Various Other Disc Herniations

Jeong Hoon Choi, Sang-Ha Shin,
and Shin-Jae Kim

1 Recurrent Disc Herniation

Jeong Hoon Choi

Abstract Revision surgery for recurrent lumbar disc herniation constitutes a challenge for the spine surgeon because it has approach-related complications. Recently, PELD has been proposed as a potentially beneficial alternative surgical management for recurrent lumbar disc herniation. Posterolateral transforaminal approach through unscarred tissue can prevent nerve injury and can prevent further damage to the posterior spinal and paraspinal structure.

Keywords Recurrent lumbar disc herniation; Percutaneous endoscopic lumbar discectomy; Open lumbar microscopic discectomy; Minimal invasive spine surgery

1.1 Introduction

Prevalence of recurrent lumbar disc herniation after open microscopic laminectomy and discectomy has been reported in 5–18%, depending on the follow-up period [1–6]. Repeated open lumbar microscopic laminectomy and discectomy (OLM) is the most commonly recommended surgical option for recurrent lumbar disc herniation [5–8]. Though repeated OLM showed comparable results to those of primary surgery, it has approach-related complications and could produce less satisfactory results than the primary operations [9–12]. Scar tissue and epidural adhesion make a repeated operation more difficult, increasing the risk of dura tear or nerve injury [12–15]. Further injury of posterior structures, especially facet joint, could increase the risk of segmental instability and cause postoperative back pain [16, 17].

In recent years, percutaneous endoscopic lumbar discectomy (PELD) has been developed with similar clinical outcomes compared with OLM [18–26]. Recently, PELD has been proposed as a potentially beneficial alternative surgical man-

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J. H. Choi
Department of Neurosurgery, Chungdam Wooridul Spine Hospital, Seoul, Republic of Korea
e-mail: cjh77@wooridul.co.kr

S.-H. Shin (✉)
Wooridul Spine Hospital, Seoul, Korea (Republic of)
e-mail: burrhoer@wooridul.co.kr

S.-J. Kim
Department of Neurosurgery, Gangbuk Wooridul Spine Hospital, Seoul, Republic of Korea
e-mail: nsdoc@wooridul.co.kr

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agement for recurrent lumbar disc herniation [27]. Posterolateral transforaminal approach through unscarred tissue can prevent nerve injury and can prevent further damage to the posterior spinal and paraspinal structure [28].

1.2 Main Text

Most spine surgeons consider that OLM is the gold standard operative treatment for lumbar disc herniation and also for recurrent lumbar disc herniation. However, nowadays, many spine surgeons choose the PELD method for the first operative treatment about lumbar disc herniation and recurrent lumbar disc herniation.

Revision surgery for recurrent lumbar disc herniation constitutes a challenge for the spine surgeon. The initial OLM results in epidural scarring, primarily encountered around dura mater and nerve roots. Hence, conduction of a revision OLM may be unfavorably associated with dural tear and nerve root damage. The incidence of dural tear during repeated OLM was reported up to 20% of the patients [29, 30]. Dural tear during lumbar disc surgery was suggested with long-term clinical sequelae and poor clinical outcomes [31].

PELD provides an approach through unscarred virgin tissue. Therefore, the surgeon can approach the target site safely without demanding dissection of the fibrotic scar tissues, and the potential risk of dural tear, nerve injury, or infection could also be decreased. Being continuously conscious, patients can be monitored by surgeons for any inadvertent physical trauma to the nervous structures. Surgeons can also monitor whether the radicular pain improves during the procedure.

Although satisfactory clinical outcomes have been demonstrated with PELD, it requires a highly experienced endoscopic surgeon. The learning curve is relatively steep, and the clinical outcomes could be affected by the surgeon's technique.

When treating patients with a recurrent lumbar disc herniation, one of the most important factors is patient selection. The authors do not believe that all recurrences can be treated with minimally invasive procedures such as PELD. In the case of a severe neurologic deficit or severe stenosis, a repeated conventional discectomy could be adequate. Sometimes, an additional fusion procedure could be necessary.

1.3 Surgical Technique [28]

The patient is placed in the prone position on a radiolucent spinal table with flexion of the back. Usually the skin entry point is approximately 8–12 cm from the midline. To determine the appropriate skin entry point, preoperative MR imaging studies are helpful and intraoperative fluoroscopy should be performed on anterior–posterior view and lateral view. An 18-gauge spinal needle is inserted after infiltration of local anesthetics on skin and muscle layer. The needle tip is positioned at the midpedicular line at the anterior–posterior fluoroscopic view and on the posterior vertebral line at the lateral fluoroscopic view. At this time, a transforaminal epidural infiltration through the spinal needle with 0.5% lidocaine is recommended to effectively prevent the approach-related pain and discomfort. After advancing the needle in the disc space, an intraoperative discography is performed with a mixture of 6 mL of contrast media and 1 mL of indigo carmine. The pathologic disc material and annular fissure can then be stained and detected easily through both the fluoroscope and endoscope.

A guide wire is then inserted through the needle into the disc space and a small skin incision is made at the entry site of the needle. After the needle is withdrawn, a tapered cannulated obturator is slid over the guide wire and introduced gently into the foramen. The tip of the obturator should be located just below the foraminal bony structures and should contact the annular surface. Foraminoplasty could be performed in case of foraminal stenosis for proper endoscope location.

The next step is the insertion of a beveled working cannula over the obturator. The bevel-ended, oval shaped working cannula secures safe and less painful transforaminal annular contact than the standard working cannula. After the obturator is withdrawn, endoscope was inserted. Through the endoscope, the surgeon can see the surface of the blue-stained annulus, pathologic disc materials, and epidural fat. In a recurrent disc herniation, fibrotic and adhesive tissues are often seen instead of normal annulus. The annular surface is clearly defined after trimming the epidural fat or other soft tissue debris using a bipolar coagulator.

After confirming the safety of the working space, the discectomy can be started with or without an annulotomy. A small annulotomy cutter cuts the annulus in a circular fashion to make a working intradiscal tunnel. Through this tunnel, a manual discectomy is then performed in the subannular region with fluoroscopic guidance.

The surgeon can see these layers: layers of superior facet, epidural fat, inflamed epidural fibrotic tissues, posterior longitudinal ligaments, and disc material through the transforaminal endoscopic view. The herniated disc and fibrotic scar tissues are then removed using endoscopic forceps and a side-firing, holmium yttrium-aluminum-garnet (Ho:YAG) laser. The soft herniated disc is generally stained blue by indigo carmine, easily movable, and can be well vaporized by the laser, whereas the whitish epidural scar is usually not stained blue. If the fibrotic adhesions anchor the herniated fragment, the side-firing Ho:YAG laser and cutting forceps useful for widen the annular fissure. Once the fibrotic anchorage has been loosened and the annular fissure is opened widely, the blue-stained herniated disc material can then be visualized and easily removed by the endoscopic forceps. When all the herniated disc material and fibrotic tissues have been removed, the endoscope is withdrawn and a sterile dressing is applied with a one-point subcutaneous suture.

1.4 Case Illustration

A 36-year-old female patient suffered from back pain and right leg radiating pain for 6 weeks. He underwent OLM L4-5 level on the right side 1 year ago. MRI showed recurrent disc herniation at L4-5 level on the right side (Fig. 1). We decided to perform PELD at L4-5 level on the right side. The surgical procedure of introducing the endoscope is mentioned above surgical technic part (Fig. 2). In intraoperative endoscopic view, we confirmed intradiscal undersurface of the annulus and tail of the herniated disc material, and after the removal of the herniated disc we confirmed that the annular fissure is well visualized (Fig. 3). Postoperative MRI showed complete removal of herniated disc and well decompression of nerve root (Fig. 4). The patient was discharged 1 day after the operation with improving state.

1.5 Summary

Revision surgery for recurrent lumbar disc herniation is a challenging surgery for the spine surgeon. PELD has many advantage compared with revision OLM. PELD for recurrent lumbar disc herniation is very effective and safe surgical method with few complication, short operating time and hospitalization, preserve disc height and a high patient satisfaction because of minimally invasive fashion.

Fig. 1 Preoperative MR showed recurrent disc extrusion at L4-5 level on the right side and L5 root impingement on the right side

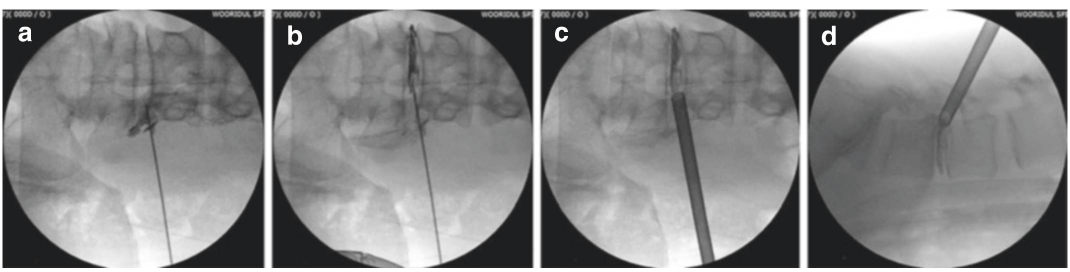

Fig. 2 (**a**) 18-gauge spinal needle is inserted at foraminal area and infiltration of radiopaque dye and local anesthetics. (**b**) Intraoperative discography is performed with a mixture of 6 mL of contrast media and 1 mL of indigo carmine. (**c** and **d**) The introduction of a beveled working cannula at intradiscal space

