A. Dezawa
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(Eds.)

State of the Art for

Minimally Invasive Spine Surgery

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With 91 Figures, Including 2 in Color

Springer

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Foreword

The second congress of the Pacific Asian Society of Minimally Invasive Spine Surgery (PASMISS) held in Phuket, Thailand, August 5–6, 2002, was highly successful. Dr. Akira Dezawa, the president, had worked hard in organizing the congress, which was well attended. All scientific papers presented were of the highest standard and were worthy of publication in book form. This scientific meeting brought to light the practice of this modern surgical technique as it is being performed by spine surgeons in the Asia–Pacific region. Dr. Dezawa has made a great effort to collect the papers from the congress, and to have them edited and published as a text that covers all aspects of the minimally invasive spine surgical approach.

Minimally invasive spinal surgery will be a highlight of operative approaches in the twenty-first century and already has been popularized worldwide. This procedure will provide surgical options that address several pathological conditions in the spinal column without producing the types of morbidity commonly seen in open surgical procedures.

The contents of this book provide highly relevant and detailed information. I certainly believe that it will be a great benefit to all orthopedic surgeons who are interested in performing minimally invasive spine surgery.

Charoen Chotigavanich, M.D.
Chairman, Spinal Section
The Royal College of Orthopedic Surgeons of Thailand

Preface

Recent decades have been characterized by revolutionary changes in spinal surgery. Concurrent progress in implant technology and functional endoscopes and the improvement of less invasive surgical techniques has opened a new dimension for spine surgery.

We now are able to perform with minimally invasive techniques the same types of procedures that traditionally were performed as open surgery. These advanced procedures bring about important benefits in the patients' quality of life, which we believe to be the main goal of therapy.

A meeting of the Pacific Asian Society of Minimally Invasive Spine Surgery (PASMISS) was held in Phuket, Thailand, in 2002. There, we discussed the challenges and responsibilities of the new techniques. Because of the increased risk of complications during the early learning phase, we must determine the training and credentials necessary for practitioners of this procedure. Regarding the course of future development, there have been calls for increased standardization of minimally invasive techniques assisted by endoscopy. More effort obviously must be devoted to establishing the guidelines and credentials for training programs.

We appreciate the valuable contributions from all the authors and are grateful for the insightful comments of Professor Charoen Chotigavanich.

We also thank the staff of our publisher, Springer-Verlag Tokyo, for their assistance and cooperation.

Akira Dezawa, M.D., Ph.D.
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Contents

A Prospective, Randomized, Controlled Trial Comparing the Results of Microdiscectomy Under Regional and General Anesthesia

Thanet Wattanawong[1], Petchara Chamnankitkosol[2], and Patarawan Woratanarat[1]

Summary. The purpose of this study was to evaluate and compare the results of microlumbar discectomy under regional anesthesia and under general anesthesia. This prospective, randomized, controlled trial was performed between October 2001 and March 2002 at Ramathibodi Hospital. Eighteen patients with lumbar disc herniation treated by microlumbar discectomy and followed in the same spinal protocol were randomly divided into two groups according to the anesthetic procedure: those under regional anesthesia and those under general anesthesia. Preoperative, postoperative, and long-term follow-up data were recorded. Ten patients were recruited to the regional anesthesia group and eight to the general anesthesia group. There were no significant differences in age, staging, severity, or operative time. The mean ambulation time in the regional anesthesia group (12 h) was significantly shorter than that in the general anesthesia group (48 h). The mean length of hospital stay was 1.3 and 4 days, respectively. In both groups, only oral analgesic drugs were needed. There was only one minor complication in the regional anesthetic group in a patient who developed orthostatic hypotension. Microlumbar discectomy is one of the best methods, with minimal invasiveness, minimal soft tissue injury, and short hospital stay, especially when performed with the patient under regional anesthesia.

Key words. Microlumbar, Discectomy, Regional anesthesia, General anesthesia, Treatment

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Introduction

Lumbar disc herniation is one of the most common causes of back pain. The failure of conservative treatment is the major indication for surgery. There are many methods of surgery, including open discectomy, microdiscectomy, and endoscopic discectomy, and also of anesthetic technique. The objective of this study was to compare the results of microlumbar discectomy under general anesthesia and under regional anesthesia.

Materials and Methods

This was a prospective, randomized, controlled trial in 18 patients with lumbar disc herniation who were treated with microlumbar discectomy at Ramathibodi Hospital between October 2001 and March 2002. The patients were divided into two groups: a general anesthesia group and a regional anesthesia group. Demographic data and the Oswestry and Roland-Morris score (functional score) of the patients were recorded before the operation. The same microlumbar discectomy procedure by the same surgeon was performed in both groups. The operative time, amount of blood loss, ambulation time, and hospital stay were recorded. All patients were reevaluated with the Oswestry and Roland-Morris score on the first day, the second and fourth weeks, and the third month, and the percentage of the functional score at each time point was calculated by the following formula:

$$\text{Precentage of functional score} = \frac{\text{Oswestry and Roland-Morris score} \times 100}{\text{Preoperative Oswestry and Roland-Morris score}}$$

For statistical analysis, Fisher's exact test and Student's t-test were used according to the type of data, and $P < 0.05$ was considered to indicate statistical significance.

Results

Demographic data and operative outcomes are shown in Table 1. There were 10 patients in the regional anesthesia group and 8 in the general anesthesia group. The former group was composed of 7 men and 3 women, and the latter group of 3 men and 5 women. The mean ages were 38.4 years and 40.0 years, respectively, and there was no significant difference in age between the groups ($P = 0.64$). In both groups the most common site of disc herniation was on the left at the level of the fourth and fifth lumbar discs. The operative time

TABLE 1. Demographic data and operative outcome of the regional and general anesthesia groups

Variable	Regional anesthesia group	General anesthesia group	*P* value
Demographic data			
No. of patients	10	8	
Sex (male : female)	7 : 3	3 : 5	0.34
Mean (range) age (yr)	26–50 (38.4)	32–49 (40.0)	0.64
Side (left : right)	9 : 1	4 : 4	0.12
Level (L4-5 : L5-S1)	7 : 3	7 : 1	1.00
Operative outcome			
Mean operative time (min)	30–105 (64.0)	45–90 (58.1)	0.59
Mean blood loss (ml)	20–50 (28.0)	20–30 (23.8)	0.40
Mean ambulation time (h)	3–48 (12.0)	24–96 (48.0)	<0.05
Mean hospital stay (days)	1–4 (1.3)	1–14 (4.0)	0.07
Complications	Orthostatic hypotension (1 patient)		

under regional anesthesia was 30–105 min (mean, 64 min), which did not significantly differ from that under general anesthesia (45–90 min; mean, 58.1 min). The amount of blood loss during the operation was similar in both groups. The mean ambulation time was 12 and 48 h respectively, a significant difference ($P < 0.05$). The mean hospitalization time was 1.3 and 4.0 days, respectively ($P > 0.05$). One patient who underwent regional anesthesia developed orthostatic hypotension at the 6th hour after operation; however, after resting for a day, he could walk well without further complications. All patients in both groups needed only oral analgesic drugs and did not need intravascular or intramuscular analgesic drugs. Long-term follow-up showed that the Oswestry and Roland-Morris score was improved in all patients; however, the improvement in the functional score in the regional anesthesia group occurred earlier than in the general anesthesia group and was also significantly different from that in the general anesthesia group on the first day and the fourth week (Table 2).

Discussion

Microlumbar discectomy is one of the best surgical treatments for disc herniation [1]. This technique uses a surgical incision of 1.5–2.5 cm and causes less soft tissue and muscle destruction than the open standard technique [2]. The patients can ambulate early with minimal blood loss [3] and have less infection. Regional anesthesia is beneficial for immediate pain reduction.

Table 2. Oswestry and Roland-Morris scores on long-term follow-up

Time	Oswestry and Roland-Morris score		% of functional score[a]		P value
	Mean ± SD	% ± SD	Mean ± SD	% ± SD	
Preoperative	42.7 ± 16.2	38.6 ± 12.9	100	100	—
1st day	30.2 ± 13.6	48.1 ± 19.9	81.1 ± 39.7	124.3 ± 28.7	0.03
2nd week	17.9 ± 11.1	32.0 ± 17.7	51.4 ± 43.6	88.9 ± 49.7	0.12
4th week	9.6 ± 5.8	21.1 ± 14.5	23.9 ± 12.3	62.1 ± 46.0	0.02
3rd month	9.6 ± 10.4	21.6 ± 15.6	25.0 ± 23.9	75.1 ± 70.5	0.05

[a] $\% \text{ of functional score} = \frac{\text{Oswestry and Roland-Morris score} \times 100}{\text{Preoperative Oswestry and Roland-Morris score}}$

When microlumbar discectomy is combined with regional anesthesia, the outcome of the operation is improved. This is shown in our study, in which there was a short ambulation time and early improvement of the functional score in the regional anesthesia group, especially on the day after operation. In contrast to the general anesthesia group, the pain increased after the day of operation and then gradually decreased. However, the most important factor that determines the result is patient selection [4], which is much more important than surgical technique, equipment, and instrumentation. Appropriate patient selection will improve the outcome of treatment, especially when combined with microscopic surgery. The surgical results will greatly improve, with fewer complications, less soft tissue destruction [5], and a decrease in the rate of mechanical back pain failure [6]. Unfortunately, one patient who had regional anesthesia developed transient orthostatic hypotension at the 6th postoperative hour after he tried to walk around the bed by himself. After a few periods of bed rest, he could walk well without further major complications. This problem could be prevented by adjustment of the level and volume of spinal anesthesia, and by postoperative care and prevention. There were no differences in the amount of blood loss, operative time, rate of complications, and overall results after 3 months between the regional anesthesia group and the general anesthesia group, because all patients underwent the same microdiscectomy by the same technique and with the same surgeon. In our study, there was no other complications, including infection, hematoma, miss level, superior rectal artery injury [7], and small intestinal injury [8].

Although only 18 patients were recruited in this study, it showed a greater benefit of regional anesthesia compared with general anesthesia in microlumbar discectomy. To confirm our findings, studies with a larger sample size should be undertaken.

Conclusions

Microlumbar discectomy is one of the best treatments because of its small incision, less soft tissue destruction, and absence of bony and laminar bone destruction. The outcome is much improved when it is performed under regional anesthesia, because the pain is decreased immediately after operation, the patients can ambulate early, and the period of hospitalization is short. Consequently, it can be performed as outpatient discectomy [9], and the long-term outcomes will be almost the same as when the operation is performed under general anesthesia.

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Nucleoplasty as an Alternative Intradiscal Therapy: Indications and Technique

Koang Hum Bak, Seong Hoon Oh, Jae Min Kim, Hyeong Joong Yi, Cheong Jin Hwan, and Choong Hyun Kim

Summary. This study was designed to determine the outcome of treatment of herniated intervertebral discs with Nucleoplasty (Arthrocare Spine, Sunnyvale, CA, USA). Nucleoplasty, a minimally invasive procedure for treating the contained herniated intervertebral discs, was introduced recently. Nucleoplasty utilizes coblation technology for ablating and coagulating soft tissue for partial disc removal. Sixty-five patients underwent Nucleoplasty at Hanyang University Hospital from August 2000. All patients had axial pain, and 49 patients had accompanying radiating pain in the leg. The mean follow-up period was 6.2 months. Fifty-six patients underwent the one-level procedure, and nine patients underwent the two-level procedure. The operated levels were L2-3 in 4 cases, L3-4 in 3 cases, L4-5 in 36 cases, and L5-S in 3 cases. The average operation time was 46 min. Most patients underwent the procedure under local anesthesia and were discharged on the same day or the next day. Ruptured or migrated disc herniations, spinal stenosis, previous major spinal surgery, and definite radiological spinal instability were contraindications. A visual analogue scale (VAS) and the MacNab classification were used to measure symptoms at each visit. The subjects were 27 men and 19 women, with a mean age of 38.5 years at the time of surgery. The surgical results according to the MacNab classification were excellent or good in 54 cases, fair in 6 cases, and poor in 5 cases. The mean VAS score was 7.5 at the time of surgery and 2.2 at 1 month after the procedure. Most patients showed symptom improvement 1 or 2 days after surgery. Difficulties were found in targeting into and navigating in the L5-S level. Three patients underwent open discectomy and one patient received an epidural steroid injection during the follow-up period. One case of discitis was treated with intravenous antibiotics as a surgery-related complication. These results indicate that Nucleoplasty is

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a new and reliable addition to the armamentarium of minimally invasive disc surgery for contained herniated intervertebral discs. Patient selection is the most important key to successful surgical results.

Key words. Herniated intervertebral disc, Intradiscal therapy, Minimally invasive spine surgery, Nucleoplasty

Introduction

Surgical treatments of chronic low back pain and herniated intervertebral discs with minimally invasive techniques have had mixed results. Automated percutaneous lumbar discectomy (APLD) [1–5], chemonucleolysis with chymopapain [6–8], laser discectomy [9], endoscopic discectomy [10], and intradiscal electrothermal therapy (IDET) [11] have been introduced. Some of these methods are still being used, while others are not used as frequently as they were because of their problems. There are many ongoing studies and new clinical procedures to address these problems.

The pathophysiology of discogenic pain is complex and not well understood. The disc is a nociceptive structure that produces pain. Granulation tissue and ingrowth of small unmyelinated nerve fibers occur in degenerative and disrupted discs. Mechanical loading of areas of degenerated and disrupted annular lamellae may cause sensitization of annulus nociceptors. Nociceptors exposed to inflammatory substances have been shown to sustain a lowered threshold of firing.

The idea of intradiscal delivery of thermal energy began with laser discectomy and IDET. Laser discectomy and IDET can be potentially hazardous to nerves and discs because of inadequate temperature control and the extent of tissue heated.

Nucleoplasty, a minimally invasive procedure for treating symptomatic patients with contained herniated intervertebral discs, was introduced in July 2000. Nucleoplasty utilizes coblation technology for ablating and coagulating soft tissue, combining both approaches for partial disc removal. Coblation ablates tissue via a low-temperature molecular dissociation process to create small channels within the disc. We report our experiences with nucleoplasty and suggest indications and contraindications to this procedure.

Methods

Sixty-five patients underwent nucleoplasty at Hanyang University Hospital from August 2001 to February 2002. There were 37 men and 28 women, with a mean age of 34.5 years (range, 21–62 years) at the time of surgery (Table 1).

TABLE 1. Age and sex distribution of patients ($n = 65$)

Sex	Age (yr)					Total
	20–29	30–39	40–49	50–59	60–69	
Male	10	14	8	3	2	37
Female	6	12	5	3	2	28
Total (%)	16 (24.6)	26 (40.0)	13 (20.0)	6 (9.2)	4 (6.1)	

TABLE 2. MRI findings of patients ($n = 65$)

Disc type	No.
Degenerative disc with annular tear	12
Herniated disc	53
Posterocentral type	12
Posterolateral type	41
Total	65

All patients had axial pain, and 49 patients had accompanying radiating pain in the leg. The minimum duration of conservative care was 3 months before the surgery. There were 53 contained herniated intervertebral discs (12 posterocentral and 41 posterolateral) and 12 diffuse bulging discs with disc degeneration and/or annular tear (Table 2).

Indications

The indications for Nucleoplasty were positive magnetic resonance imaging (MRI) for focal soft disc herniation; a disc herniation measuring less than 33% of the sagittal diameter of the spinal canal; failure of conservative management; a positive discogram for recreation of concordant pain; and axial and radicular pain.

Contraindications

The contraindications to Nucleoplasty were a disc space narrowing of more than 50%, with extruded and sequestered disc; disc herniation more than 33% of the sagittal diameter of the spinal canal; spinal stenosis; spinal fracture or tumor; and obesity.

Ruptured or migrated disc herniations, spinal stenosis, and definite radiological spinal instability were contraindications to nucleoplasty. None of the patients had previous invasive spinal surgeries.

Operation Procedures

All patients underwent the procedure under local anesthesia. The patient was placed in the lateral decubitus position with the symptomatic side up, or in the prone position, according to the operator's preference. The skin was punctured with an access needle (17 gauge × 5″ length Crawford-type) at 8 to 11 cm from the midline. The access needle was introduced into the disc at the annulus-nucleus junction under fluoroscopy. After provocative discography, a Perc-D catheter (Arthrocare Spine, Sunnyvale, CA, USA) was introduced approximately 5 mm beyond the access needle and stopped. The access needle was retracted into the posterior annulus. A circumferential reference mark was placed on the Perc-D shaft to use as a starting position. The Perc-D tip was advanced into the anterior annulus-nucleus junction and stopped. Another reference mark was placed on the Perc-D shaft at the anterior annulus-nucleus junction as an ending position. The Perc-D tip was advanced in ablation mode and retracted in coagulation mode creating channels at the 12, 2, 4, 6, 8, and 10 o'clock positions (Fig. 2). A sterile dressing was placed over the needle puncture site. The average operation time was 41 min. Most patients were discharged next day. Postoperatively, the patients were not limited in their walking, standing, and sitting. The patients returned to sedentary or light work within 2 to 4 days after the operation. We experienced difficulties in targeting and accessing the L5-S1 interspace and failures requiring open discectomy at this level in our early series. We abandoned this procedure at the L5-S1 level thereafter. Demographic data and patient information were collected at the time of study enrollment. A 10-point visual analogue scale (VAS) and MacNab classification [12] were used to measure symptoms at all visits.

Results

A total of 74 levels were operated on (56 patients underwent a one-level procedure, and 9 patients underwent a two-level procedure). The operated level was L2-3 in 8 cases, L3-4 in 17 cases, L4-5 in 46 cases, and L5-S in 3 cases. The mean follow-up period was 12.2 months. The surgical results according to the MacNab classification were excellent in 7 cases, good in 47 cases, fair in 6 cases, and poor in 5 cases. The mean VAS score was 7.5 at the time of surgery and 2.2 1 month after the procedure (Fig. 1). Most patients had symptom improvement immediately after surgery. Their walking and sitting ability was improved after surgery. Three patients underwent an open discectomy during the follow-up period. Two patients were operated on at the L5–S1 level, and we determined that disc removal was insufficient due to difficulties in targeting and wandering at the L5-S1 level. One patient, who had a preoperative MRI 3 months before the procedure, was operated on at the L4-5 level. He had symptom aggravation immediately before the procedure, but we did not recommend a repeated MRI. The postoperative MRI showed

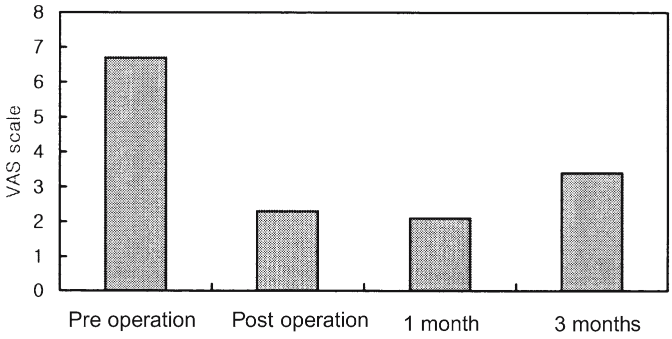

FIG. 1. Visual analogue scale (VAS) results for the patients

FIG. 2. Intraoperative photograph of nucleoplasty

a ruptured disc fragment, and the patient underwent an open discectomy. There was a case of discitis as a surgery-related complication.

Discussion

Lumbar discectomy has been a standard procedure for herniated intervertebral discs since the publication of Mixter and Barr [13]. There are many ongoing efforts to treat lumbar herniated intervertebral discs with minimally invasive surgery. Chemonucleolysis with chymopapain was initiated by Lyman [6, 18] in 1963 and approved by the US Food and Drug Administration (FDA) in 1982. More than 400 000 chemonucleolysis procedures had been performed throughout the world up to 2000, and the success rate varies widely. The major problems of chemonucleolysis are excessive nucleus absorption with disc collapse, hypersensitivity reaction (0.5%–1%), and transverse myelitis [7, 14].

Automated percutaneous lumbar discectomy (APLD), introduced by Onik and Maroon [2–5, 9–11], has had a success rate of 62%–88% but has limited indications [1, 15]. Williams [16] used a surgical microscope to minimize the skin incision for lumbar discectomy in 1987. Microscopic lumbar discectomy did not have a large difference in surgical outcome when compared with the conventional procedure.

Saal [11] introduced intradiscal electrothermal therapy (IDET) in 1988. The IDET system generates annular heating to modify collagen and thermocoagulate nociceptors within the annulus. Even when the temperature is controlled, the level of heat (55°–65°C) generated in IDET is sufficient to create tissue charring or destruction of the disc and nerve root. There have been reports of nerve injury after IDET.

Nucleoplasty utilizes controlled coblation (controlled ablation) technology for ablating and coagulating soft tissue, combining both approaches for partial disc removal. During coblation, radiofrequency (RF) energy is applied to convert conductive fluid into an ionized vapor layer called "plasma." These charged particles (excited ions) disintegrate the molecular bonds of the disc. Coblation ablates tissue by a low-temperature molecular dissociation process to create small channels within the disc. During the nucleoplasty procedure, a percutaneous approach (Perc-D SpineWand) is used to ablate disc tissue at low temperatures, while alternating with thermal energy for coagulation. When it is advanced, the Perc-D creates small, controlled channels in the nucleus (temperature, 45°–55°C). On withdrawal, the channels are thermally treated, producing a zone of thermal coagulation (temperature, 70°C) (Table 3).

Although the follow-up period in this study may be too short to allow assessment of the efficacy of spine surgery, the length of the follow-up period should be considered in the context of the invasiveness and morbidity associated with the invention studied. The results of our study showed that nucleoplasty is a reliable procedure for contained herniated lumbar discs. Patient selection is the most important key to a successful surgical result.

We found that access to L5-S1 was difficult, especially in women with high iliac crests. A pillow under the iliac crest was helpful to make the spine scoliotic to open the access side in the lateral position. Even though access to the L5-S1 interspace was possible, advancing the Perc-D catheter was extremely

TABLE 3. Nucleoplasty vs. intradiscal electrothermal therapy (IDET)

Feature	Nucleoplasty	IDET
Therapy	Ablation and coagulation: contraction of nucleus and stiffening of the disc	Coagulation: coagulation of nociceptors and collagens in annular fissures
Patient selection	Axial and radicular	Axial
Device access	Tip positions in nucleus area	Tip positions around the junction
Tip temperature	40°–70°C	90°C
Thermal effect	Localized	Diffuse
Proximity to nerve root	Confined to nucleus	?
Therapy time	5–8 min/disc	17 min/disc
Post operative management	Light activities for 2 wk	Bracing, strictly limited activity for months
	No "flare-up"	Inflammatory "flare-up"
	Rapid pain reduction	3–6 mo for most improvement

difficult in the L5-S1 interspace. Because we had a poor surgical outcome in the L5-S1 interspace in our early series, we did not recommend Nucleoplasty.

Conclusions

These results indicate that Nucleoplasty is a new and reliable addition to the armamentarium of minimally invasive disc surgery for contained herniated lumbar discs. Patient selection is the most important key to a successful surgical result. Long-term data are needed for further evaluation.

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Surgical Procedures and Clinical Results of Endoscopic Decompression for Lumbar Canal Stenosis

Munehito Yoshida, Akitaka Ueyoshi, Kazuhiro Maio, Masaki Kawai, and Yukihiro Nakagawa

Summary. The purpose of this study was to evaluate the surgical indication and clinical outcomes of endoscopic decompression for lumbar spinal canal stenosis. From September 1998 to March 2002, 250 consecutive patients underwent posterior endoscopic surgery for lumbar radiculopathy. Among these patients, 27 were treated by posterior endoscopic decompression for lumbar canal stenosis. There were 19 men and 8 women, and their average age was 60 ± 12.8 years. The major preoperative symptom was neurologic claudication, sometimes accompanied by sciatica. Clinical outcomes were evaluated by the Japanese Orthopedic Association (JOA) scoring system for lumbar disease (maximum score, 29). Among the 27 patients, the average JOA score was 13.7 ± 3.8 preoperatively, which improved to 26.4 ± 2.8 postoperatively. The average operation time was 56 min for one level, and the average blood loss was 46 ml for one level. There were no interoperative complications. The microendoscopic decompression technique is characterized by a small skin incision, less invasion of paraspinal muscle, and a small dead space. The ipisilateral approach and contralateral endoscopic decompression can be performed under the midline posterior structures the same as microsurgical decompression. This endoscopical decompression minimizes resection of the pathologic compression tissues and affords a safe procedure. The clinical outcome was excellent and patient satisfaction was good in most cases.

Key words. Lumbar canal stenosis, Endoscopic surgery, Microendoscopic discectomy, Surgical procedure, Clinical outcome

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Introduction

For the treatment of lumbar canal stenosis, laminectomy and wide fenestration have mainly been performed [1–4]. These two methods rely on detaching the paraspinal muscle tissue attached to the lamina on both sides of the spine. Accordingly, patients suffer atrophy and denervation [5, 6], which contribute to lower back pain postoperatively. Moreover, the resection of the interspinous and supraspinous ligamentum complex causes a decrease in the postoperative stability of the lumbar spine [7, 8] because of the destruction of a large amount of the posterior supporting tissues. Therefore, since 1998 we have aimed to develop a less invasive form of surgery based on the methods of posterior endoscopic surgery, microendoscopic discectomy (MED), as developed by Foley and Smith in 1996 [9]. This method does not involve the removal of paraspinal muscle, and it is possible to operate within only a 16-mm skin incision. MED was usually applied in cases of lumbar disc herniation and had not been applied in cases of lumbar canal stenosis. Based on our experience in performing MED [10, 11], we thought that endoscopic decompression could be applied to lumbar canal stenosis. Using this method, it is possible to address problems on the contralateral side in addition to those on the ipsilateral side. In this study, we describe the techniques for addressing lumbar canal stenosis and the evaluation of the clinical results.

Materials and Methods

From September 1998 to March 2002, 250 consecutive patients underwent posterior endoscopic surgery for lumbar radiculopathy. Among these patients, 27 were treated by posterior endoscopic decompression for lumbar canal stenosis. There were 19 men and 8 women, and their average age was 60 ± 12.8 years. The major preoperative symptoms were neurologic claudication, sometimes accompanied by sciatica. Clinical outcomes were evaluated by the Japanese Orthopedic Association (JOA) scoring system for lumbar disease (maximum score, 29).

Surgical Technique

At first, we used a curved chisel to cut the inferior part of the lamina and the medial side of the inferior facet, because the interlaminar space is very narrow in cases of lumbar canal stenosis. Then we removed the remnants of lamina with Kerrison rongeurs. In the next stage, we cut the ligamentum flavum by use of the sheathed knife blade, transversely, and divided the shallow and deeper layers. Using a ball probe, we dissected the underlying ligamentum flavum and removed the ligamentum flavum piece by piece with the Kerrison rongeur.

It was extended from cephalad until the insertion of the ligamentum flavum was reached. We proceeded in the same fashion on the ipsilateral caudal lamina. On reaching the dural tube and nerve root, we retracted the nerve with the Penfield retractor and the nerve root medially. By using a curved chisel, we removed an additional medial facet. We continued to use the pituitary rongeur to remove a small chip of shaved lamina. Also, to stop unexpected bleeding, we used a bipolar coagulator. In executing the surgical procedure in this fashion, we successfully completed the ipsilateral decompression (Figs. 1, 2).

Next, we addressed contralateral decompression. We moved the tubular retractor to the medial side through and beneath the interspinous ligament (Fig. 3). Then, we removed the ligamentum flavum and medial facet by using the Kerrison rongeur from the contralateral side and exposed the dural tube and contralateral nerve root (Fig. 4).

It should be noted that this technique does not damage the contralateral paraspinal muscle tissue. As an added safety advantage, the Kerrison rongeur was always oriented away from the nerve root during the decompression procedure on the contralateral side (Fig. 3).

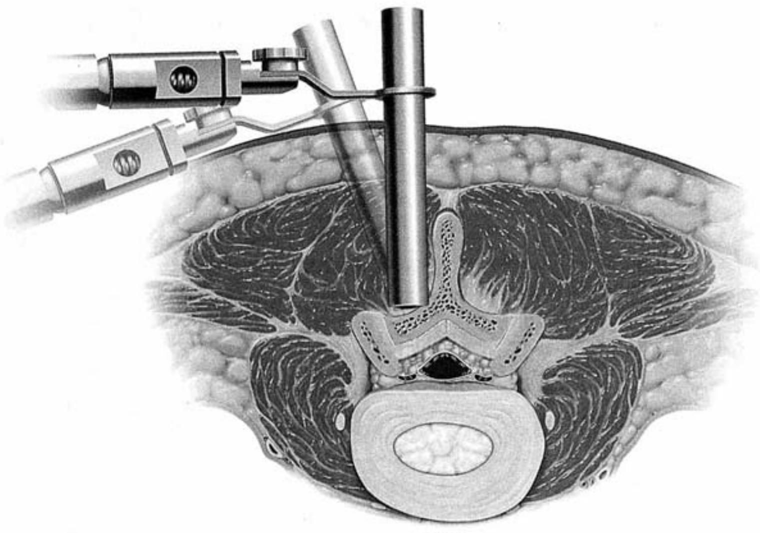


Fig. 1. Initial approach phase of unilateral endoscopic hemilaminotomy and medial facetectomy for bilateral decompression of lumbar canal stenosis

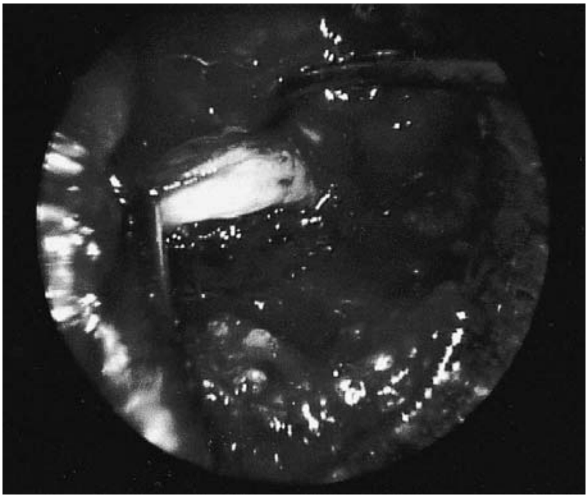


Fig. 2. Intraoperative endoscopic photograph shows satisfactory decompression of ipsilateral nerve root

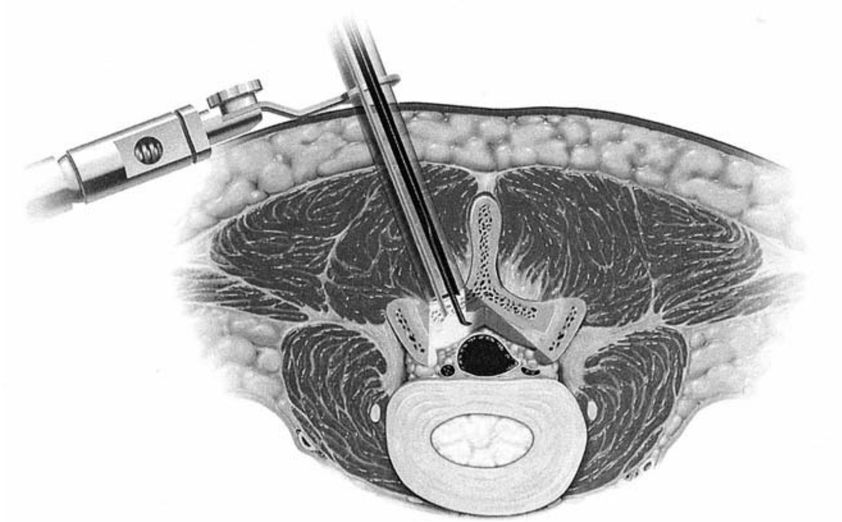
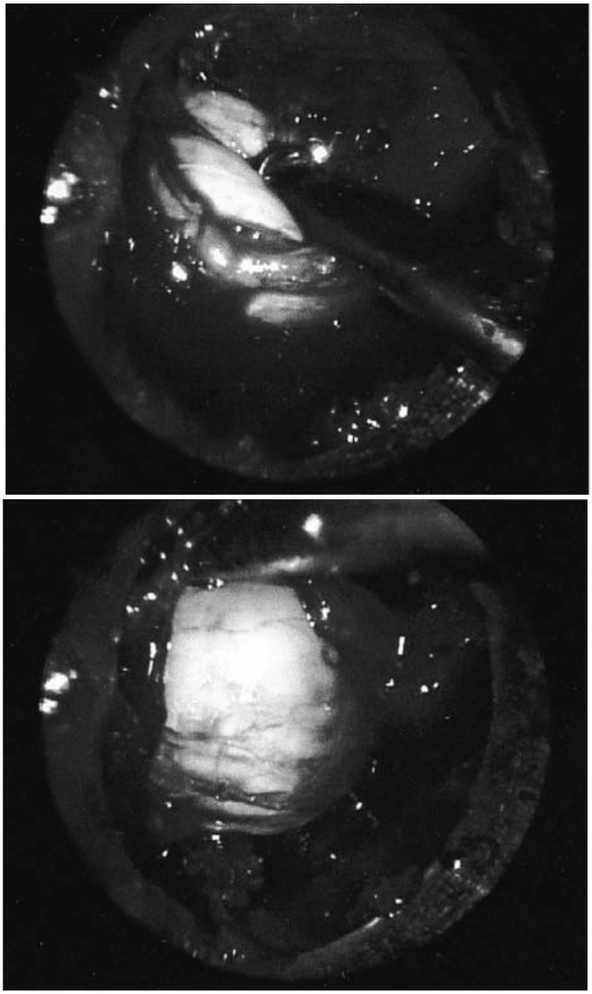


Fig. 3. Contralateral decompression under the midline posterior structures in unilateral laminotomy



a

b

FIG. 4. **a** Intraoperative endoscopic photograph shows satisfactory decompression of contralateral nerve root from ipsilateral laminotomy. **b** Photograph shows that bilateral decompression was performed completely in this procedure

Results

Among the 27 patients, unilateral endoscopic laminotomy was performed in 3 patients and the ipsilateral endoscopic approach for bilateral decompression was performed in 24 patients (Figs. 5, 6). The average JOA score was 13.7 ± 3.8 preoperatively, which improved to 26.4 ± 2.8 postoperatively. The average operation time was 56 mins for one level, and the average blood loss was 46 ml for one level. Eighteen patients had one level decompressed, 7 had two levels, and 2 had three levels (Fig. 7). There were no interoperative complications.

