disc space (Table I, Fig. 1).

Surgical techniques

Two surgical approaches are used on the basis of this classification. One is designed for near-migrated discs and is termed as the "half-and-half" technique (Fig. 2a). In this technique, a beveled working sheath is laid across the disc space to the epidural space. The other is the "epiduroscopic" technique used for far-migrated discs, which involves introducing the endoscope into the epidural space directly for far-migrated discs (Fig. 2b). The major difference between these two approaches is the extent to which the working sheath is introduced into the epidural space, i.e. perfectly or partially.

All the procedures are performed in prone position under local anesthesia. An imaginary line drawn to the fragment through the foramen designates the entry point and the surgical trajectory. According to this guideline, the entry point is 9 to 13 cm from the midline in Korean patients. Under fluoroscopic guidance, an 18 G needle is inserted. The ideal position of the needle tip just prior to puncture of the disc is on the posterior vertebral body line on the lateral C-arm view, and on the medial pedicular line on the anteroposterior view, especially below the L_{3-4} level. This should correspond to the safe triangle in the axillary area between the exiting and traversing nerve roots.[18] The location of the nerve roots is

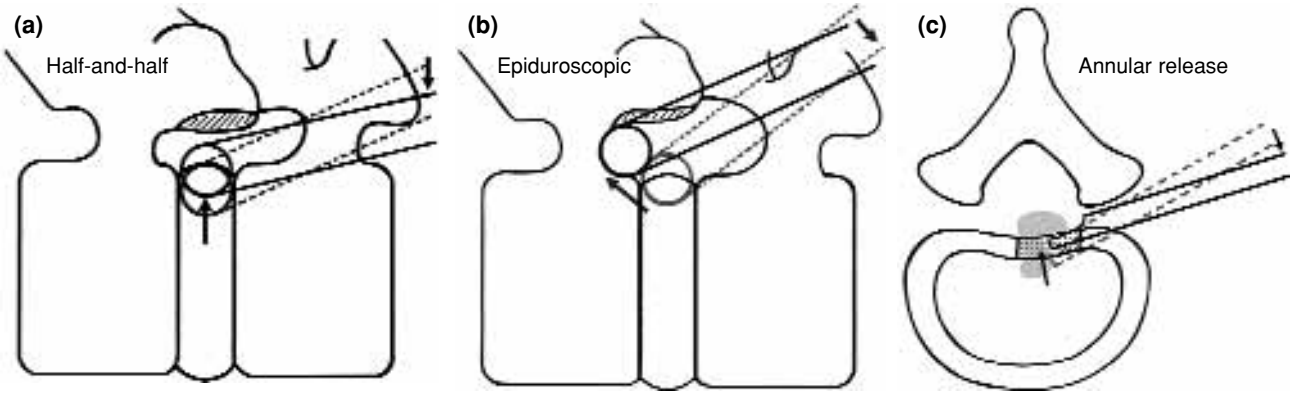

Fig. 2. Illustration of the techniques used. **(a)** The "half-and-half" technique involves positioning of the opening of beveled working sheath across the disc space to the epidural space. **(b)** The "epiduroscopic" technique involves introducing an endoscope directly into the epidural space. These two approaches are possible after release of the annulus and removal of the inferior part of the superior articular process and ligamentum flavum. **(c)** The annulus, which traps the disc fragment, is removed so that the tip of the working sheath is readily advanced over the posterior vertebral body level. The disc material which is located in the epidural space can be removed easily. It is usually performed from inside to outside.

confirmed with the use of epidurogram. Then, an obturator is used to introduce the working sheath into the disc space. At this point, a small amount of disc is removed using large forceps to create working space. Approximately one-third of the posterior nucleus pulposus and annulus is removed before removing the ruptured fragment. This provides adequate room for effective handling of the working sheath. To bring the opening of the working tube to the epidural space, annular release is the key procedure. Then, the tip of the working tube is lifted (Fig. 2c). Annular release is usually performed from inside to outside. Both the "epiduroscopic" and "half-and-half" techniques are essential for the removal of disc fragments at zone 1 and 4. For this procedure, additional foraminoplasty is needed in patients with a small foraminal size and/or far-migrated disc herniation (zone 1 and 4) (Fig. 2a, b). Epidural bleeding is controlled with the use of a bipolar coagulator (Ellman,; Ellman Innovations LLC, USA) under cold saline irrigation. The side-firing laser is helpful for annular release and foraminoplasty. The well-decompressed nerve roots are confirmed by visualization of the thecal sac and nerve root pulsation following respiration and Valsalva.