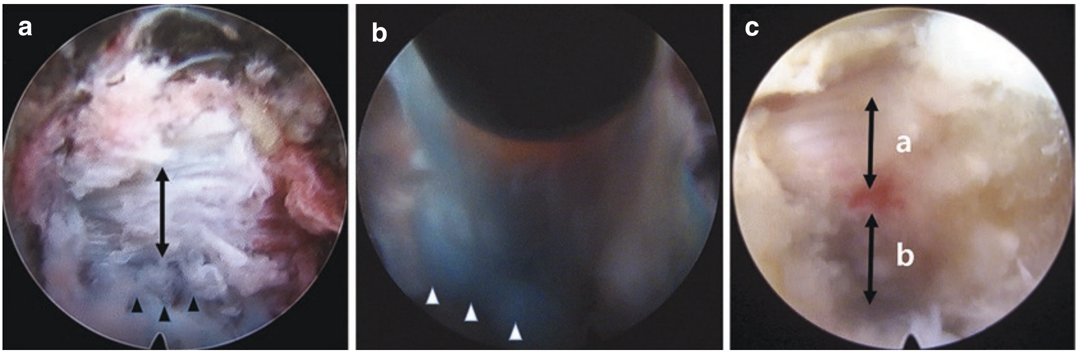

Fig. 3 Intraoperative endoscopic view. (**a**) Initial intraoperative endoscopic view. Black arrow indicated annulus. Black arrowhead indicated herniated disc. (**b**) Removal of herniated disc (white arrowhead) using endoscopic forceps. (**c**) Final intraoperative endoscopic view after removal of herniated disc. Traversing nerve root was seen (*a*) and annulus was seen (*b*)

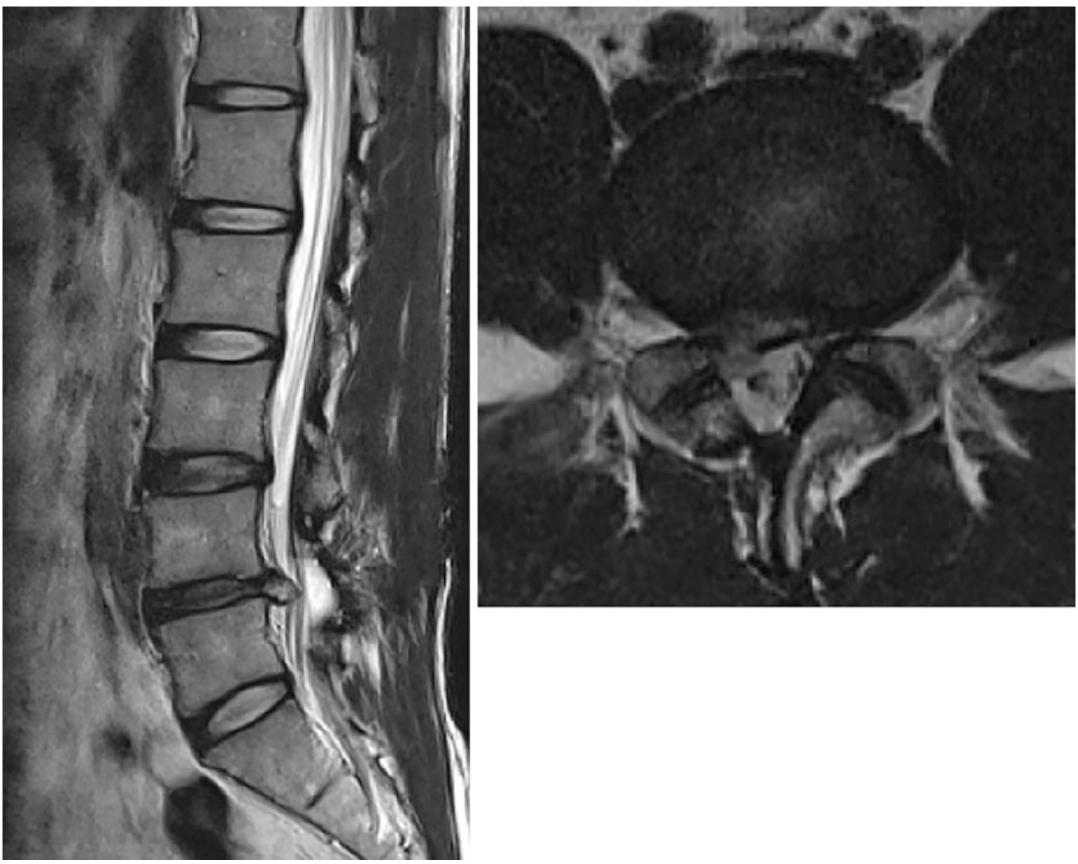

Fig. 4 Postoperative MR showed well removed state of recurrent disc materials at L4-5 level on the right side and well decompression of L5 root on the right side

2 Huge Central Disc Herniation

Sang-Ha Shin

Abstract A large disc herniation is inherently more disadvantageous, as it is more likely to cause such issues as a large prolapsed disc with a severe annular defect. Pathoanatomical and clinical research provide persuasive evidence that normal disc tissue removal including iatrogenic damages may cause “post-discectomy syndrome” with reduced disc height, segmental instability, and retrolisthesis, being the sources of chronic post-surgical pain [32–37]. The authors describe a technique for percutaneous endoscopic herniotomy using an intra-annular subligamentous approach for the treatment of large central herniated discs, which preserves non-pathologic disc tissues by avoiding removal of intradiscal nucleus and cutting of annulus tissue.

Keywords Lumbar disc herniation; Large disc; Huge disc; Endoscopic discectomy

2.1 Presentation of the Patient and Illustrated Cases

Case 1

A 20-year-old male patient presented with right posterolateral radiating leg pain for 3 months. MR image showed a large central disc herniation which compressed neural structures at L4-5 (Fig. 5a). After IASH (intra-annular subligamentous herniotomy) (Fig. 5b, c), the patient’s symptoms were relieved and MR image showed complete removal of herniated disc (Fig. 5d). Six months later, she sent us 6-month follow-up MR images. The MR image showed recovery of the annular disruption.

Case 2

A 22-year-old male patient presented with bilateral with left side dominant posterolateral leg pain. MR images showed a large central disc herniation with severe neural compression at L4-5 level (Fig. 6a). The patient underwent IASH via the right side. After surgery, the patient’s symptoms were relieved. Postoperative MR image confirmed complete decompression (Fig. 6b).

2.2 Preoperative Planning

To determine the appropriate entry point, preoperative imaging studies and intraoperative fluoroscopy should be performed. The distance from the midline to the skin entry point is confirmed using axial MR or CT images before the operation in order to advance the working cannula through the optimal route. The skin entry point is approximately 12–13 cm from the midline. The approach angle is approximately 15 degrees from the horizontal plane on the axial section (Fig. 7a) which is much lower than that of the conventional transforaminal approach (Fig. 7b).

2.3 Surgical Steps

The procedure is performed under local anesthesia. The patient is placed in the prone position on a radiolucent table. Conscious sedation by anesthesiologist allows continuous feedback from the patient during the entire procedure.

An 18-gauge spinal needle is inserted after administering the local anesthetics. To identify the exiting nerve root and epidural space, epidurography is performed using contrast medium. At this time, transforaminal epidural block is recommended to decrease approach-related pain. The proper position of the needle is passing just under the surface of the superior facet. The needle tip is positioned at midpedicular line in the anteroposterior view and on the posterior annulus in the lateral view. After inserting the needle to disc space, discography is performed using mixture of indigo carmine and contrast media which selectively stains the degenerated nucleus blue in order to identify the pathological fragment. A guide wire is then inserted into the disc space through needle cannulation. After the needle withdrawal, a serial dilating system is used to widen the trajectory. A cannulated obturator is passed over the guide wire until its tip reached the midline as observed on the AP view. An 8 mm working cannula is passed

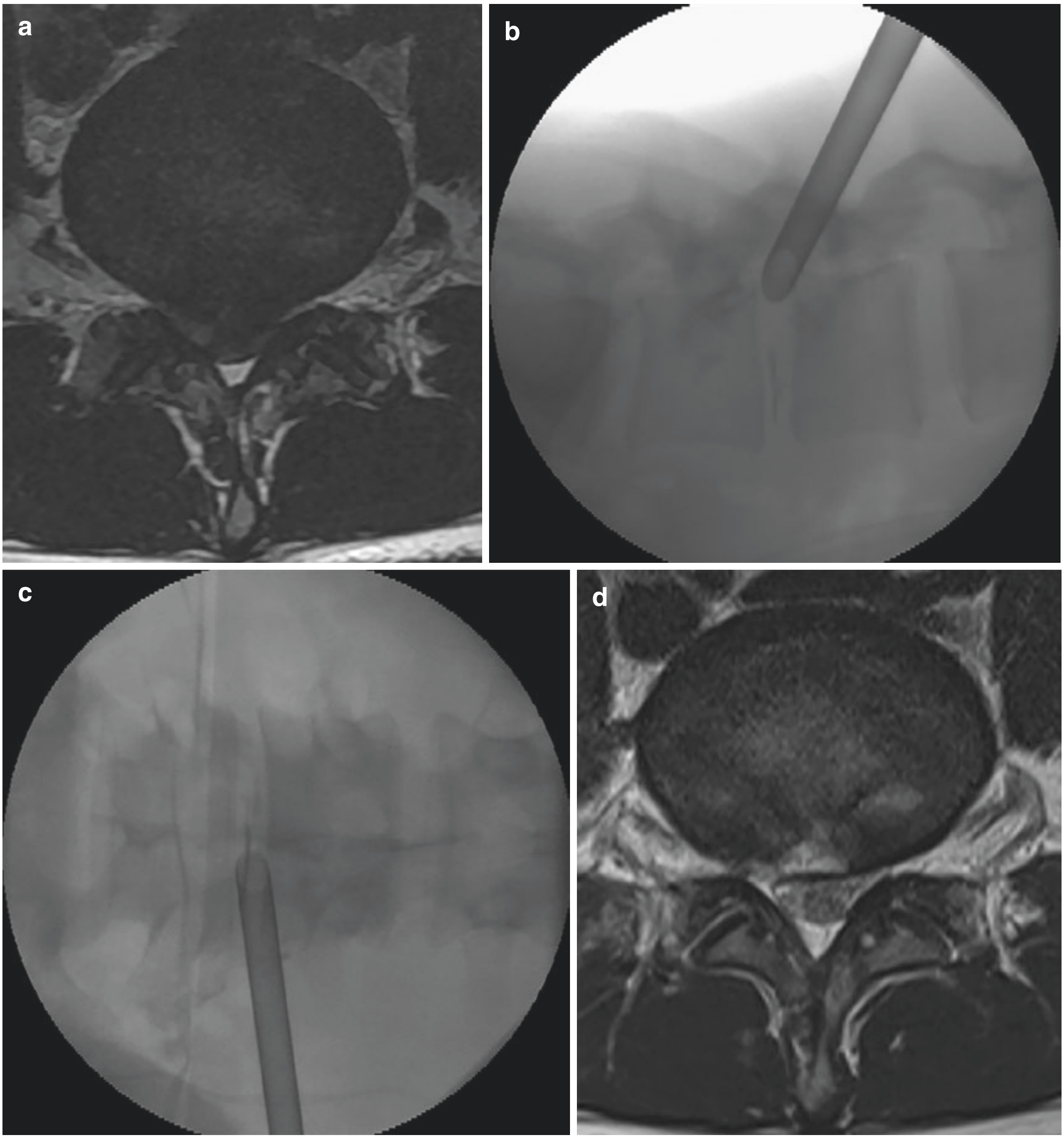

Fig. 5 (**a**) Preoperative MR revealed a large centrally herniated disc. (**b** and **c**) Intraoperative C-arm image, The approach angle was approximately 15 degrees from the horizontal plane on the axial section. (**d**) Postoperative MR confirmed complete decompression