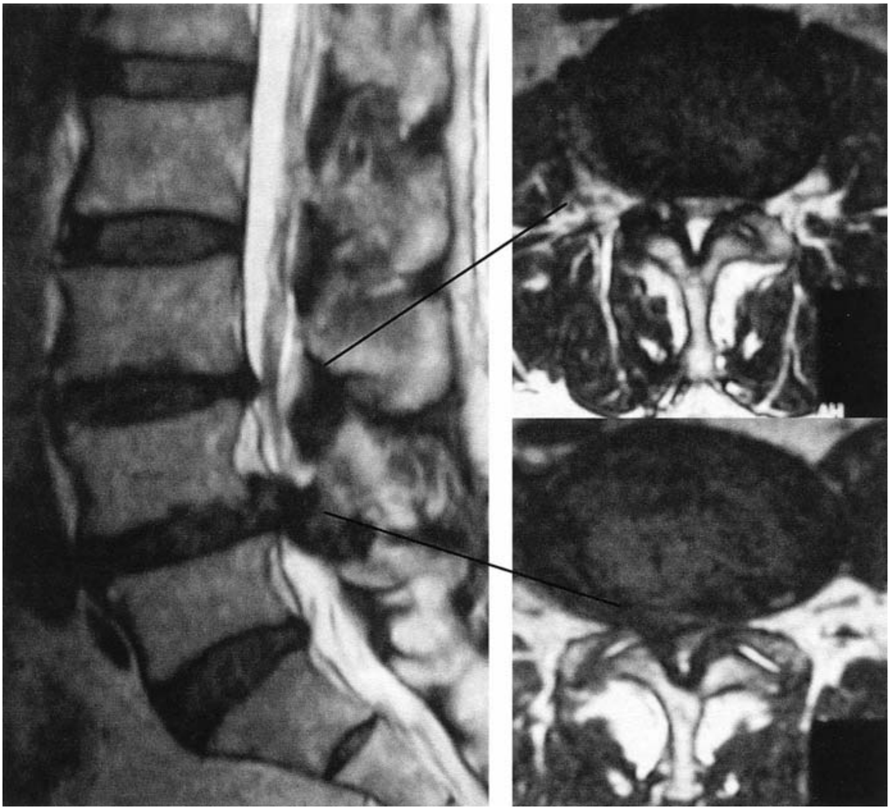
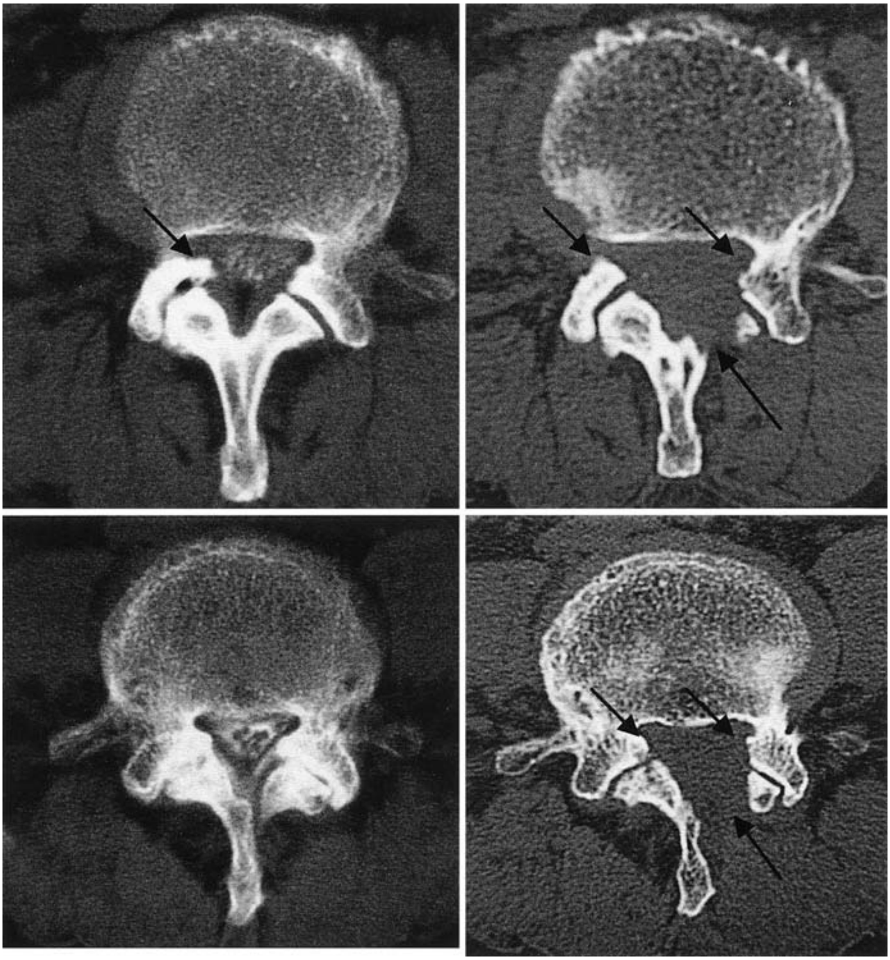


Fig. 5. Magnetic resonance imaging (MRI) of 74-year-old man shows severe lumbar canal stenosis at L3-4, L4-5

Discussion

In cases of degenerative stenosis, the major site of neurological compression is at the level of the interlaminar space. Accordingly, for the treatment of lumbar canal stenosis, wide laminectomy has been used to bring about adequate decompression of the dural tube and nerve roots beneath the lateral recess [1]. However, it was noted that the hypertrophied ligamentum flavum [12] and the medial parts of the superior facet compressed the nerve roots and dural tube at the lateral recess. As a result, wide fenestration has become a standard method of treatment [2]. However, these traditional treatments of lumbar stenosis cause extensive damage to the posterior spinal supporting tissues, such as the paraspinal muscle, the interspinous ligaments, the spinous



a

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Fig. 6. **a** Preoperative CTM shows severe encroachment of superior facet joint at L3-4, L4-5. **b** Postoperative computed tomography (CT) shows bilateral decompression from ipisilateral laminotomy at L3-4, L4-5

processes, and portions of the facet joints, capsule, and ligamentum flavum. As a result, it is associated with significant postoperative pain, considerable hospitalization, prolonged recovery periods, and undesirable postoperative consequences. See and Kraft [5] described these concerns in their observation of chronic denervation and electromyographic abnormalities of the paraspinal muscles after open surgery. Sihvonen et al. [6] reported that this iatrogenic injury of the paraspinal muscle is correlated with an increased in-

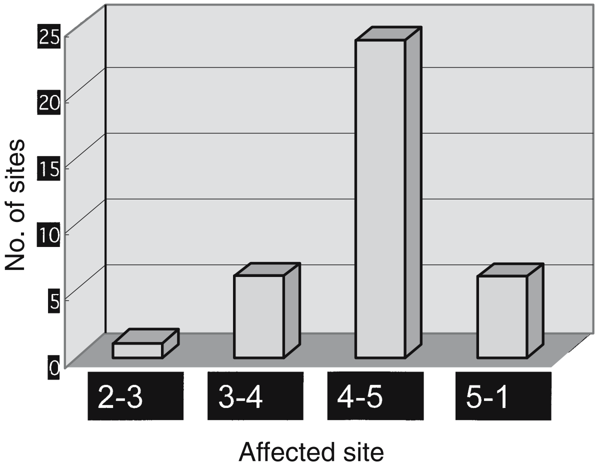

Fig. 7. Distribution of affected sites

cidence of postoperative unstable back syndrome. The loss of the midline supraspinous and infraspinous ligament complex can also lead to an increased risk of delayed spinal instability [7, 8]. In light of these factors, it was reported that microscopic contralateral flavectomy and sublaminoplasty should be applied from an ipsilateral approach, and this method became the favored operative method for bilateral decompression. The clinical results of this unilateral method, as described by McCulloch [13] and by Weiner et al., [14] were shown to be similar to those of the traditional methods, despite the less extensive resection of the posterior bony elements. Recently, endoscopic assisted procedures have been applied for the treatment of pathologic conditions of the spine. In the lumbar posterior approach, the MED system has advantages that conventional methods do not. A small skin incision causes less invasion of paraspinal muscle, and a small dead space characterizes the microendoscopic decompression technique. An ipsilateral approach and contralateral endoscopic decompression can be performed under the midline posterior structures in a similar manner as microsurgical decompression. The first advantage is that this method is less invasive, because the paraspinal muscle is not detached from the lamina. Second, it is possible to gain easier access to the contralateral side from the ipisilateral side than by current microscopic methods. In the endoscopic procedure, approaches can more readily be made by tilting the tubular retractor about 20° to 30° medially. Also, we can address damaged areas that we cannot access by direct vision. By using an endoscope angled at 25°, we can reach previously inaccessible areas. Accordingly, it is possible to resect the hypertrophied ligamentum flavum and the superior facet of the contralateral side. Moreover, we can confirm the compressed nerve root directly under the hypertrophied superior facet, which is not possible by direct vision. In carrying out the maneuver of decompression, we can keep track of the anatomical position and perform the decompression procedure while observing the compressed nerve root on the video monitor during endoscopic surgery. Third, the method has the added advantage that a two-segment approach can be carried out within one skin incision for neighboring segments. Fourth, endoscopic surgery permits a quick return to work, and not as much bed rest is needed compared with the traditional method, which requires 3 to 7 days at a minimum. However, endoscopic surgery for the spine is not without its drawbacks. It is a demanding technique and has a steep learning curve. The field of view through the endoscope is limited, which makes it difficult to appreciate the amount of bony resection that has been performed. However, it is necessary to become accustomed to the two-dimensional view and to acquire eye-hand coordination for endoscopic surgery. Applying this technique for lumbar canal stenosis is not recommended for those in the initial stages of the curve, and it should be applied only after mastering the endoscopic procedure for lumbar disc herniation. Furthermore, it is necessary to make a new, specialized instrument for lumbar canal stenosis. This technique should be indicated initially for lateral recess stenosis, because the interlaminar space is relatively wide. It can also be applied to cases of moderate central canal stenosis. Cases of severe stenosis with multilevel involvement and severely hypertrophied facet joints with congenital stenosis often regime complete laminectomy. Obviously, this technique cannot be applied in this patient population.

Conclusions

This form of endoscopic decompression minimizes resection of the pathologic compression tissues and affords a safe procedure. The clinical outcome was excellent and patient satisfaction was good in most cases.

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Videotape-Assisted Thoracoscopy (VAT) for Anterior Release in Neuromuscular Scoliosis

Thanet Wattanawong

Summary. This study reports the case of a 14-year-old Thai girl with neuromuscular scoliosis. She received a diagnosis of neuromuscular scoliosis with asymptomatic syringomyelia that can be conservatively treated and closely followed up by the neurosurgeon. The cob angle from T_3 to T_{11} was 95° and the kyphotic angle was 90°. The first stage was performed by videotape-assisted thoracoscopy (VAT) for anterior release, followed by second-stage posterior derotation and fusion with the pedicle screw technique from T_2 to T_{12}. The final cob angle was 30°, and the kyphosis angle was 18° with normal sagittal balance without complications, and the hospital stay was 20 days post-operation. VAT for anterior release and second-stage posterior pedicle screw fusion can achieve a good result with a less invasive operation, less blood loss, and less soft tissue destruction. VAT for anterior release in neuromuscular scoliosis is a safe and less invasive technique that achieves a good result.

Key words. Videotape assisted, Thoracoscopic, Anterior release, Anterior decompression, Neuromuscular scoliosis

Introduction

The conventional approach for the severe curve of kyphoscoliosis deformity is open transthoracic anterior release and posterior fusion with instrumentation. After 1992, there were many reports of the use of video-tape-assisted thoracoscopy (VAT) for the anterior approach, such as in patients with thoracic disc [1–6], idiopathic scoliosis [7–9], and fractures [10]. In Thailand in the year 2000 [11], we began to treat severe cases of neuromuscular scoliosis,

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for which anterior instrumentation is too dangerous, with VAT for anterior release and posterior pedicle screw fusion.

Materials and Method

This study reports the case of a 14-year-old Thai girl. She received a diagnosis of neuromuscular scoliosis with asymptomatic syringomyelia that can be conservatively treated but the problem was thoracic kyphoscoliosis with severe pulmonary restriction. The physical examination (Figs. 1 and 2) found

FIG. 1. Posterior view of the patient

Fig. 2. Forward-bending view of the patient

Fig. 3. Preoperative X-ray: thoracic spine AP view

a height of 125 cm, a body weight of 40 kg, pelvic obliquity, a thoracic rib hump on the right of 6 cm, normal neurovascular status, and negative long tract sign. The cob angle from T_3 to T_{11} was 95°, and the kyphotic angle was 90° (Figs. 3 and 4). The force bending film X-ray was 95° on the right side bending and 85° on the left side bending. The pulmonary function test showed severe lung restriction. First-stage anterior decompression and discectomy was performed at the apex $T_{6\text{-}7}$ and $T_{7\text{-}8}$ with partial vertebrectomy at the T_7 vertebral body under three portals VAT technique. We recorded the operative time, blood loss, degree of correction of the deformity, trunk balance, neurological status, ambulation time, hospital stay, and complications up to 3 months postoperation.

Fig. 4. Preoperative X-ray: thoracic spine lateral view

Results

In the first-stage VAT for anterior decompression, the operative time was 240 min with only three portals and three incisions. The length of each incision was 1.5 cm. The operations were discectomy at $T_{6\text{-}7}$ and $T_{7\text{-}8}$ and partial excision of the T_7 vertebral body without rib excision. The amount of bleeding was about 200 ml. Six days later, second-stage posterior fusion was performed with an RSS pedicle screw from T_2 to T_{12} (Figs. 5 and 6). The operative time was 100 min; the operative blood loss was 300 ml; the cob angle postoperation was 30° and the postoperative kyphotic angle was 18°. The patient could walk without external support 6 days after the second operation. The trunk

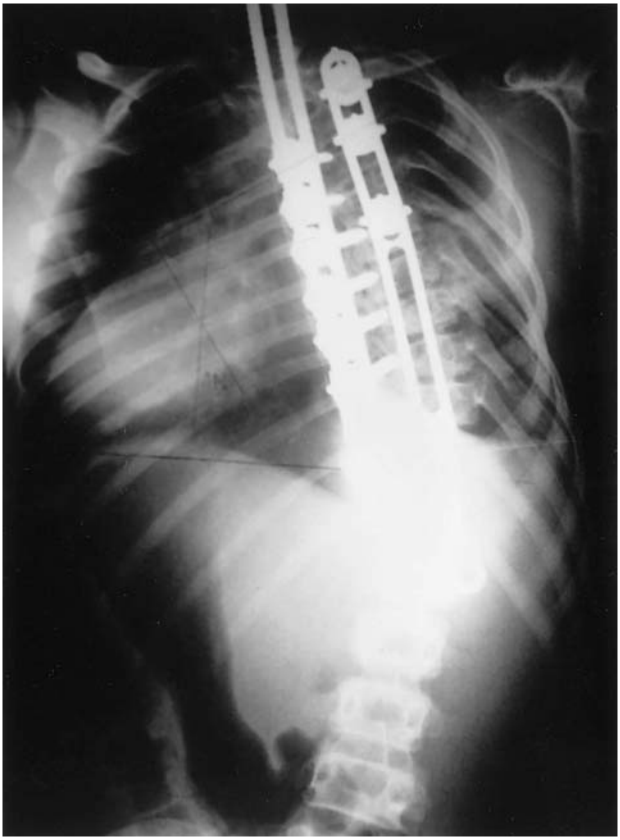

Fig. 5. Postoperative X-ray: thoracic spine AP view

balance postoperation was normal (Figs. 7 and 8). The rib humb was 2.5 cm. The height increased from 125 to 130 cm. At the third month postoperation, the patient could walk well without support and with no complications.

Discussion

VAT has many advantages when compared with open thoracotomy, such as decreased length of incision [12], blood loss, soft tissue damage, and infection, without limited range of motion of the rib and shoulder joint. The patient has better cosmesis, faster ambulation, a shorter recovery period, and a shorter hospital stay. This patient recovered well after the first-stage thora-

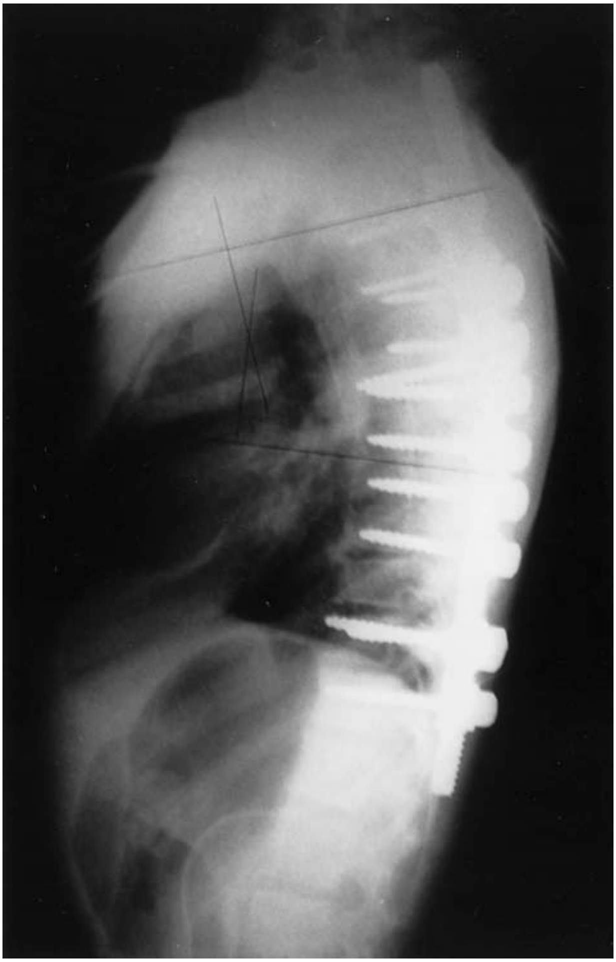

Fig. 6. Postoperative X-ray: thoracic spine lateral view

coscopic anterior release, without intercostal nerve neuralgia and without complications. Six days later she underwent the second-stage posterior correction with a pedicle screw from T_2 to T_{12}. Finally she could walk without postoperative external support. The hospital stay was 20 days without any complications such as hemorrhage, injury to the aorta and large vessels [10], transient peripheral nerve irritation, plural effusion, and infection. The major advantage of posterior pedicle screw fusion is the strength of the device,

Fig. 7. Posterior view of the patient postoperation

which allows her to ambulate without postoperative external support. The deformity was well corrected: the cob angle decreased from 95° to 30° (68.4% correction), and the kyphotic angle decreased from 90° to 18° (80% correction), with improved trunk balance and cosmesis posture. Long-term monitoring should be performed for the percentage loss of correction, pseudarthrosis, implant failure, and other complications.

Fig. 8. Side view of the patient postoperation

Conclusions

VAT for anterior decompression and posterior fusion with a pedicle screw is one of the best operations, with less invasive technique, less soft tissue destruction without thoracotomy and rib excision, less postoperative pain, faster ambulation, a shorter hospital stay, fewer complications, and less bleeding, even in the surgeon on a learning curve.

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Clinical Outcomes of Microendoscopic Discectomy for Extraforaminal Lumbar Disc Herniation

Kazuhiro Maio[1] and Munehito Yoshida[2]

Summary. The microendoscopic discectomy (MED) system for lumbar disc herniation has been developed in recent years. We applied the MED system to the treatment of extraforaminal lumbar disc herniation. The purpose of this Chapter is to present the clinical results of the MED system for cases of extraforaminal lumbar disc herniation. We performed operations using the MED system on eight patients suffering from extraforaminal lumbar disc herniation. The mean age was 57.4 years. Herniation affected discs at the L2-3 (one patient), L3-4 (one patient), L4-5 (two patients), and L5-S1 (four patients) levels. We recorded the operation time, blood loss, and time until the resumption of walking, and used the Japanese Orthopaedic Association (JOA) score for low back pain in evaluating the clinical results. The mean operation time was 90.1 min. The mean blood loss was 12.3 g. All patients began to walk within 6 h postoperatively. The mean JOA score improved from a preoperative 8.2 to a postoperative 25.8. There were no complications. The MED system allows treatment of extraforaminal lumbar disc herniation with good visualization, less pain, and early return to daily activity. Our results showed that the MED system is beneficial in the treatment of extraforaminal lumbar disc herniation.

Key words. Microendoscopy, Discectomy, Extraforaminal, Lumbar spine, Disc herniation

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Introduction

The concept of extraforaminal lumbar disc herniation was initially described by Macnab [1] in 1971, and Abdullah et al. [2] started to use the term "extraforaminal lumbar disc herniation" in 1974. Since then, cases of extraforaminal lumbar disc herniation have been reported occasionally. The rate of extraforaminal lumbar disc herniation is 0.2%–12.1% of all lumbar disc herniations [1, 3]. Imaging diagnostic technology, computed tomography (CT), and magnetic resonance imaging (MRI) have helped us diagnose extraforaminal lumbar disc herniation. Therefore, the number of cases has been increasing in recent years.

Conventional surgical operations for extraforaminal lumbar disc herniation involve lateral fenestration, facetectomy with posterolateral fusion, osteoplastic hemilaminectomy without fusion, and so on. But those procedures are invasive and involve the risk of inducing spinal instability and persistent low back pain.

The microendoscopic discectomy (MED) system [4] developed in recent years has enabled us to remove lumbar disc herniation as accurately as when the standard open procedure is used. In addition, we have applied the MED system to extraforaminal lumbar disc herniation. The purpose of this study is to present the clinical results of the MED system for extraforaminal lumbar disc herniation.

Materials and Methods

We treated 250 patients suffering from lumbar disc herniation by the MED system between September 1998 and February 2002. Eight of the 250 patients were treated for extraforaminal lumbar disc herniation. There were three men and five women, with a mean age of 57.4 years (range, 32–68 years). We recorded the operation time, blood loss, and period until the resumption of walking, and used the Japanese Orthopaedic Association (JOA) score for low back pain to evaluate the clinical results. The affected vertebral levels of extraforaminal lumbar disc herniation were L2-3 in one patient, L3-4 in one patient, L4-5 in two patients, and L5-S1 in four patients. Three of eight patients were found also to have lumbar canal stenosis. For these particular patients, the nerves damaged by lumbar canal stenosis were decompressed by using an additional skin incision. Discography, radiculography, and MRI were very valuable for the diagnosis of extraforaminal lumbar disc herniation (Table 1).

Table 1. Case summaries and results: patients with extraforaminal lumbar disc herniation

Case	Age (yr)	Sex	Level	Level accompanied with LCS	Operating time (min)	Blood loss (g)	JOA score	
							Preoperative	Postoperative
1	32	F	L5-S1	None	59	8	1	29
2	68	M	L5-S1	None	95	Trace	7	24
3	55	M	L4-5	L4-5	95	Trace	15	25
4	53	F	L2-3	None	155	80	11	24
5	64	F	L5-S1	L4-5	93	Trace	16	25
6	65	M	L3-4	None	49	Trace	3	26
7	65	F	L4-5	None	95	Trace	6	28
8	58	F	L5-S1	L4-5	80	Trace	16	24
Average	57.4	—	—	—	90.1	11	9.4	25.6

LCS, Lumbar canal stenosis; JOA, Japanese Orthopaedic Association.

Results

The mean operation time was 90.1 min (range, 49–155 min). The mean blood loss was 12.3 g (ranging from a trace to 80 g), and no blood transfusions were needed. All patients began to walk again within 5 hs postoperatively. The mean JOA score improved from a preoperative 8.2 to a postoperative 25.8 (Table 1). Pain at the incision site was minimal. There were no interoperative or postoperative complications.

Surgical Technique

Under general anesthesia, the patient was placed in the prone position on a laminectomy frame. After verifying the location of the pathologic disc by fluoroscopy, a mark was made on the skin 5 cm from the midline. The MED was than inserted at an entry point above the corner of the transverse process and the lateral edge of the lamina. Preoperative imaging study was conducted to ascertain the correct position of the tubular retractor (Fig. 1), in addition to intraoperative fluoroscopy. The predetermined entry site was then infiltrated with local anesthetic (procainamide 1% with 1 : 200,000 epinephrine).

The marked skin was incised for about 1.6 cm. The muscles were not incised but were separated by the dilator. The tubular retractor was placed on the transverse process. The caudal side of the transverse process was partially removed by a Kerrison rongeur. With assurance that there was no adhesion of the intertransverse ligament and the dura by ball probe, the intertransverse

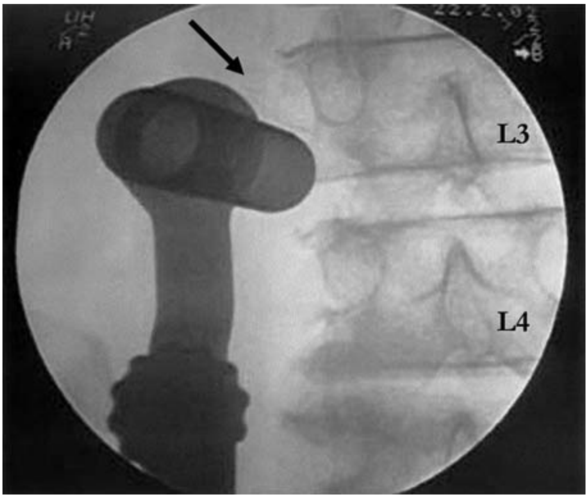


Fig. 1. L3-4 extraforaminal lumbar disc herniation on the left. Imaging study was conducted to confirm that the tubular retractor was located at the corner of the appropriate transverse process (*arrow*)

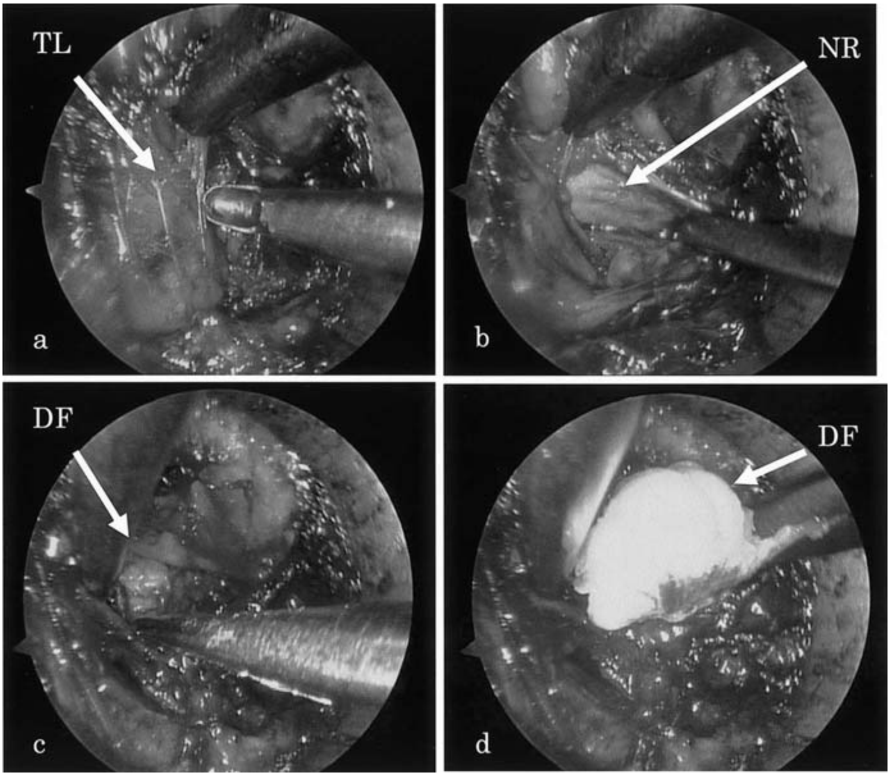
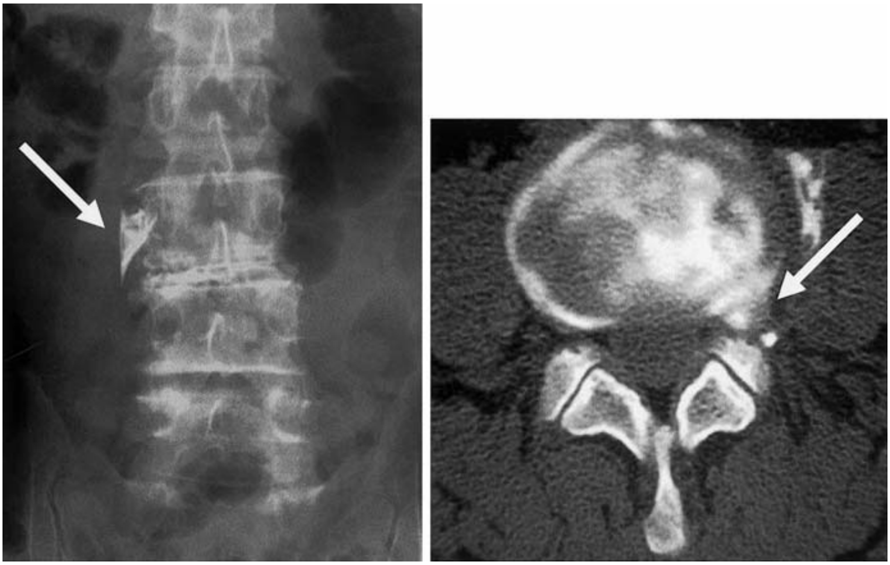


Fig. 2. Intraoperative photographs showing the endoscopic view. *TL*, Transverse ligament; *NR*, nerve root; *DF*, disc fragment. The *upper side* of each photograph is the medial side, the *lower side* is the lateral side, the *left side* is the cranial side, and the *right side* is the caudal side

ligament was removed by using the Kerrison rongeur. The nerve was than retracted to the cranial side with a nerve retractor. The herniation could be extracted with the rongeurs, and subsequently the nerve root was completely decompressed (Fig. 2).

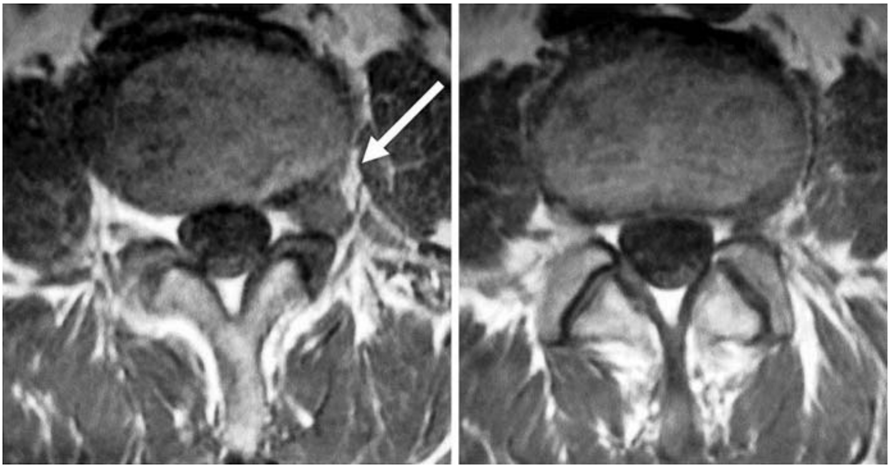
Case 6: 65-Year Old Man, Left Side L3-4 Extraforaminal Lumbar Disc Herniation

The patient's chief complaint was left thigh pain and inability to walk due to severe pain. Discography showed leaking of the contrast medium on the left side of L3-4 (Fig. 3). The herniation mass shown in the preoperative MRI was removed, as shown in the postoperative MRI (Fig. 4). It took six hours for the patient to walk without feeling thigh pain caused by herniation.



a b

FIG. 3. Preoperative discography (**a**) and computed tomographic (CT) discography (**b**). Leaked dye (*arrows*) shows extraforaminal lumbar disc herniation



a b

FIG. 4. Preoperative MRI (**a**) shows that extraforaminal lumbar disc herniation (*arrow*) is on the left side at L3-4. Postoperative MRI (**b**) shows that extraforaminal lumbar disc herniation has been removed

Discussion

Conventional open surgery involving both midline and paramedian approaches has been performed to treat extraforaminal lumbar disc herniation. Lateral fenestration, facetectomy with posterolateral fusion, and osteoplastic hemilaminectomy without fusion have yielded satisfactory treatment results, but these procedures are invasive and require considerable bed rest postoperatively. Furthermore, postoperative wound pain is severe and is an additional factor accounting for the spinal instability.

Recently, various approaches for extraforaminal lumbar disc herniation have been considered. A posterolateral approach for extraforaminal lumbar disc herniation at L1-2, L2-3, and L3-4 and an interlaminal approach for herniation occurring at L4-5 and L5-S1 by using a 45° angled rongeur are useful. Moreover, interlaminal approaches performed by the use of a microscope [5] were carried out.

Transforaminal percutaneous endoscopic discectomy has been reported [6], but we think it poses a difficulty for discectomy at L5-S1. A paramedian tangential approach for extraforaminal lumbar disc herniation at L5-S1 has been reported [7]. With this approach, the L5-S1 facet joint remains intact. But this approach is difficult in endoscopic surgery, because a large amount of bone needs to be resected.

An intertransverse approach [8, 9] has been considered a good method for open surgery because it is safe and leads to good treatment results. Therefore, microendoscopic surgery adopted this approach to see whether it could yield the satisfactory results we expected. We performed microendoscopic surgery for extraforaminal lumbar disc herniation and had good results.

The MED system is less invasive [10] than conventional procedures. The skin is incised minimally. The MED system allows treatment of extraforaminal lumbar disc herniation with good visualization, less pain, and an early return to daily activity. The endoscope is angled 25° obliquely, so the visual field is wider than in microsurgery. In particular, herniation can be found under the transverse process. Our results show that the MED system is beneficial in the treatment of extraforaminal lumbar disc herniation and offers the possibility of being an alternative to the conventional operation for extraforaminal lumbar disc herniation.

Conclusions

In this study, we have demonstrated the clinical outcomes of the MED system for extraforaminal lumbar disc herniation. The MED system is less invasive than conventional procedures for extraforaminal lumbar disc herniation and is beneficial for the treatment of extraforaminal lumbar disc herniation.

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Percutaneous Vertebroplasty with Hydroxyapatite for the Treatment of Osteoporotic Vertebral Burst Fracture of Thoracolumbar Spine

Shigeki Urayama

Summary. Seven patients (ages 52–86 years) were included in this study. Five patients were injured at T12 and the other two at L1. They were followed for one to five years. After reduction, a metal working sleeve was carefully advanced into the anterior third of the vertebral body under local anesthesia using a single-side posterolateral approach. As much hydroxyapatite (HA) as possible in granules and/or pellets was introduced through the sleeve. Six patients were relieved of low back pain within 6 weeks after surgery, and one patient who underwent the operation 4 months after injury was also relieved of pain 11 weeks after surgery. The compression rate of the anterior vertebral height was 40%–73% (mean, 51%) on admission and improved to 6%–25% (mean, 13%) at the latest observation. The compression rate of the middle vertebral height was 52%–70% (mean, 62%) on admission and improved to 29%–38% (mean, 33%). The ratio of the bony fragment retropulsed into the spinal canal initially was 9%–37% (mean, 24%) and gradually diminished to 8%–17% (mean, 11%). In conclusion, percutaneous vertebroplasty of osteoporotic vertebral burst fracture with HA successfully recovered the anterior and middle height of the vertebral body and gradually restored the spinal canal. In addition, early pain relief could be achieved.

Key words. Osteoporosis, Vertebral fracture, Burst fracture, Vertebroplasty, Hydroxyapatite

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Introduction

Reduction of the severe collapse of the osteoporotic vertebral body causes a large bone defect in the anterior third of the vertebral body. This defect is not readily repaired, and the anterior column does not easily unite. Such conditions result in a relapse of vertebral collapse after removal of the body cast. To prevent the relapse, it is very important to fill the defect with a specific spacer. Hydroxyapatite (HA) works well as a spacer material [1].

Patients

Seven patients (three men and four women) were included in this study; their ages ranged from 52 to 86 years (mean, 70 years). The time from injury to operation was 2 to 3 weeks in five early-treatment cases (cases 2, 3, 4, 5, and 7), and 3 to 4 months in two delayed-treatment cases (cases 1 and 6). Five patients were injured at T12 and the other two at the L1 level (Table 1). The indication for operation in the early-treatment cases was a large bone defect in the anterior part of the vertebral body after preoperative reduction; in the delayed-treatment cases, the anterior column did not unite and there was a large bone cavity in the vertebral body more than 3 months after injury. One patient with an L1 injury complained of a vesicourinary disturbance. The follow-up period was 1 to 5 years.

Materials

HA (Apaceram, supplied by Pentax, Tokyo, Japan) was used in the form of granules and/or pellets. The granules were 0.6 to 4 mm in diameter. The pellets were made by cutting a 3-cm HA rod (Apaceram, B-75–99Φ4 L30) into five pieces. The diameter of the HA rod was 4 mm, the pore rate was 55%, and the weight was 0.56 g (Fig. 1). In the first two cases, only HA granules were used to fill the bone defect. In the remaining five cases, both HA pellets and HA granules were used.