A. Near-migrated disc herniation (zone 2 and 3): The "half-and-half" technique is sufficient to remove near-migrated disc fragments under the endoscopic view. The working sheath should be placed in the direction of the migrated disc. If the half of the working sheath is placed beyond the posterior vertebral bodyline, disc fragments can easily be removed using forceps (Fig. 3a). So the release of the annulus and the posterior longitudinal ligament is the key procedure for free movement of the working sheath. Moreover, the annulus usually traps the ruptured nucleus pulposus. Endoscopic views are shown in Fig. 4. The working sheath is laid across the disc space to the epidural space (Fig. 4a). After the annular release, the tip of the working sheath is advanced to the epidural space. Then, the extruded disc can be removed using forceps (Fig. 4b). Finally, the traversing nerve root and epidural fat remain unimpeded (Fig. 4c).

B. Far-migrated disc herniation (zone 1 and 4): The "epiduroscopic" technique is needed for far-migrated discs. If the disc is not fragmented, it can be grabbed at the proximal end by forceps. However, if the migrated disc is broken into pieces, the "epiduroscopic" technique should be combined with foraminoplasty. The working sheath should be placed in the direction of the migrated disc (Fig. 3b). As mentioned before, the annular cutting procedure is also essential. Then, foraminal ligaments and the ventral part of the superior facet should be removed using laser and the bone cutter (Shaded area in Fig. 2b). A widened foramen allows comfortable access to the pathologic lesion. A clinical case with an up-

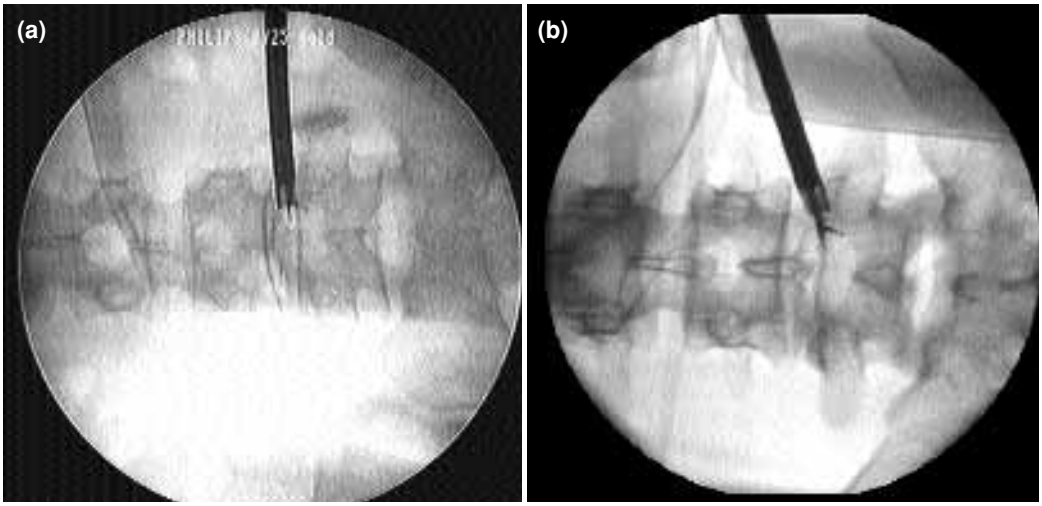

Fig. 3. Intraoperative C-arm views for down-migrated discs. **(a)**: Annular release allows the forceps to enter the epidural space. With the "half-and-half" technique, the fragment located at zone 3 can be removed. **(b)**: After foraminoplasty, the working sheath can be directly advanced to the epidural space so that the fragment at zone 4 can be removed.