over the obturator. After the removal of the obturator and guide wire, an endoscope (YESS II system; Richard Wolf, Knittlingen, Germany) is positioned at the annular defect site. Under the endoscopic vision, the surgeon can identify the surface of the blue-stained annulus and an epidural fat. Before removing the herniated disc, the annular anchorage of the herniated fragment is released using a side-firing Holmium:YAG laser (Lumenis Inc., NY). It is then possible to perform a manual herniotomy in the subannular region with the working channel being level with the posterior outer layer of the annulus. The herniated fragment is selectively removed by the laser or bipolar radiofrequency coagulator (Ellman International, Hewlett, NY) and/or removed with

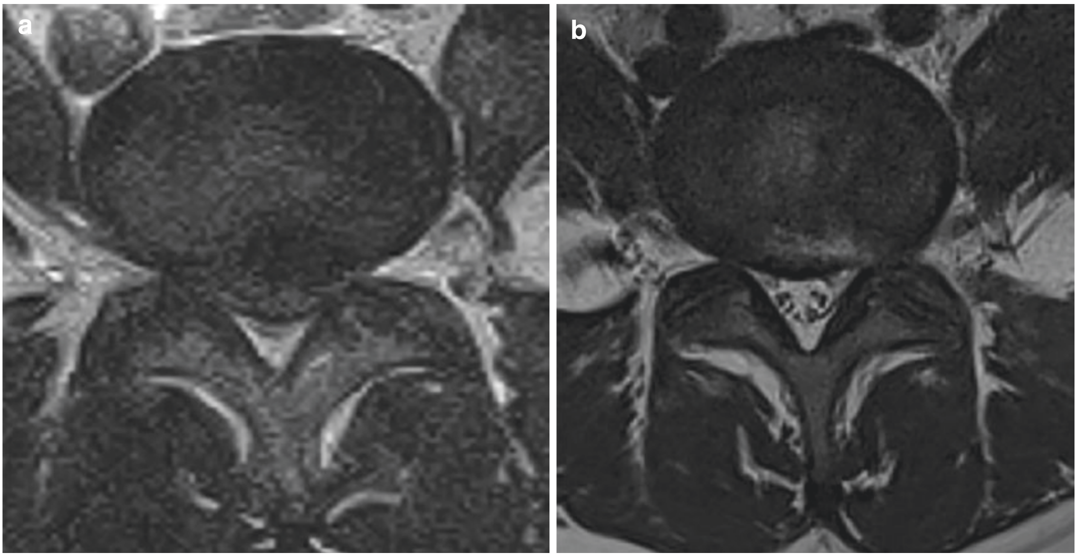

Fig. 6 (**a**) Preoperative MR showed large central disc herniation compressing the neural element. (**b**) Postoperative MR revealed the complete removal of the herniated disc

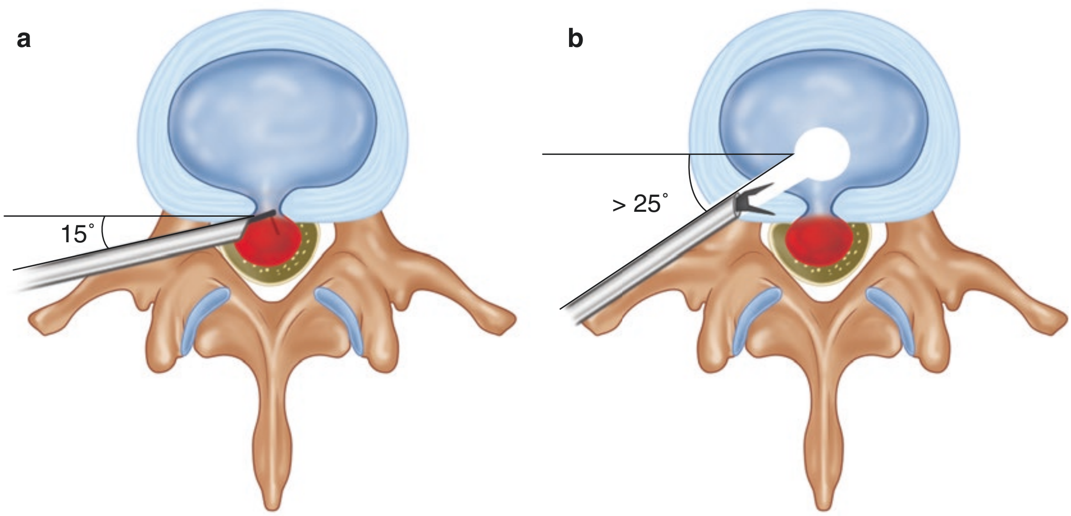

Fig. 7 (**a**) Schematic picture of percutaneous endoscopic intra-annular subligamentous herniotomy. The approach angle is approximately 15 degrees from the horizontal plane on the axial section. (**b**) Schematic picture of conventional percutaneous transforaminal endoscopic approach. Approach angle is much higher than that of the intra-annular subligamentous herniotomy

the cutting forceps. After widening of the posterior longitudinal ligament (PLL) tear, levering the cannula in order to make it more downward-tilting allows it to advance into the spinal canal space along with providing direct visualization of the extruded fragment. The removal of the herniated mass toward the canal area is performed by pulling the tip of the fragment. And then annular fissure is thermocoagulated using bipolar radiofrequency coagulator. Complete decompression can be confirmed by the identification of the epidural pulsation.

2.4 Commentary

Cambin et al. [38] reported on minimal access surgery in lumbar disc herniation in 1983.

But the early endoscopic procedures were limited by the absence of a working channel arthroscope. The scope was developed in 1997 and was approved for use by the FDA in March 1998. Since then endoscopic discectomy has rapidly gained worldwide **popularity,** due to the development of endoscopic devices and an increased need by patients.

Yeung and Tsou [26] reported the surgical outcome, technique of decompressing radiculopathy secondary to intracanal lumbar disc herniation using the YESS system in 2002. The study included noncontained herniations. The excellent or good results were 88.1% of the 219 patients and 91.2% for the questionnaire subgroup. These initial results demonstrated that endoscopic surgery could provide equivalent results to reported results of open microdiscectomy. Ahn et al. [39] reported the surgical technique and outcomes of endoscopic discectomy for recurrent disc herniations in 2004. In their report, 81.4% showed excellent or good outcomes. And they concluded percutaneous endoscopic lumbar discectomy is effective for recurrent disc herniations in selected cases. At present, endoscopic discectomy is being applied to treat almost all types of lumbar disc herniations. Moreover many authors have reported the results of endoscopic surgery for lumbar disc herniation comparable to those of open lumbar discectomy [40–43].

In this chapter the author has described the novel technique of percutaneous endoscopic herniotomy using a unilateral intra-annular subligamentous approach for the treatment of large centrally herniated disc. Chronic low back pain and postoperative spinal instability might occur in patients with large disc herniation due to heavy loss of the nucleus pulposus and large annular defect from herniation [44, 45]. Disc excision from bilateral laminectomy may cause injuries to posterior supporting structures such as facet joint, ligaments, muscles, and annulus fibrosus [46, 47].

The necessity of spinal fusion in these patients has been a subject of controversy [48, 49].

Transforaminal endoscopic lumbar discectomy (TELD) is a minimally invasive spinal technique and has many advantages compared with open lumbar discectomy such as quick rehabilitation, reduced surgery-induced tissue injury, facilitation of revision operations, and relative preservation of intervertebral disc height [50, 51]. This procedure is widely performed by interventional pain physicians as well as by spine surgeons because it requires no general anesthesia or admission to a hospital.

A large disc herniation is inherently more disadvantageous, as it is more likely to cause such issues as a large prolapsed disc with a severe annular defect. Pathoanatomical and clinical research provides persuasive evidence that normal disc tissue removal including iatrogenic damages may cause "post-discectomy syndrome" with reduced disc height, segmental instability, and retrolisthesis, being the sources of chronic post-surgical pain [32–37]. The authors describe a new technique for percutaneous endoscopic herniotomy using an intra-annular subligamentous approach for the treatment of large central herniated discs, which preserves non-pathologic disc tissues by avoiding removal of intradiscal nucleus and cutting of annulus tissue.

This approach can be applied to the patient with types of disc herniation in which the herniated mass has been gathered into the shape of a half-moon, confined by the PLL. This technique is not recommended for cases in which the extruded fragment has penetrated the PLL, for sequestrated or migrated disc herniations, or for cases with foraminal or disc space narrowing. The merit of this procedure is to preserve intact disc tissues that can reduce postoperative spinal instability and intervertebral disc space collapse.

3 Bilateral Disc Herniation

Sang-Ha Shin

Abstract Lumbar disc herniation is mostly central or unilateral herniation and causes unilateral leg pain along with back pain. On the one hand, patients with bilateral disc herniation may exhibit

bilateral symptoms due to compression on both sides of the nerve. Current gold standard of surgical management for bilateral disc herniation is open discectomy after bilateral laminectomy. But chronic low back pain and postoperative spinal instability might occur in patients with bilateral disc herniation due to heavy loss of the nucleus pulposus and large annular defect from herniation. In this chapter, the author describes a new technique for endoscopic fragmentectomy using a unilateral transforaminal approach for the treatment of bilateral herniated discs, which preserves non-pathologic disc tissues by avoiding removal of intradiscal nucleus and cutting of annulus tissue.