Methods

Before the operation, the fracture was reduced in the hyperextended position or by using a Boehler cast. To support the reduction, a small pillow was placed under the chest of the patient in the prone position during the operation. Surgery was performed under local anesthesia (1% mepivacaine hydrochloride 20 ml). Under X-ray imaging, a metal working sleeve (internal diameter, 4.2 mm; external diameter, 5.2 mm) was carefully advanced into the anterior

TABLE 1. Clinical profile of patients

Case no.	Age	Sex	Bone density (L2-4,DEXA) (g/cm^2)	Complications	Level of fracture	Neurological deficit	Time before operation (wk)	Operating time (h)	Fibrin glue	Total HA (g)	HA pellets	HA leakage	Walking (days after operation)	Body cast (days after operation)
1	52	M	0.608	Hemiplegia	T12	–	12	3	–	4.5	–	+	20	36
2	62	F	0.661	—	L1	–	3	3	+	7	–	+	24	66
3	70	M		Hepatoma	L1	+	3	1.5	+	4	+	–	24	59
4	61	F	0.51	Parkinson's disease	T12	–	2	1.5	+	6	+	–	21	49
5	78	M	0.771	—	T12	–	3	1	+	8	+	–	14	31
6	83	F	0.565	—	T12	–	16	1	+	4	+	–	3	—
7	86	F	0.586	—	T12	–	3	0.5	+	2	+	–	19	—

HA, hydroxyapatite.

TABLE 2. Results following percutaneous vertebroplasty

Case no.	Compression rate of anterior of vertebra (%)		Compression rate of middle of vertebra (%)		Angle of kyphosis (°)		Ratio of bony f ragment retropulsed into spinal canal (%)		Union of anterior column on CT (weeks after operation)	Relief from low back pain (weeks after operation)	Follow-up (yr)	ADL limitation
	On admission	Final evaluation	On admission	Final evaluation	On admission	Final evaluation	On admission	Final evaluation				
1	73	25	64	32	37	23	30	10	19	6	5	—
2	44	8	59	31	18	15	35	15	9	1	3.5	—
3	47	13	52	29	35	35	37	17	16	6	1	Dullness
4	58	8	61	37	34	18	25	9	9	4	3.5	—
5	61	10	70	36	21	10	23	12	10	1	2.5	—
6	40	6	56	30	40	27		12	17	11	1	—
7	38	19	69	38	17	12	9	8	11	3	1	—

CT, computed tomography; ADL, activities of daily living.

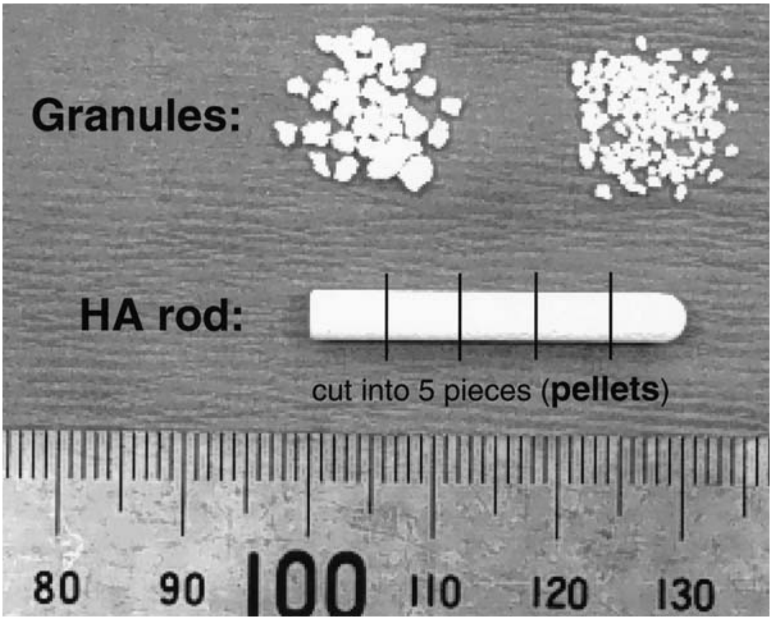


FIG. 1. Hydroxyapatite (*HA*) granules and pellets. Granules are 0.6–4 mm in diameter. Pellets are made by cutting a 3-cm HA rod into five pieces. The diameter of the HA rod is 4 mm, pore rate 55%, and weight 0.56 g

third of the vertebral body using a single-side posterolateral approach. The working sleeve could be freely moved in the osteoporotic vertebral body. Segmental vessels are never injured during this procedure.

HA pellets were first introduced into the anterior part of the vertebral body through the working sleeve. HA granules were then introduced to fill the center. Following irrigation with saline, 0.5–1 ml of fibrin glue (Bolheal, supplied by Fujisawa Pharmaceutical, Osaka, Japan) was injected [2]. Finally, the insertion hole was closed with additional HA pellets. As much HA as possible should be introduced (Fig. 2). A total of 2 to 8 g of HA was used.

Results

There were no complications such as neurovascular damage. HA leakage occurred in the first two cases. All of the patients began to walk with a body cast or brace 3 to 24 days after operation (Table 1).

The vesicourinary disturbance in one patient functionally recovered 2 months after injury. The five early-treatment cases were relieved of low back pain within 6 weeks after operation, and in the two delayed-treatment cases

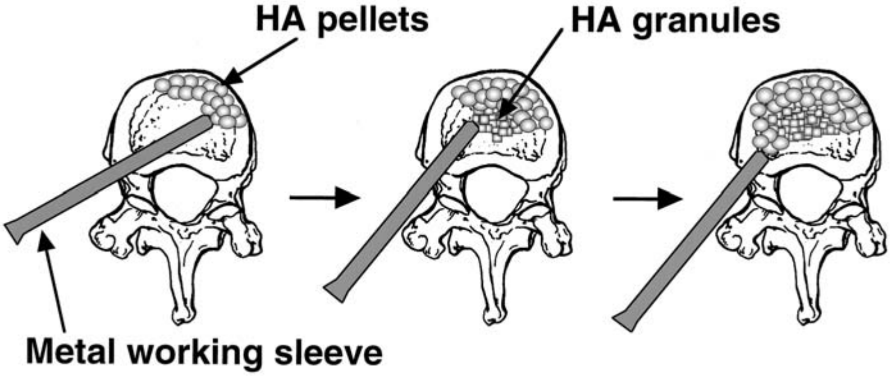


FIG. 2. Technique for percutaneous HA introduction. Under X-ray imaging, a metal working sleeve is carefully advanced into the anterior third of the vertebral body using a single-side posterolateral approach. The working sleeve can be freely moved in the osteoporotic vertebral body. First, HA pellets are introduced into the anterior part of the vertebral body through the working sleeve. HA granules are then introduced to fill the center. Finally, the insertion hole is closed with additional HA pellets. As much HA as possible should be introduced

the pain was relieved 6 and 11 weeks after operation. However, two patients (cases 1 and 3), complained again of low back pain for 2 months from 3 and 6 months after operation, because of relapse of the operated vertebral bodies. All of the patients could return to their daily activities. According to computed tomographic (CT) evaluation, the anterior column was completely united 9 to 16 weeks after operation in the five early-treatment cases and 19 and 17 weeks after operation in the two delayed-treatment cases (Table 2).

The compression rate of the anterior and middle height of the vertebral body (Fig. 3) was calculated before and after operation. The compression rate of the anterior vertebral height was 38%–73% (mean, 51%) on admission, which was reduced to 0%–11% (mean, 4%) after reduction, and it was maintained at 6%–25% (mean, 13%) at the final evaluation (Fig. 4). In the two delayed-treatment cases, the compression rate increased even after 3 months. The five early-treatment cases, however, achieved stabilization of the anterior column within 3 months.

The compression rate of the middle vertebral height was 52%–70% (mean, 61%) on admission, which was reduced to 10%–30% (mean, 22%) after reduction, but it was increased to 29%–38% (mean, 33%) at the latest observation (Fig. 5). One case (case 3) showed an increased compression rate after 3 months. This patient had a depression in the middle of the vertebral body and an increased angle of kyphosis.

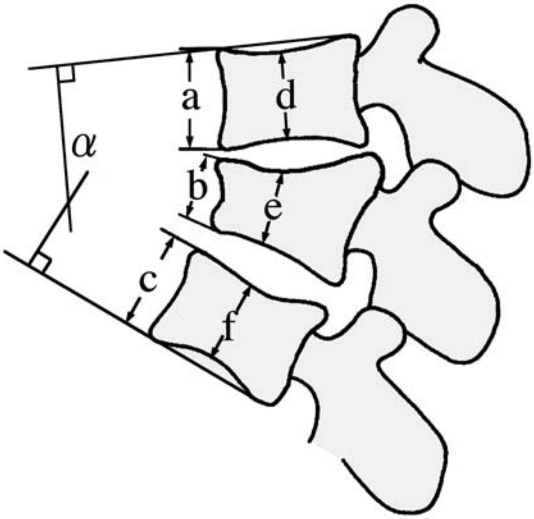


Fig. 3. Compression rate of the anterior and middle height of the vertebral body, and angle of kyphosis.

Compression rate of the anterior height of the vertebral body
$\{1 - 2b/(a + c)\} \times 100\%$

Compression rate of the middle height of the vertebral body
$\{1 - 2e/(d + f)\} \times 100\%$

Angle of kyphosis: α

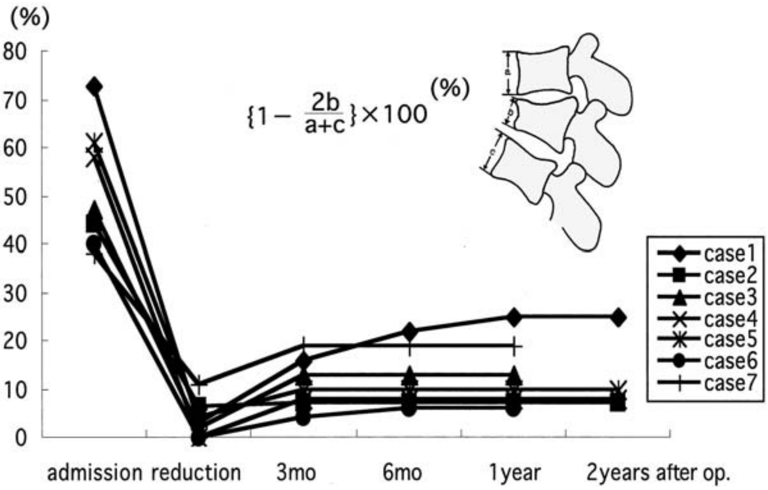


Fig. 4. Compression rate of the anterior height of the vertebral body

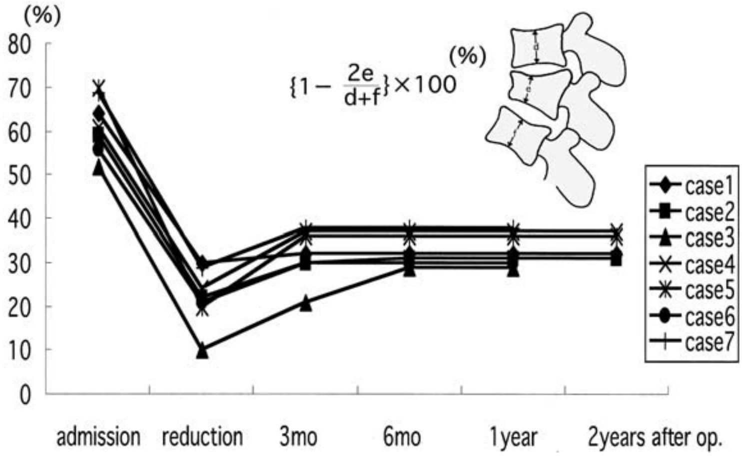
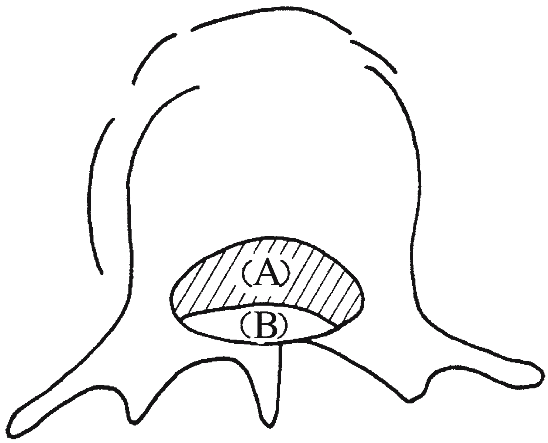


Fig. 5. Compression rate of the middle height of the vertebral body

Fig. 6. Ratio of the estimated area of the bony fragment retropulsed into the spinal canal as analyzed using computed tomographic (CT) imaging: $A/(A + B) \times 100\%$



The angle of kyphosis (Fig. 3) was 17°–40° (mean, 29°) on admission. It was reduced to 0°–25° (mean, 8°) after reduction and increased to 10°–35° (mean, 13°) at the latest evaluation (Table 2).

The ratio of the estimated area of the bony fragment retropulsed into the spinal canal by CT imaging (Fig. 6) [3] initially was 9%–38% (mean, 24%), and it was gradually diminished to 9%–17% (mean, 12%) at the final follow-up (Fig. 7). The spinal canal widened not only after reduction but also after the operation.

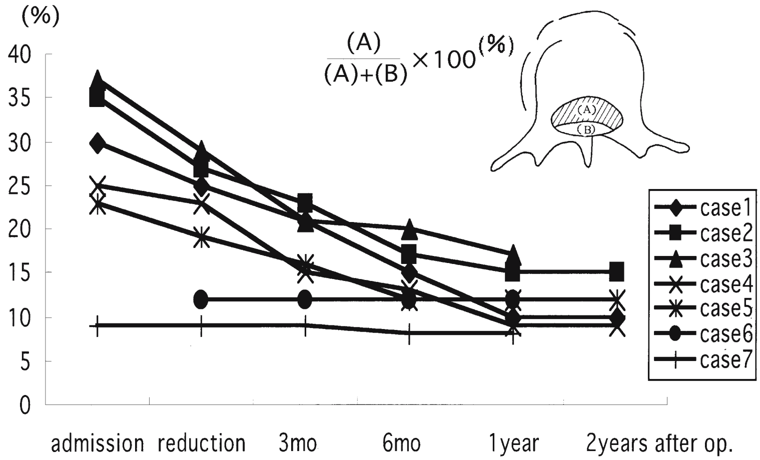


Fig. 7. Ratio of the estimated area of the bony fragment retropulsed into the spinal canal

Sample Cases

Case 1. A 52-year-old man had a T12 burst fracture injury upon falling. The bone mineral density of his lumbar spine (L2-4) was 0.608 g/cm^2 by dual-energy x-ray absorptiometry (DEXA) (XR-26, produced by Norland, WI, USA). The complications were diabetes mellitus, renal failure, and right hemiplegia. Neurological deficits could not be found. The compression rate of the anterior height of the vertebral body was 73%, and the angle of kyphosis was 37°. The ratio of the estimated area of the bony fragment retropulsed into the spinal canal was 30% (Fig. 8a). A Boehler cast was immediately put on in the hyperextended position. However, a large bone defect became apparent in the anterior part of the vertebral body on CT imaging (Fig. 8b). This large defect could not be repaired, and the anterior column did not unite in the reduced position under conservative treatment with bed rest for 3 months (Fig. 8c). This large defect could easily cause a spinal deformity after the removal of the body cast and the resumption of walking. To prevent such deformity, it was thought necessary to fill the defect with HA. A total of 4.5 g of HA granules only was introduced 3 months after the injury (Fig. 8d). Some granules immediately extruded from the vertebral body through the posterolateral insertion hole, and some HA granules migrated into the spinal canal. Moderate ilioinguinal pain occurred, but it disappeared in 2 days. Walking with a body cast was allowed 3 weeks after surgery. The body cast was worn for 5 weeks. The low back pain subsided 6 weeks after surgery. However, the patient fell again 12 weeks after surgery, and he complained of

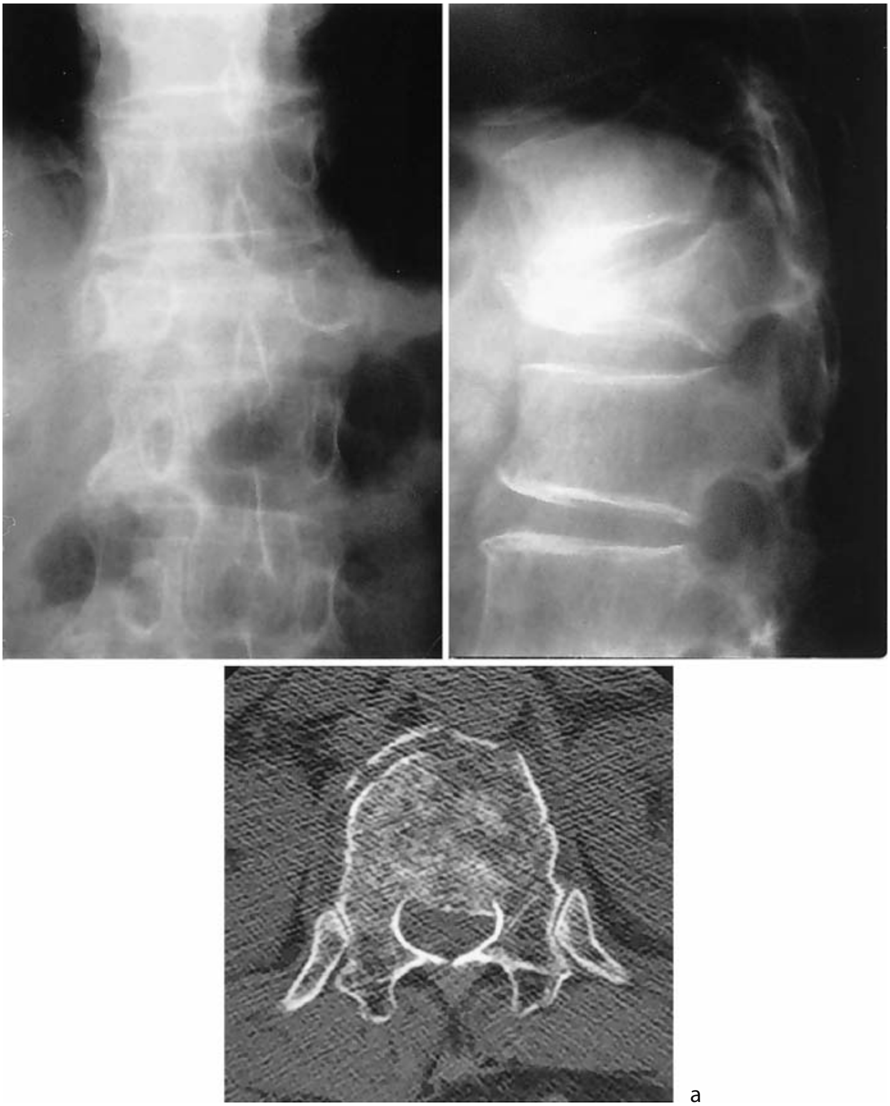
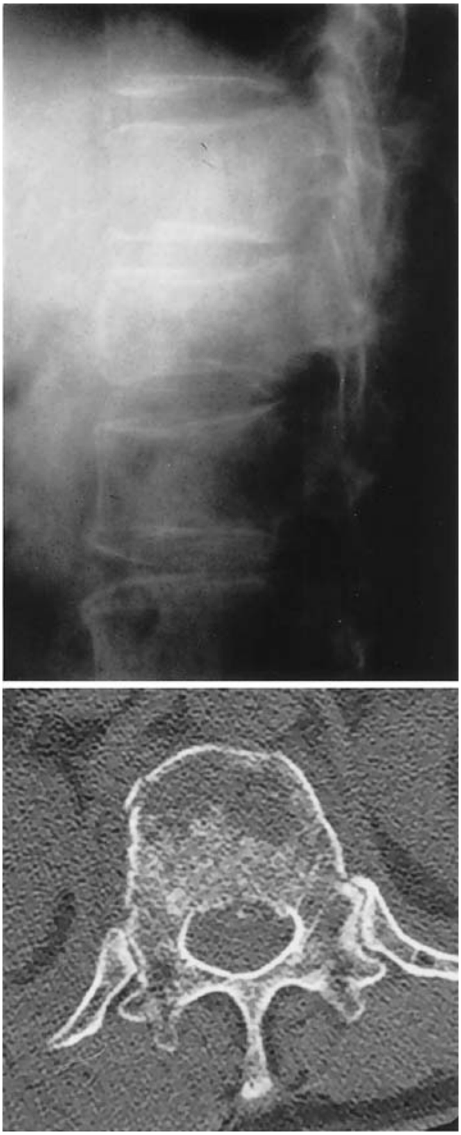


Fig. 8. Case 1. 52-year-old man. T12 burst fracture. **a** On admission, the compression rate of the anterior height of the vertebral body was 73%. The ratio of the estimated area of bony fragment retropulsed into the spinal canal was 30%. **b** After reduction, a large bone defect became apparent in the anterior part of the vertebral body on CT. **c** 2.5 months after injury, this large defect could not be repaired, and the anterior column did not unite. **d** 4.5 g of HA granules only were introduced 3 months after injury. However, some HA granules immediately extruded through the posterolateral insertion hole, and some granules migrated into the spinal canal. **e** At 4.5 years, the fracture healed with a compression rate of the anterior vertebral height of 25%, and a ratio of retropulsed fragment of 10%



b

Fig. 8. *Continued*

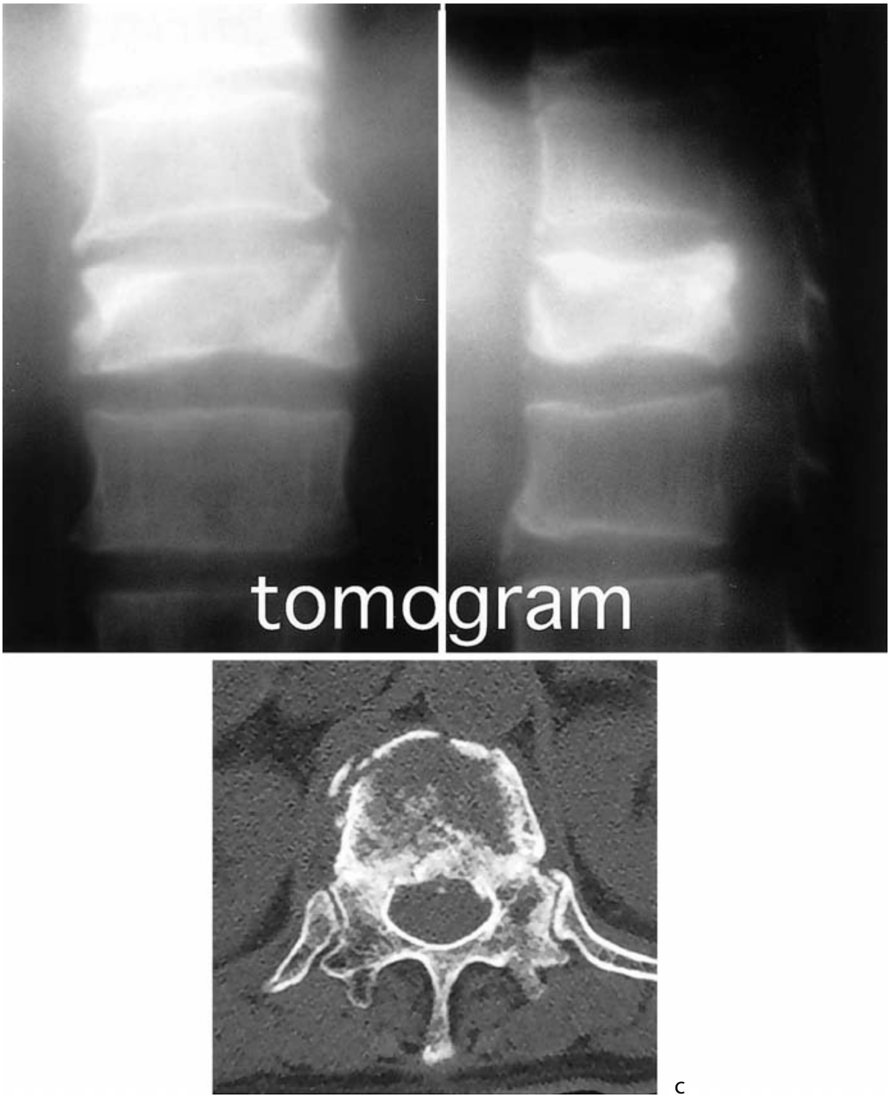
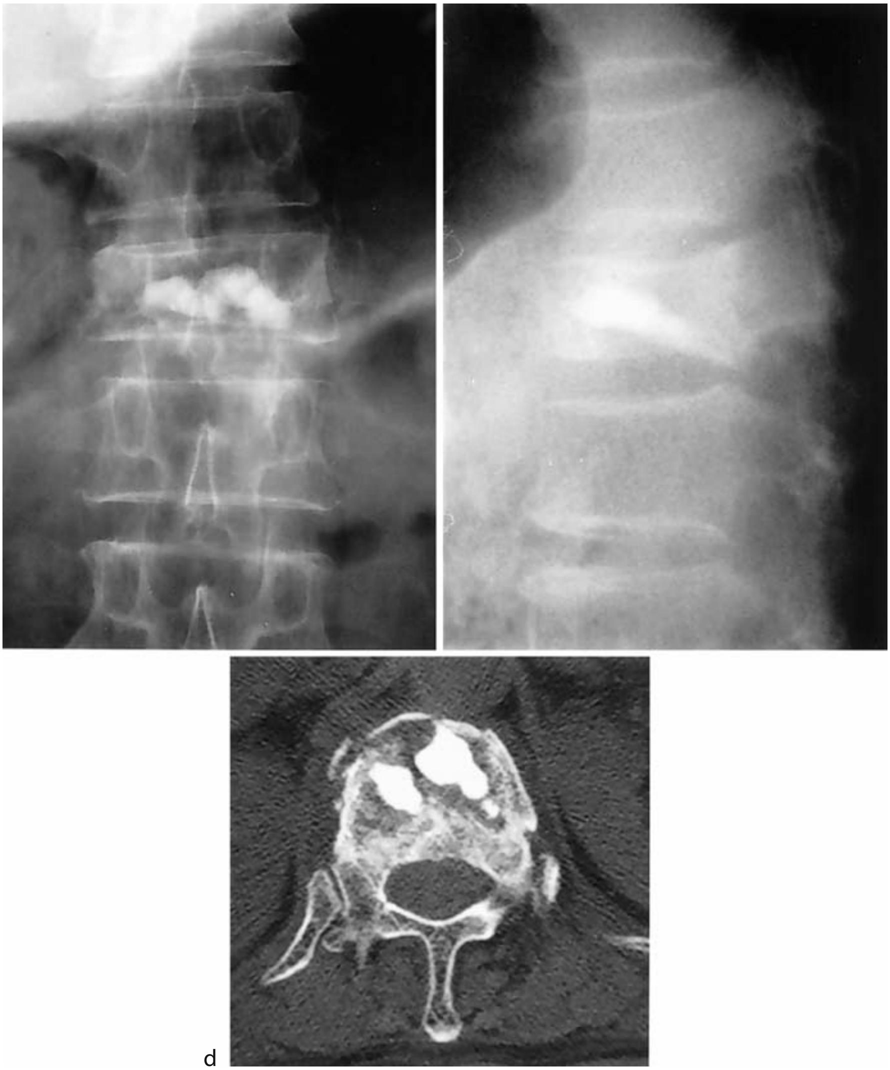


Fig. 8. *Continued*



d

Fig. 8. *Continued*

e

FIG. 8. *Continued*

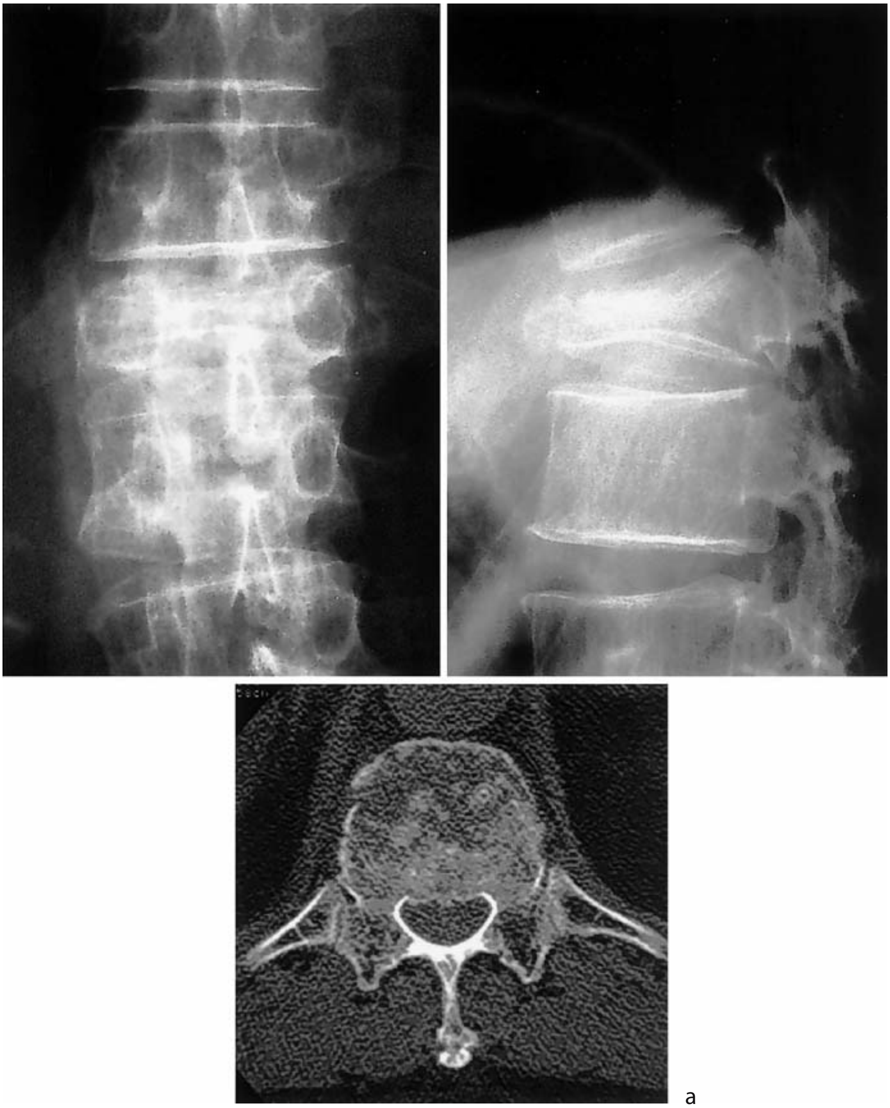
low back pain for 2 months, because of relapse. Five years after the operation, he has no low back pain or neurological deficit. The fracture healed with a compression rate of the anterior vertebral height of 25% and an angle of kyphosis of 23°. At 4.5 years, a CT scan indicated widening and remodeling of the spinal canal. The ratio of the estimated area of the bony fragment retropulsed into the spinal canal was 10% (Fig. 8e).

Case 5. A 78-year-old man had a T12 burst fracture injury from a fall. On admission the compression rate of the anterior vertebral height was 61% (Fig. 9a). Reduction in the hyperextended position achieved a good alignment, but a large bone defect was clearly seen in the anterior part of the vertebral body (Fig. 9b). A total of 8 g of HA in pellets and granules with 1 ml of fibrin glue was introduced 3 weeks after the injury (Fig. 9c). The patient's back pain disappeared after 1 week. HA did not leak from the vertebral body. Walking with a body cast was allowed 2 weeks after surgery. The body cast was taken off 1 month after surgery. At 2 years after the operation, the patient can work vigorously with no low back pain or neurological deficit. The compression rate of the anterior vertebral height improved to 10%, and the ratio of the estimated area of the bony fragment retropulsed into the spinal canal also improved from 23% to 12% at 2 years after surgery (Fig. 9d).

Discussion

Reduction of the osteoporotic vertebral burst fracture, in particular of the severe collapse of the vertebral body, causes a large bone defect in the anterior third of the vertebral body. Under conservative treatment, this large defect is not readily repaired, and the anterior column does not easily unite, as shown in case 1. This can cause a spinal deformity after the removal of the body cast [4]. To prevent such deformity, it is critical to fill the defect with as much as possible of a specific spacer material. HA, in particular in a combination of pellets and granules, seems to be the best material for such a spacer. When only HA granules were introduced, some granules were extruded from the vertebral body. If only HA pellets were to be used, they would not be dense enough to pack the cavity. The combination of pellets and granules seems to be the best to fill the bone defect fully. A body cast is necessary to maintain the reduction for severe collapse, because HA is not cement, but only a spacer material.