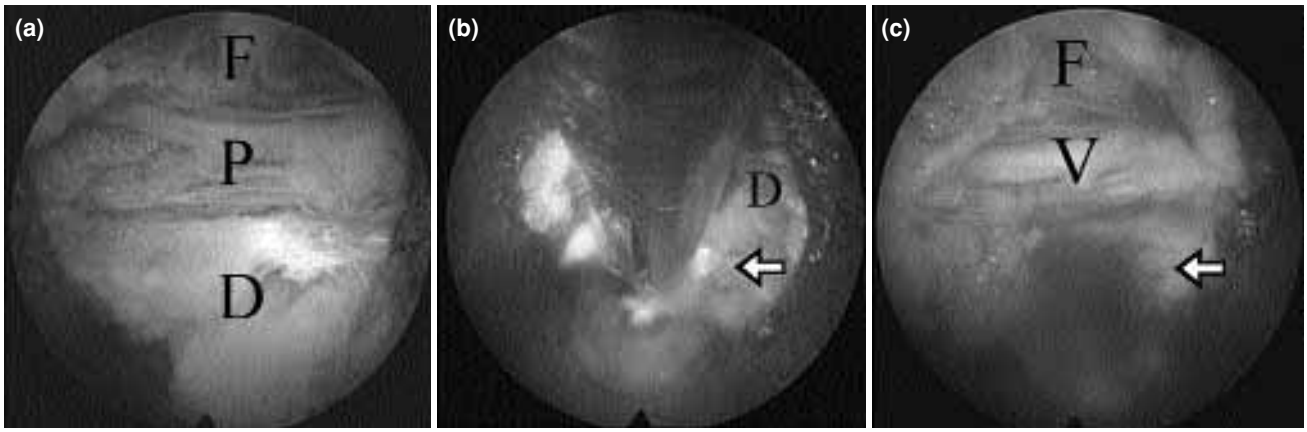

Fig. 4. Intraoperative endoscopic views. **(a)** Initial appearance of the "half-and-half" technique: The working sheath is laid across the disc space to the epidural space. **(b)** After annular release, the tip of the working sheath is advanced to the epidural space. The extruded disc can be removed by forceps. **(c)** Final appearance. The arrow indicates the posterior margin of the vertebral body. (D: Herniated disc stained by indigo carmine; F: Epidural fat; P: Posterior longitudinal ligament; V: Epidural veins.)

migrated disc is illustrated in Fig. 5 and 6. The up-migrated disc was located at zone 1 from the foraminal area to the paramedian area (Fig. 5a). Annular release was performed from inside to outside and the forceps was gradually approached to the main migrated disc fragment. The far-migrated disc fragment totally disappeared after surgery (Fig. 5b).

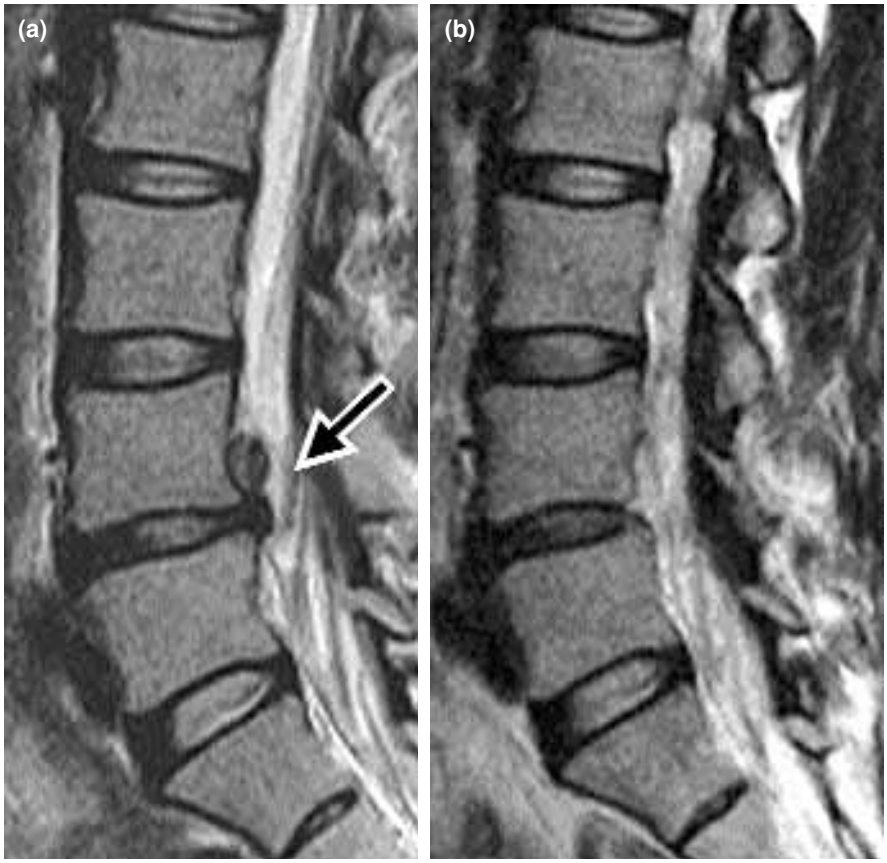

Fig. 5. Magnetic resonance images **(a)** before and **(b)** after the procedure. **(a)** Up-migrated disc fragment (zone 1). **(b)** The far-migrated disc fragment totally disappeared.