Keywords Lumbar disc herniation; Bilateral disc; Large disc; Endoscopic discectomy

3.1 Presentation of the Patient and Illustrated Cases

Case 1 (Bilateral Transligamentous Down-Migrated Disc Herniation)

A 41-year-old female patient presented with bilateral radiating leg pain for 3 months. MR image showed a bilateral transligamentous down-migrated disc herniation which compressed neural structures at L4-5 (Fig. 8a). After transforaminal

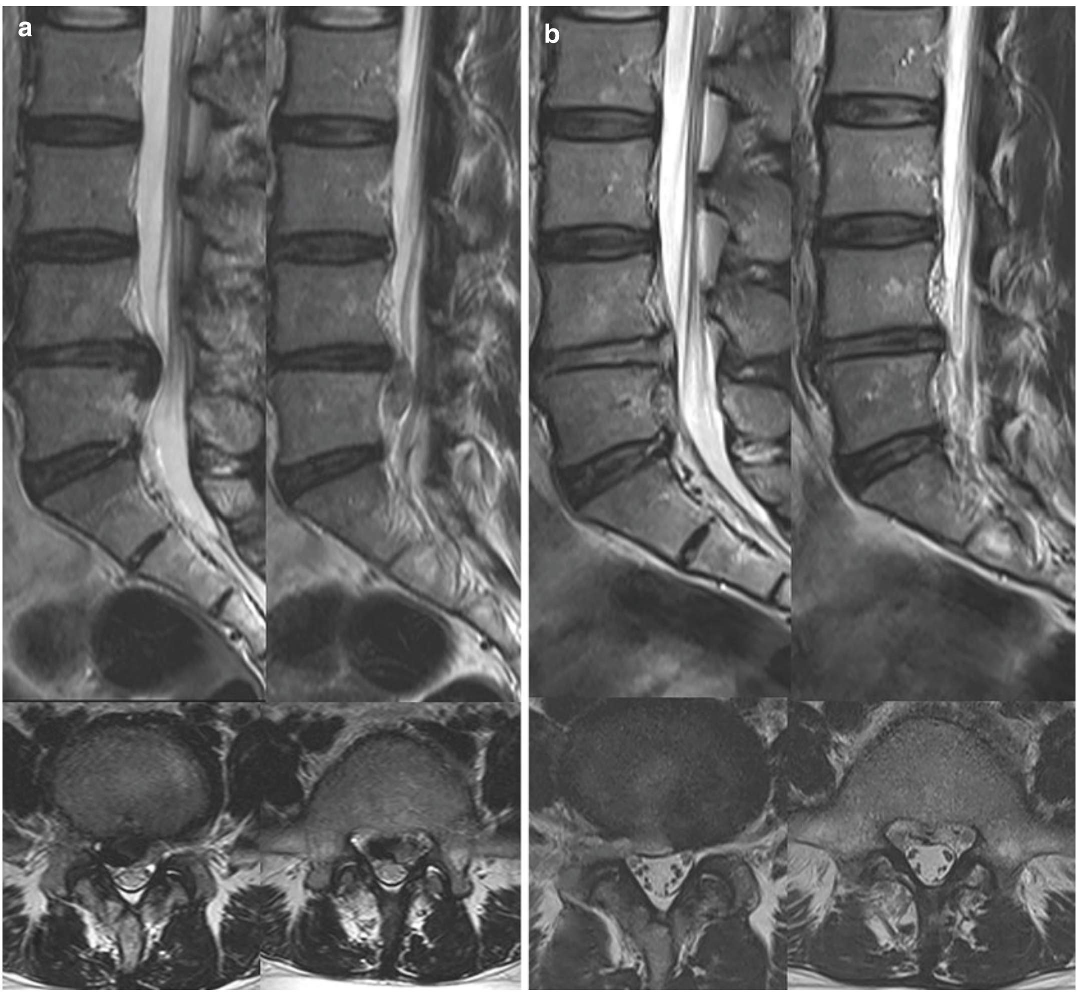

Fig. 8 Illustrative case of bilateral transligamentous down-migrated disc herniation. (**a**) Preoperative magnetic resonance (MR) images showing a bilateral disc herniation. (**b**) Postoperative MR images showing decompression of the bilateral disc

endoscopic discectomy, the patient's symptoms were relieved and MR image showed complete removal of bilateral herniated disc (Fig. 8b) (Video 1).

Case 2 (Bilateral Transligamentous Up-Migrated Disc Herniation)
A 52-year-old male patient presented with bilateral posterolateral leg pain. MR images showed a bilateral transligamentous up-migrated disc herniation with neural compression at L4-5 level (Fig. 9a). The patient underwent transforaminal endoscopic discectomy. After surgery, the patient's symptoms were improved. Postoperative MR image confirmed complete decompression of bilateral herniated disc (Fig. 9b).

Case 3 (Bilateral Subligamentous Disc Herniation)
A 78-year-old male patient presented with back and bilateral posterolateral leg pain. MR images showed a bilateral subligamentous disc herniation with neural compression at L4-5 level (Fig. 10a). The patient underwent transforaminal endoscopic discectomy. After surgery, the patient's symptoms were alleviated. Postoperative MR image demonstrated complete decompression of bilateral herniated disc (Fig. 10b).

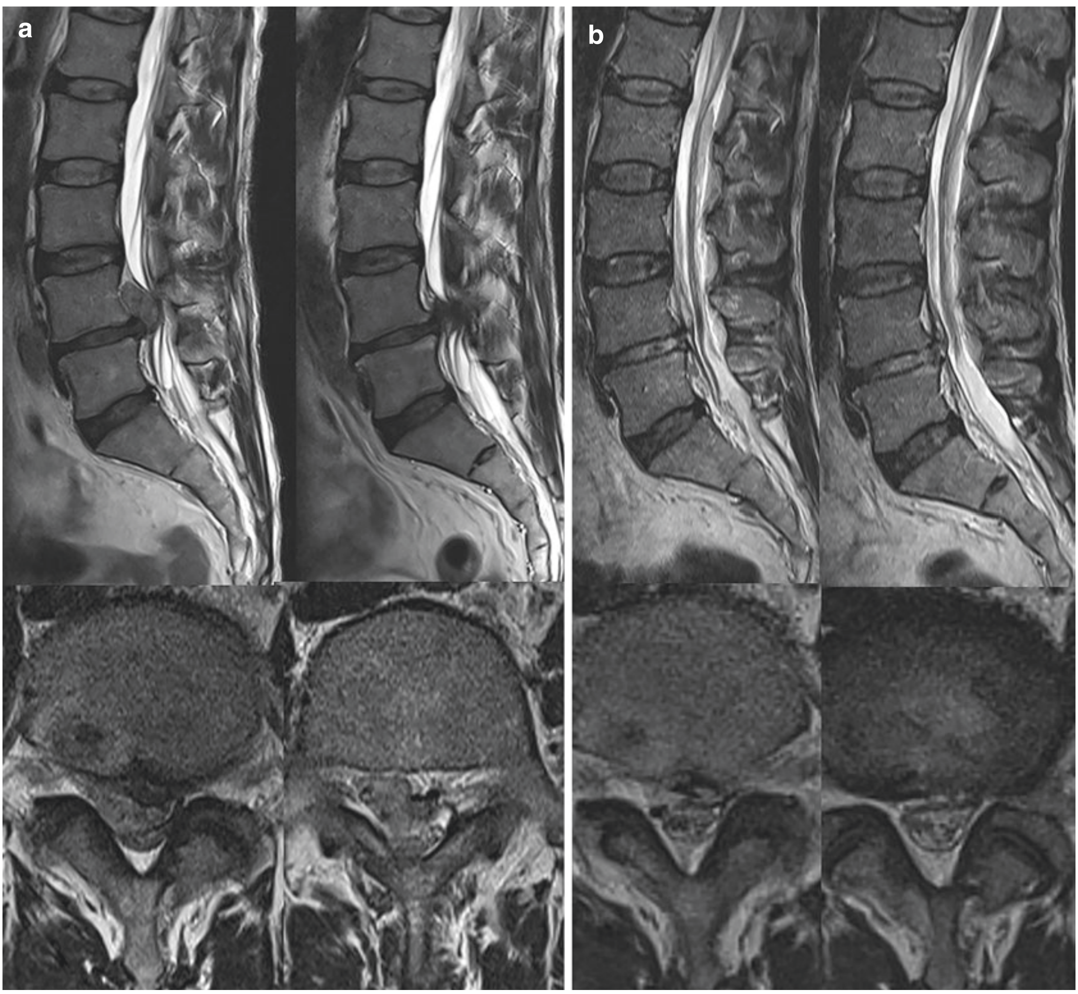

Fig. 9 Illustrative case of bilateral transligamentous up-migrated disc herniation. (**a**) Preoperative MR images showing bilateral disc herniation. (**b**) Postoperative MR image showing decompression of the bilateral disc