In conclusion, percutaneous vertebroplasty employing HA for the treatment of osteoporotic vertebral burst fracture is minimally invasive, achieves early relief from low back pain, facilitates recovery of the anterior and middle height of the vertebral body from vertebral collapse, and gradually restores the spinal canal. In addition, early bone union can be achieved. This



a

Fig. 9. Case 5. 78-year-old man. T12 burst fracture. **a** On admission, the compression rate of the anterior height of the vertebral body was 61%. The ratio of the estimated area of the retropulsed fragment into the spinal canal was 23%. **b** After preoperative reduction, a large bone defect was clearly seen in the anterior part of the vertebral body on CT. **c** 8 g of HA pellets and granules was introduced 3 weeks after injury. **d** At 2 years, the fracture healed with a compression rate of the anterior vertebral height of 10%, and a ratio of retropulsed fragment of 12%

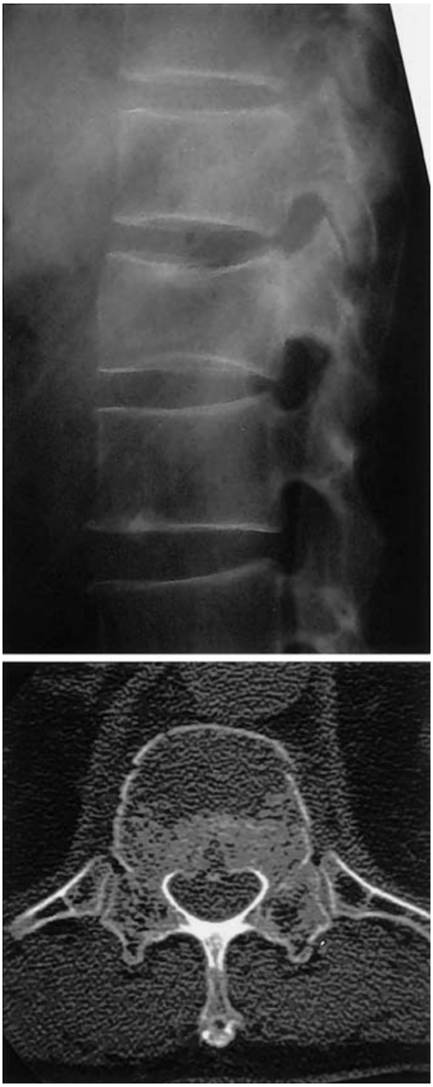


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Fig. 9. *Continued*

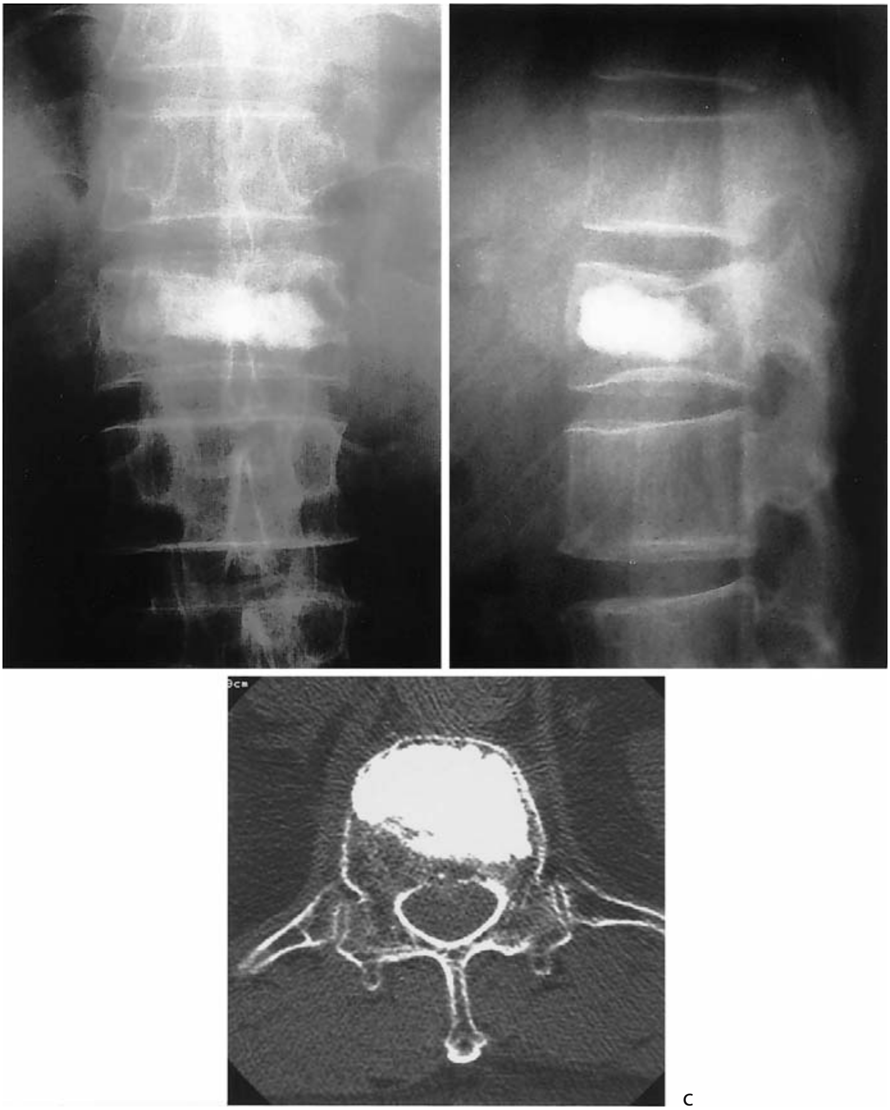

Fig. 9. *Continued*

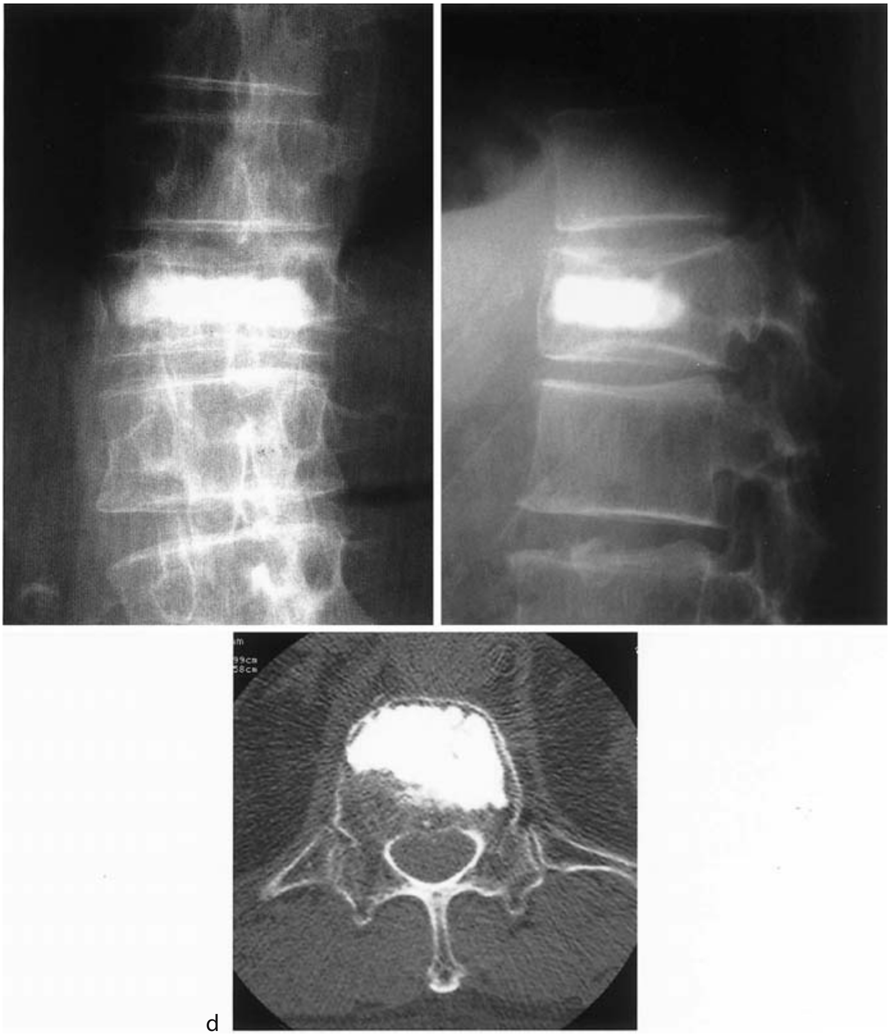

Fig. 9. *Continued*

Minimally invasive procedure
Early relief from low back pain
Recovery of anterior and middle height of vertebral body from vertebral collapse
Gradual restoration of spinal canal
Early bone union

↓

This operation is a useful procedure for osteoporotic vertebral burst fracture , irrespective of whether the cases are early or delayed

Fig. 10. Characteristics of percutaneous vertebroplasty with HA for treatment of osteoporotic vertebral burst fracture

operation is a useful procedure for osteoporotic vertebral burst fracture, irrespective of whether the cases are early or delayed (Fig. 10).

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Surgical Results of Endoscopic Discectomy for Lumbar Disc Herniation: Three-Year Follow-up

Eiji Hanaoka[1], Masatsune Yamagata[2], Kazuhisa Takahashi[3], Tatsuo Morinaga[4], and Hideshige Moriya[3]

Summary. Three years of follow-up results in lumbar disc herniation patients after endoscopic discectomy were evaluated using the Japanese Orthopaedic Association (JOA) scoring system by direct examination and questionnaires. The average postoperative JOA score was 28.4 points, and the average recovery rate was 91.9%. Eighty percent of patients doing light labor were able to return to their preoperative work within 1 month postoperatively. One patient was pregnant 2 years after surgery, and there was no adverse event related to childbirth and the discectomy. Within 3 months postoperatively 96.2% of the patients were able to return to their occupation. At 3 years, there was 92.3% follow-up. Endoscopic discectomy results were excellent at 3 years of follow-up.

Key words. Lumbar disc herniation, Endoscope, 3-year follow-up, Employment

Introduction

Since 1997, we have performed endoscopic lumbar discectomy in 97 cases using the instruments developed by our institution [1, 2].

Conventional discectomy is the preferred management technique, and it has favorable outcomes for lumbar disc herniation as demonstrated by numerous studies among the majority of surgeons [3–5]. However, these reports have noted that residual low back pain and recurrent herniation are major postoperative problems; i.e., recurrent herniation at the same level,

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heavy labor, age (under 35 years), disc degeneration, instability, and disc-high ratio are factors associated with recurrence. Weinstein et al. [6] reported that patients should return to work after having obtained complete symptomatic recovery or a minimum convalescence of 12 weeks. Psychological factors also have an impact on the outcome of the discectomy. These are some major postoperative problems encountered after conventional discectomy, as mentioned above. In this Chapter we evaluate the long-term surgical results of endoscopic lumbar discectomy.

Patients and Method of Analysis

Clinical records were obtained for 34 patients who underwent endoscpopic lumbar discectomy from February 1997 to August 1999 at Chiba University Hospital, Inoue Memorial Hospital, and Kashiwa Hospital. Twenty-six patients were available for this study (survey rate, 76.5%); 8 patients could not be contacted. The indication for endoscopic lumbar discectomy was severe leg pain that had not resolved after at least 3 months of conservative management. Preoperative magnetic resonance imaging (MRI) and myelography confirmed the diagnosis of lumbar disc herniation in all patients.

The study group was composed of 11 men and 15 women, whose ages at the time of surgery ranged from 16 to 56 years (average, 32.4 years). The follow-up period ranged from 36 to 54 months. The levels involved were L4-L5 in 11 cases and L5-S1 in 15 cases. The type of herniation was classified according to the modified Macnab's system by reviewing appropriate studies and surgical records. Based on this evaluation, 10 cases were classified as protrusion, 10 as subligamentous extrusion, 4 as transligamentous extrusion, and 2 as sequestration.

The patients' pre- and postoperative Japanese Orthopaedic Association (JOA) scores (Table 1) for management of low back pain [subjective symptoms, clinical signs, activities of daily living (ADL), and urinary bladder function; 29-point system] were scored. The JOA score results show the final follow-up data, but data from recurrent cases of lumbar disc herniation are excluded.

Occupational activity has been divided into three categories according to the criteria of physical involvement needed: light labor (office job) in 10 cases, moderate labor (including household tasks) in 8 cases, and heavy labor (construction work, truck driving) in 8 cases. Postoperative return to work was tracked for each occupation. There was no time restriction for light labor. However, there were 12 weeks of restriction before return to heavy and moderate labor. Each patient wore a corset for 3 months after the operation.

Table 1. Scoring system of the Japanese Orthopaedic Association for low back pain (JOA score)

1. Subjective symptoms (9 points)
   A. Low back pain
      None (3) occasional mild pain (2), frequent mild or occasional severe pain (1), frequent or continuous severe pain (0)
   B. Leg pain and/or tingling
      None (3), occasional slight symptoms (2), frequent slight or occasional severe symptoms (1), frequent or continuous severe symptoms (0)
   C. Gait
      Normal (3)
      Able to walk farther than 500 m, although it results in pain, tingling, and/or muscle weakness (2)
      Unable to walk farther than 500 m owing to leg pain, tingling, and/or muscle weakness (1)
      Unable to walk farther than 100 m owing to leg pain, tingling, and/or muscle weakness (0)
2. Clinical signs (6 points)
   A. Straight leg-raising test (SLR) (including tight hamstrings)
      Normal (2), 30°–70° (1), less than 30° (0)
   B. Sensory disturbance
      None (2), slight disturbance (not subjective) (1), marked weakness (grade 3–0) (0)
   C. Motor disturbance (MMT)
      Normal (grade 5) (2), slight weakness (grade 4) (1), marked weakness (grade 3–0) (0)
3. Restriction of activities of daily living (ADL) (14 points)
   Turn over while lying
   Leaning forwards: moderate restriction (1)
   Sitting (about 1 h): severe restriction (0)
   Lifting or holding heavy objects
   Walking
4. Urinary bladder function (–6 points)
   Normal (0), mild dysuria (–3), severe dysuria (–6)

15 point system: 1(9 pts) + 2(6 pts) + 4(–6 pts).
Recovery rate: (B-A/15-A)*100(%).
A: Preoperative JOA score.
B: JOA score at final follow-up.

Surgical Technique

The patient is placed in the prone position with knees flexed. The flare sheath that was designed according to our instructions is inserted to retract the muscle. A 5-mm, 30 degree rigid endoscope is inserted from the cephalad direction through a flexible sheath, made of polyurethane membrane and designed to fix to the interlaminar space (Fig. 1). This feature allows an un-

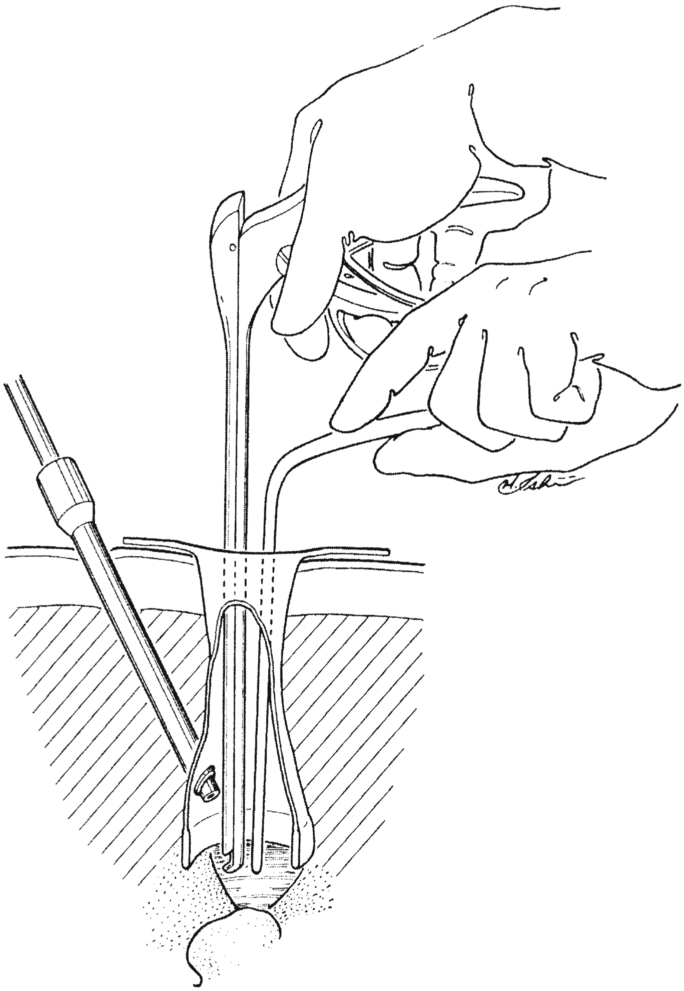

Fig. 1. The 30 degree rigid endoscope is inserted from the cranial side. The flare sheath has a wide working space for the instrument

obstructed view and wide working space for the instrument (Fig. 2). The ligamentum flavum is removed by a Kerrison rongeur and the lamina is cut using a round-shaped chisel and rongeur. Next, the fat tissue of the epidural space is seen under the ligamentum flavum. The dural tube and the nerve roots are retracted by a Penfield retractor, and the herniated mass is inspected. The affected nerve root is freed until it becomes loose and the entrance zone of the foramen is wide enough for the nerve root to pass through. Only one or two stitches are necessary to close the fascia of the back muscles (Fig. 3).

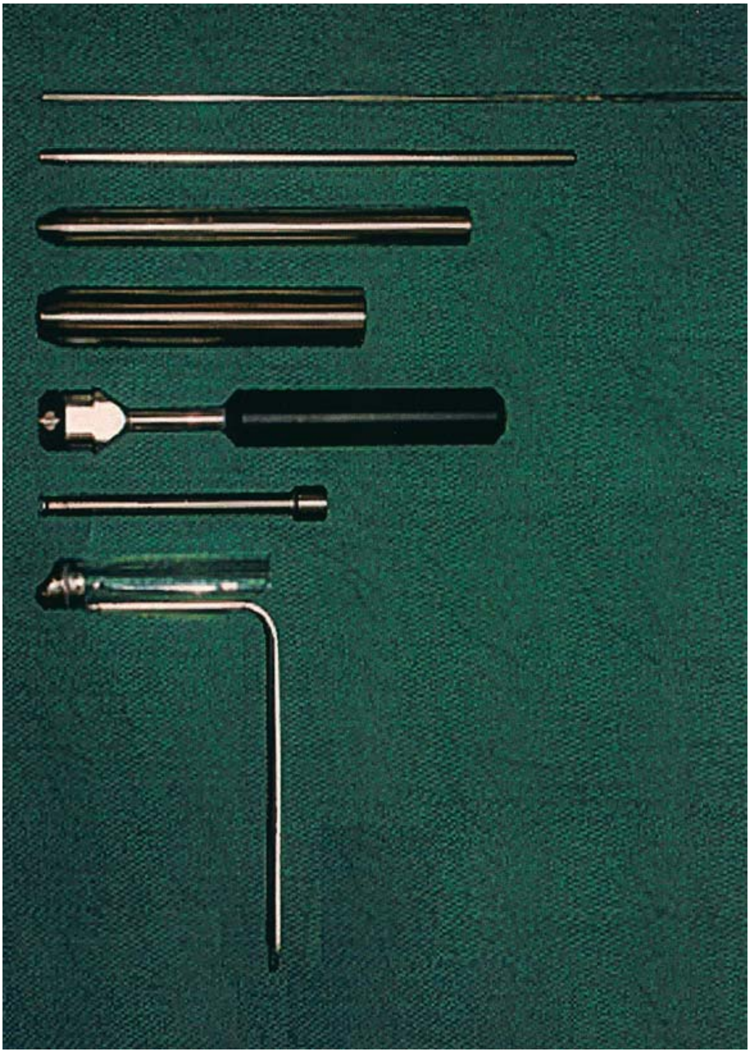

Fig. 2. Instruments (*above to below*) for endoscopic discectomy: introductory, dilator, sound, mandrin, pusher, side sheath, and flare sheath

Surgical Results

The patients' leg pain, low back pain, and daily activities were evaluated by the JOA score. In this system, the maximum score is 29 points. The average preoperative JOA score was 12.0 points. After 1 year, the average postopera-

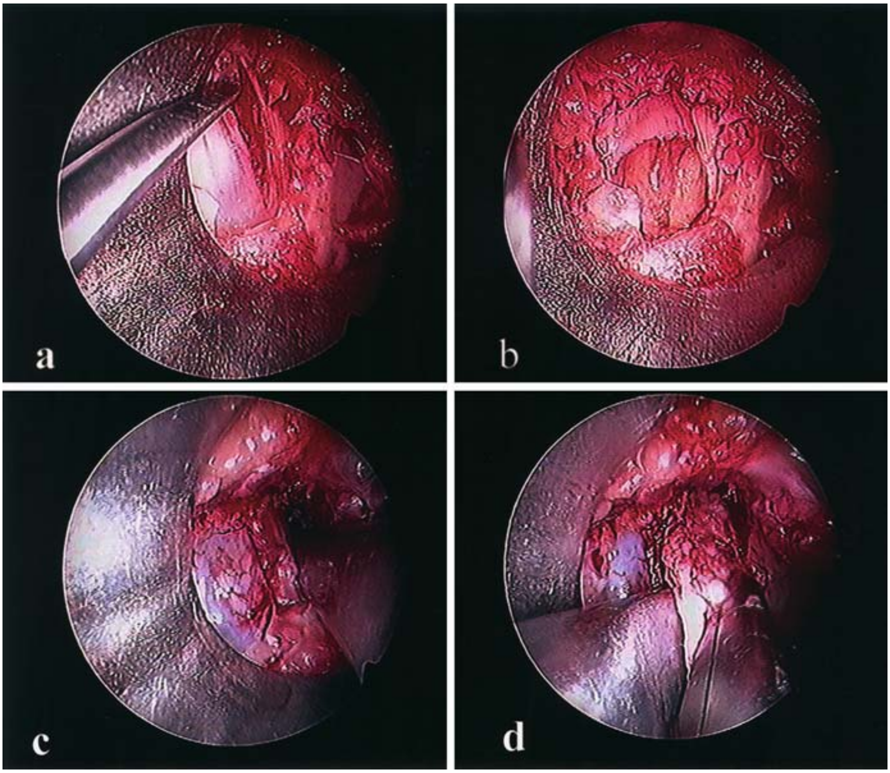

Fig. 3. **a** The ligamentum flavum is removed by a Kerrison rongeur. **b** The fat tissue of the epidural space is seen under the ligamentum flavum. **c** The dural tube and the nerve root are retracted by a Penfield retractor. **d** The herniated mass is respected

tive JOA score was 27.2 points and the average recovery rate was 89.4%. After 3 years, the average postoperative JOA score was 28.4 points and the average recovery rate was 91.9%. All patients could walk the day after the operation.

Subjective Symptoms

Preoperatively, low back pain was noticed in 25 patients (96.2%). After 3 years, residual low back pain lingered in five patients (21.7%). An interbody fusion was subsequently performed on two patients because of severe, chronic low back pain. Preoperatively, leg pain and tingling was noticed in all patients; after 3 years of postoperative follow-up, these remained in four patients (17.6%). Preoperatively, 23 patients had gait disturbance, whereas at 3 years postoperatively all patients had recovered (Fig. 4a).

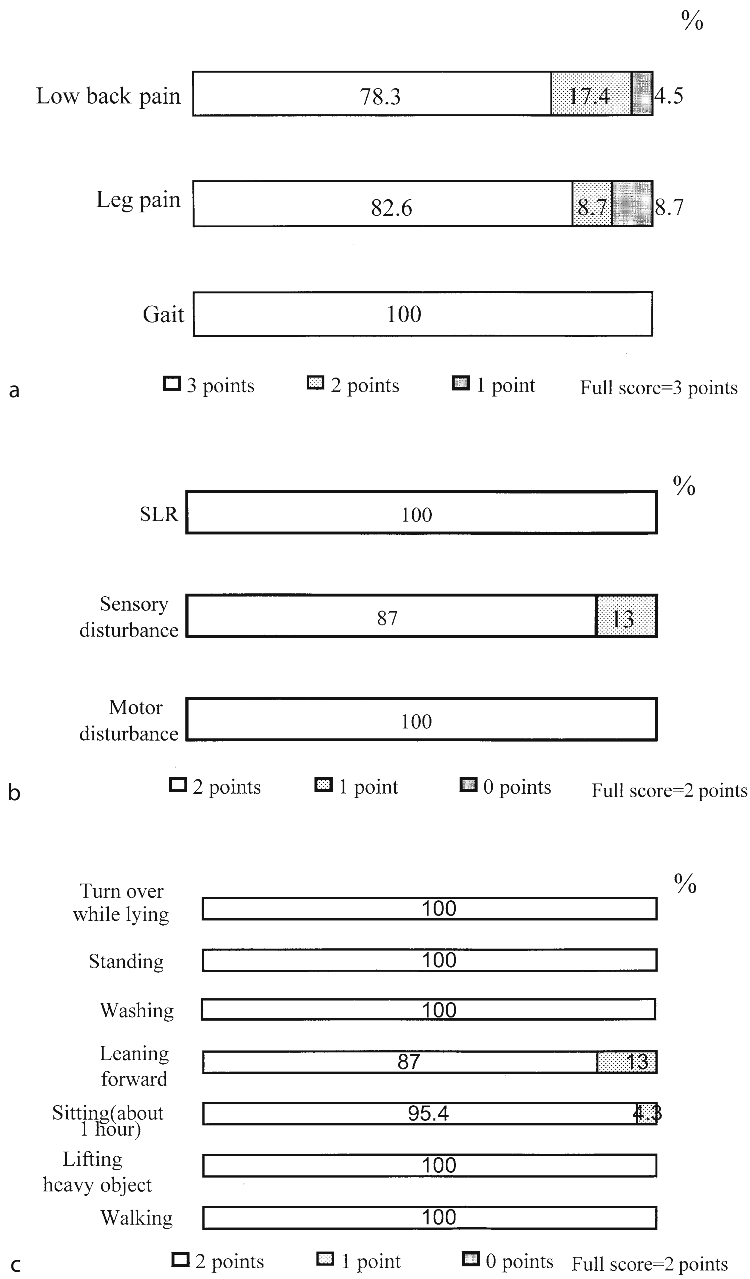

FIG. 4. Japanese Orthopaedic Association (JOA) score at final follow-up examination. **a** Subjective symptoms. **b** Clinical signs. *SLR*, Straight leg-raising test. **c** Activities of daily living

Clinical Signs

Preoperatively the straight leg raising test (SLR) was positive in all patients except one. The average SLR was 40.6°. Nineteen patients (76.9%) had motor weakness. Fourteen patients (53.8%) had a sensory disturbance. After 3 years, the postoperative SLR was negative in all patients, and there was no motor weakness. Sensory disturbance remained in only three patients (13%) (Fig. 4b).

Activities of Daily Living

The maximum ADL score is 14 points. Preoperatively, the ADL was 5.6 points. Postoperatively, ADL scores were excellent overall except for two patients. One patient when leaning forward and one patient when sitting for about 1 h experienced discomfort (Fig. 4c).

These are the excellent results of endoscopic discectomy with 3 years of follow-up. In the early stages of developing our technique, the three patients had dura mater tears. The JOA scores of these patients were excellent postoperatively. Complications occurred in four cases during the 3 years of follow-up. Two patients had recurrent herniation of the same disc, and reoperation was performed at 6 months and 1.4 years after surgery.

Employment Results

The occupation return rate was 96.2%, and at present 93.2% are working in their previous occupation. Each occupation was analyzed according to labor levels is demand.

Eighty percent of patients doing light labor were able to return to their preoperative work within 1 month postoperatively. One patient was pregnant 2 years after surgery and had a safe childbirth. One hundred percent of patients doing moderate labor were able to return to their preoperative work within 3 months postoperatively. However, one patient retired for reasons related to age. Another patient changed occupation from taxi driver to guard. Of those doing heavy labor, 87.5% were able to return to their preoperative work within 3 months postoperatively. One patient could not return to his original job because of persistent low back pain. Thus, 24 of the 26 patients were able to return to their preoperative work. One patient was even able to engage in heavier work compared with his preoperative occupation (Fig. 5).

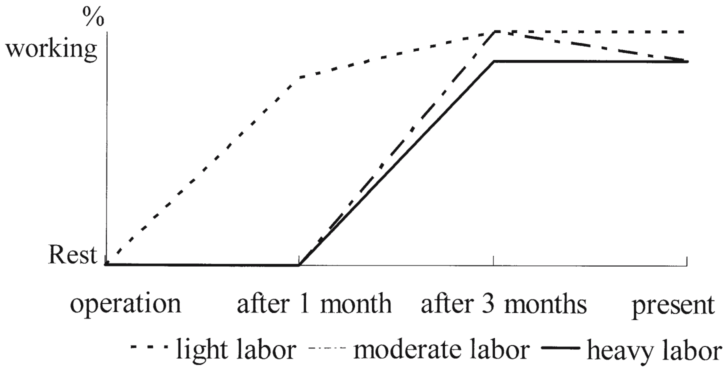

Fig. 5. Occupation return rates according to occupational activity up to 3 months after operation

Table 2. Long-term outcome of lumbar discectomy

Author	Year	Patients	Follow-up period (yr)	Success rate (%)	Recurrence rate (%)
Smyth [7]	1983	105	?	87	4
Weber [5]	1983		1.4.10	93	?
Dvorak [8]	1988	371	4–10	17	
Abernathey [9]	1990	236	~10	87	10.8
Williams [10]	1990	989	~15	85.2	14.8
Pappas [11]	1992	654	~4.5	76.3	9.3
Moore [12]	1994	984	10.8	89	6
Findlay [13]	1998	79	1–10	83	6.3
Yorimitsu [14]	2001	72	10	73.5	12.5

Discussion

We performed endoscopic lumbar discectomy in 97 cases from February 1997 to August 2002. The average surgical time was 109 min, and the average blood loss was 41 g. Postoperative pain control was examined and compared with that in a control group. The control group was treated by conventional open discectomy between 1991 and 1997. After the operation, the suppository was used an average of 1.2 times in the endoscopic group versus 3.7 times in the conventional group. These data showed one-third less usage when compared with the control group. The average bed rest in endoscopic group patients was 1.0 day. Endoscopic discectomy has various advantages, including the facts that it is less invasive, has less blood loss, causes less pain, requires less medication after the operation, and allows an early return to daily activities.

There are many reports about the long-term outcome of conventional discectomy. The success rates range from 73% to 93%, and the recurrence rates range from 4% to 17% at 4 to 10 years after the operation (Table 2). Our results are almost consistent with the previous literature. However, we believe our success rate and recurrence rate would be better with more patients enrolled in the study.

Yajiri et al. [15] reported on employment at 3 to 5 years of follow-up after the conventional open operation. In that study, the rate of return to work at the original occupation was 92%, and the follow-up return rate was 80%. The results with endoscopic discectomy were better with respect to employment. Weinstein et al. [6] reported that the rate of return to work after conventional discectomy was 30.1% at less than 6 weeks, 31.4% at 6 weeks to 3 months, and 4.3% at 6 months to 1 year. The rate of return at more than 1 year was 11.3% in this study.

The above-mentioned operative results with endoscopic lumbar discectomy for disc herniation were better than the those with open method. Almost all light laborers were able to return to their preoperative work within 1 month postoperatively. Short-term studies with less than 2 years of follow-up after the conventional method tend to give an overall success rate that exceeds 90%. On other hand, studies with long-term follow-up have shown unsatisfactory results, up to 60%. Davis [3] suggested that in order to evaluate the results of surgery for herniated lumbar disc, the follow-up period should be more than 4 years. Our patients will continue to be followed for 4 years.

The indication for endoscopic lumbar discectomy is unresolved symptoms after 3 months of conservative treatment. These results suggest that the indication for endoscopic lumbar discectomy will be expanded to include patients who need to return to work as soon as possible. In this study, almost all patients could return to the same occupation within 3 months, and the light laborers even returned to the same occupation after 1 month. Weber [5] reported that patients had almost the same result at 10 years whether they had the conventional operation or conservative treatment. When lumbar disc herniation is diagnosed in a patient who also has discogenic pain, we must consider the case carefully. In our study, 25 patients (96.2%) had low back pain preoperatively, and after 3 years postoperatively, 5 patients had residual low back pain. Three patients were able to return to moderate labor, even though one patient had an interbody fusion. JOA scores have not clearly differentiated between low back pain, lumbago, and buttock pain. Therefore a diagnosis must carefully distinguish low back pain. Endoscopic lumbar discectomy should be chosen only in the absence of discogenic pain.

Conclusions

After endoscopic lumbar discectomy, most patients returned to their original occupation. Endoscopic lumbar discectomy showed excellent surgical results, even at 3 years of follow-up.

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Laparoscopy-Assisted Mini-Open Lateral Approach for Anterior Lumbar Interbody Fusion

Chong Suh Lee, Sung Soo Chung, and Kwang Hoon Chung

Summary. The purpose of this study was to introduce a new approach for anterior lumbar interbody fusion (ALIF) and investigate the advantages, technical pitfalls, and complications of the laparoscopy-assisted mini-open lateral approach. Thirty-five patients with various disease entities were included. Blood loss, operation time, incision size, postoperative time to mobility, length of hospital stay, technical problems, and complications were analyzed. With this approach, we can reach from T12 to L5 subdiaphragmatically. The blood loss and operation time of patients who underwent simple ALIF were 45.7 ml and 82.8 min for one level, 103.2 ml and 107.6 min for two levels, 272.5 ml and 150 min for three levels, and 520 ml and 190 min for four levels of fusion, respectively. The complications were retroperitoneal hematoma in two cases, pneumonia in one case, and transient lumbosacral plexus palsy in three cases. The laparoscopy-assisted mini-open lateral approach is an advantageous approach with a very short learning curve. However, special attention is required to complications, such as transient lumbosacral plexus palsy.

Key words. Spine, Lumbar, Laparoscopy, Mini-open lateral approach, Interbody fusion

Introduction

There are various advantages of minimally invasive surgery, such as smaller incisions, minimal tissue dissection and injury, reduced blood loss, and reduced hospital stay, with quicker recovery and rehabilitation time, as well as improved cosmetic results. The current trend toward increased application of minimally invasive surgery in all surgical fields, in conjunction with

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patients' demands for such medical practice, are likely to change the trend of spine surgery as well.

The minimally invasive operation in lumbar spine surgery has been drawing attention since Obenchain [1] first reported intervertebral discectomy and Mathews et al. [2] reported intervertebral body fusion by laparoscopy. After the report of closed laparoscopic anterior lumbar interbody fusion [3, 4], a mini-open lumbar interbody fusion technique was also introduced [4]. Nowadays, surgical incisions tend to be minimized with the aid of surgical microscopy or laparoscopy. There are also several kinds of mini-open approaches that can be assisted by laparoscopy or microscopy, and sometimes with the naked eye. For mini-open anterior lumbar interbody fusion, the paramedian and anterolateral approaches, which start at the lateral aspect of the rectus abdominis, are commonly used.

Because the laparoscopy-assisted mini-open lateral approach is commonly used for anterior lumbar interbody fusion at our center, we investigated the advantages, disadvantages, and technical problems that should be considered when using this method.

Materials and Methods

Patients

Thirty-five patients who underwent surgery by the laparoscopy-assisted mini-open lateral approach from September 2000 to July 2002 formed the basis of this study. There were 15 cases with one level, 13 cases with two levels, 5 cases with three levels, and 2 cases with four levels of fusion (Table 1). There were 18 men and 17 women with an average age of 42.6 and 53.4 years, respectively. There were two cases of painful Schmorl's node, seven cases of fracture, three cases of tuberculous spondylitis, three cases of pyogenic spondylitis, one case of fungal infection secondary to acute lymphocytic leukemia, four cases of internal disc derangement, seven cases of degenerative lumbar kyphosis along with spinal stenosis, three cases of junctional kyphosis, one case of nonunion, one case of Charcot's spine, one case of postdiscectomy syndrome, one case of idiopathic scoliosis, and one case of lumbar Scheuermann's disease. The posterior approach was additionally used in 18 of these cases, excluding internal disc derangement, painful Schmorl's node, infection, postdiscectomy syndrome, idiopathic scoliosis, lumbar Scheuermann's disease, and one case of fracture. Among these 18 cases, anterior lumbar interbody fusion was conducted on the same day in 13 cases, and the anterior approach was used with an interval of 7 days in the others. Blood loss, operation time, incision size, time to standing and to ambulation for more than 10 min, admission period, complications, technical problems, and the advantages and disadvantages of

Table 1. Fusion levels and number of cases

Fusion level	No.
1 level (15 cases)	
L1-2	3
L2-3	3
L3-4	2
L4-5	7
2 levels (13 cases)	
T12-L2	3
L1-3	4
L2-4	2
L3-5	3
L1-2, L4-5	1
3 levels (5 cases)	
T12-L3	1
L1-4	2
L2-5	2
4 levels (2 cases)	
L1-5	2

the surgical method were investigated in all patients who underwent the laparoscopy-assisted mini-open lateral approach. For evaluation of blood loss and operation time, the patients were divided into two groups: 19 who underwent intervertebral lumbar interbody fusion after discectomy and 16 who underwent additional manipulation of the vertebral body and soft tissue due to infection, fracture, or deformity (idiopathic scoliosis, Charcot's spine). The time to standing and to ambulation for more than 10 min and the admission period were investigated only for those who underwent discectomy and one-level anterior lumbar interbody fusion. Those who underwent more than two levels of fusion were excluded, because most of them were treated by the combined posterior approach due to deformities such as kyphosis, or due to systemic factors or delay in the ambulation period caused by infections or fractures. One-level cases in which posterior manipulation was conducted were also excluded.

Surgical Technique

The patient was laid in true lateral position on the operating table. The table was bent about 20° at the waist level, and the hip and knee joints were flexed about 30°. Under the guidance of a C-arm, an intervertebral disc and the anterior and posterior margin of the upper and lower adjacent vertebral bodies, which were to be fused, were outlined. A line was drawn connecting the center of the upper and lower vertebral bodies to serve as the guide for the incision

Fig. 1. Incision line between the center of the upper vertebral body and the center of the lower vertebral body under fluoroscopic guidance

(Fig. 1). The abdominal muscles were split in the direction of the muscle fibers, and after the posterior peritoneal fat pad had been retracted to the anterior side, the retroperitoneum was exposed and the psoas muscle, which covers the intervertebral disc, was split in the direction of the muscle fibers to expose the disc (Fig. 2). The anterior and posterior longitudinal ligaments were preserved, and the intervertebral disc was excised. An auto-graft bone was harvested at the anterior iliac crest. If the height of the fusion gap was over 15 mm, one mesh cage was inserted, and if the height was less than 14 mm, two lateral titanium-threaded cages were utilized for insertion. In case of infection, only the auto-graft bone was inserted for fusion.