TABLE II

Clinical and radiological outcomes according to the modified Macnab criteria

	Excellent		Good		Fair		Poor		*Total*
	n	%	n	%	n	%	n	%	
Levels									
L_{2-3}	–		1	100.0	–		–		1
L_{3-4}	1	33.3	2	66.7	–		–		3
L_{4-5}	25	35.7	37	52.9	7	10.0	1	1.4	70
L_5-S_1	26	61.9	14	33.3	1	2.4	1	2.4	42
Zones									
1	–		3	75.0	1	25.0	–		4
2	3	60.0	2	40.0	–		–		5
3	39	53.4	32	43.8	1	1.4	1	1.4	73
4	10	29.4	17	50.0	1	3.0	6	17.6	34

RESULTS

The L_{4-5} disc was the most commonly herniated level (70 cases, 60.3%) followed by L_{5-S1} (42 cases, 36.2%). The lesions were at L_{3-4} in three patients (2.6%) and L_{2-3} in one patient (0.9%). The direction of disc herniation was to a lower level in 107 cases (92.2%) and to a upper level in nine cases (7.8%). Herniations were localized at zones 1 to 4 in four (3.5%), five (4.3%), 73 (62.9%), and 34 (29.3%) cases, respectively.

According to the modified Macnab criteria, satisfactory (excellent or good) results were distributed as follows: 91.6% (98/107) in the down-migrated discs, 88.9% (8/9) in the up-migrated discs; 97.4% (76/78) in the near-migrated discs, and 78.9% (30/38) in the far-migrated discs (Table II).

The mean preoperative and postoperative VAS scores are shown in Table III. The mean VAS score significantly decreased from 7.5±1.7 to 2.6±1.8 at the final follow-up ($p<0.0001$). The difference between the pre- and postoperative VAS scores of far-migrated discs (zone 1 and 4) was statistically lower than that of near-migrated discs (zone 2 and 3). The mean time to return to work was 12.5 days. There were no approach-related complications.

DISCUSSION

Theoretically, percutaneous endoscopic surgery has many advantages over open surgery, the main advantage being early return to work. However, it has not been so popular because of technical considerations and the limited indications. Recently, due to advances in instrumentation and tech-

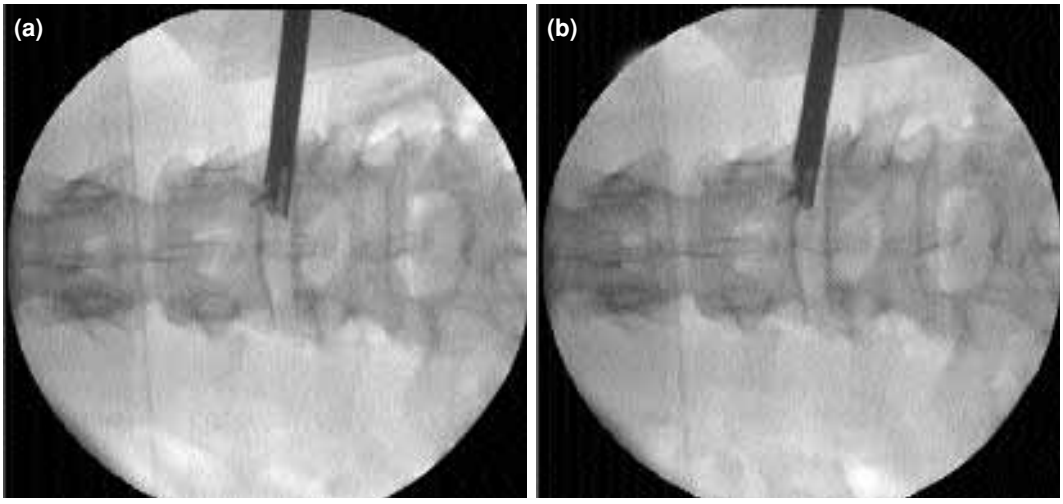

Fig. 6. (a, b) Intraoperative C-arm views: After annular release, the forceps can be freely advanced to the migrated disc fragment.