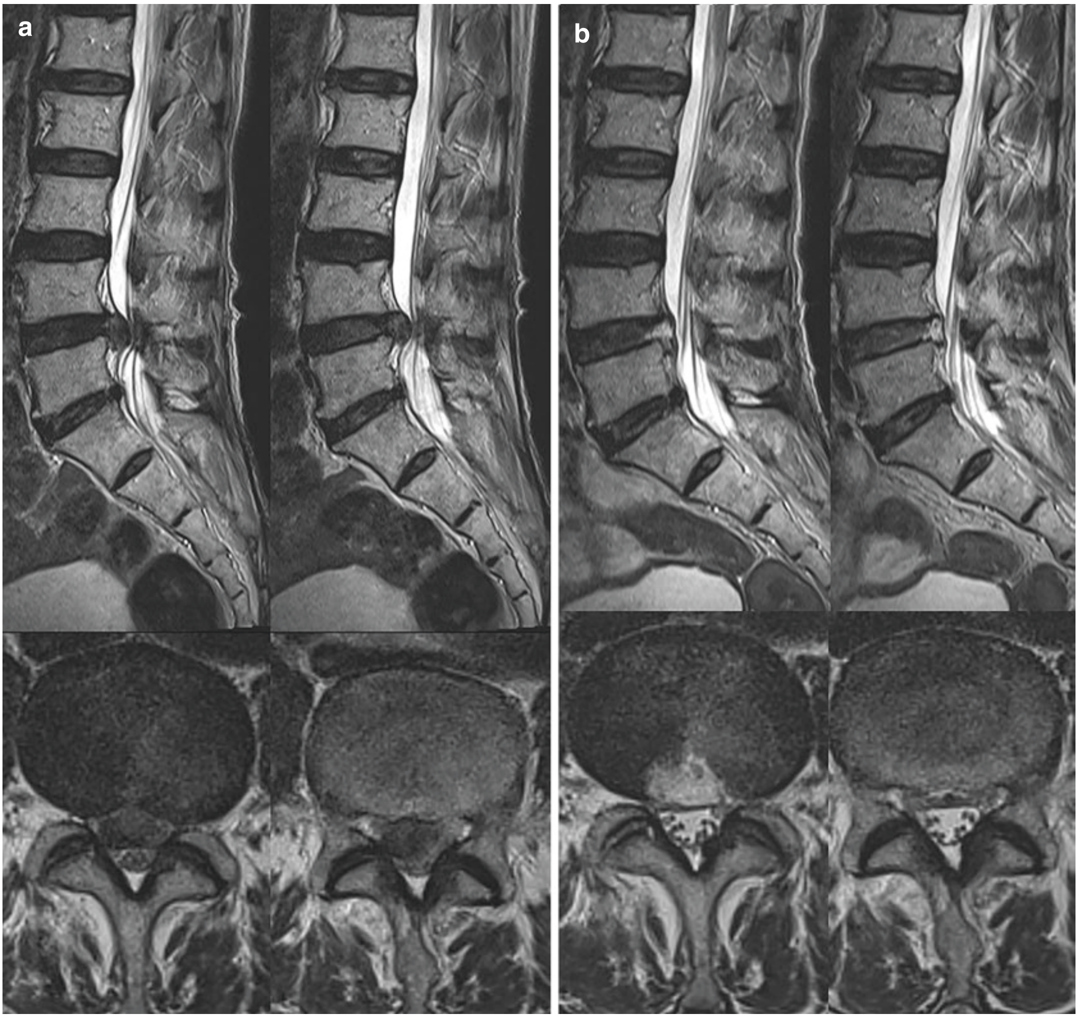

Fig. 10 Illustrative case of bilateral subligamentous disc herniation. (**a**) Preoperative MR images showing bilateral disc herniation. (**b**) Postoperative MR image showing decompression of the bilateral hard disc

3.2 Preoperative Planning

The distance from the midline to the skin entry point was calculated using a preoperative axial MRI and was approximately 12–16 cm, which is farther than the distance of a typical transforaminal approach. The access angle approaches approximately 15° in the horizontal plane of the axial image. As in the conventional transforaminal approach, approaching the angle of 30° can be difficult to obtain visibility when removing the contralateral herniated disc. The craniocaudal skin entry point was determined parallel to the disc space because it provides the best working mobility during contralateral decompression.

3.3 Surgical Steps

The procedure was performed under local anesthesia. The patient was placed in the prone position on a radiolucent table. Midazolam or fentanyl was given intravenously to relieve pain and sedation during procedure. The degree of sedation was controlled to respond to the physician's verbal command during the procedure.

After administration of local anesthetics, an 18-gauge introducer needle was inserted at the skin entry point. Transforaminal block was performed to reduce pain during procedure after accessing the foramen. The contrast was then injected to confirm the lateral margin of the dural sac and the location of the exiting nerve root. The needle was pulled back and landed to the lateral edge of the superior articular process. The inferior part of the superior articular process was undercut to the medial pedicular line on the fluoroscopic anteroposterior image using a serial bone reamer or endoscopic drill. Then, a working cannula and an endoscope are inserted along the reamed hole. Laser and drill can be used to remove remnant osseous fragments and the ligamentum flavum to expose the traversing nerve root and extruded disc. In the epidural space, a probe can be used to dissect between the ipsilateral herniated disc and the traversing nerve root. Generally, the soft hernia mass is anchored by the fibrotic annular fissure. The annular anchorage can be loosened by the laser or scissors. After loosening the annular anchorage, ipsilateral herniated disc can be removed by forceps. After ipsilateral decompression, the annulus, posterior longitudinal ligament, and dura of the central zone are confirmed through an endoscopic view. After that, by using the levering technique to make the angle of approach of the endoscope more horizontal, observe the undersurface of the annulus and check the herniated route of the disc. After Dissection between the herniated disc and the dura using a probe, perform central decompression. The endoscopic working cavity becomes wider, and the undersurface of the annulus in the contralateral portion and the herniated route of the disc can be identified. After that, the disc of the contralateral portion is removed using a navigable or straight forceps. Finally, the epidural pulsation can be checked using the valsalva maneuver, and the decompressed ipsilateral traversing nerve root, central dura, and contralateral traversing nerve root can be directly observed through the endoscopic field of view (Fig. 11).

3.4 Commentary

Lumbar disc herniation is mostly central or unilateral herniation and causes unilateral leg pain along with back pain. On the one hand, patients with bilateral disc herniation may exhibit bilateral symptoms due to compression on both sides of the nerve. In these patients, if leg or back pain persists without response to conservative treatment or there is a neurological deficit such as

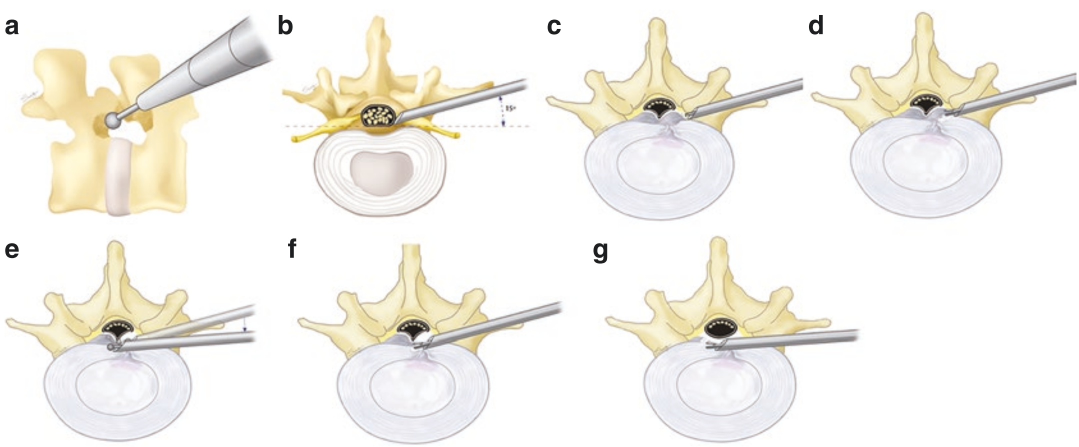

Fig. 11 Schematic illustrations of endoscopic discectomy for bilateral lumbar disc herniation. (**a**, **b**) Extreme lateral transforaminal approach. (**c**) Removal of the ligamentum flavum in lateral portion. (**d**) Ipsilateral decompression of the herniated disc. (**e**) Identification of the herniated route and dissection between the central dura and herniated disc. (**f**) Central decompression. (**g**) Contralateral decompression of the herniated disc

motor weakness or sensory loss, surgical treatment is required.

Current gold standard of surgical management for bilateral disc herniation is open discectomy after bilateral laminectomy. But chronic low back pain and postoperative spinal instability might occur in patients with bilateral disc herniation due to heavy loss of the nucleus pulposus and large annular defect from herniation [44, 45]. Disc excision from bilateral laminectomy may cause injuries to posterior supporting structures such as facet joint, ligaments, muscles, and annulus fibrosus [46, 47]. The necessity of spinal fusion in these patients has been a subject of controversy [48, 49].

Transforaminal endoscopic lumbar discectomy (TELD) is a minimally invasive spinal technique and has many advantages compared with open lumbar discectomy such as quick rehabilitation, reduced surgery-induced tissue injury, facilitation of revision operations, and relative preservation of intervertebral disc height [50, 51], and this procedure is widely performed by spine surgeons because it requires no general anesthesia or admission to a hospital. In this chapter, the author describes a new technique for endoscopic fragmentectomy using a unilateral transforaminal approach for the treatment of bilateral herniated discs, which preserves non-pathologic disc tissues by avoiding removal of intradiscal nucleus and cutting of annulus tissue.

Several authors have reported the clinical results of endoscopic treatment in patients with bilateral radiculopathy due to large disc herniation. The study they reported focused on patients with half-moon-shaped large disc herniation located in the central zone and approached the side with the most severe symptoms to decompress the herniate disc. Our cases differs from theirs in the following points.

First, in the previous study, the disc to be removed was located in the central zone. In this study, decompression was performed on the disc located from the ipsilateral subarticular zone to the central zone and the contralateral zone.

Second, while the previous study focused on patients with half-moon shape large disc herniation, this study aimed at patients with double-humped shape or multiple fragments.

Third, in this study, for access to the contralateral side, ipsilateral vertical foraminal widening was performed after the extreme lateral approach to secure working mobility, and the decompression was performed after direct visualization of the neural element of the contralateral side using a levering technique. With the existing conventional approach, it was difficult to decompress the contralateral zone.

Fourth, in this study, the approach was determined from the side with the annular tear point. In the previous study, the approach was decided on the symptomatic side, but in this study, ipsilateral decompression was performed after approaching the annular tear site, and contralateral decompression was performed after dissection after finding the herniated route, regardless of the severity of symptoms.

This technique has the following advantages.

First, bilateral decompression is possible through a unilateral approach under local anesthesia. Therefore, compared to the conventional treatment method, the operation time is short and it can show less blood loss. This can be safely performed in medically compromised patients or old age patients. Second, it is possible to preserve the annulus as much as possible by not creating an iatrogenic annular window by approaching the annular tear point. In addition, since bilateral laminectomy can be avoided, facet joint damage is minimal and postoperative instability can be minimized.

Third, decompression is possible without nerve traction while directly observing the ipsilateral traversing, central dura, and contralateral traversing nerve roots located in the ventral portion in the endoscopic view at the same time. In open lumbar discectomy, the traversing nerve root and dura located in the dorsal portion of the ipsilateral side can be observed, but the traversing nerve root or central dura of the ventral part is difficult to observe without nerve traction, and the contralateral traversing nerve root cannot be observed either.