Results

Blood Loss and Operation Time

The blood loss and operation time of the patients, who underwent discectomy without manipulation of the vertebral body and soft tissue followed by fusion, were 45.7 ml and 82.8 min for one level (nine cases) and 103.2 ml and

Fig. 2. Abdominopelvic computed tomography (CT) demonstrating the planes of mini-open lateral approach

Table 2. Blood loss and Operation time in simple ALIF

Level (no. of patients)	EBL (ml)	operation time (min)
1 level (9)	45.7	82.8
2 levels (5)	103.2	107.6
3 levels (4)	272.5	150
4 levels (1)	520	190

ALIF, Anterior lumbar interbody fusion; EBL, estimated blood loss.

Table 3. Blood loss and Operation time (additional debridement and corpectomy)

Level (no. of patients)	EBL (ml)	Operation time (min)
1 level (6)	385	108
2 levels (8)	470.5	122.6
3 levels (1)	420	240
4 levels (1)	1300	230

EBL, Estimated blood loss.

107.6 min for two levels (five cases), respectively (Table 2). When debridement and corpectomy were additionally conducted due to infection or fracture, the blood loss and operation time showed increments (Table 3).

Size of Incision, Time to Standing and Ambulation, and Admission Period

The average length (range) of the surgical incision was 4.1 cm (3.4–5.1 cm) for one level, 6.2 cm (5.1–7.2 cm) for two levels, 8.2 cm (7.0–9.4 cm) for three levels, and 10.1 cm (9.7–10.5 cm) for four levels of fusion. The average times to standing and to ambulation were 1.2 and 2 days, respectively, in patients who had no fracture or sign of infection and underwent only one level of anterior fusion without any posterior manipulation. The average admission period was 6.8 days.

Complications

Retroperitoneal hematoma occurred in two cases, pneumonia in one case, transient paralysis of the lumbosacral plexus in three cases, inadequate correction of kyphosis in one case, and failure to insert two lateral cages during anterior lumbar interbody fusion of the L4-5 body in one case. Retroperitoneal hematoma occurred in one patient who had acute lymphocytic leukemia with lumbar abscess and in one patient who underwent four levels of anterior and posterior lumbar fusion. Pneumonia occurred in a patient with active pulmonary tuberculosis. Transient lumbosacral plexus palsy occurred in three women who were over 60 years of age; two of these patients underwent a posterior operation in addition to one level and two levels of anterior lumbar interbody fusion, and the other underwent anterior lumbar interbody fusion alone of one level. Since the L4-5 interbody disc was seated deep to the iliac crests in one obese patient, an adequate exposure of the interbody disc was difficult, and insertion of only one lateral cage in an unparallel fashion was possible. Therefore this patient underwent additional posterior instrumentation and fusion in consideration of postoperative instability or nonunion (Fig. 3).

Technical Advantages and Disadvantages

With the laparoscopy-assisted mini-open lateral approach, access to the T12-L1 vertebral body was possible without incising the diaphragm, and in one case of idiopathic scoliosis, screw insertion at the T12 vertebral body was also possible. Moreover, with this approach, surgical treatment of various diseases, such as correction of spinal deformities and corpectomy, was also feasible. However, if the L4-5 interverteral disc was deeply seated between the iliac crest, partial excision of the lumbar crest was required, and to approach the T12-L1 and L1-2 intervertebral discs, rib resection may be needed.

Discussion

Ever since closed laparoscopic anterior lumbar interbody fusion was introduced, the minimally invasive approach for anterior lumbar interbody fusion has been gaining interest [4, 5]. Although closed laparoscopic anterior lumbar

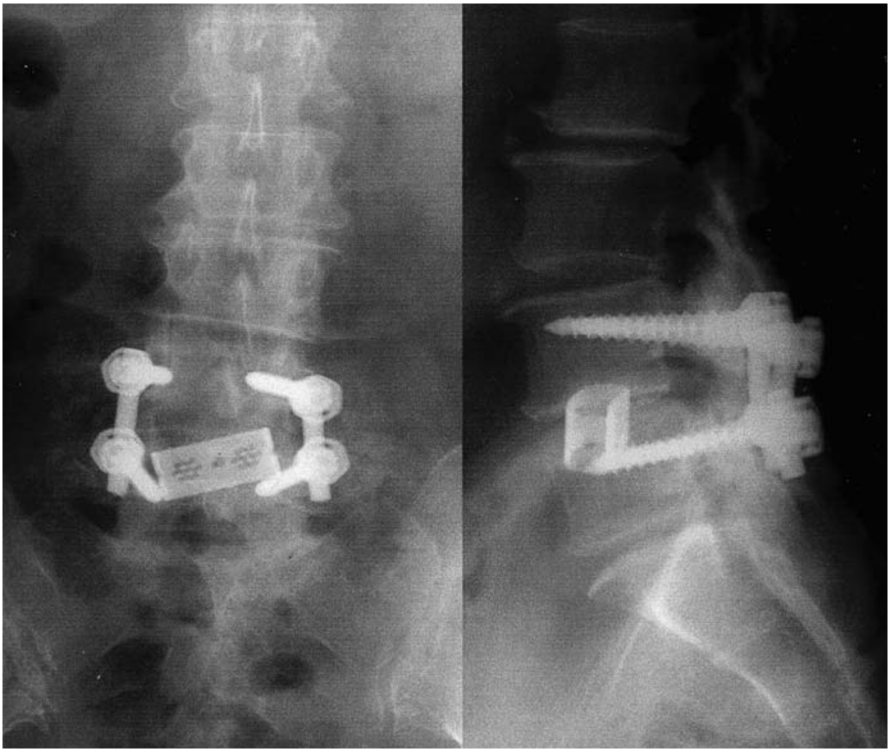

FIG. 3. Malpositioning of cage due to obstruction by a high iliac crest

interbody fusion has advantages in terms of reduced blood loss, less pain, reduced admission and rehabilitation periods, and superior cosmetic effects, there are also some disadvantages [2, 5–11]. First, in addition to the long learning curve, there are relatively high rates of occurrence of vascular, intestinal, and peritoneal injury, ranging from 16.7% to 29.4%. Moreover, the operation time is reported to be much longer than that with open surgery. In particular, it is more difficult to approach the L4-L5 vertebral bodies for fusion than the L5-S1 bodies, thus posing higher complication rates [5, 11]. Since exposure is not easy, conversion to open surgery occurs in approximately 10% of cases [9]. Special surgical instruments are also required for laparoscopic surgery, and carbon dioxide is required to fill the intraperitoneal space. As a consequence, the blood carbon dioxide concentration may increase, and complications such as increased blood acidity or, rarely, carbon dioxide embolism are also reported to occur [8]. Although the technique is minimally invasive, because it is conducted inside the peritoneum intestinal adhesion does occur. Leverant et al. [6] reported intestinal adhesion in 79 of 124 patients who underwent cholecystectomy through laparoscopic surgery. Moreover, the probability of retrograde ejaculation is higher than that with the retroperitoneal approach. Retrograde ejaculation is reported to occur in about 5% of cases [10]. Thus, currently the retroperitoneal approach without the use of gas is the preferred method of approach.

For closed laparoscopic anterior lumbar interbody fusion of L4-5, the approach from the retroperitoneum without utilization of gas is under study [7]. Thus, regarding such trends, we believe that a mini-open lateral approach is the most adequate treatment option. The mini-open lateral retroperitoneal approach does not necessitate the use of gas, and any surgeon who is experienced with the conventional anterior approach of the lumbar body can easily learn with the utilization of conventional surgical instruments. The mini-open lateral approach can be conducted without the aid of surgical microscopy or laparoscopy. However, it has the disadvantage of a deep and narrow surgical field. Thus, only the operator can adequately visualize the region of interest, whereas other assistants or scrub nurses may not be aware of the progression of the operation because of poor visualization and lighting, and it may subsequently become difficult to conduct work that requires precision. Thus, combining the mini-open approach with laparoscopy has the advantage of securing a brighter and wider view of the region of interest. As a result, the assistants and scrub nurses can all visualize the operation and thus can actively participate in the operation, and recording of the operation may also become easier. Also, compared with closed laparoscopic surgery, even a surgeon who does not have experience with visualization of the surgical field through a video monitor can compare the field with the monitor, thus gaining a chance to learn more easily.

However, if one is not dexterous with the use of laparoscopy, there is a disadvantage of time lost due to additional manipulation. Zdeblick and David [11] compared closed laparoscopic surgery with the mini-open approach for L4-5 anterior lumbar interbody fusion. They found that the rate of complications, such as vascular injury, was 20% for closed laparoscopic surgery, whereas it was 4% for mini-open surgery. The rate of failure to insert two cages due to inadequate exposure was 16% for closed laparoscopic surgery, whereas there were no failures to insert in mini-open surgery.

The mini-open lateral approach has several advantages compared with the conventional mini-open approach. The other conventional mini-open approaches allow access to the L2-3 bodies proximally, whereas the mini-open lateral approach allows a subdiaphragmatic approach to the T12-L1 bodies. In accessing, there is no need to visualize the peritoneum or great vessels, and there is virtually no chance of damaging such structures. Moreover, because the anterior and posterior longitudinal ligament is preserved, there is no risk of bone or cage displacement. Since the approach continues to go straight down from the lateral aspect, it is a very simple approach method compared with others and is easier to learn. Since the technique approaches the side of the vertebral body, there is an advantage of anterior fixation of screws. However, by this method, the L5-S1 bodies cannot be approached, and if the L4-5 disc is seated deep to iliac crests, access is difficult. In our study, we also experienced difficulty in reaching the L4-5 disc space, which resulted in skewed placement of the cage in the direction of the vertebral disc. Thus, in such cases we partially excise the iliac crest for approach. In the approach to the L1-2 and T12-L1 bodies, the 11th and 10th ribs may interfere. Thus, these ribs need to be cut and temporarily retracted laterally and replaced after the main procedures are completed.

The main disadvantage of this method is the need to split the psoas muscle in the mid-portion, thus creating a risk of lumbosacral plexus injury. Three of our patients had such injuries, although all recovered within 3 months. Thus, currently we split the psoas muscle at the anterior one-third instead of at the right middle portion. However, since transient lumbosacral plexus injury is also being reported in closed laparoscopic surgery through the retroperitoneum [5], it should not be considered as a complication limited to the lateral approach, although the risk may be higher in the mini-open lateral approach.

This approach is most adequate for the operation for one or two levels of degenerative disc disease with chronic low back pain or radiculopathy due to foraminal narrowing or internal disc derangement, like other mini-open approaches or closed laparoscopic surgery [9, 11]. However, we have employed the method more often for the correction of burst fracture, infection, and kyphosis. Thus, this method could be utilized in such indications; however, in cases of rigid kyphosis that require release of the anterior longitudinal ligament, an adequate correction may be difficult, and thus this method should be avoided.

In our case, in an attempt to correct one case of flat back syndrome, an adequate correction was not attained. In the correction of one case of idiopathic scoliosis, by making an incision of 10 cm and performing anterior instrumentation, a satisfactory result was gained, and thus application in a case of lumbar scoliosis was possible. Thus, it could be employed for the correction of thoracolumbar scoliosis through the anterior approach combined with thoracoscopy.

Regan et al. [9] conducted a multicenter comparison of the results of the laparoscopy-assisted mini-open approach and the closed laparoscopic approach and found that mini-open surgery required much less operation time than closed laparoscopic surgery, but that there was more bleeding and a slightly longer duration of hospital stay with this approach. The amount of blood loss with L4-5 interbody fusion was 232.3 and 134.4 ml, the operation time was 147.9 and 223.6 min, and the admission period was 4.1 and 3.2 days, respectively. Zdeblick and David [11] reported that there were no significant differences in blood loss, operation time, and admission period between the two groups; however, in closed laparoscopic surgery, the complication rate was four times higher. In general, blood loss and operation time were smaller in our study than in others, but, the average admission period was longer. This may be due to the fact that the lateral approach involves no risk to major vessels during the approach, and the approach method is relatively simple. The longer admission period could be due to different cultures of medical practice in different countries. The first ambulation was accomplished an average of 2 days after surgery, and pain in the bone donor site was the major factor hindering ambulation.

Conclusion

With the laparoscopy-assisted mini-open lateral approach for anterior lumbar interbody fusion, relatively wide access to the T12-L5 bodies is possible, and it is a safe operative technique, which involves practically no damage to the blood vessels, peritoneum, and intestines. It also has all the advantages of minimally invasive surgery. It is an effective method of approach, which could be applied to various diseases. However, one should be cautious about the possibility of complications such as lumbosacral plexus paralysis.

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Treatment of Internal Disc Derangement by Posterior Lumbar Interbody Fusion and Posterior Instrumentation

Chul-Hyung Kang

Summary. Internal disc derangement (IDD) is characterized by chronic low-back pain and referred pain in the legs. This condition is easily misdiagnosed as a disc herniation, resulting in failed back surgery, or it could be ignored by a doctor as malingering or a psychological problem. The indication of surgery has been intractable low-back pain with or without leg pain in spite of conservative treatment over 6 months. Discography was performed before surgery, and painful disc(s) were identified by concordant pain provocation. Subtotal disc excision and posterior lumbar interbody fusion (PLIF) with posterior instrumentation were performed. A successful clinical and radiological result was obtained by these procedures. The cause of IDD and the mechanisms of pain are discussed.

Key words. Internal disc derangement, PLIF

Introduction

Internal disc disruption or derangement (IDD) was first described by Crock [1, 2] and is characterized by chronic low-back pain and referred pain in the legs. The terminology of this condition has not yet been clearly defined (see the Discussion). Contrary to acute low back pain, which shows spontaneous recovery within a few weeks or months [3], chronic low back pain tends to be chronic or intermittent [4, 5]. When the clinical symptoms of IDD are mild, it may be controlled by conservative measures, including medication, patient education, epidural injection, physical therapy, exercise, and so on. When the symptoms are severe, however, this condition is usually resistant to most forms of conservative treatment. When the symptoms are severe enough to

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endanger a patient's daily activity in spite of conservative treatment over 6 months, surgery may be indicated. When surgery was indicated, discography was performed first, and then posterior lumbars intabody fusion (PLIF) with posterior instrumentation was performed at the involved levels. The clinical and radiological results were successful after PLIF and posterior instrumentation.

Materials and Methods

Forty-nine patients with IDD were treated by PLIF and posterior instrumentation in our hospital from 1994 to 2001. Three of these patients were excluded due to loss of follow-up. All of the surgeries and discograms were performed by one surgeon. The surgery was confined to those who showed intractable low back pain and/or leg pain in spite of conservative treatment over 6 months. A clinical diagnosis was made before admission by careful history taking and physical examination. Before surgery, painful disc(s) were identified by discography and computed tomographic (CT) scan. The surgical technique for PLIF was that of Cloward [6, 7], and all patients had autogenous posterior iliac cortico-cancellous bone blocks removing for bone grafting. Forty-six of the 49 cases of internal disc derangement treated by PLIF and posterior instrumentation were followed for more than 6 months. Two-level fusion was performed in 23 cases, one-level fusion in 20 cases, and three-level fusion in 3 cases. In 43 of 46 cases, painful discs showed signs of degeneration according to lumbar magnetic resonance imaging (MRI), but there was no disc degeneration in 3 cases. There was a definite history of trauma in 38 cases, but in 8 cases there was no history of trauma. Clinical outcome was determined by a questionnaire and interpreted by Lin's criteria [8]. Fusion status was interpreted by trabecular bridging in simple x-ray or no motion in flexion-extension views.

Results

Solid fusion was obtained in all cases except one. In a recently found case (Fig. 1), breakage of pedicular screws and a slight motion were noted in flexion-extension views, and this case was interpreted as a pseudoathrosis. The clinical outcome in this case was scored as fair. The fusion rate was 45/46 (97.8%).

The clinical symptoms of the patients were much improved at the last follow-up, with a score of good or more in 38/46 (82.6%) cases. By Lin's criteria, the clinical outcome of surgical treatment was scored as excellent in 18 cases, good in 20 cases, fair in 5 cases, and poor in 3 cases (Table 1).

Fig. 1. **a** Anteroposterior (AP) radiograph of a 32-year-old male patient (case 3). Posterior lumbar interbody fusion (PLIF) and instrumentation were performed on the L5-S1 disc level due to severe low back pain after falling from a height. **b** Lateral radiograph of case 3. **c** Flexion view of lumbar spine of case 3. Breakage of screws and motion in flexion (**c**) and extension (**d**) views. The clinical outcome was scored as fair. **d** Extension radiograph of case 3. Breakage of screws and motion in flexion (**c**) and extension (**d**) views. The clinical outcome was scored as fair

TABLE 1. Clinical results of posterior lumbar interbody fusion and posterior instrumentation in internal disc derangements

Result	No. of cases
Excellent	18
Good	20
Fair	5
Poor	3

Discussion

Internal disc disruption was first described by Crock [1] in 1970, and the characteristic symptoms are well summarized in Crock's presidential address to the ISSLS in 1986 [2]. However, different authors use different terms for this condition. Crock's term "internal disc disruption" means a painful disc without disc space narrowing or diffuse bulging of the disc [1]. Kirkaldy-Willis [9] also used the term "internal disruption," and he noted a painful disc with disc space narrowing and complete tearing of the disc from side to side and from front to back without herniation. Later, Lee [10] used the more comprehensive term "internal disc derangements" referring to painful disc(s) with or without disc height loss, including the concepts of both of Crock and Kirkaldy-Willis.

The clinical symptoms of IDD are characterized by chronic low back pain and pain referred to the legs [1, 2]. In contrast to the acute low back pain syndrome, chronic low back pain tends to be chronic on intermittent [3–5]. The pain of IDD is aggravated by sitting for a long time or bending forward [10]. Often, sudden extension after bending forward is also painful. The patient complains of difficulty in sitting for a long time and in suddenly standing up after sitting for a long time. When the pain is mild, the patients have only low back pain; when it becomes severe, the pain is referred to the buttocks, thighs, lower legs, or feet. The pain is deep, aching, and poorly localized in most cases. However, there are no definite neurological signs or reflex changes. Imaging studies of patients with IDD are usually normal in spite of severe clinical symptoms. Thus a doctor can easily ignore the symptoms of IDD patients because there is no significant disc herniation, spinal stenois, or instability. Some doctors insist that the patient has a psychological problem or a litigation problem; however, the physical cause of the pain should be thoroughly investigated first, and then a psychological problem should be sought when there is no physical illness. I have seen many patients who were diagnosed as having a litigation problem or pain of psychological origin by previous doctors who had discogenic low back pain that was confirmed by later discography. When there is minimal disc protrusion or diffuse bulging of a disc, this condition can easily be misdiagnosed as disc herniation, which can result in a failed back syndrome.

Discogenic low-back pain is far more common than facet joint pain in the outpatient clinic, and most of these patients can be managed by conservative measures, including patient education, physical therapy, medication, and so on. However, in severe cases, the symptoms are very resistant to most forms of conservative treatment and require surgical intervention.

A clinical diagnosis of IDD is made on the basis of the symptom of peculiar discogenic pain and its chronicity. Patients with IDD have chronic low back pain with or without pain in the buttocks, thighs, lower legs, or feet, and they have more pain in the sitting than in the standing posture. A definite tenderness is noted in almost all cases at the exact level of the involved disc, and the patient may have a limitation in the straight leg-raising test because forward bending is painful. The clinical symptoms presented by these patients are usually atypical and nonspecific for the diagnosis of herniated lumbar disc. However, herniated disc was the most common diagnosis made by previous doctors. Ten patients had undergone a previous operation on the lower back. Six patients were treated by simple disc excision, two by decompression and posterolateral fusion, and two by interbody fusion with cages. All complained of severe pain, even after surgery. IDD was commonly misdiagnosed as disc herniation or as malingering. A thorough knowledge of IDD is mandatory for accurate diagnosis and to reduce the risk of failed back surgery. The concept that the referred pain does not go down below the knee is wrong [10]. Many patients had pain shooting down to the lower legs or feet without disc herniation. Patients may have varying degrees of depression and insomnia [2] due to severe chronic pain.

Traditionally, the disc was thought to be aneural, and the disc was believed to be a nonpainful structure. Recently, the disc has been discovered to be richly innervated at the outer layers of the annulus by the sinuvertebral nerve and the sympathetic nerves [11, 12]. Thus the disc itself may become painful without a disc herniation, although the exact mechanism is not yet clear.

The exact etiology of IDD is not yet clearly known, but it is suggested that after trauma [2, 13] internal tearing of the disc occurs and some chemicals that cause pain are produced from the torn disc [2]. In our series, 38 46 patients had a positive history of trauma, including heavy lifting (14), slipping and falling on the buttocks (10), motor vehicle accident (9), and falling from a height (5). No definite trauma was noted in eight cases (17.4%). The mechanism of pain provocation in IDD is not clear yet. Possible pain mechanisms arising from the disc have been reported [14–16], including the

a b c d

Fig. 2. **a** AP radiograph of lumbar spine of a 34-year-old man (case 1). He had intractable chronic low back pain and leg pain for 14 months following a car accident. No definite abnormal findings are seen on simple X-ray. **b** Lateral radiograph of lumbar spine of case 1. **c** Degeneration of the L5-S1 disc is noted in T2-weighted magnetic resonance images (MRI). **d** Severe identical pain is produced on discography at the level of the L4-5 and L5-S1 discs. There was pain provocation at the L3-4 level. **e** AP views 16 months after PLIF and posterior instrumentation. Clinical symptoms were excellent after operation. **f** Lateral view of lumbar spine 16 months after operation

e f

Fig. 2. *Continued*

involvement of substance P and other pain mediators or stimulation of nociceptors by abnormal local stress or strain.

Most of the painful discs appear as degenerated discs on MRI (Fig. 2c). However, in some cases the disc may become painful without disc degeneration [17]. Disc degeneration itself is not a specific sign of IDD. We should consider the fact that degenerated discs are found in normal subjects without any low back pain [18]. In three cases of our series, no disc degeneration was noted on MRI, but there was pain provocation on discography (Fig. 3d). In some cases, a high-signal-intensity zone (HIZ) was noted on T2-weighted sagittal MRI (Fig. 4). When this sign is present, the possibility is high that the involved disc is painful (19, 20). This sign (HIZ) was noted in 15 of 46 cases in our series.

A definite diagnosis of IDD cannot be made by X-ray findings, CT scan, or MRI findings only. After a clinical diagnosis of IDD, discography (Figs. 2d and 3e,f) is performed for definite diagnosis. Discography performed by modern techniques is the only method for the definite diagnosis of IDD [21]. If discography is performed without a clinical diagnosis of IDD, the possibility of a false positive is high. Because discography is an invasive procedure and has the possible complication of discitis [22] or more severe pain, discography is performed when surgery is indicated and the patient wants the operation.

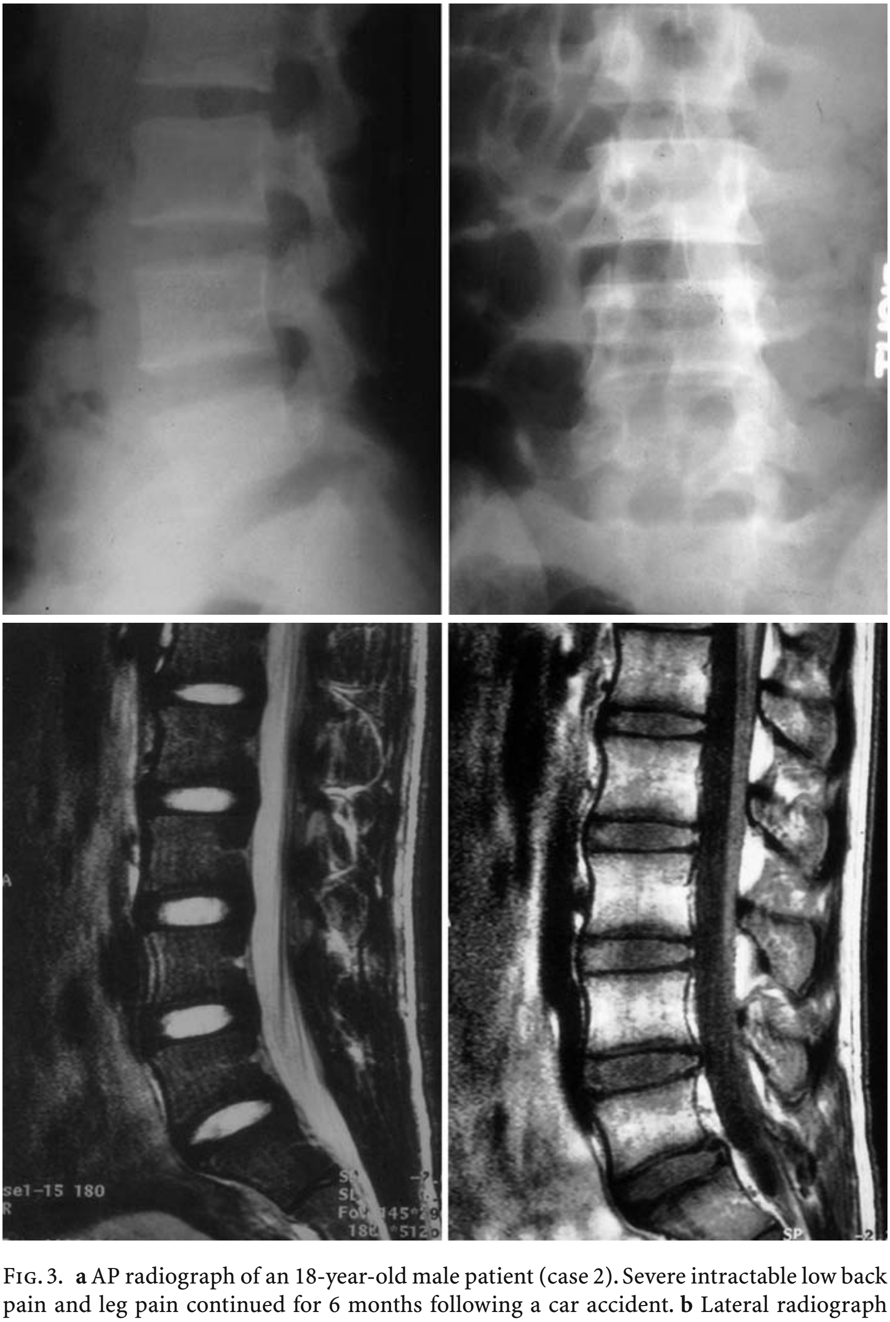

Fig. 3. **a** AP radiograph of an 18-year-old male patient (case 2). Severe intractable low back pain and leg pain continued for 6 months following a car accident. **b** Lateral radiograph of case 2. **c** T1-weighted sagittal images of lumbar spine (case 2). **d** T2-weighted image of lumbar spine (case 2). No disc degeneration is noted. **e** Severe identical pain is produced in discogram-computed tomography (CT) of the L5-S1 disc (case 2). Inner tear of the annulus is seen. **f** Discogram-CT finding of L4-5 disc of case 2. No pain is produced at this level. **g** AP radiograph of lumbar spine of case 2 at 30 months after posterior lumbar interbody fusion and instrumentation at the L5-S1 level. **h** Lateral radiograph of lumbar spine of case 2 at 30 months after operation

e f g h

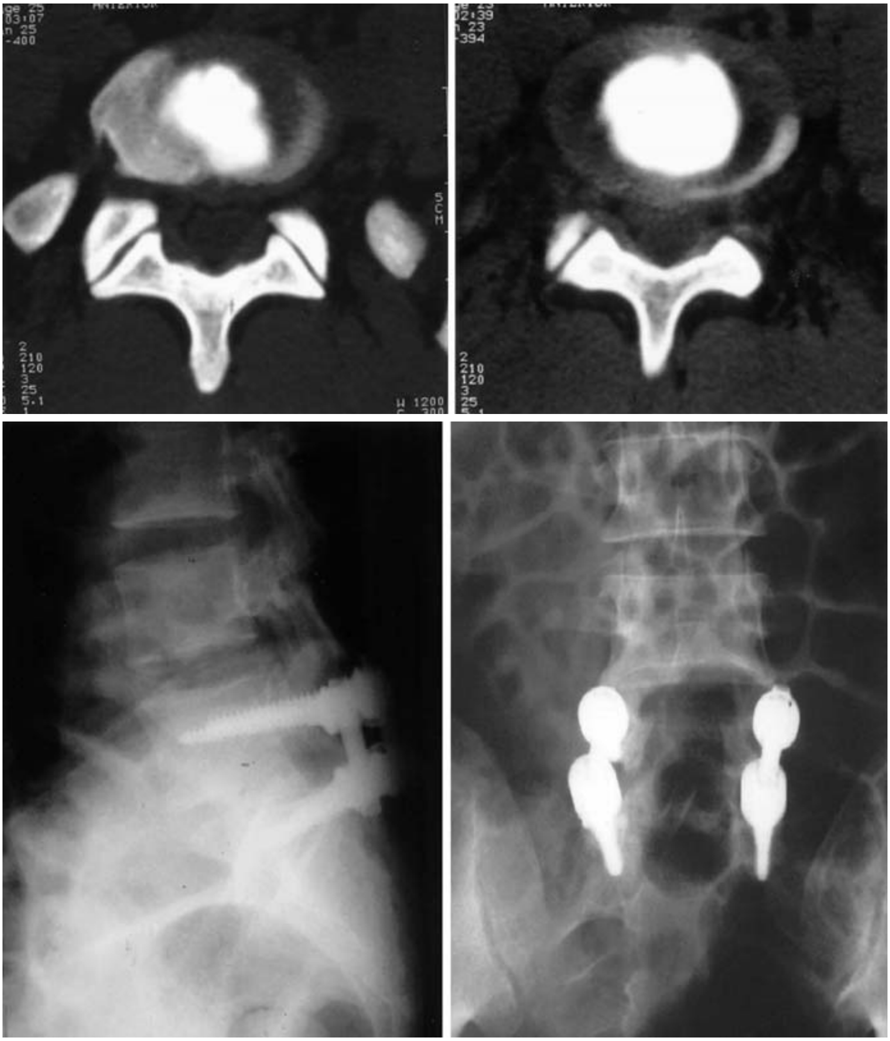

Fig. 3. *Continued*

Surgery is performed on those disc(s) that show concordant pain on discography.

Some surgeons prefer anterior interbody fusion [13, 23], whereas others prefer posterior lumbar interbody fusion [6–8, 10, 24]. Anterior or posterior lumbar interbody fusion has peculiar advantages and disadvantages. The surgical procedures of subtotal disc excision and anterior or posterior interbody fusion with strut bone grafts eliminate the possible source of biochemical substances and eliminate the abnormal stress or strain. In view of ablation of

Fig. 4. T2-weighted sagittal image of lumbar spine of a patient with chronic low back pain. Disc degeneration and high-intensity zone (HIZ) are noted at the level of the L4-5 disc (*arrow*)

the sinuvertebral nerve, posterior lumbar interbody fusion has an advantage over the anterior fusion. Posterior or posterolateral fusion seems not to be effective in this condition [25]. Recently the artificial disc has been used for disc pathology [26], although it is not yet popular.

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Endoscopic Discectomy for Extraforaminal Lumbar Disc Herniation

Yuichi Takano and Nobuhiro Yuasa

Summary. The microendoscopic discectomy (MED) technique has been one of the promising surgeries for lumbar disc herniation in the last few years. The purpose of this study is to report the feasibility of a minimally invasive technique for extraforaminal lumbar disc herniation. Ten patients with extraforaminal lumbar disc herniation (one at L3-4, four at L4-5, and five at L5-S1) underwent MED using the METRx system. A tubular retractor was inserted posterolaterally adjacent to the caudal base of the transverse process at the level of the affected disc. The nerve root was carefully distinguished from its surrounding tissues, and then the herniated disc was excised. The mean length of the preoperative clinical course was 7 months. The pain in the lower extremity was relieved in all patients. The clinical results in the MED group were the same as those in the open surgery group. Endoscopic herniotomy requires much less extensive muscle dissection than open surgery. The MED technique for extraforaminal lumbar disc herniation can be performed safely and effectively. There is a learning curve to this procedure.

Key words. Extraforaminal lumbar disc herniation, Microendoscopic discectomy (MED), Far-lateral herniation

Introduction

Foley and Smith [1] reported that endoscopic disectomy has been one of the promising surgeries for lumbar disc diseases in the last few years. They also reported five cases of far-lateral discs. However, few authors have reported

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endoscopic techniques for extraforaminal lumbar disc herniation [2, 3], especially L5-S1 extraforaminal lumbar disc herniation [2, 4].

For the posterolateral type of lumbar disc herniation, microendoscopic discectomy (MED) is a minimally invasive surgery that does not invade the paravertebral muscles [2]. For the extraforaminal type of lumbar disc herniation, open surgery requires more extensive muscle dissection than that for the posterolateral type of lumbar disc herniation. Moreover, open surgery for extraforaminal lumbar disc herniation provides a narrow operative field, especially at the L5-S1 extraforaminal region. MED may give us a pinpoint approach even for L5-S1 extraforaminal lumbar disc herniation [4].

The purposes of this study were to determine the feasibility of an endoscopic technique for extraforaminal decompression of disc disease, to extend the indication for L5-S1 extraforaminal lumbar disc herniation, and to compare the advantages and disadvantages of MED with those of open surgery.

Materials and Methods

From December 2000 to September 2002, 10 patients (4 men and 6 women) with extraforaminal herniated lumbar disc disease underwent MED using the METRx system [1, 2]. The mean patient age was 58 years (range, 42–70 years). The mean duration of symptoms was 7 months (range, 0.5–24 months). The levels operated on were one L3-4, four L4-5, and five L5/S1. From January 2000 to November 2000, two patients (one man and one woman) with extraforaminal lumbar disc herniation underwent open surgery. The mean patient age was 64 years (range, 53–75 years). The affected disc levels operated on were one L4-5 and one L5-S1. All patients underwent MED or open surgery under general anesthesia.

MED was performed using the METRx system (Medtronic Sofamor Danek, Memphis, TN, USA) (Fig. 1). The patient was positioned prone with the abdomen free and the spine flexed to open the interlaminar space. A C-arm fluoroscope was positioned so that lateral fluoroscopic images of the operative lumbar interspace were obtained (Fig. 2). After the lateral images were checked, the patient was prepared and draped. The surgeon stood on the left side of the patient, and a videomonitor was placed on the right side. A 16-mm skin incision was made 5 cm lateral from the midline. A muscle-splitting approach to the lumbar disc disease was performed using a series of sequential dilators and a tubular retractor system [2]. The tubular retractor was inserted posterolaterally adjacent to the caudal base of the transverse process at the affected disc level and was locked to a flexible arm assembly system that was secured to the operating table. Before the L5-S1 extraforaminal lumbar

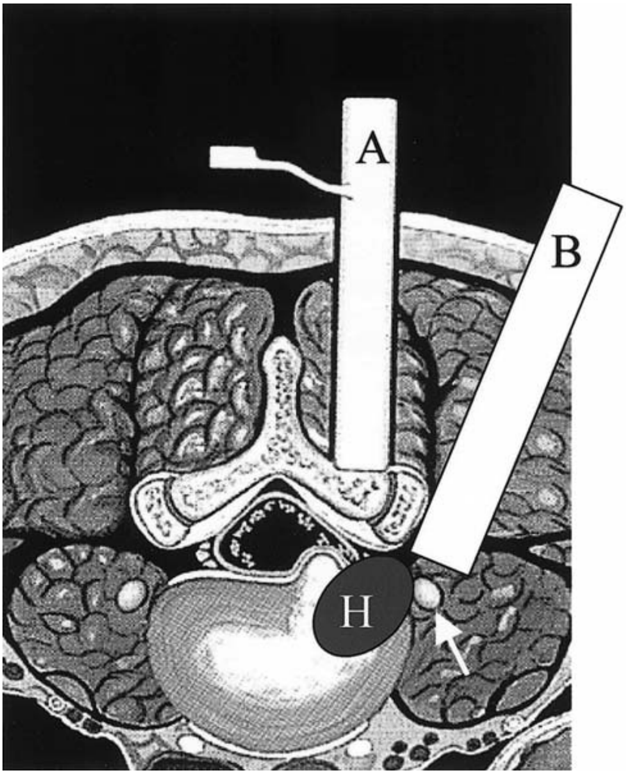


Fig. 1. Axial view illustrating nerve root (*arrow*) compressed by extraforaminal lumbar disc herniation (*H*). Illustration of the tubular retractors for intracanal lumbar disc herniation (*A*) and for extraforaminal lumbar disc herniation (*B*)

herniated disc was exposed, the L5 nerve root was carefully distinguished from its surrounding tissues. The endoscopic image on the videomonitor (Fig. 3) showed the right L5 nerve root retracted cranially and the herniated disc exposed at the extraforaminal region. Then the herniated disc was excised. In open surgery, a 10-cm midline skin incision was made. After the paravertebral muscle was retracted, the herniated disc was excised.