TABLE III

Comparison of the mean preoperative and postoperative VAS scores according to gender, level and zone

		The mean VAS score		
	No. of patients	Preoperative	Postoperative	Difference
Gender				
Male	73	7.56	2.81	4.75
Female	43	7.45	2.50	4.95
Level				
L_{2-3}	1	9.00	4.00	5.00
L_{3-4}	3	8.50	2.50	6.00
L_{4-5}	70	7.03	2.74	4.29
L_5-S_1	42	8.14	2.57	5.57
Zones				
1	4	5.50	2.00	3.50
2	5	5.67	1.00	4.67
3	73	8.06	2.36	5.69
4	34	6.94	3.76	3.18

niques, indications for percutaneous endoscopic surgery have expanded. Ahn et al.[12] reported the use of this technique together with their results in the treatment of lateral recess and exiting zone stenosis. Nonetheless, some spine surgeons still wonder whether percutaneous endoscopic surgery can be an alternative to conventional open surgery for the treatment of radiculopathy due to migrated discs.[19-21]

The results of this study show excellently high success rates in all migrated discs, regardless of the direction or distance from the disc space. Although Kambin et al.[14,15] reported similar results with transforaminal endoscopic surgery compared to open microdiscectomy for the same indications and good surgical results for lateral recess stenosis and fragmentectomy, they did not employ radiologic classification and provide a detailed technical description for the removal of migrated disc fragments.[13] The authors defined the location of the migrated discs in four zones. This classification can be a yardstick for preoperative evaluation and in determining the proper technique. Moreover, a comprehensive account is given on each surgical procedure for each zone. Some surgeons use an extremely lateral entry to approach the epidural space, which carries a serious risk for peritoneal perforation. In contrast, the "half-and-half" and "epiduroscopic" techniques involving the release of the annulus can minimize potential risks; it provides an easy and direct access to the fragment, as well. Yet, the "epiduroscopic" technique presents such problems as epidural bleeding, risk for neural injuries, and pain, and it requires the removal of the inferior part of the superior articular process, which has an adverse effect on the outcome as seen in Table II.

The difference between the pre- and postoperative VAS scores for the far-migrated discs (zone 1 and 4) was statistically lower than that of the near-migrated discs (zone 2 and 3) (Table III). This indicates that patients with far-migrated discs have less favorable outcomes than those with near-migrated discs. If the disc is fragmented, there is a higher likelihood of failure. Our results show that the majority of poor outcomes were associated with zone 4. This implies that far-migrated discs may require special attention.

As we know, the main reason for incomplete symptom relief is the presence of remnant fragments. For this reason, annular release is needed during which remnant fragments can be caught by annular trapping.

The opening to the epidural space may give rise to perineural adhesions, but these are of negligible importance due to the small area involved. Moreover, the "epidural approach" may present some risks for neural and vascular injuries even in the "half-and-half" technique. Such injuries can be

avoided by taking epidurograms before the insertion of the needle into the disc space. No neural or vascular complications developed in our patients.

The long-term results of open surgery show that many patients suffer from low back pain following open discectomy. Patients in whom a large amount of disc had been removed showed lower recurrence rates on one hand, but experienced a more severe back pain, on the other.[22] In this study, the authors performed a mere herniectomy with minimal removal of the dorsal part of the nucleus and tried to preserve the anterior two-third as much as possible. Although some patients complained of low back discomfort, none developed recurrences throughout the follow-up period. Therefore, the results of endoscopic surgery in the long-term with respect to back pain and recurrences have yet to be evaluated.

The mean time to return to work in this study was 12.5 days, which was remarkably shorter than that of traditional microdiscectomy or microendoscopic discectomy. This is one of the most notable advantages of percutaneous endoscopic discectomy. The clinical outcomes were also comparable or superior to those of traditional open surgeries, with a lower incidence of complications. These are sufficiently good reasons for a surgeon to consider the percutaneous approach.

The most important point for successful endoscopic treatment is the accurate approach to the proper indication. The authors consider open surgery if there is possibility of incomplete removal of the disc fragment, as in patients with a sequestered disc in zone 1 and 4. In addition, endoscopic surgery requires appreciation of the endoscopic anatomy matching the fluoroscopic view. After mastering surgical anatomy and with strict adherence to technical guidelines, endoscopic surgery does not present difficulties for dealing with migrated discs.

In conclusion, disc migration can be classified into four zones based on the direction and distance from the disc space. Two techniques of PELD can be used according to this classification: the "half-and-half" technique for near-migrated discs and the "epiduroscopic" technique for far-migrated discs. The authors believe that the results of this study will contribute to the establishment of surgical guidelines for PELD in the treatment of migrated disc herniation, and that any experienced spine surgeon can safely perform these approaches, with the understanding that far-migrated discs may need a more careful attention.