4 Calcified or Hard Disc Herniation

Sang-Ha Shin

Abstract Hard or calcified discs are often adherent to surrounding nerve tissue. The whole herniated disc is difficult to remove by pulling part of the hernia mass, which makes obtaining good results through endoscopic treatment difficult. We describe the details of the transforaminal endoscopic lumbar discectomy technique for a hard or calcified disc in this chapter. We conclude that transforaminal endoscopic discectomy could be an effective treatment method for a selected group of patients with hard or calcified lumbar disc herniation.

Keywords Hard disc; Calcified disc; Lumbar disc herniation; Endoscopic discectomy

4.1 Presentation of the Patient and Illustrated Cases

Case 1 (Calcified Disc Herniation)
A 30-year-old female patient presented with left posterior radiating leg pain for 3 months. MR image showed a calcified disc herniation which compressed neural structures at L5-S1 (Fig. 12a). After transforaminal endoscopic discectomy, the patient's symptoms were relieved and MR image showed complete removal of calcified herniated disc (Fig. 12b).

Case 2 (Hard Disc Herniation)
A 24-year-old male patient presented with left posterolateral leg pain. MR images showed a hard disc herniation with neural compression at L4-5 level (Fig. 13a). The patient underwent transforaminal endoscopic discectomy. After surgery, the patient's symptoms improved.

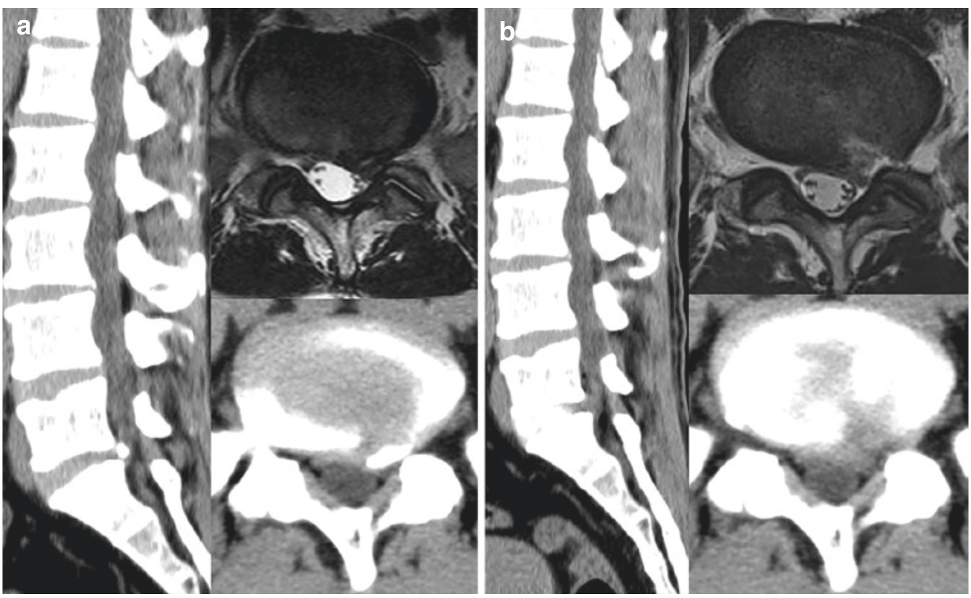

Fig. 12 Illustrative case of calcified disc herniation. (**a**) Preoperative computed tomography (CT) and magnetic resonance (MR) images showing a calcified disc herniation. (**b**) Postoperative CT and MR images showing decompression of the calcified disc

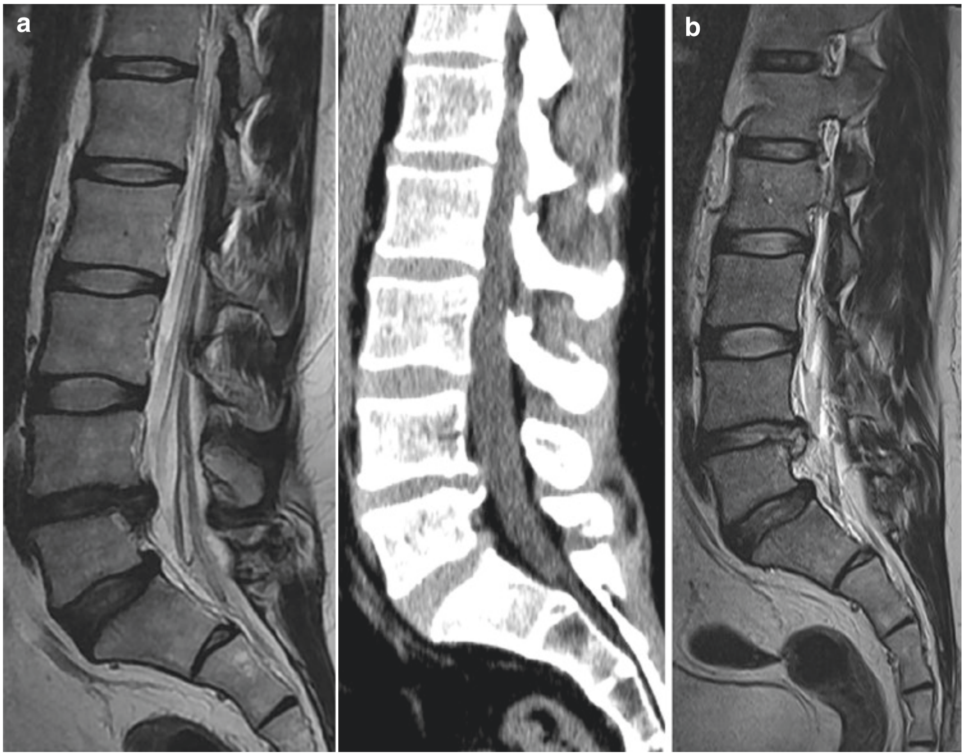

Fig. 13 Illustrative case of hard disc herniation. (**a**) Preoperative CT and MR images showing hard disc herniation. (**b**) Postoperative MR image showing decompression of the hard disc

Postoperative MR image confirmed complete decompression of hard herniated disc (Fig. 13b).

4.2 Preoperative Planning

4.2.1 Calcified Disc Herniation

The distance from the midline to the skin entry point was calculated using a preoperative axial MRI and was approximately 8–14 cm. The approach angle was approximately 30° in the horizontal section of the axial image (Fig. 14a, b).

4.2.2 Hard Disc Herniation

For hard discs, a foraminoplastic approach is required to reach the migrated portion. If the approach angle is 30°, the target is difficult to reach without significant resection of the facet joint. In this study, foraminoplasty was performed through the extreme lateral approach to reach the target. The access angle approaches approximately 15° in the horizontal plane of the axial image. The distance from the midline to the skin entry point was calculated via axial MRI evaluation. The distance is approximately 13–17 cm, which is farther than the distance of a typical transforaminal approach. The craniocaudal skin entry point was determined parallel to the disc space because it provides the best working mobility vertically during dissection.

4.3 Surgical Steps

4.3.1 Calcified Disc Herniation

After landing the working cannula into the disc using a transforaminal route, internal decompression of the degenerated disc is first performed to secure the empty space (Fig. 14c). Unlike soft disk herniation, calcified disc herniation usually does not fall into the decompressed intradiscal space even after internal decompres-

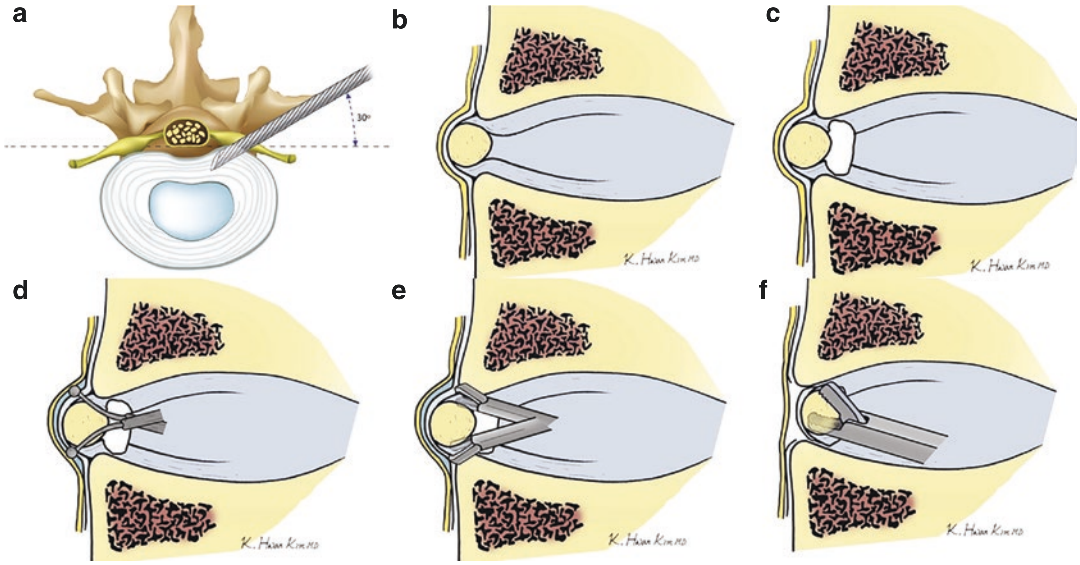

Fig. 14 Schematic illustrations of endoscopic discectomy for calcified lumbar disc herniation. (**a**) Conventional transforaminal approach. (**b**) Approach to the disc space. (**c**) Internal decompression of the degenerated disc. (**d**) Dissection between the traversing nerve root and the calcified disk. (**e**) Cutting the annulus along both the upper and lower end plates. (**f**) Removal of the calcified disc using forceps

sion. The decompressed intradiscal space provides a wide field of view for epidural dissection and allows the calcified disc to be dropped into the decompressed space after dissection, to facilitate removal. After internal decompression, the working cannula is pulled back and placed in the epidural space. At this moment, the herniated disc can be visible in the endoscopic view, but the traversing nerve root may be difficult to observe because of the dorsal lifting by the herniated disc. By using the levering technique, the traversing nerve root can be identified after moving the working cannula to the dorsal side. Then, at the discal level, dissection is performed between the traversing nerve root and the calcified disc along the upper and lower end plates by using a probe (Fig. 14d). If epidural bleeding occurs during the dissection, the visual field may become cloudy, and care should be taken for hemostasis. Pain may be induced when the nerve is touched, and pain control may be required using intravenous analgesics. The calcified disc and traversing nerve root are separated through dissection from the annular window to the central zone. The annulus is then cut from the annular window of the foraminal zone to the central zone by using endoscopic scissors (Fig. 14e). The calcified disc is then dropped into the decompressed intradiscal space, and the distal part of the herniated disc is cut using a laser or bipolar coagulator and then removed using forceps (Fig. 14f). The calcified disc can be successfully removed without foraminoplasty by using this technique.