Neurological assessment was conducted in accordance with the scoring system of the Japanese Orthopaedic Association (JOA). In this system, a 29-point score represents the normal (maximum) score, and the extent (rate) of relative neurological improvement was calculated by the following equation: improvement rate = (final JOA score − initial JOA score)/(29 − initial JOA score) $*$ 100 [5, 6].

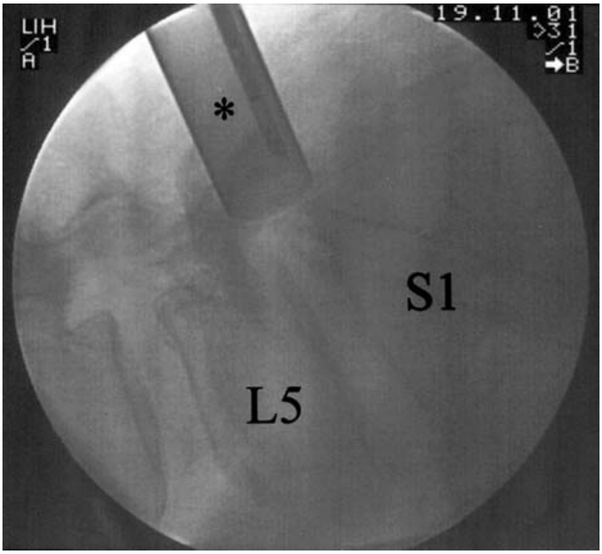


FIG. 2. Lateral fluoroscopic view of tubular retractor placement (*asterisk*) for *L5-S1* extraforaminal lumbar disc herniation

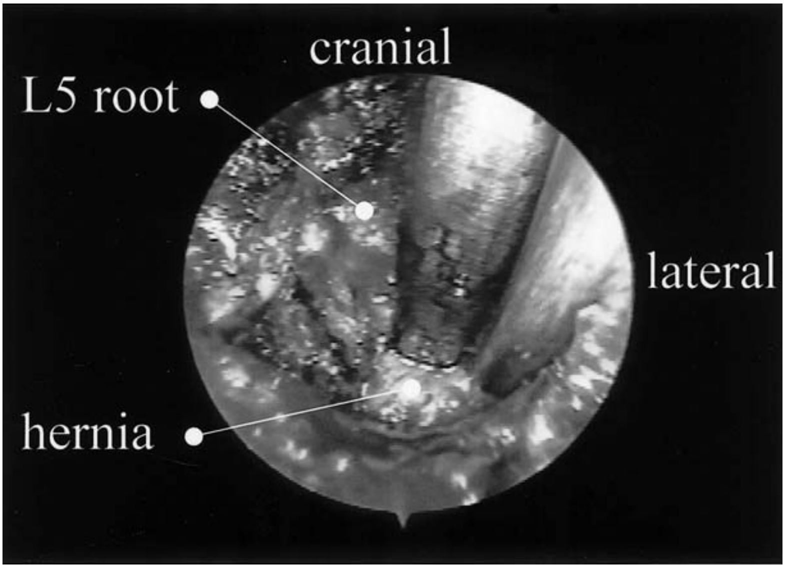


FIG. 3. Actual endoscopic view, as it appears on the video monitor, is circled. The right L5 root is retracted cranially and the contained herniated disc is exposed at the right L5-S1 extraforaminal region

Results

The mean follow-up period was 12 months for MED and 18 months for open surgery. The average JOA score in the MED group was 11 preoperatively and 25 postoperatively. In the MED group, the postoperative JOA score was significantly higher than the preoperative score. In the open surgery group, the preoperative score was 14 and the postoperative score was 25. The average JOA was 78% in the MED group and 75% in the open surgery group. The average blood loss was 37 ml in the MED group and 80 ml in the open surgery group. The average frequency of prescription of a nonstersidal antiinflammatory drug (NSAID) was 1.25 in the MED group and 2 in the open surgery group. The maximum body temperature was 37.6°C in the MED group and 37.8°C in the open surgery group. The period until normal temperature was reached was 2.25 days in the MED group and 2.5 days in the open surgery group. The mean operative time was 155 min (range, 60–275 min) in the MED group (Fig. 4) and 88 min in the open surgery group. No recurrence was observed during the follow-up period.

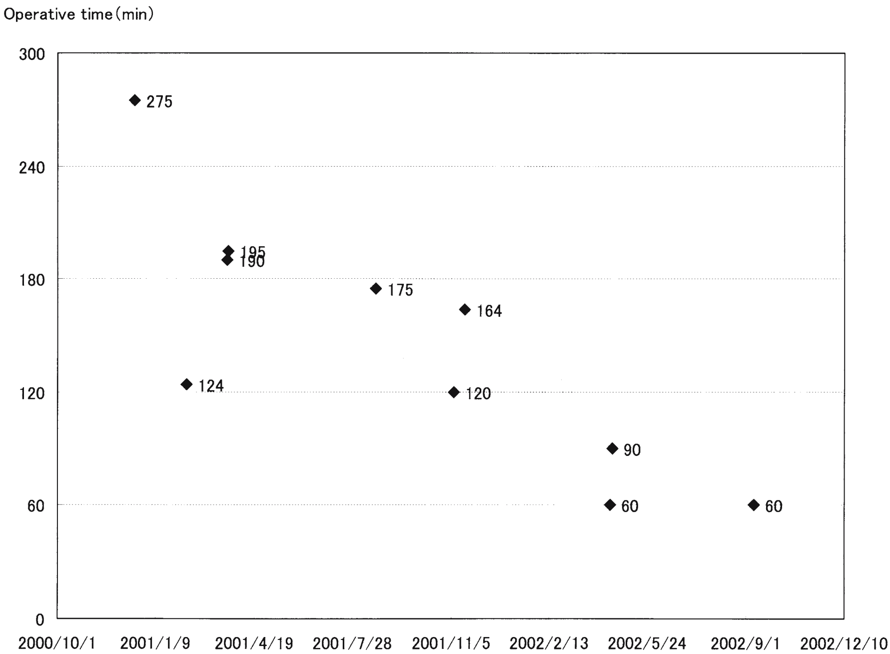
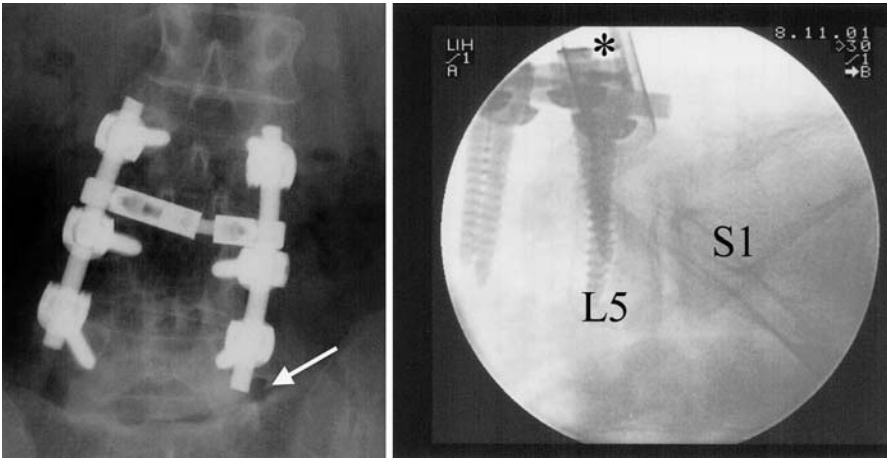


Fig. 4. Our learning curve for endoscopic extraforaminal lumbar discectomy. *X-axis*, learning period; *Y-axis*, operation time (min)



a b

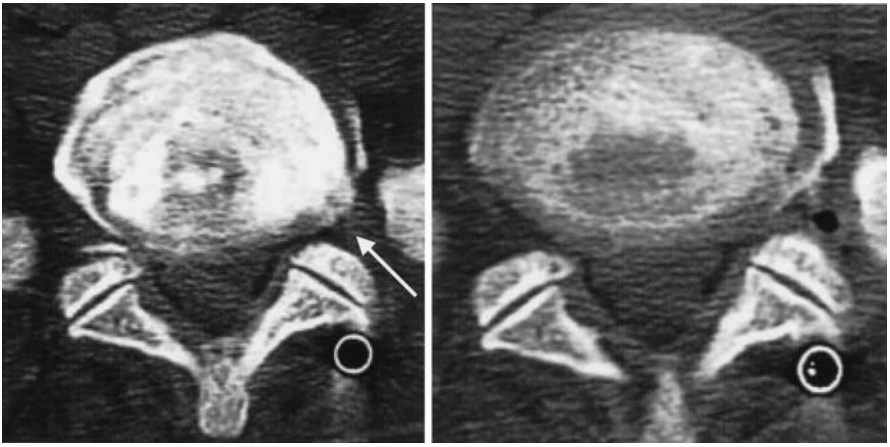
Fig. 5. Images of a 58-year-old woman with left L5-S1 extraforaminal lumbar disc herniation (*arrow*) who underwent L3-4 and L4-5 posterior lumbar interbody fusion (PLIF) using posterior instrumention 2 years before the onset of symptoms. **a** Anteropostero radiograph showing L3-4 and L4-5 PLIF using posterior instrumentation. **b** Lateral fluoroscopic view of tubular retractor placement (*asterisk*) for left *L5-S1* extraforaminal lumbar disc herniation

Case Report

A 58-year-old woman suffering from L3-4 and L4-5 degenerative disc disease underwent posterior lumbar interbody fusion (PLIF) and an additional posterior instrumentation (Fig. 5a). Two years after surgery, she experienced acute low back pain and severe pain in the right lower extremity. Although conservative treatment had been maintained for a year, severe pain in the left lower extremity had been prolonged. Computed tomograms after discography revealed left L5-S1 extraforaminal lumbar disc herniation (Fig. 6a). She underwent endoscopic disectomy using the METRx system (Fig. 5b). The severe pain in the left lower extremity disappeared within 1 week. After surgery, the JOA recovery rate of this patient was 80% (Fig. 6b). She was able to return to normal work and activities.

Discussion

The microendoscopic discectomy (MED) technique using the METRx system is safe and effective for performing minimally invasive lumbar microdiscectomy [1, 2], even for extraforaminal lumbar disc herniation [3, 4]. Generally, the advantages of MED are the small skin incision, less involvement of par-



a b

Fig. 6. **a** Preoperative computed tomogram after discography at the L5-S1 disc level showing left extraforaminal lumbar disc herniation (*arrow*). **b** Postoperative plain computed tomogram at the *L5-S1* disc level

avertebral muscle, and short bed rest [1]. Its disadvantages are the technical demands and loss of depth perception, which may cause prolongation of the operative time [1, 4]. In this study, there was a learning curve for using the MED system efficiently and safely for extraforaminal lumbar disc herniation [2, 4].

Our learning curve showed that operative times decreased rapidly to 60 min after 1 year (Fig. 4). In the first case, most of the operative time was occupied with setting the METRx system and checking the C-fluoroscopic images frequently. In the last two cases, it took about 30 min to expose the affected nerve root and the herniated disc in the extraforaminal region. A few reports demonstrate the clinical anatomy in the extraforaminal region [7]. Exposure of the fat tissues around the nerve root was important for this procedure. Endoscopic discectomy for extraforaminal lumbar disc herniation has technical demands and requires depth perception [4].

Open surgery for extraforaminal lumbar disc herniation usually requires bone resection on the lateral portion of the facet joint. In the first patient with L3-4 extraforaminal lumbar disc herniation who underwent MED, the lateral portion of the facet joint was partially resected. Recently no bone resection was required except at the L5-S1 extraforaminal lumbar disc herniation. We performed MED for L5-S1 extraforaminal disc herniation in five cases. In the first patient with L5-S1 extraforaminal lumbar disc herniation who underwent MED, more manipulation of the nerve root and ganglion was necessary to dissect the disc herniation after resection of the lateral portion of the L5 root foramen and the lateral portion of the L5-S1 facet joint. After surgery, mild dysesthesia was observed in this patient [7]. Recently, for L5-S1 disc herniation, we partially resected the lateral portion of the superior articular process of the sacrum using chisels and exposed the L5 nerve root, which was compressed cranially by the L5-S1 herniated disc (Fig. 3).

MED using the METRx system was effective for the patient with L5-S1 extraforaminal lumbar disc herniation who underwent posterior lumbar interbody fusion (PLIF) 2 years before MED. Once the surgeon is comfortable performing lumbar MED, further indications for the use of this technique include cervical discectomy, thoracic discectomy, lumbar laminectomy, and interbody lumbar fusion [2].

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Anterolateral Approach to the Lumbar Spine

Shinichi Kusano, Akira Dezawa, Kiyoshi Yoshihara, and Koh Katoh

Summary. An anterolateral approach to achieve decompression for a far-lateral disc lesion in the lumbar spine or removal of paravertebral neurinoma without disrupting the facet is described. This new surgical technique is presented in detail, and the results of a surgical trial are reviewed. The incidence of lumbar disc herniation lateral to the facet has been reported to be between 0.7% and 11.7% over all sites of lumbar disc herniation. Some cases have been reported in which all fragments compressing the nerve root were removed without destruction of the overlying facet joint, but with some limitations. The retroperitoneoscopic lateral lumbar approach to levels L1-2, L2-3, L3-4, L4-5, and L5-S1 is described. This approach uses balloon inflation to form a retroperitoneal surgical cavity under endoscopic vision through the transparent balloon membrane. The operating space is maintained by using a powered mechanical lift and a flat inflatable retractor or a pneumoperitoneum procedure to make a longitudinal separation between the psoas major and the quadratus lumborum. The far-lateral disc herniation is excised through the lateral side with retraction of the spinal nerve root under retroperitoneoscopy. This approach permits the use of a conventional spine instrument for removal of the disc herniation. Magnification of the image through the retroperitoneal scope provides the surgeon with a very accurate identification of the anatomical structures. We have successfully performed this technique in 49 cases using retroperitoneoscopy. The best indications for this new procedure are lateral disc herniation at the L5-S1 level or around the epiconus at the L1-2 level. It is too early to tell whether the described procedure provides adequate exposure necessary for extraforaminal exploration, discectomy, and nerve root decompression and is sufficient for treatment of extreme lateral

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lumbar herniation localized to the L1-S1 level and for the treatment of a spinal nerve root tumor.

Key words. Retroperitoneoscopy, Laparoscopy, Lumbar interbody fusion, Extraforaminal herniation

Introduction

Since the concept of surgical disc excision was reported by Dandy in 1926 and by Mixter and Barr in 1934, the surgical technique of discectomy continues to be refined and improved in alternative and less invasive procedures. Recently, a laparoscopic approach for anterior interbody fusion at the lumbosacral level has been reported. Although this laparoscopic approach to the lumbar spine can also be applied, it may be technically difficult to access the spinal root. A lateral approach based on the technique of Watkins [1]—while providing excellent access to the root and extraforaminal disc—does not permit adequate visualization of a far-lateral extraforaminal area from the posterior approach. To resolve this, we propose a novel lateral lumbar approach using retroperitoneoscopy for decompression of extreme lateral disc involvement, making a longitudinal separation between the psoas major and the quadratus lumborum. The surgical technique required newly developed longer tools for restricted access and new methods of visualizing, illuminating, and magnifying the operative field. The present report also describes our preliminary clinical experience.

Methods

The full series of 49 patients who underwent excision of isolated far-lateral disc fragments at the conus level, with excision of ossification in the posterior longitudinal ligament and disc spur at the L5-S1 level, was included in this study. The follow-up period has ranged from 15 to 68 months. The indication for surgery was lumbar lateral involvement with radiculopathy. In all patients, there was failure of a conservative regimen that consisted of rest, nonsteroidal antiinflammatory drugs, and physical therapy for at least 3 months prior to surgical therapy.

Description of the Technique

The patient is placed in the lateral decubitus position on an adjustable surgical table to allow the abdominal organs to fall away from the lumbar spine. The whole table is then tilted under fluoroscopic control to achieve a parallel projection of the vertebral endplates of the level to be approached. A 1- to 2-cm initial skin incision is made along the anterior axial line around the superior anterior iliac crest and is deepened by blunt dissection using an optical dissecting trocar. The dissection is performed down to the muscular level. The external oblique, internal oblique, and transversus muscles are then bluntly separated to expose the paraspinal transverse fat layer. Visual confirmation of the dark-yellow coloration indicative of the extraperitoneal fat layers assures the surgeon of the correct placement. The surgeon's index or little finger is introduced into the retroperitoneum, which is gently dissected to create a small space. The scope is advanced into the center of the balloon, and it may be pivoted in all directions to visualize the target organs within the cavity. An elliptical-shaped preperitoneal dissection balloon cannula is used to expose the extraperitoneal cavity widely. The balloon is keep inflated for 5–7 min to establish hemostasis. The next step is the emplacement of a retracting port and a video port for the optical fiber channel in the anterior axillary line under retroperitoneoscopic management. A third port is emplaced in the middle axillary line to establish a working portal for instrument access across from the desired disc space (Fig. 1). It is essential to use

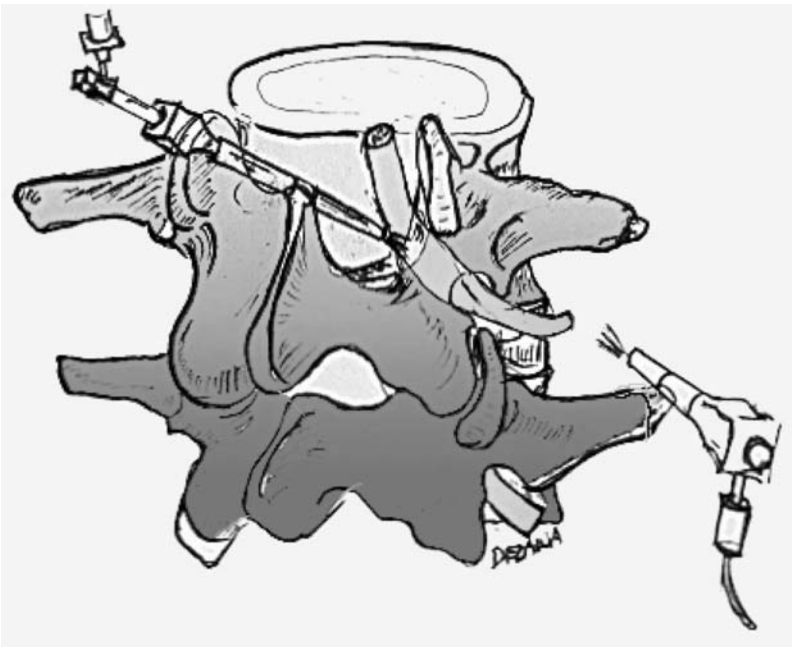

Fig. 1. Operative setup for lateral lumbar approach

fluoroscopy in order to identify the correct level at decompression. When the psoas major is divided from the quadratus lumborum, fibers of the psoas muscle are bluntly displaced anteriorly to expose the disc space (Fig. 2). When the psoas major is retracted anteriorly, great care must be taken to avoid damage to the great vessels, plexus lumbalis, or lumbosacralis. The muscle fibers can be separated from the aponeurosis rather bloodlessly. In cases needing fusion of the intervertebral disc, the psoas major is retracted posteriorly, as in the conventional approach (Fig. 3). The obliquely directed placement of interbody threaded fusion cages is easy to achieve with a parallel projection of the vertebral endplates under fluoroscopic control without injuring the anterior and posterior longitudinal ligament.

The first assistant manages the camera and helps in changing instruments, while a second assistant uses the anterior port to retract the psoas major anteriorly. The option of a 30° or 0° endoscope allows extensive visualization of the lumbar lateral anatomy, exceeding that possible with an open incision. An endoretractor is advanced parallel into the vertebral body above and below the involved disc to enlarge and maintain the disc height. Sometimes the most helpful structure that leads to the root is the neurovascular bundle around the root. The segmental artery arising from the aorta, which passes around the vertebral body, connects the artery around the root. Mobilization of these vascular structures adjacent to the spine may be accomplished via the paramedian ports. Endoclips may be used to occlude any vessel, such as the iliolumbar vessel or segmental artery, as necessary. Exposure and excision of multiple lumbar levels are easily performed in the usual fashion. The disc annulus is incised using a newly developed long-handled scalpel carefully to resect the herniation and osteophyte. Once the extruded discs have been

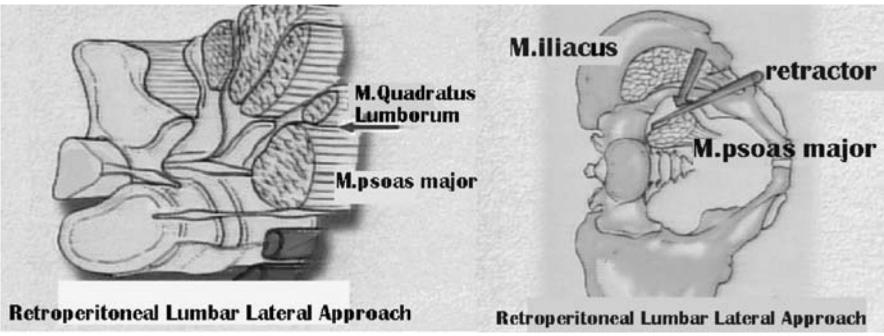

Fig. 2. Operative drawing of lateral lumbar approach. When the psoas major is divided from the quadratus lumborum, the fibers of the psoas muscle are bluntly displaced anteriorly to expose the disc space

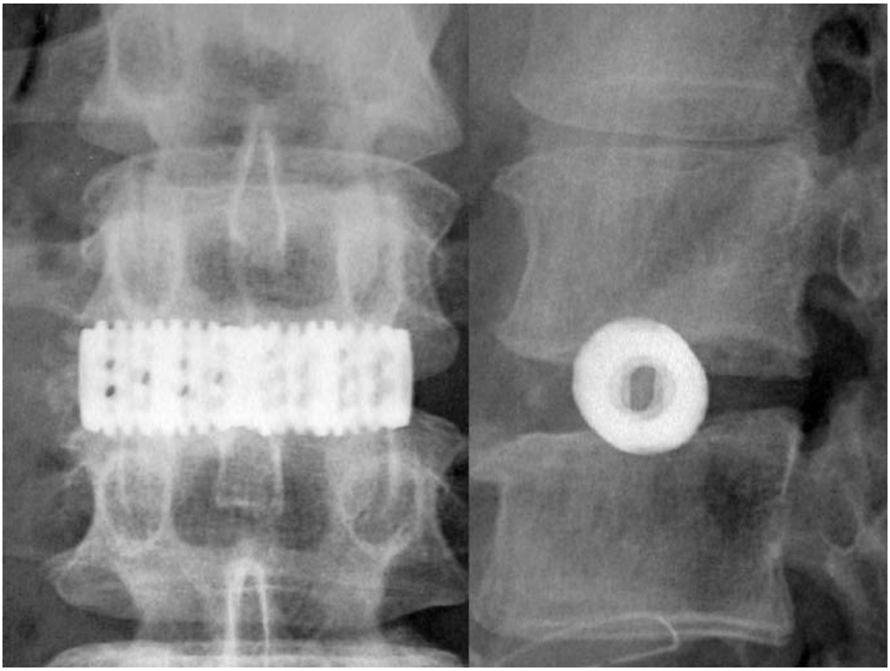

FIG. 3. The fusion case after removal of an extrusion herniation at the L2-3 disc level was seen to compress the L3 root

mobilized, they are gently extracted under direct vision. Considerable care must be taken to avoid stretching a compromised root. When the root is under too much pressure to be retracted caudally with difficulty, the root should not be retracted but decompressed cranially with partial resection of the pedicle. The inferior pedicle may be burred away, undercut with the burr and collapsed away, and cut with a small osteotome. Small Kerrison rongeurs also are useful to resect the pedicle partially. The indication of this procedure for disc herniation is the conus medullaris at the L1-2 level. In some cases, rather than locating the nerve in the upper part of the foramen, as with the usual stenotic case with far-lateral herniation, the nerve may happen to be located to pass anteriorly to the transverse process or ala.

In cases of Wiltse's far-out syndrome in L5-S1 [2] the patient is placed in the supine position. Dividing between the iliac and the psoas major muscle under direct vision to preserve the femoral nerve, the ala of S1 is exposed to add to interbody fusion from a medial approach, if necessary. In order to achieve good decompression throughout the foraminal canal, it is often necessary to resect part of the inferior aspect of the L5 pedicle or superior portions of the sacral ala. For a prominent osteophyte, a small, sharp osteotome

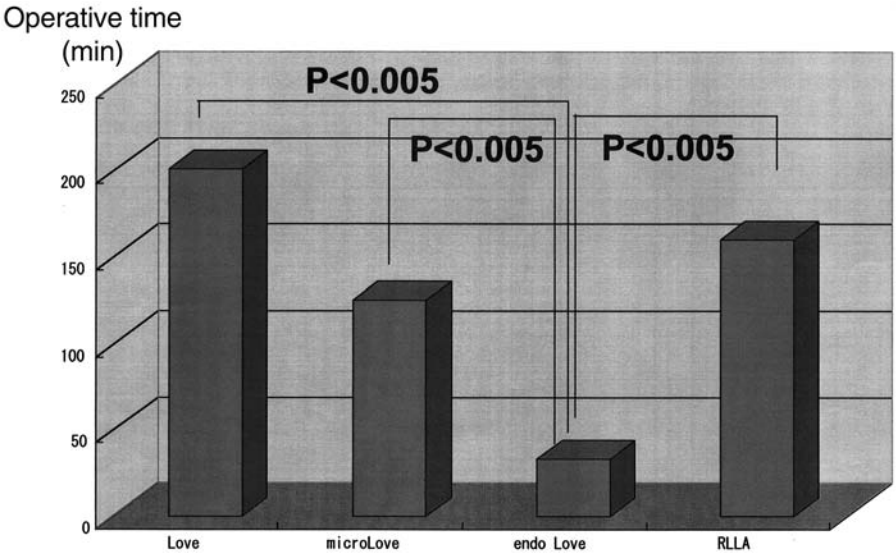

FIG. 4. Blood loss in different operative procedures. *RLLA*, Retroperitoneoscopic lateral lumbar approach

may be used to cut a triangular wedge from the sides of the osteophyte's attachment to the vertebral body. One must identify the nerve near the foramen and follow it laterally as it curves within the retropelvic space. Good results from surgery depend on correct atraumatic manipulation of the root and surrounding tissue. Postoperatively, the patient is permitted to ambulate within 2 days after surgery. The patient is instructed to wear a flexible corset when out of bed and to limit activity, relying on the level of pain as a guide to regulate rehabilitation for the first 2 months after surgery.

Results

From 1995 to 2002, 49 patients were treated by this retroperitoneoscopic lateral lumbar approach. The disc level was single in one patient; L1-2 ($n = 5$), L2-L3 ($n = 3$), L3-L4 ($n = 15$), L4-L5 ($n = 20$), L5-S1 ($n = 6$), and was double in three patients; L1-3 ($n = 1$), L2-4 ($n = 1$), L3-5 ($n = 3$), and L4-S1 ($n = 1$). Decompression without fusion was achieved in 15 preselected patients. All 49 patients were followed up for at least 24 months. The average age at operation was 62.1 years (range, 40–77 years). The follow-up period averaged 35.5 months, with a minimum of 15 months and a maximum of 68 months.

Although our initial clinical results were encouraging, the average surgical blood loss was 326 ml (ranging from negligible to 965 ml). The average operative time recorded was 185 min (ranging from 70 to 335 min). The patients underwent gasless mechanical lift system under retroperitoneoscopic control, to achieve a good field of vision (Fig. 4).

There were no intraoperative complications. No patient developed thrombophlebitis or pulmonary embolus. Thirty-eight patients (77.6%) had substantial relief from radiculopathy. Patients with satisfactory results exhibited improvement immediately after the operation. There was no correlation between age and outcome.

Fusion was judged by a total flexion-extension rotation of less than 3°, with maintenance of visible bone inside the cage on radiographs. Fusion success in 15 patients who underwent fusion with root decompression was evaluated by an independent radiologist. Eleven patients returned to their previous work by 4 months after the operation.

Discussion

There are several lateral approaches to reach the lateral discs utilizing a paramedian muscle-dividing method [3–8]. Watkins in 1953 first described an approach lateral to the sacrospinalis. In his approach, he removed a thin flake of muscle to retract the iliocostalis, the longissimus, and part of the multifidus upwards and medially [1]. The approach described by Ray was also made between the lateral border of the sacrospinalis and the quadratus lumborum [9]. In this approach, the muscles were split, unlike Watkins' approach, in which a flake of bone is left attached at its medial end and is turned cranially and medially. The paraspinal approach described by Wiltse in 1968 differed from that of Watkins in that it involved a longitudinal separation of the sacrospinalis between the multifidus and the longissimus for posterolateral fusion of the lumbar and lumbosacral spine [10]. Enslin introduced the iliolumbar approach to incise the sacrospinalis in the manner of Wiltse on the lateral sides of the vertebral bodies or fusion with removal of the unilateral facet joint [5].

Endoscopic disc surgery for foraminal and extraforaminal herniation has been reported recently. However, at the conus medullaris level and the L5-S1 level, it is dangerous and difficult to explore the feasibility of the posterior route [6, 11]. The first purpose of our surgery was the extirpation of a spinal nerve root tumor (Eden type 4; foraminal and paravertebral type) [12, 13]. This retroperitoneal lateral lumbar approach was a new procedure that exposed the lateral lumbar vertebra to decompress the dural sac and nerve root. The laparoscopic approach to the lumbar spine was initially described by Obenchain for the treatment of lumbar disc herniation [14].

The retroperitoneoscopic approach, initially described by Gauer and McDougall for urologic procedures, was established by application of laparoscopic approaches to the lumbar spine by McAfee [8, 15, 16]. Visualization and extirpation of a lesion are easier through such a posterolateral approach.

The procedure may involve exposing the lesion using a gasless mechanical lift system or pneumoperitoneum. However, the use of pneumoperitoneum during laparoscopic spinal surgery increases the risk to the patient due to the proximity of major blood vessels adjacent to the spine, with risk of perforation of the iliac vein or vena cava. Such risks remain a serious concern not only for blood loss, but for the possibility of an air embolism from CO_2 insufflation. Cardiovascular or pulmonary compromise may occur as a result of positive intraabdominal pressure [17].

We have proposed this gasless approach as an alternative to laparoscopic lumbar discectomy and anterior body fusion at the L1-L5 levels. The application of a gasless mechanical lift system permits the introduction of conventional instruments into the endoscopic operating cavity. The procedure introduced in this article has the following advantages compared with posterior discectomy: Excellent access to the lateral side of the spine at the L5-S1 level, which in many patients is very difficult to achieve access to via the posterior lateral approach, secondary to the limited access overlap of the high iliac crest. Easy access to multiple levels; Excellent visualization of the affected nerve root for improved safety during the course of the procedure; Potential to complement the lateral endoscopic technique and increase indications for minimally invasive spine surgery; Preservation of the normal posterior element of the spine.

The illumination and magnification available through the retroperitoneoscope opens a small window for decompression of the nerve root in the lateral zone with minimal dissection of the psoas major, quadratus lumborum, and abdominal muscles, without invasion of the posterior paraspinal muscles. The retroperitoneal procedure has major advantages in examination and treatment of the lumbar spine, enabling safe access to a spinal nerve root tumor. The procedure also allows free fragment disc pathology, as well as access to ossification in the posterior longitudinal ligament and to disc spurs, such as in the far-out syndrome or spondylolisthesis with lateral entrapment, without sacrificing the pedicle, facet joint, or transverse process. A variety of operative procedures have been used to treat foraminal and extraforaminal herniation. Successful results after surgical decompression for lateral stenosis or far-lateral lesions in the lumbar spine will depend on understanding the precise location and pathological condition at each level.

Conclusions

It is too early to tell if the described procedure provides adequate exposure for extraforaminal exploration, discectomy, and nerve root decompression and is sufficient for the treatment of extreme lateral lumbar herniation localized to the L1-S1 level and for the treatment of spinal nerve root tumor. Twenty-two cases are not a large series, but the results offer the potential of a direct, efficient anatomical route to the lateral involvement of the lumbar and lumbosacral spine and offer the advantages of minimally invasive surgery compared with alternative procedures. Prospective, multicenter studies and longer follow-up studies are necessary to determine whether the minimally invasive lateral approach allows for less postoperative morbidity, a potential for reduced recovery time, decreased incisional discomfort, and less tissue trauma. Technical progress made in laparoscopy and technological improvement in the fields of instrument design and endoscopic visualization capabilities have facilitated the application of this technique to the treatment of spine disorders and should become widely recognized.

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Posterior Endoscopic Discectomy Using as Endoscopic Lumbar Discectomy System Developed in Japan

Yutaka Hiraizumi

Summary. The characteristics of the endoscopic lumbar discectomy system (ELDS) developed in Japan are introduced, and the first 50 cases are clinically evaluated. The patients included four cases of double disc herniation at two levels, one of cranially and three of caudally migrated discs, three of spinal canal stenosis, one of synovial cyst, and three of persistent ring apophysis. In four central disc herniation cases, one case was approached bilaterally and the other three cases unilaterally. Using a step-dilator system, the targeting interlaminar space was exposed and a tubular retractor of either 16 or 18 mm diameter was inserted through the paravertebral muscle. A 30° endoscope of 3-mm diameter was installed into a tubular retractor. Partial laminectomy and resection of the ligamentum flavum were performed using microsurgical instruments, followed by medial retraction of the symptomatic nerve root and incision of the herniated disc. The average surgery time was 119 min, and the average estimated blood loss was 49.1 g. The patients left their beds at an average of 1.9 days postoperatively, and the average hospital stay was 11.5 days. The recovery ratio of the Japanese Orthopaedic Association (JOA) score was 80.7%. The average visual analogue pain score on the first postoperative day was 2.9 cm, and the C-reactive protein level on the 7th day was 0.4 mg/dl. Adjacent two-level discectomy was possible with one midline skin incision. Coexistence of severe lumbar spinal canal stenosis was the most technically demanding pathology. The ELDS provided a brightened and magnified surgery field. This can be an effective assistant for minimally invasive lumbar disc surgery.