REFERENCES

1. Kambin P, Gellman H. Percutaneous lateral discectomy of the lumbar spine. A preliminary report. Clin Ortho 1983;174:127-32.
2. Hijikata S, Yamagishi M, Nakayama T, Oomori K. Percutaneous nucleotomy: a new treatment method for lumbar disc herniation. J Toden Hosp 1975;5:5-13.
3. Knight MT, Goswami AK. Endoscopic laser foraminoplasty. In: Savitz MH, Chiu JC, Yeung AT, editors. The practice of minimally invasive spinal technique. 1st ed. Richmond, VA: American Academy of Minimally Invasive Spinal Medicine and Surgery Education Press; 2000. p. 337-40.
4. Onik G, Mooney V, Maroon JC, Wiltse L, Helms C, Schweigel J, et al. Automated percutaneous discectomy: a prospective multi-institutional study. Neurosurgery 1990;26:228-33.
5. Sherk HH, Black JD, Prodoehl JA, Cummings RS. Laser diskectomy. Orthopedics 1993;16:573-6.
6. Hoyland JA, Freemont AJ, Jayson MI. Intervertebral foramen venous obstruction. A cause of periradicular fibrosis? Spine 1989;14:558-68.
7. Olmarker K, Rydevik B, Holm S. Edema formation in spinal nerve roots induced by experimental, graded compression. An experimental study on the pig cauda equina with special reference to differences in effects between rapid and slow onset of compression. Spine 1989;14:569-73.
8. Parke WW. The significance of venous return impairment in ischemic radiculopathy and myelopathy. Orthop Clin North Am 1991;22:213-21.
9. Kambin P, Cohen LF, Brooks M, Schaffer JL. Development of degenerative spondylosis of the lumbar spine after partial discectomy. Comparison of laminotomy, discectomy, and posterolateral discectomy. Spine 1995;20:599-607.
10. Rantanen J, Hurme M, Falck B, Alaranta H, Nykvist F, Lehto M, et al. The lumbar multifidus muscle five years after surgery for a lumbar intervertebral disc herniation. Spine 1993;18:568-74.
11. Weber BR, Grob D, Dvorak J, Muntener M. Posterior surgical approach to the lumbar spine and its effect on the multifidus muscle. Spine 1997;22:1765-72.
12. Ahn Y, Lee SH, Park WM, Lee HY. Posterolateral percutaneous endoscopic lumbar foraminotomy for L5-S1 foraminal or lateral exit zone stenosis. Technical note. J Neurosurg Spine 2003;99:320-3.
13. Hermantin FU, Peters T, Quartararo L, Kambin P. A prospective, randomized study comparing the results of open discectomy with those of video-assisted arthroscopic microdiscectomy. J Bone Joint Surg [Am] 1999; 81:958-65.

14. Kambin P, Casey K, O'Brien E, Zhou L. Transforaminal arthroscopic decompression of lateral recess stenosis. J Neurosurg 1996;84:462-7.
15. Kambin P, O'Brien E, Zhou L, Schaffer JL. Arthroscopic microdiscectomy and selective fragmentectomy. Clin Orthop 1998;(347):150-67.
16. Yeung AT, Tsou PM. Posterolateral endoscopic excision for lumbar disc herniation: Surgical technique, outcome, and complications in 307 consecutive cases. Spine 2002;27:722-31.
17. Macnab I. Negative disc exploration. An analysis of the causes of nerve-root involvement in sixty-eight patients. J Bone Joint Surg [Am] 1971;53:891-903.
18. Kambin P, Savitz MH. Arthroscopic microdiscectomy: an alternative to open disc surgery. Mt Sinai J Med 2000; 67:283-7.
19. Mikhael MA, Ciric I, Tarkington JA, Vick NA. Neuroradiological evaluation of lateral recess syndrome. Radiology 1981;140:97-107.
20. Prere J, Manelfe C, Salvolini U. Pathology of the neural arch, spinal stenosis, and spondylolisthesis. In: Manelfe C, editor. Imaging of the spine and spinal cord. New York: Raven Press; 1992. p. 342-53.
21. Yoshida M, Shima K, Taniguchi Y, Tamaki T, Tanaka T. Hypertrophied ligamentum flavum in lumbar spinal canal stenosis. Pathogenesis and morphologic and immunohistochemical observation. Spine 1992;17: 1353-60.
22. Yorimitsu E, Chiba K, Toyama Y, Hirabayashi K. Long-term outcomes of standard discectomy for lumbar disc herniation: a follow-up study of more than 10 years. Spine 2001;26:652-7.