4.3.2 Hard Disc Herniation

The lateral edge of the superior articular process is approached using an 18-gauge introducer needle in the prone position under local anesthesia. The inferior part of the superior articular process undercuts the medial pedicular line on the fluoroscopic anteroposterior image by using a serial bone reamer or endoscopic drill (Fig. 15a). Then, a working cannula and an endoscope are inserted along the reamed hole (Fig. 15b). Laser and drill can be used to remove remnant osseous fragments and the ligamentum flavum to expose the traversing nerve root and extruded disc (Fig. 15c, d). Internal decompression of the degenerated disc in the disc space is first performed to secure

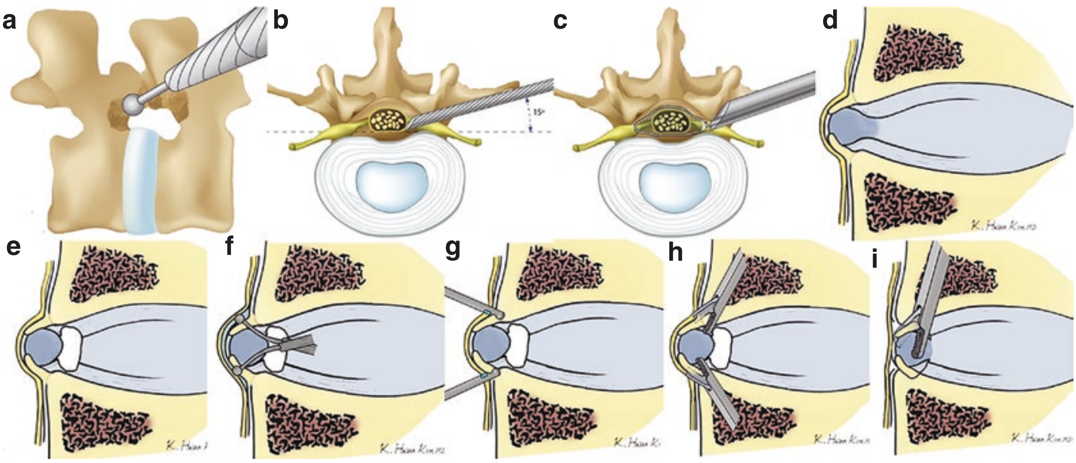

Fig. 15 Schematic illustrations of endoscopic discectomy for hard lumbar disc herniation. (**a**, **b**) Extreme lateral transforaminal approach. (**c**) Removal of the ligamentum flavum. (**d**) Approach to the disc space. (**e**) Internal decompression of the degenerated disc. (**f**) Dissection between the traversing nerve root and the hard disc. (**g**) Thinning of the hard disc using laser. (**h**) Breakage of the hard disc. (**i**) Removal of the hard disc using forceps

the intradiscal space in which the herniated disc can be dropped later (Fig. 15e). In the epidural space, a probe can be used to dissect between the traversing nerve root and the hard disc (Fig. 15f). The laser probe is inserted between the hard disc and the traversing nerve root, the opening site of the side-firing laser is directed to the hard disc, the closing site is directed to the nerve, and the laser is used to thin the hard disc (Fig. 15g). Endoscopic scissors are then used to break the hard disc (Fig. 15h). Forceps are used to pull the broken hard disc down into the decompressed disc space and remove it (Fig. 15i). Hard disc herniation can be successfully removed using the foraminoplastic approach through the above-mentioned technical method (Video 2).

4.3.3 Foraminal Hard Disc Herniation

In patients with foraminal hard disc herniation, the distance from the midline to the skin entry point is closer, and the approach angle to reach the target point is steeper than that in the case of intracanalicular herniation. The distance from the midline to the skin entry point, calculated on preoperative MRI, is approximately 6–10 cm, and the approach angle is approximately 40–70°. As with intracanalicular disc herniation, a working cannula is inserted in the disc space, and internal discal decompression is performed first. The working cannula is then withdrawn from the disc space and placed in the annular window, where the working cannula can move freely in all directions. Then, punch is used to remove the foraminal ligament to identify the exiting nerve root, and a probe is used to dissect between the hard disc and the exiting nerve root. The laser is inserted between the nerve and the hard disc, making the hard disc thin. Then, the hard disc is broken using scissors and removed using forceps.

4.4 Commentary

A hard disc is defined as a disc containing calcification or ossification in the displaced portion of the herniated disc and is often associated with apophyseal osteophytes. A calcified disc is defined as calcification within the disc space, excluding the disc at the periphery of the disc space [52]. Chronic inflammatory reactions to herniated disc can cause calcification. Calcification usually occurs when herniated discs last >6 months [53]. Hard or calcified discs are often adherent to surrounding nerve tissue. As the whole herniated disc is difficult to remove by pulling part of the hernia mass, obtaining good results through endoscopic treatment is difficult [54, 55].

Since Kambin and Gellman introduced the concept of posterolateral percutaneous lumbar disc decompression in 1983, endoscopic discectomies have been developed into effective treatment methods for selected groups of patients with disc herniation [56]. Endoscopic discectomy can be performed under local anesthesia, is associated with rapid recovery, does not require excessive bone and joint tissue resection, and minimizes postoperative spinal instability [57]. Indications for endoscopic discectomy are becoming increasingly widespread owing to the increasing patient demand and development of endoscopic devices [58–60]. The surgical results of endoscopic discectomy in selected cases have been reported to be similar to those of conventional open discectomy [61, 62]. However, compared with open surgery, endoscopic treatment is difficult to apply for all forms of disc herniation because of the small operating field, limited equipment available, and limited working mobility. Therefore, determining the appropriate indication to obtain successful surgical results is highly important.

Ruetten et al. [63] reported a 2-year follow-up of endoscopic discectomy in 232 patients with lumbar disc herniation. After 2 years of surgery, 84% of the patients had no further leg pain, and 12% had occasional pain. However, 21 patients with hard-tissue compression had poor results. Of the 21 patients, 6 had additional open decompression and 4 required fusion surgery. Back pain and symptom duration for longer than 6 months showed a significant relationship with hard-tissue compression. A hard or calcified disc was difficult to treat using endoscopy for the following reasons: First, hard disc herniation usually has a long duration of herniation, which is often accompanied by severe adhesion to surrounding nerve tissue. Second, unlike soft disc herniation, the herniated mass does not drop into the decompressed space after internal decompression of the degenerated disc, making it difficult to reach the target to be removed. Third, it is not removed by pulling after just grasping the tip of the hernia mass. For these reasons, endoscopic removal of hard disc herniation was difficult. To date, the practical application of endoscopic discectomy has been limited to soft disc herniation, and the successful outcome of endoscopic treatment for hard disc herniation has hardly been reported. In this study, successful surgical results were obtained in patients with hard disc herniation using the new surgical technique.

Some authors reported the results of endoscopic discectomy for partially calcified discs [53, 64]. The conventional transforaminal approach was used to decompress the calcified disc. The use of the extreme lateral approach to preserve facet joints differs from previous studies. In our clinical series, patients with hard or calcified disc improved back and leg pains and did not show major complications such as hematoma, infection, and neurological deficit after endoscopic treatment. These results are comparable with those of other published decompression techniques [53, 64–67].

Endoscopic discectomy has the following advantages to open discectomy in patients with hard disc herniation: First, sophisticated dissection can be performed with simultaneous viewing of anatomical structures such as the dura, posterior longitudinal ligament, annulus, and herniated disc through an endoscopic view. Thus, the risk of nerve injury can be reduced. Second, nerve retraction is minimized because dissection is performed using an obtuse angle. In the posterior lateral endoscopic approach, the dissection angle between the nerve and disc is approximately 150–165°. This is different from open discectomy, which requires a sharp angle dissection. Third, in the case of severe adhesion between the dura and the posterior longitudinal ligament, only the annular calcification can be selectively removed while leaving the posterior longitudinal ligament, reducing the risk of dural tears. In the case of open discectomy, the posterior longitudinal ligament and extruded disc are removed simultaneously after dissection between the nerve root and posterior longitudinal ligament. However, in the case of endoscopic discectomy, the extruded disc can be selectively removed, leaving the posterior longitudinal ligament.

Endoscopic treatment of hard discs has the following limitations: First, hard disc extrusion should not compromise >50% for the spinal canal. In the case of soft disc herniation, most herniated discs can be removed because the herniated mass tends to drop into the decompressed space after internal discal decompression. In the case of a hard disc, the herniated mass does not move to the decompressed space even after internal discal decompression and thus requires foraminoplasty to approach the target. However, if the canal cross-sectional area compromises >50% of the hard disc, reaching the dissection plane to the target without significant resection of the facet joint is difficult. Second, the transforaminal route is difficult to access in patients with high iliac crest at the L5/S1 level. In such cases, an interlaminar approach can be considered. Third, the hard disc located bilaterally is difficult to remove with only one side access. Fourth, primary repair is difficult when dural tear occurs during the procedure.

We conclude that transforaminal endoscopic discectomy could be an effective treatment method for selected groups of patients with hard or calcified lumbar disc herniation. It can be performed under local anesthesia and has a short operative time and less blood loss.

5 Double Compartment Herniation

Shin-Jae Kim and Sang-Ha Shin

Abstract As the technical skill of TELD advances, its indication is also expanding. When encountered a case in which paramedian disc protrusion and extra-foraminal disc protrusion coexisted, we thought of decompression or TLIF surgery first. However, these cases can also be resolved using TELD. Key point of this technique is to decompress the paramedian protruded disc first, and after the working space becomes sufficiently flexible, the extra-foraminal lesion is secondarily decompressed [68, 69].