Key words. Endoscopic discectomy, Lumbar spine, Disc herniation, Microendoscopy, Endoscopic surgery

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Introduction

Spinal surgery under endoscopic guidance is a technology [1] that began in 1990. Spinal surgery under endoscopy has provided a bright and magnified view as well as advantages such as decreased blood loss, reduced tissue injury, and reduced wound pain after operation and thus has enabled shortening of the postsurgical treatment program [2, 3]. Endoscopic lumbar discectomy for herniated disc (microendoscopic discectomy) was reported by Foley et al. [4] in 1997 and has been used in Japan since 1998 [5]. Currently, two widely used different types of microendoscopic discectomy system are provided, one in North America by Medtronic Sofamor Danek (Memphis, TN, USA) and the other in Europe by Karl Storz (Tuttlingen, Germany). In Japan, the first prototype microendoscopic discectomy system appeared in 1997, and after repeated improvements, the last product was completed in 2001. In this Chapter, the characteristics of this new endoscopic lumbar discectomy system (ELDS) are introduced, and the early clinical results of the first 50 cases are reported.

Materials and Methods

Characteristics of ELDS

In this system, all microsurgical instruments, consisting of an endoscope (3 mm in diameter), suction pipe, knife, osteotome, nerve root retractor, Kerrison rongeur, curette, and pituitary rongeur, are slimmed and designed to be operated simultaneously in a tubular retractor (16 mm in diameter) (Fig. 1). Step-dilators of 1-mm intervals were produced in order to introduce a tubular retractor through the paravertebral muscular fibers (Fig. 2). A main characteristic of this system is the ability to connect a tubular retractor and an endoscope by using a slot-in connector with a one-touch, two-finger maneuver (Fig. 3).

Establishment of ELDS

Under the knee-chest position, X-ray fluoroscopy of the side image is performed in order to identify the level and inclination of the approaching disc and to determine the optimal skin incision point (Fig. 4). A para-midline skin incision 15 to 20 mm in length is made. A guide pin is inserted through the muscle layer of the paravertebral muscle and is stabbed onto the most appropriate approaching site, for instance, for the case of L4-5 disc herniation, the caudal third of the L4 lamina and between the base of the L4 spinous process

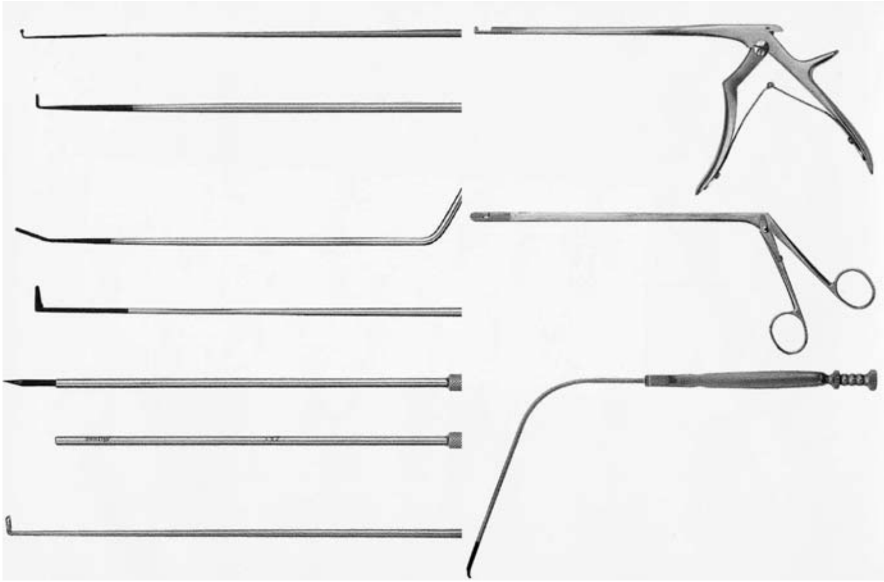

Fig. 1. Microsurgical instruments. Every instrument is slimmed and designed to operate simultaneously in a 16-mm tubular retractor. *Left column*: nerve hook, nerve dissector, nerve root retractor, rectangular knife, disc knife, osteotome, and curette. *Right column*: Kerrison rongeur, pituitary rongeur, and nerve root retractor with suction

and the medial margin of the L4-5 facet, under X-ray fluoroscopy. The microsurgical instruments can be moved in only a parallel direction in a narrow tubular retractor, so that the optimal establishment of the tubular retractor should be the position at which the caudal half of the cranial lamina and the interlaminar space are in a sufficient visual field through the tubular retractor (Fig. 5). Through the guide pin fixed to the surface of the cranial lamina, the step-dilator system is used to spread the intra-muscular layer of the paravertebral muscle, followed by insertion of a tubular retractor. The tubular retractor is then fixed to a side rail of the operating table with a powerful holding-arm system. A slot-in connector is quickly attached to the top of a tubular retractor, and a 30° endoscope is dropped in to the connector (Fig. 6).

Surgical Technique

The case of a 22-year-old, man with left L4-5 disc herniation is shown (Fig. 7). Through the established tubular retractor, microsurgical instruments such as the suction tube, nerve root retractor, and pituitary rongeur can be

FIG. 2. Step-dilator system. Paravertebral muscle fibers are bluntly dissected by using step-dilators with 1-mm intervals

operated simultaneously (Fig. 8). After the target interlaminar space and the caudal side of the cranial lamina have been exposed, the ligamentum flavum is partially cut using an endo-knife. The sectioned ligamentum flavum is gently dissected from the dura with rectangular nerve dissectors and is removed with a Kerrison rongeur. Partial laminectomy of the cranial lamina as well as medial facetectomy is performed with an osteotome and Kerrison rongeur if necessary. After the symptomatic compressed nerve root has been identified, nerve root retractor combined with suction is used to gently retract the symptomatic nerve root medially and to expose the herniated disc. The herniated disc is incised with an endo-knife, as a result of which the herniated nucleus pulposus strands are spouted out. Herniotomy is then performed with a pituitary rongeur until the disc prominence disappears and the

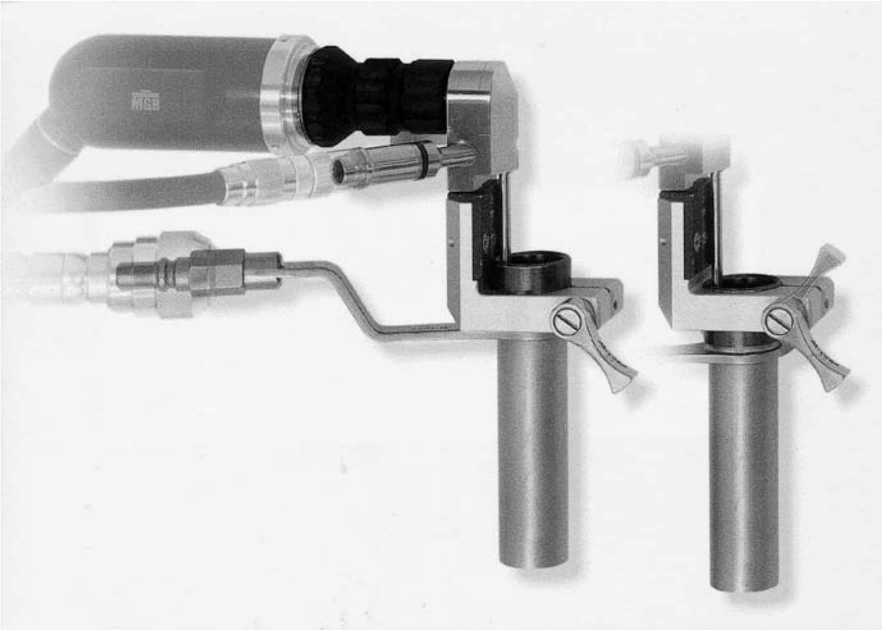

Fig. 3. Attachment of endoscope to tubular retractor. A slot-in connector that enables loading and unloading of the endoscope to a tubular retractor with quick two-finger maneuver is a main characteristic of the endoscopic lumbar discectomy system (ELDS)

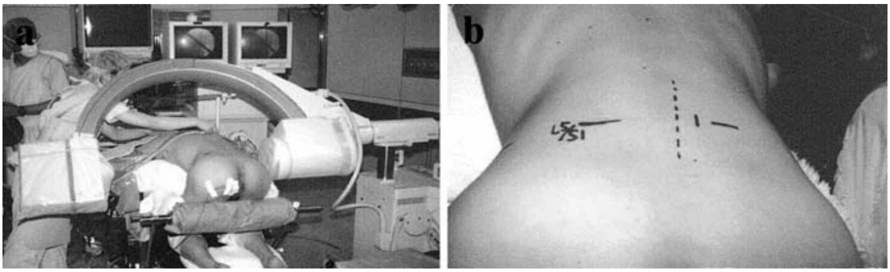

Fig. 4. Patient positioning and skin marking. Under knee-chest position, X-ray fluoroscopy of the side image is done in order to identify the level and inclination of the approaching disc and to determine the optimal skin incision point

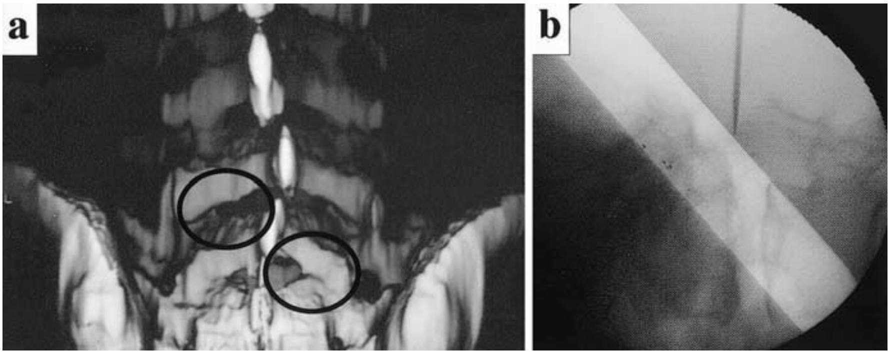

FIG. 5. Optimal establishment point for guide pin and tubular retractor. **a** The optimal establishment of the tubular retractor should be the position where the caudal half of the cranial lamina and the interlaminar space are in a sufficient visual field through the tubular retractor. **b** To introduce a tubular retractor to the optimal position, the guide pin should be stabbed onto the midpoint between the interlaminar foramen and the herniated disc, using X-ray fluoroscopy

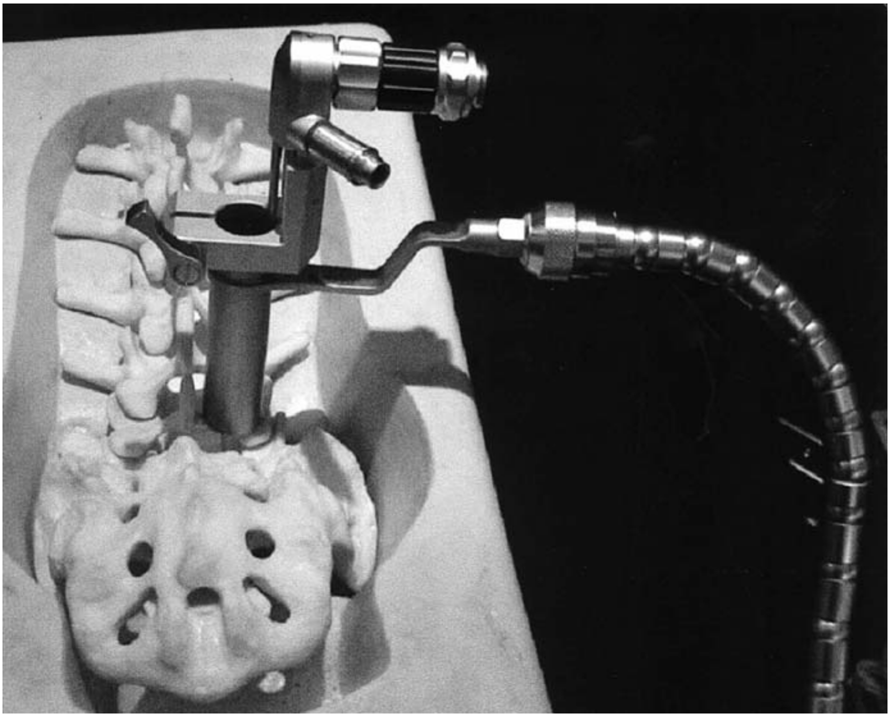

FIG. 6. Establishment of the tubular retractor. The tip of the endoscope is dropped-in to a tubular retractor via a slot-in connector. The tubular retractor is then fixed to a side rail of the operating table with a powerful holding-arm system

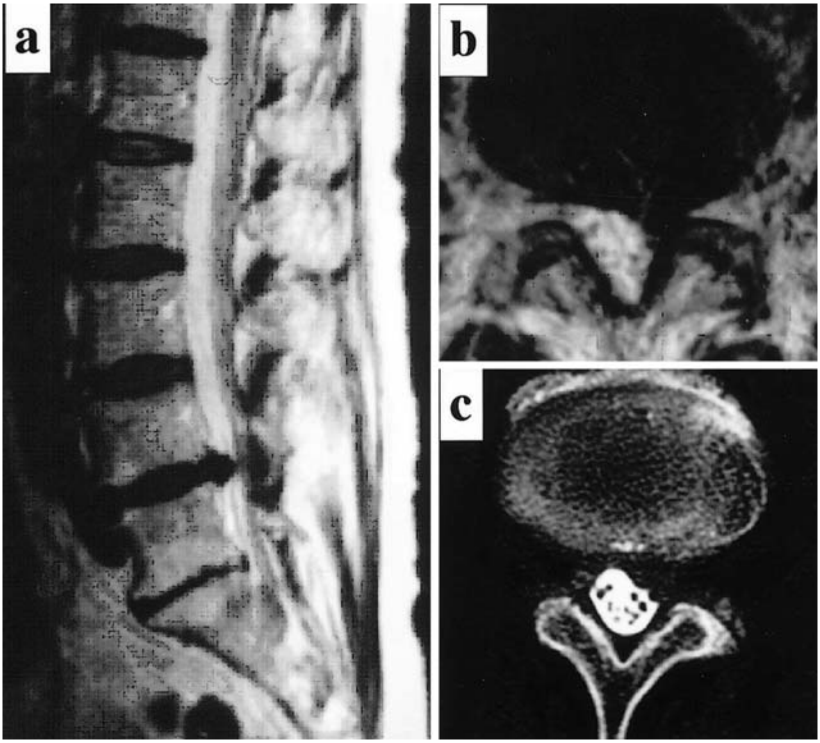

Fig. 7. Twenty-two-year-old man with the L4-5 disc herniation. **a** Magnetic resonance imaging (MRI) T2-weighted sagittal section. **b** MRI T2-weighted axial section. **c** Computed tomographic (CT) myelogram

symptomatic nerve root is decompressed. Thorough investigation of any residual disc fragments is performed (Fig. 9).

Postoperative Treatment

Sitting and walking on a lumbar-sacral orthosis are allowed the day after operation if postoperative pain is under control. Discharge from the hospital occurs when the patient becomes confident to walk by himself or herself.

Clinical Evaluation

Fifty patients (29 males and 21 females) with lumbar disc herniation have been treated by the ELDS system; their ages ranged from 14 to 77 years, with an average of 34.4 ± 14.4 years. The level of symptomatic disc herniation was L3-4 in 1 patient, L4-5 in 32 patients, and L5-S1 in 26 patients. There were four cases of central disc herniation, four cases of double-disc herniation at

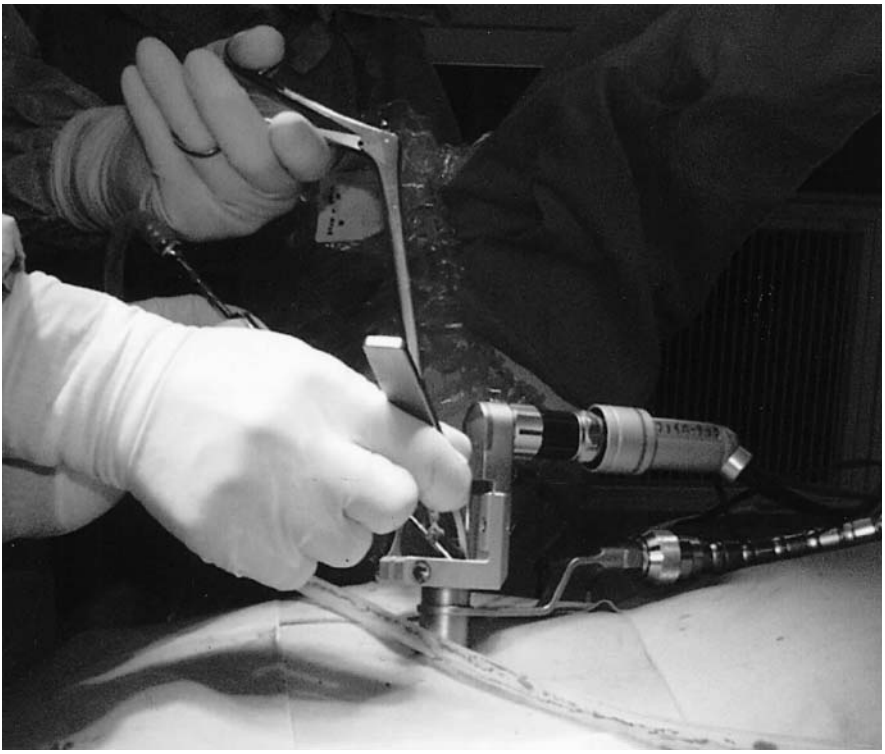

Fig. 8. Outside view during removal of the herniated disc. Through the 16-mm tubular retractor, microsurgergical instruments, such as the suction tube, nerve root retractor, and pituitary rongeur, can be operated simultaneously

two adjacent levels, five cases of migrated disc sequestration (one cranially and four caudally), three cases of combined spinal canal stenosis, one case of synovial cyst, and three cases of persistent ring apophysis (Table 1). The follow-up period ranged from 4 to 70 months, with an average of 29.7 months. The Japanese Orthopaedic Association (JOA) score was used to evaluate post-operative outcomes. Those results were compared with those for the microscopic discectomy group (Caspar) and the conventional open surgery group (Love) previously reported by the author [6].

Results

In four cases of centrally located disc herniation, a bilateral approach with one midline skin incision was used in the first case, and a unilateral approach was used in the last three cases. In four cases of double disc herniation at two

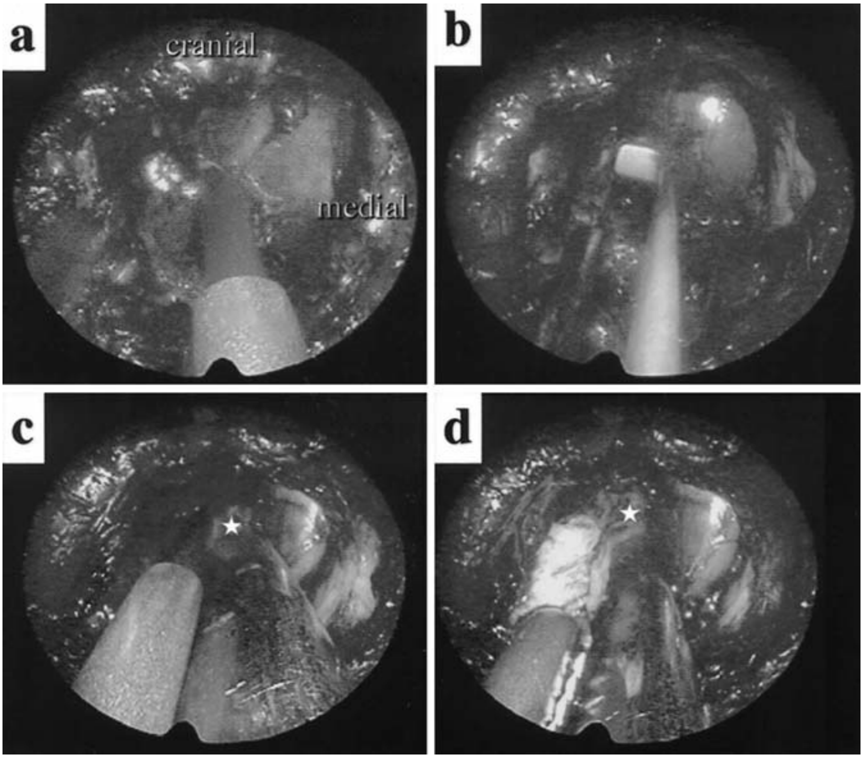

Fig. 9. Surgical procedures of ELDS. **a** After exposure of the interlaminar space and the caudal side of the cranial lamina, the ligamentum flavum is cut with an endo-knife. **b** The sectioned ligamentum flavum is gently dissected from the dura with a rectangular nerve dissector. **c** The symptomatic nerve root is gently retracted medially with a nerve root retractor. The herniated disc (*star*) is incised with an endo-knife. **d** Herniotomy is then performed with a micropituitary rongeur

Table 1. Special pathology of disc herniation

Pathology	No. of cases	Treatment
Central type	4	1 bilateral approach, 3 unilateral approach
Double herniation at 2 adjacent levels	4	Double discectomy with 1 midline skin incision
Cranial migration	1	Partial laminectomy of the cranial lamina
Caudal migration	4	Partial laminectomy of the caudal lamina
Spinal canal stenosis	3	Internal laminectomy with decompression of the dura
Synovial cyst	1	Excision of the cyst
Persistent ring apophysis	3	Excision of the osteophyte

adjacent levels, three cases of ipsilateral herniation were approached unilaterally and two cases of contralateral herniation were approached bilaterally with one midline skin incision. Sequestrated cases in which either cranial or caudal migration occurred were approached by adding partial laminectomy. In combined types of spinal canal stenosis, an internal laminectomy procedure was performed for intracanal nerve decompression. Synovial cyst was removed by partial facetectomy with an osteotome. In three young patients with persistent ring apophysis, a vertebral osteophyte was removed by an osteotome (Table 1).

The average operation time was 78 to 180 min, with an average of 119 ± 23 min. The ELDS procedure took a longer time than the Caspar or Love procedures, because additional time was needed to set the endoscope system. The estimated blood loss ranged from a trace to 170 g, with an average of 49 ± 58 g, equivalent to the blood loss with Caspar's procedure; blood loss was low because both procedures were performed by microsurgical techniques (Table 2). The visual analogue pain score on the first postoperative day ranged from 0 to 7 cm, with an average of 2.9 ± 1.6 cm. The blood serum C-reactive protein level on the 7th postoperative day was 0.1 to 1.9 mg/dl, with an average of 0.4 ± 0.4 mg/dl. The period until normalization of body temperature postoperatively was 0 to 5 days, with an average of 1.9 ± 1.5 days. The patients were allowed to leave their beds as soon as their wound pain became tolerable, from 1 to 5 days postoperatively with an average of 2.7 ± 1.3 days. The hospital stay ranged from 5 to 35 days, with an average of 11.5 ± 5.9 days (Table 2). The average preoperative JOA score was 14.0 ± 4.3 (range, 8–21), which increased to 26.2 ± 1.9 (range, 23–29) postoperatively. The average recovery ratio was 80.7 ± 12.4% (range, 58.3%–100%). The recovery ratio was greater than that with Caspar's and Love's procedures (Table 3). Complications included four cases of dural tears, one case of laminar fracture, and one case of level misrecognition. Dural tear occurred when the guide pin was inserted without X-ray fluoroscopy, when medial facetectomy was done using a high-speed burr, when the ligamentum flavum combined with dural adhesion was

TABLE 2. Comparison of results of endoscopic (ELDS), microscopic (Caspar), and conventional (Love) lumbar discectomy[a]

Variable	ELDS	Caspar	Love
Age (yr)	14–77 (34.4)	15–65 (38.1)	12–62 (31.3)
Operation time (min)	78–180 (118.8)	25–105 (51.5)	30–85 (47.0)
Estimated blood loss (g)	0–170 (49.1)	0–125 (31.4)	21–285 (92.7)
Days until leaving bed	0–5 (1.9)	1–17 (8.3)	8–20 (14.7)
Days until discharge	5–35 (11.5)	10–47 (19.6)	15–53 (27.9)

[a] Values are range with average.

Table 3. Comparison of mean Japanese Orthopaedic Association (JOA) score among patients undergoing endoscopic (ELDS), microscopic (Caspar), and conventional (Love) lumbar discectomy

Variable	ELDS	Caspar	Love
Preoperative JOA score (points)	14.0 ± 4.3	12.5 ± 5.3	10.1 ± 4.4
Postoperative JOA score (points)	26.2 ± 1.9	24.6 ± 2.4	21.5 ± 4.4
Recovery ratio (%)[a]	80.7 ± 12.4	73.3 ± 13.6	60.3 ± 13.8

[a] Recovery ratio = (postoperative score − preoperative score) / (29 − preoperative score) × 100.

Table 4. Complications

Complication	No. of cases	Causes
Dural tear	4	Guide pin, high-speed burr, Kerrison rongeur, nerve root retractor
Laminar fracture	1	Osteotome
Level misrecognition	1	Disorientation due to hyperlordosis

removed with a Kerrison rongeur, and when the nerve root that adhered to the herniated disc was bluntly retracted medially with the nerve root retractor. Laminar fracture occurred in one patient whose herniated disc was located in the neural foramen. In this case, partial laminectomy was needed more laterally, so that the lateral mass became thick to induce fatigue fracture. Level misrecognition occurred in one case during approach to the L5-S1 disc that showed hyperlordosis of the lumbar-sacral junction (Table 4).

Discussion

Advantages of Microendoscopic Discectomy as Minimally Invasive Surgery

Surgical intervention for lumbar disc herniation became widespread after Love and co-workers developed partial laminectomy [7]. Since microscopic discectomy was reported by Caspar et al. in 1977, this procedure has been acknowledged as low invasive surgery [8]. In our institution, 292 microscopic discectomy procedures have been performed since 1985 [9]. The first 50 cases of ELDS were compared with cases treated by Caspar's and Love's procedures [6].

Because the spine surgeon requires considerable time to become familiar with this microendoscopic procedure, ELDS at first had the longest operation time of the three procedures. However, high resolution of the microendoscope, empty severed epidural veins, residual deep strands of ligamentum flavum, strands of annulus, and some strands of proteoglycan-filled nucleus could take on the appearance of nerve rootlets during surgery, which subsequently resulted in decreased total blood loss. The major advantage of this procedure lies in its reduction of unnecessary exposure and tissue trauma [10]. The reduced size of the skin incision (usually less than 2 cm) and the reduced amount of tissue disruption resulted in less postoperative wound pain, which subsequently resulted in early leaving of the bed and discharge from hospital among patients undergoing microendoscopic surgery. The postoperative JOA score was greater and its recovery ratio was higher than with the other two procedures, because ELDS provided a brightened and magnified operative field allowing minimal invasion of the fragile nerve tissues.

Surgical Indications and Limitations of Microendoscopic Discectomy

The surgical indications for this newly developed discectomy system are basically the same as those for the conventional Love's procedure. Owing to the powerful holding arm system, the tubular retractor could be moved and stabilized, and therefore simultaneous adjacent two-level discectomy was possible with one midline skin incision. In the case of far lateral disc herniation, the retroperitoneal endoscopic approach is available instead [11]. Although the combined type of spinal canal stenosis could be decompressed in several cases, severe lumbar spinal canal stenosis still seemed the most technically demanding pathology for treatment with this technique [12]. The two-dimensional view and hand-eye spatial separation of the endoscopic view can also be extremely disorienting. The coexistence of severely hypertrophied ligamentum flavum and the superior interarticular process tends to injure the dura and the nerve root. If such pathology was found, the surgeon should not hesitate to convert to open surgery to avoid complications.

Possible Complications and Their Prevention

Skin wounds may become infected or necrotic if they are expanded tightly because the skin incision is too small compared with the size of the tubular retractor. To facilitate primary wound healing, the surgeon should not make the skin incision too small. The use of a guide pin to establish the proper location of the tubular retractor is the key to facilitating operation inside the tubular retractor while watching the video monitor. To avoid misinsertion of the guide pin into the interlaminar space, X-ray fluoroscopy is mandatory. Inappropriate placement of the tubular retractor as well as insufficient skill in the use of microendoscopic instruments tends to induce dural tear and nerve root injury. The use of a high-speed burr when performing medial facetectomy or laminectomy often induces complicated dural tearing or even nerve root injury that hardly recovers, and therefore the surgeon must pay attention when using the burr. Iatrogenic spondylolysis or level misdiagnosis occurs due to disorientation inside the narrow tubular retractor. The moment the surgeon limits a surgical incision, the more imperative it becomes for the surgeon to know exactly where to position the incision and exactly what is to be found when the surgical field was exposed. This forces the surgeon to look at the patient and the imaging investigation more critically. The pathology to be found and its exact location must be localized precisely before the limited skin incision is made [13].

The author himself underwent this newly developed technique and was convinced of its great advantages, such as minimal wound pain and early resumption of work as a spine surgeon. However, a small incision does not mean a small surgery, and even if the operation is minimally invasive, it must not be done by an insufficient operation than that done by a conventional open surgery. Therefore, the surgeon should master the basic skills of conventional open surgery before undertaking microendoscopic surgery.

Conclusions

Newly developed ELDS provided a stabilized and magnified surgery field for minimally invasive disc surgery. The microendoscopic procedure is attractive because of its small skin incision, gentle tissue dissection, excellent visualization, and ability to achieve results equivalent to those with open techniques.

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Intraspinal Examination with a Spinal Fiberscope (Myelofiberscope)

Akira Dezawa, Taroh Kitagawa, Koh Katoh, Isao Shibuya, and Shinichi Kusano

Summary. We first examined the inner aspect of the vertebral canal in monkeys using a fiberscope 0.75 mm in diameter in 1987. We have used this scope in humans for clinical examination of cervical spinal cord injury. This has made possible the examination of a relatively wide area of spinal cord cranial to the cauda equina possible, to which rigid endoscopy used to be limited. We have evaluated the safety of the technique by applying it to the examination of cervical myelopathy, intraspinal tumors, and adhesive arachnoiditis.

Key words. Myelofiberscope, Adhesive arachnoiditis, Redundant nerve

Introduction

The endoscope, a device used to directly observe the inner aspect of the body, was applied to examine the larynx and the internal ear by Helmholtz in the first half of the nineteenth century, and it has developed remarkably since then. Edison's invention of the light bulb using carbon fibers stimulated improvements in all types of endoscope, and the cystoscope was widely accepted by the end of the nineteenth century. In 1931, Furman succeeded in examining the inner aspect of the vertebral canal for the first time in a cadaver by applying an arthroscope. Stern observed the lower lumbar spine in 1936 with an instrument that he called the spinoscope. In 1938, Pool made in vivo observations of the lumbosacral spinal cord in 400 cases using myeloscopes 2.5–3.2 mm in diameter. In 1974, Slinger developed a 17G needle endoscope (rigid fiberscope) and examined the inner aspect of the vertebral canal in 50 dogs and 6 human cadavers. In 1985, Hertz used a spinaloscope 2.7 mm in

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diameter in autopsy. In Japan, endoscopy of the spinal canal was started in 1969 by Oh using a rigid fiberscope 5.6 mm in diameter. Today, the instrument has been improved to a diameter of 1.8 mm, and there have been reports of more than 300 cases of endoscopic examination of the vertebral cavity. However, intraspinal exploration using an endoscope has been limited to the lumbosacral region because of the rigidity of the instrument.

A general international definition of the fiberscope is a flexible fiberscope consisting of an image guide and a light guide composed of fiber bundles. Methods presently available for observation of body cavities include the specular, rigid-type telescope and the flexible fiberscope. Of the conventional endoscopic systems, myeloscopes correspond to the last two categories, but they are mostly rigid, and their areas of access have been markedly limited, although they provide clear images. On the other hand, myelofiberscopes are smaller in diameter and are highly flexible, so that they can be advanced relatively freely to regions that have been difficult to approach with conventional instruments. Therefore, we first examined the inner aspect of the vertebral canal in monkeys using a fiberscope 0.75 mm in diameter, and in 1987 we attempted clinical examination and diagnosis of injuries of the cervical spine. This has made examination of a relatively wide area of the spinal cord possible cranial to the cauda equina, to which endoscopy used to be limited. We have since evaluated the safety of this technique sufficiently by applying it to examination of ossification of the posterior longitudinal ligament (OPLL), cervical myelopathy, and intraspinal tumors.

Instruments

Principles of the Flexible Fiberscope

With a fiberscope, the image formed in the two-dimensional arrangement of the object lens is transmitted to the eyepiece, and the observer sees the image magnified by the eyepiece. Recently, models incorporating a tip articulation mechanism have become available with the use of shape memory alloys, and their effectiveness is anticipated. This fiber imaging system contains 3000–4000 ultrathin image fibers (picture elements) of quartz, each measuring 5.5 m in diameter, and a light guide in the fiber catheter 0.75 mm in diameter. Therefore, it can be inserted percutaneously through an 18G Tuohy needle. It is extremely flexible, providing a visual field angle of 55°–60°, an observation depth of 0.3–3 mm, and a radius of minimum curvature of 1 mm. However, it is readily breakable if handled violently. Methods incorporating fluoroscopy are used for confirmation of the height and nerve roots, but the resolution is slightly deteriorated. Presently, a less breakable fiberscope system that can be used in association with an arthroscopic system is being tentatively applied. In this system, the quartz image fibers and light guide are coated with polyethylene, and it can be flashed with a common light source for arthroscopes. Similarly to the arthroscope, it can be operated under real-time video monitoring. A variety of improvements have been made to date.

Rigid-Type Telescope

Since the image caught by the object lens is transmitted serially with multiple relay lenses (diverting lenses and light-collector lenses), the rigid-type telescope allows an excellent resolution. A large volume of work has been accumulated by investigators, including Oh, Pool, and Furman. The reports to date have been limited to the unconstricted level of the cauda equina, probably because the target object has been observed from the side. Examination of other sites is considered to be impossible with a rigid-type telescope became of safety concerns, even if a very small endoscope is developed. However, even clearer images are needed for evaluation of the hemodynamics of the cauda equina. We may use rigid fiberscopes 0.9 or 1.1 mm in diameter. These can be used repeatedly, thus lowering costs.

Methods

No premedication is needed in principle. We inject atropine sulfate (1A) and Atarax-P (25 mg) in selected patients to prevent unexpected accidents, but we have seldom done this recently. The puncture site is anesthetized sufficiently from the skin surface to the extradural space with 1% xylocaine.

For myelofiberscopy, the patient is placed in the lateral decubitus position, as when lumbar puncture is performed. Examination is possible in either the sitting position or the prone position, but the latter is recommended when insertion of the fiberscope is extremely difficult. If the patient suffers from intense pain, such as in disc herniation, the patient is laid with the limb showing nerve root symptoms up to allow maximum anterior curvature of the lumbar spine. In a flexible-type myeloscopic system, a fiber catheter 0.75 mm in diameter is inserted carefully and slowly, primarily at L4-5 or L5-S1, using a 17G or 18G epidural catheter as a guide. Insertion from the hiatus sacralis is effective for observation of the extradural space. Attention must be paid to epidural hemorrhage in insertion of the introducer, such as the epidural needle, because the visual field is mostly blocked if hemorrhage from the epidural space extends to the subarachnoid space. There is a relatively wide space, and fat and blood vessels running on the epidural surface can be observed. We have recently prepared a side tube for the epidural needle, which prevents leakage of cerebrospinal fluid via the epidural needle and sufficiently flushes the extradural space with physiologic saline, as part of our efforts

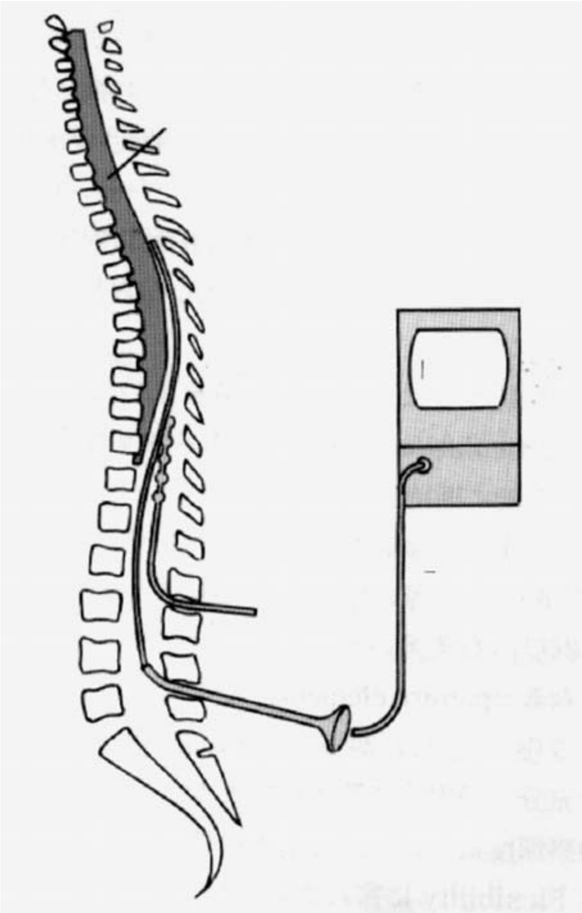

Fig. 1. Myelofiberscope procedure and recording system

to prevent postoperative low-spinal-pressure headache and to improve the quality of images. The surface of the myelofiberscope, which is made of synthetic resin, cannot be sterilized by boiling or high-pressure steaming. Sterilization is achieved primarily with oxidized ethylene gas or a cold gas (Fig. 1).

Subjects

Myelofiberscopy has been performed in 238 cases (112 males and 126 females), and it has been diagnostically useful in 215 cases. The mean age of the patients was 57.8 years for males and 53.4 years for females. There were 112 cases of lumbar spinal canal stenosis, 34 of spinal cord injury, 15 of cervical spondylosis, 12 of lumbar disc herniation, 12 of spinal cord tumor, 11 of adhesive arachnoiditis, 9 of syringomyelia, 5 of ossification of the posterior longitudinal and yellow ligament, 4 of arachnoid cyst, and 1 of spinal meningocele.

Documentation of the myelofiberscopic findings is as follows: Color, luster, and irregularity on the surface of the cauda equina and spinal cord (spinal canal stenosis); Pattern of distribution of subarachnoid trabeculae and its dynamic changes (adhesive arachnoiditis); Vascularization and changes in the vessel size and blood flow on the surface of the cauda equina and spinal cord (spinal canal stenosis) (Fig. 2); Color and vascularization on the surface of the subarachnoid tumor (Fig. 3); Observation of the spinal cord cavity; Contrast media and foreign bodies in the subarachnoid cavity (Fig. 4); Dynamic changes in the denticulate ligament; Fat, space-occupying lesions, and connective tissue bands in the extradural space; Flow of the cerebrospinal fluid and dynamic changes in the cauda equina; Nerve abnormalities at the thoracolumbar junction.

Examination of changes in these items with changes in body position, exercise of the lower extremities, drug administration, and electrical stimulation may lead to clarification of various pathologic conditions.

Results

Magnified observations of dynamic changes of the trabeculae and vessels in the cisterna magna can be made from the caudal direction. The technique

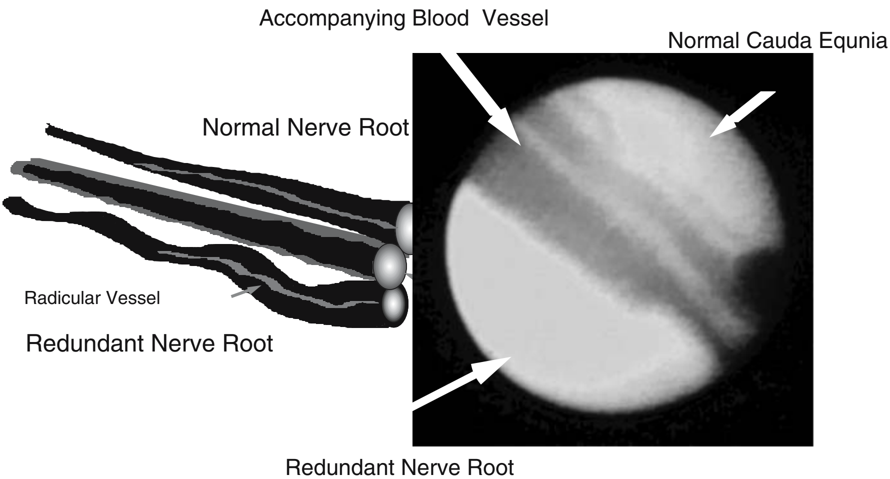

Fig. 2. Accompanying vessel over the redundant nerve

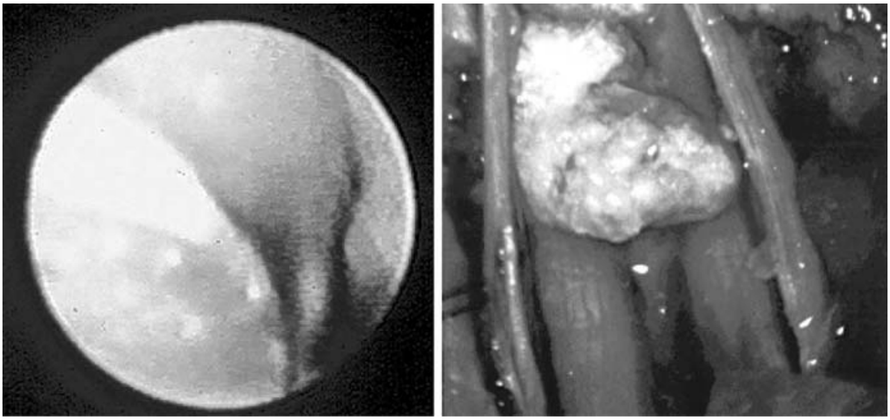

Fig. 3. Findings of myelofiberscopy in lipoma

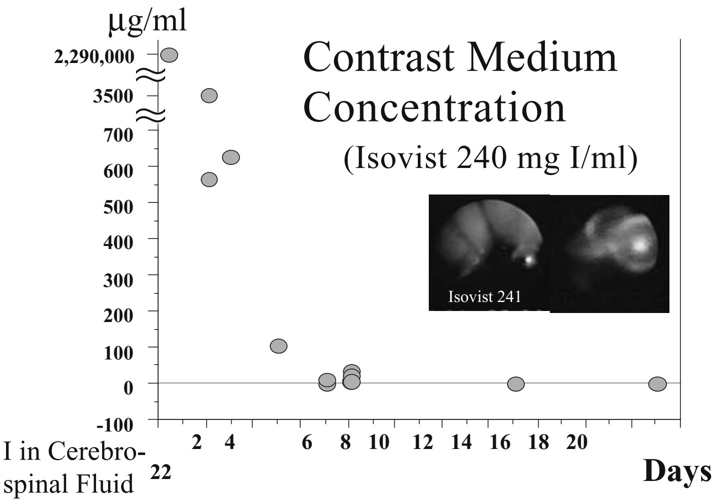

Fig. 4. Decrease in concentration after injection of subarachnoid space with contrast medium (Isovist)

may prove to be useful as an adjunct examination for aqueduct stenosis, but its safety for this purpose has not been established.

Displacement by the denticular ligament, OPLL, and listesis can be observed from the subarachnoid space. The relationship between a spinal tumor and the surrounding cauda equina can be examined by direct observation primarily from the caudal direction, and distinction between normal and abnormal vessels is possible. Myelofiberscopy was especially valuable for distinguishing between lipoma and neurinoma. It also provided information useful for selection of anterior fixation for buttered nerve and adhesive changes in the subarachnoid space in salvage operations (multiply operative back) after posterior decompression. Examination of vascularization on the spinal pia mater may be helpful for the judgment of whether the dural canal would enlarge after laminoplasty for cervical spinal cord injury.

We have been able to observe dilation of vessels running parallel to the cauda equina and changes in the blood flow in 12 patients. We also observed changes in the blood flow induced by intravenous injection of Lipo PGE1 and electrical stimulation of the peripheral nerves at 1 Hz in eight patients who had intermittent claudication as the primary symptom. With regard to pathologic changes in the spinal cord and cauda equina after spinal cord injury, the relationship between the extradural bone fragment that is compressing the spinal cord and the injured nerves will be evaluated sufficiently.

Myelofiberscopy is excellent for examination of the extradural adipose tissues and vessels, but examination of the thoracic or cervical spine is extremely difficult.

Prior to insertion of the s-s shunt tube, the inner aspect of the cavity was carefully examined with regard to the structure of the inner wall of the cavity, flow of cerebrospinal fluid as observed from the inside, and pulsation of the spinal cord. Such examination becomes impossible if the cerebrospinal fluid is not retained in the cavity in fiber insertion.

Case Study

A 53-year-old man had lumbar spinal canal stenosis showing intermittent claudication. Myelofiberscopy was performed to examine the hemodynamics. Intermittent claudication was 220 m, L5 nerve root symptoms were observed, and sensory marching was noted. The fiber scope was inserted from L4-5, and the conus medullaris was examined from the caudal direction. The right cauda equina was displaced by surrounding structures, was slightly reddened and atrophied, and showed no pulsation. The left cauda equina appeared nearly normal, but no pulsation synchronous with the heartbeat was noted. No other abnormalities were noted in the color or the size of the cauda equina, except that partly dilated radicular arteries were noted among accompanying vessels. By moving the fiberscope cranially, the tip of the fiber, which pointed to the front, was turned to the side near T11, allowing observation of the departure of the nerve root out into the pedicle from the caudal direction. Dynamic changes were difficult to evaluate. The relative blood flow (vascular cross-sectional area flow velocity) was increased 3.34 and 4.11 times by electrical stimulation and Lipo PGE1, respectively.

Discussion

The advantages of myelofiberscopy are the following: 1. It makes inaccessible objects visibl. Endoscopy enables detailed and accurate evaluation of lesions in body cavities not observable by the naked eye in close-up enlargements under sufficient illumination. Information on regional morphological changes by direct observation, along with information derived by imaging techniques such as radiography and magnetic resonance imaging (MRI), allows comprehensive diagnosis. 2. Endoscopy makes accurate recording possible. 3. Endoscopy under sufficient illumination can be applied to therapeutic as well as diagnostic purposes in the future. 4. Evaluation of dynamic changes has become possible by the introduction of video tape recorder (VTR).

The complications were three cases of low cerebrospinal fluid pressure headache. We observed low cerebrospinal fluid pressure headache in two early cases, but little intraoperative leakage of cerebrospinal fluid through the epidural needle is observed today because of improvements in the technique. However, careful manipulation is still needed to prevent damage to soft nerves and infection by the instruments.

The problems were as follows: 1. Angle of visual field and depth of focus. Because a fine fiber is inserted into the narrow space of the intraspinal cavity, a large focal depth and a wide angle of visual field are goals in the development of the myelofiberscope. 2. The development of the 90 degree lateral-view type and the posterior oblique-view type myelofiberscopes will reduce the blind spots in the anterior and lateral portions of the intraspinal cavity in the cervical and high thoracic spine to some extent. However, many technical problems remain with ultrathin flexible myeloscopes.

Various measures have been devised against damage to the light guide, but the breakability of the instrument has not been sufficiently overcome. It is still disposed of after being used several times.

The development of the diagnostic technique that directly contributes to treatment is the greatest and, in fact, the only problem. A concrete example is resection of the tight film terminalis under direct observation. The use of lasers may allow nonsurgical treatment of blood vessels in conditions such as arterio-veneous malformation (AVM).

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Clinical Outcomes of Posterior Endoscopic Discectomy for Central Disc Herniation and Posterior Endplate Lesions in the Lumbar Spine

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Summary. The purpose of this study was to evaluate the results and the reliability of microendoscopic discectomy (MED) on the central protruded lumbar disc. From September 1998 to December 2001, we performed MED on 200 patients (mean age, 36.3 ± 15.1 years) . Among these, 28 patients who present with central disc protrusion underwent disc extraction. Central disc herniation was seen in 17 patients (mean age, 29.8 ± 8.4 years). Posterior endplate lesions were found in 11 patients (mean age, 16.8 ± 5.6 years). Evaluation of the operative results used the Japanese Orthopaedic Association (JOA) scoring sytem. Twenty-seven of 28 patients underwent endoscopic surgery. The remaining patient was a case of open conversion in which the early version of the disposable endoscope was used. The METRx reusable endoscope posed no special problems. The average JOA score of patients with central disc herniation was 12.9 ± 0.9 preoperatively, which improved to 27.8 ± 0.9 postoperatively. The average operation time was 66.5 min per segment. The average JOA score of those with endplate lesions was 17.7 ± 1.8, which improved to 27.8 ± 1.8. The average operative time was 105.9 min. There were no special interoperative complications to report.

Key words. Lumbar spine, Posterior endoscopic surgery, Central disc herniation, Posterior endplate lesion, MED system

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Introduction

From September 1998, in order to cause minimum invasion, we have mainly used microendoscopic disectomy (MED) to treat lumbar nerve root disorder. This method utilizes endoscopic surgery, which provides a clearer video picture by combining a 3CCD camera with a reusable endoscope (METRx).

The purpose of this study is to evaluate the results and the reliability of endoscopic surgery on the central protruded lumbar disc, and to determine the safety of MED.

We also explored the advantages of this operative technique, which capitalizes on the efficient features of the endoscope, compared with conventional methods, such as the Love procedure and standard microscopic discectomy.

Materials and Methods

From September 1998 to December 2001, we performed MED on 200 patients for the treatment of lumbar nerve root disorder after conservative therapy at least for 1 month or more. The mean age of the patients was 36.3 ± 15.1 years.

Among these, 28 patients who presented with central disc protrusion underwent disc extraction. Central disc herniation was seen in 17 patients, whose average age at the time of operation was 29.8 ± 8.4 years. Eleven patients, with an average age of 16.8 ± 5.6 years, underwent the treatment for posterior endplate lesions.

The operative results were evaluated using the Japan Orthopaedic Association (JOA) score for the lumbar spine.

Results

All 28 patients underwent endoscopic surgery. One was a case of open conversion in which the early version of the disposable endoscope was used. Afterwards, the METRx system posed no special problems. Although there were no interoperative complications, reoperation was conducted in one case 1 year subsequent to the operation.

Posterior endoscopic surgery for all of the central disc protrusions could be carried out from one side by moving the tip of the tubular retractor to the target area gradually and by tilting the endoscope to the contralateral side, without changing the insertion point.

The average JOA score of patients with central disc herniation was 12.9 ± 0.9 preoperatively, which improved to 27.8 ± 0.9 postoperatively. The average operative time was 66.5 min per segment. The mean JOA score for those with endplate lesions was 17.7 ± 1.8, which improved to 27.8 ± 1.8. The average operative time was 105.9 min.

Case Study: Posterior Endplate Lesion of L5

The proximal endplate at the 5th lumbar spine level was seriously defective, and the endplates migrated to the lumbar canal and compressed the dural tube remarkably (Fig. 1). The chief complaint was left sciatica. Straight leg raising (SLR) was positive at 20°, and the JOA score was 20 points. Initially we made a 16-mm skin incision and approached from the left side using MED. The 4-mm bone chisel was used to cut the endplate (Fig. 2). The nerve root was exposed, and the lateral recess was excised adequately (Fig. 3A). The nerve root was retracted inside, and the protruded endplate was exposed (Fig. 3B). The protruded endplates were cut into pieces with the bone chisel, and then the endplates were resected by the Kerrison rongeur (Fig. 3C). After the nerve root had been decompressed sufficiently (Fig. 3D), the tubular retractor was gradually moved to the center. After the contralateral root was identified (Fig.

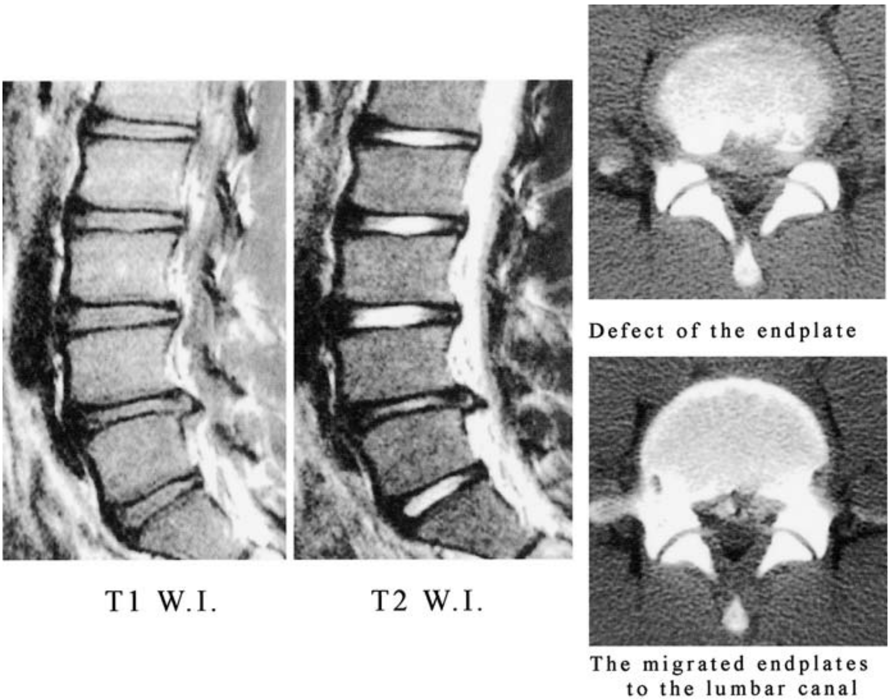


Fig. 1. A Fifteen-year-old male patient: posterior endplate lesion of L5

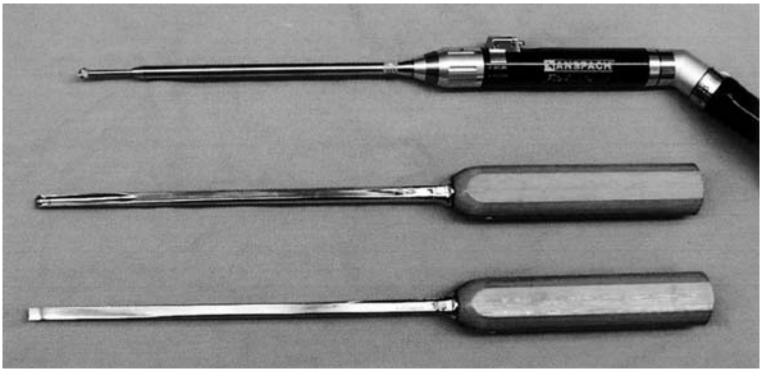
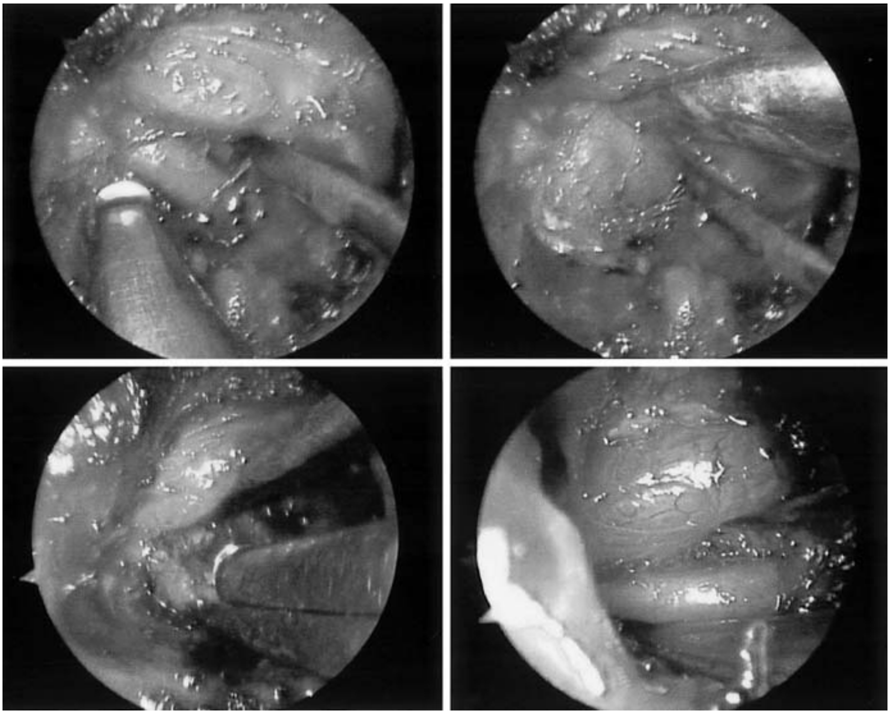
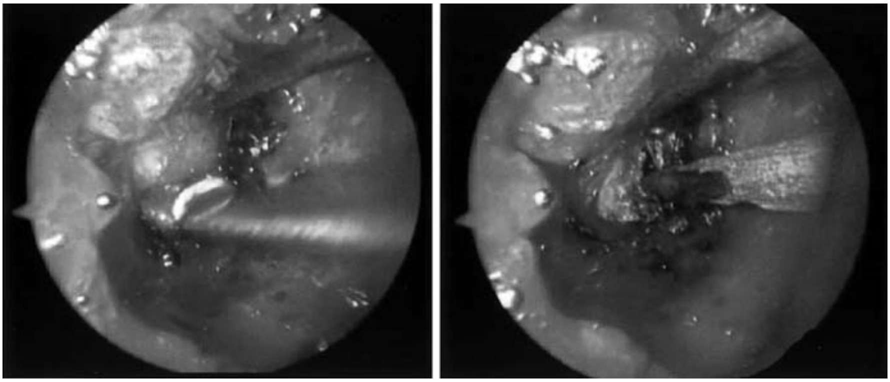


Fig. 2. High-speed drill and bone chisel of 4-mm diameter



A B C D

Fig. 3. Microendoscopic images. Left side is cranial and right side is caudal. Upper side is medial and lower side is lateral



A B

FIG. 4. Contralateral microendoscopic images. Left side is cranial and right side is caudal. Upper side is contralateral and lower side is medial

4A) and the endoscope was turned contralaterally, the rest of the endplates were resected (Fig. 4B). One week after the operation, the JOA score improved to 29. The decompression was performed sufficiently (Fig. 5).

Discussion

Central disc herniation is usually caused by a degenerative disc. Posterior endplate lesions are most often seen in young athletes, and the disc herniation type is usually seen as a bulging disc or a protruded disc and rarely as a migrated disc [1–3]. Thus, these present as central disc protrusion.

In conventional operations such as the Love procedure and standard microscopic disectomy, it is noted that the nerve roots are pressed to the outside in most cases of central disc herniation and are compressed at the lateral recess severely.

Because of the severe compression to the dural tube in this series, the usual surgical procedure was unilateral laminotomy to identify and free the compressed nerve roots.

In the Love procedure, the operation requires a wider approach. On the other hand, in standard microscopic surgery, although we can see the expanded operative field and perform the operation more safely, it is difficult to recognize the anatomical relation between the nerve root and the disc herniation in three dimensions.

In microendoscopic surgery (MED) [4], the camera is a squint-eye scope of 25°; therefore we can confirm the nerve root from directly above clearly by moving the tip of the tubular retractor gradually to view the operative area and by using a clearer video monitor that employs a 3CCD camera. We can

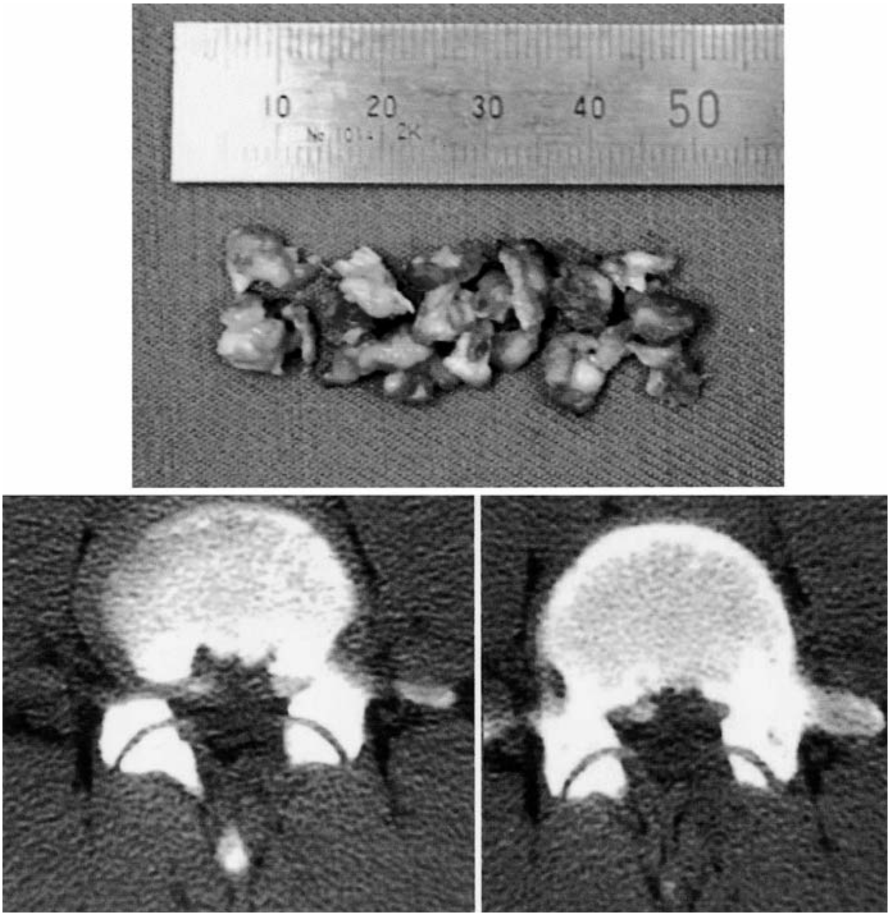


FIG. 5. Resected endplates and postoperative computed tomography (CT)

perform decompression safely and reliably from the ipsilateral side within one minimal skin incision. These are the advantages of this operative technique.

Our procedure highlights two important points. One is to resect the lateral recess widely until the nerve root is exposed adequately. The other is to perform bilateral decompression in the initial stage from the ipsilateral approach.

Conclusions

We were able to resect the central protruded lumbar disc, such as the central disc herniation and the posterior endplate lesions, safely and reliably with posterior endoscopic surgery from the ipsilateral side within one skin incsion.

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Diagnosis and Endoscopic Release of the Piriformis Muscle Under Local Anesthesia for Piriformis Syndrome

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Summary. We developed a minimally invasive technique for releasing the piriformis muscle under endoscopic control for entrapment neuropathy of the sciatic nerve due to tension and contraction of the piriformis muscle. This is a technical report on minimally invasive arthroscopic release of the piriformis muscle. This surgical technique was performed in patients who fulfilled at least five of nine diagnostic criteria (Fig. 1) that we established and who did not respond to conservative therapy for 6 months or more. While a cavity was maintained using a disposable syringe (10 ml) with a cut tip, an arthroscope (4 mm in diameter) was inserted at an oblique viewing angle of 30°, and the muscle was identified. The area from the musculotendinous junction to the muscle was gradually incised using a special scraper. Pain disappeared simultaneously with release of the piriformis muscle during operation. In this technique of releasing the piriformis muscle, an adequate cavity can be produced and maintained in a manner similar to that in the posterior endoscopic operation for intervertebral disc herniation. This technique is useful for reducing postoperative pain and allows an early return to society.

Key words. Piriformis syndrome, Endoscopy, Local anesthesia

Introduction

Functionally, the piriformis muscle acts as an external rotator during extension of the hip joint and as an abductor during its flexion. Anatomically, this muscle is innervated by L5-S2 and runs from the anterior surface of the sacral spine, reaching the greater trochanter. The sciatic nerve runs on the dorsal

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Diagnosis of piriformis syndrome

1. Tenderness of sciatic notch
2. Provocation pain with touching pain during surgery
3. Pain & weakness on resisted abd external rotation of the thigh
4. Tenderness on rectal examination
5. Pain on internal rotation of the hip
6. Neurological deficit absent
7. Exacerbation of the pain by stooping or lifting
8. Gluteal atrophy present
9. Effectiveness of sciatic nerve block

FIG. 1. Diagnosis of piriformis syndrome

side of the piriformis muscle in the sacral spinal area. In the ischiatic notch, various anomalies occur at the crossing of the sciatic nerve and the piriformis muscle. In addition, the sciatic nerve runs close to the dorsal area of the iliaus, and the piriformis muscle runs on the dorsal side of the sciatic nerve. Muscle contractions develop according to the limb position (flexion, internal rotation), which tends to compress the sciatic nerve from the ventral and dorsal sides [1, 2]. Anomalies, trauma, and tumors are sometimes secondarily involved [3]. Since there are many young patients with this syndrome caused by sports, we developed arthroscopic release of the piriformis muscle under local anesthesia that is minimally invasive and allows an early return to society. For carpal tunnel syndrome, endoscopic incision of the entrapped nerve has been already developed, and excellent results have been reported. We performed this arthroscopic, minimally invasive technique for piriformis syndrome, which often affects young people such as athletes, in six patients (eight limbs) and observed good results in all of them.

Operative Technique

Surgical Technique

Anesthesia was induced with 10 ml of 1% Xylocaine using a cathelin needle from the subcutaneous area to the gluteus medius and minimus muscles, during which the ischiatic notch was confirmed. An incision of about 2 cm was made toward the ischiatic notch using the posterior margin of the greater trochanter in 30–60 degree flexion of the hip joint. The incision was extended to the fascia of the tensor fasciae latae muscle. This portion is already transitional to the gluteus maximus muscle, and the ventral portion to the gluteus

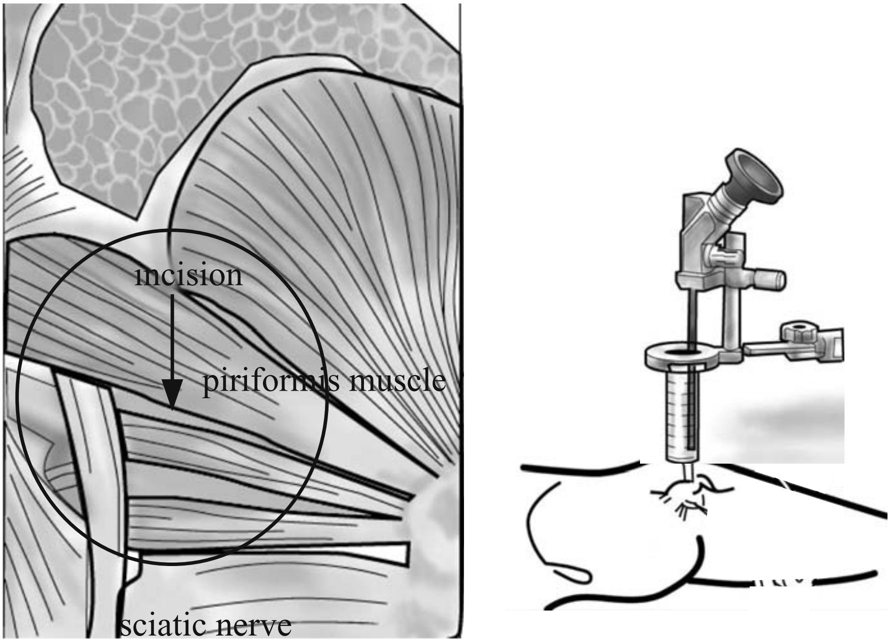

Fig. 2. Illustration of the procedure of arthroscopic release of the piriformis muscle

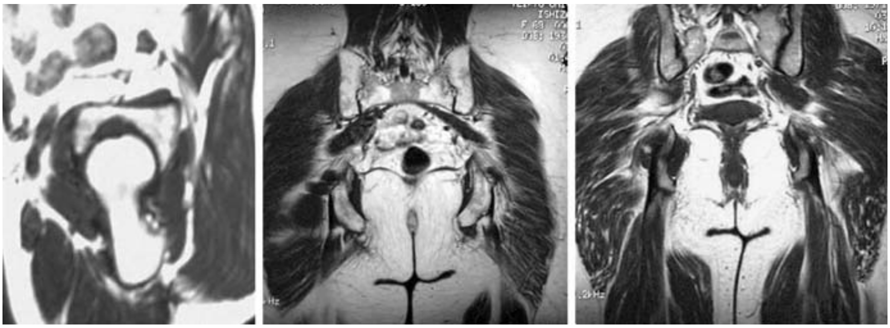

Fig. 3. Magnetic resonance imaging (MRI) findings. **a** Sagittal section (parallel to femoral neck). **b** Frontal section before surgery. **c** After surgery

maximus muscle was incised bluntly. After unfolding along the posterior margin of the gluteus medius and minimus muscles, the ischiatic notch was touched, and a working portal was established on the anteroinferior ischial area (Fig. 2). The index or middle finger was inserted into the cavity, and the ventral portion of the piriformis muscle located at the ischiatic notch was touched to confirm reproduction of severe pain. By this procedure, the patient confirmed the pain, which allowed tomical relationship with the superior and inferior gemellus muscles. The cavity was maintained using a 10-ml syringe, an arthroscope (4 mm in diameter) was inserted at an oblique viewing angle of 30°, and the muscle was identified. The muscle was incised gradually from the musculotendinous junction using a special scraper. The surgical treatment is the neurolysis of the sciatic nerve and the muscle section at the musculotendinous junction (Fig. 3). Decompression of the sciatic nerve was confirmed by disappearance of the symptoms on flexion and internal rotation of the hip joint.

Discussion

Surgical Procedures

The conventional first treatment choices for this syndrome have been transanal massage, piriformis muscle stretching exercise, and intramuscular injection of local anesthetics or steroids [4, 5]. There have been many studies on release of the piriformis muscle in patients who do not respond to these conservative measures [6, 7]. The sites of incision have been the greater trochanter side and an area distal to the piriformis muscle. Remission of symptoms has also been reported by release at the insertion site of the piriformis muscle [8], release at the crossing of the piriformis muscle and the nerve [2], or resection of the gluteal muscle, iliotibial ligament, superior gemellus muscle, or internal obturator muscle. However, many pathologic conditions may be caused by compression of the piriformis muscle at the ischiatic notch. Therefore, we previously performed release at a site proximal to the greater trochanter where the release was the easiest. Recently, incision of the piriformis muscle at the ventral side of the ischiatic notch has been performed, which also allows observation of the pathologic state of the sciatic nerve. To our knowledge, there have been no studies on arthroscopic release of the piriformis muscle under local anesthesia.

Characteristics of Release of the Piriformis Muscle under Local Anesthesia

The advantages are the following:

1. Preoperative pain can be reproduced by palpation of the piriformis muscle, which provides a definite diagnosis.
2. As a result, the piriformis muscle can be identified among the four closely located external rotator muscles.
3. Postoperative management is easy.
4. The immediate effects of release of the piriformis muscle can be evaluated during operation.
5. This technique is safe, because intraoperative monitoring of the sciatic nerve injury is possible.
6. The disadvantage is pain control during operation.

Characteristics of Arthroscopic Minimally Invasive Technique

The advantages are the following:

1. Postoperative pain is slight.
2. This syndrome often affects young people, and this technique is aesthetically more acceptable.
3. Postoperative recovery is observed early.
4. Accurate manipulation in a bright extended visual field is possible.

The disadvantages are that devices are necessary for the production and maintenance of a cavity using a dilator and that training is necessary.

To realize these advantages, recognition of deep sensation and learning of tactile sensation of the piriformis muscle are necessary. In addition, training of cooperative movements between manual sensation and visual sensation should be performed for anatomically accurate arrival of the dilator at the ischiatic notch and accurate manipulation. Patients in whom this procedure is difficult can be dealt with by changing the size of the tubular retractor of the syringe to 20 or 30 ml.

In this technique of releasing the piriformis muscle, a cavity can be produced and maintained by a procedure similar to posterior endoscopic lumbar discectomy for intervertebral disc herniation. This technique is useful for reducing postoperative pain and achieving an early return to society.

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Key Word Index