Keywords Endoscopy; Transforaminal endoscopy; TELD; Double compartment herniation

5.1 Introduction

TELD usually targets only one of the paramedian discs or extra-foraminal discs. In case of patients who have been diagnosed with two types of discs at the same time, open microscopic decompression surgery is considered rather than TELD. This chapter introduces the technical skill that can remove both of these discs at the same index level.

5.2 Indications

Paramedian disc and extra-foraminal disc at the same index level.

5.3 Surgical Technique

The standard paramedian TELD approach (inside-out technique) is as follows [70, 71]:

1. The patient is placed in a prone position with some lumbar flexion.
2. IVG anesthesia is applied after aseptic preparation.
3. An 18G needle is inserted into the disc space 12 cm away from the midline.
4. Discography is done to confirm concordant pain.
5. Serial dilation and insertion of the obturator and working channel are done under C-arm fluoroscopy.

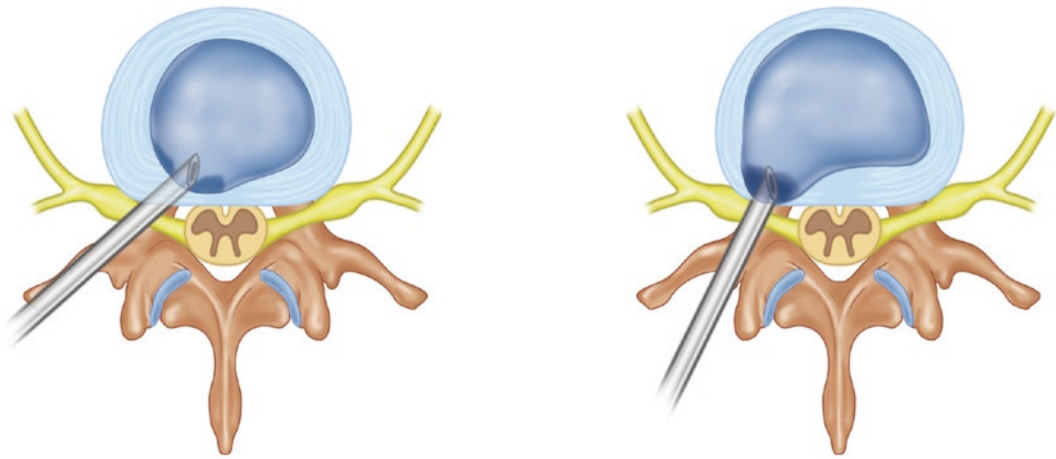

Fig. 16 (1) Approaching the paramedian lesion first. (2) Secondary approach to extra-foraminal lesion

6. Confirmation of appropriate position of the working channel is done using AP and lateral fluoroscopy.
7. Disc herniation is confirmed and removed using side-firing laser and pituitary forceps until satisfactory decompression is done.
8. After confirming adequate decompression, injection of mixed solution of dexamethasone and lidocaine is done through the working channel before removal.
9. Finally, subcuticular sutures are done. All procedure is done under full communication with the patient.

TELD starts to the target of paramedian disc at first stage. After decompression of the paramedian part, space inside the annulus gets flexible sufficiently to move the cannula. After cannula withdrawal, the convergence of the cannula should be steeper and targeted the extra-foraminal area of the disc (Figs. 16 and 17) (Video 3). Since the convergence of the cannula should be steeper than the inside-out technique, this might contain a higher risk of exiting root injury. "Rotate to retract technique [72]" is useful for safe retraction and decompression of the exiting neural structures (Fig. 18).

5.4 Case Illustration

A 44 year-old male patient with left leg numbness and radiating pain which started from 3 months ago and aggravated from 3 days ago visited hospital. Left paramedian disc protrusion with extra-foraminal disc protrusion on L5-S1 level was diagnosed (Fig. 19). Considering patient's age and radiographic finding, TELD with both lesion decompression was done (Fig. 20).

5.5 Summary

Paramedian disc and extra-foraminal disc at the same index level can be removed with TELD at the same time. Paramedian disc should be approached first and extra-foraminal disc after the working space gets flexible.

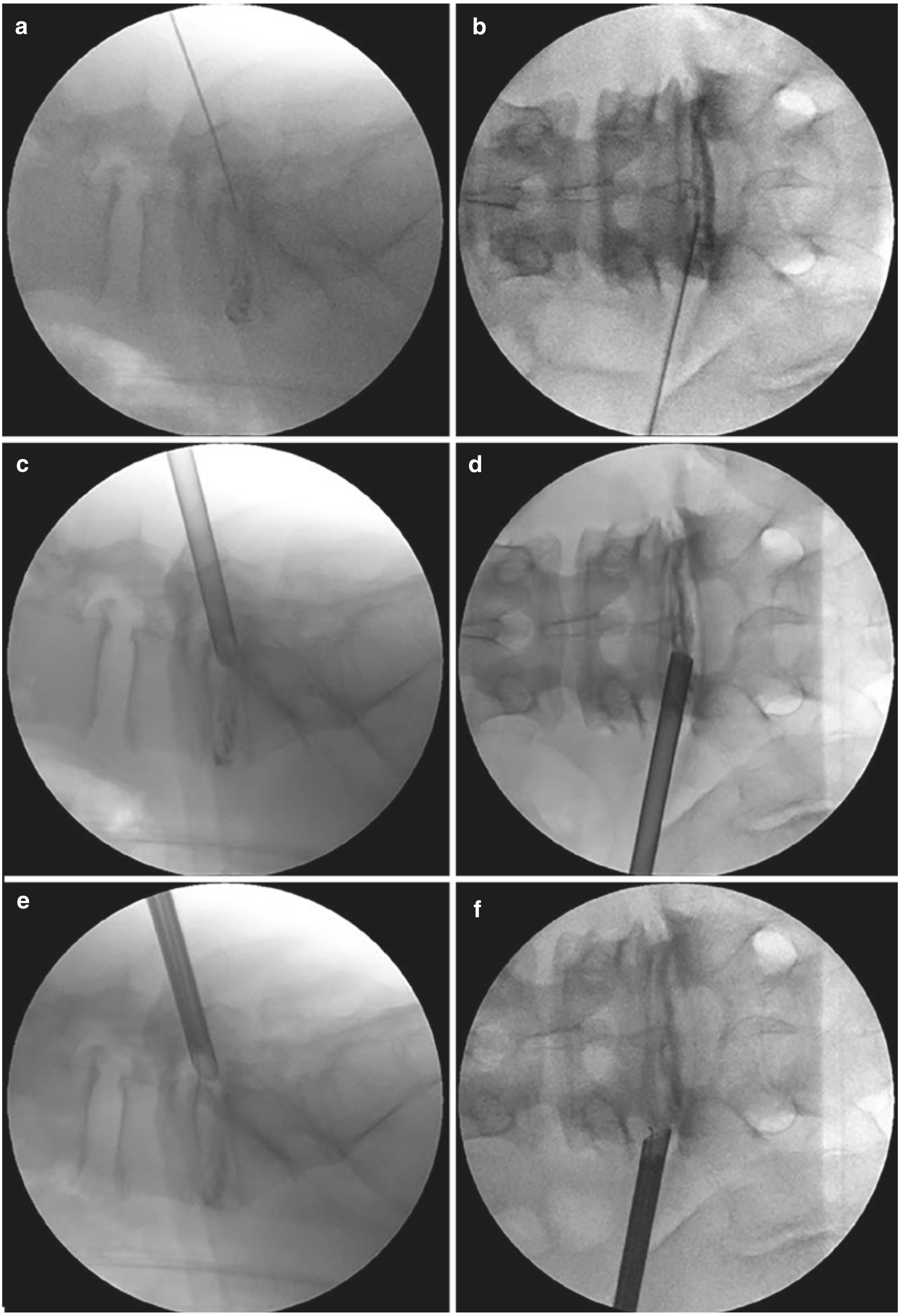

Fig. 17 C-arm images show the approach of the endoscope. (**a**, **b**). Indo carmine dye injection. (**c**, **d**). Working cannula is inserted and para-central inner annulus decompression is done at the first stage. (**e**, **f**). After para-central decompression is done, working cannula is pulled and inserted more steeply to reach the extra-foraminal annulus

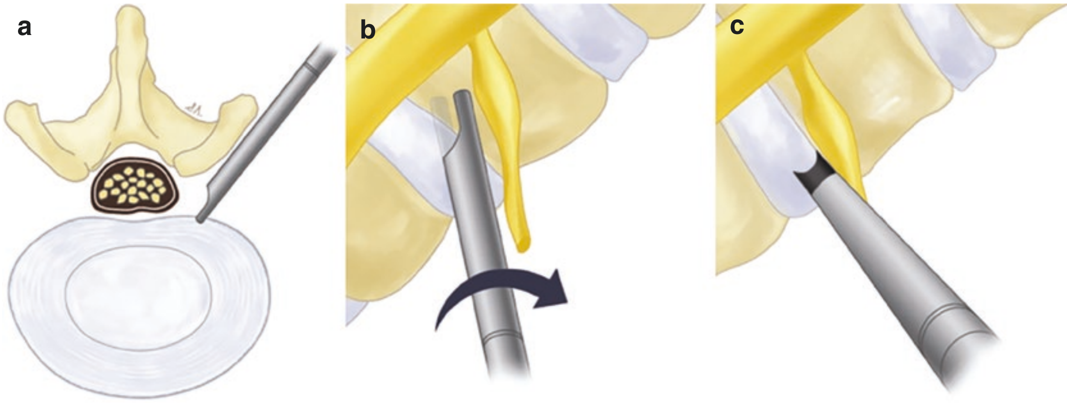

Fig. 18 (**a**) The working cannula is slightly pulled out until it is located outside the annulus. (**b**) The tip of the working cannula is rotated clockwise, which resulted in spontaneous retraction of the exiting nerve root. (**c**) The tips of the working cannula are placed laterally, which may retract the exiting root. Devices inserted through the opening side may remove the disc fragment safely

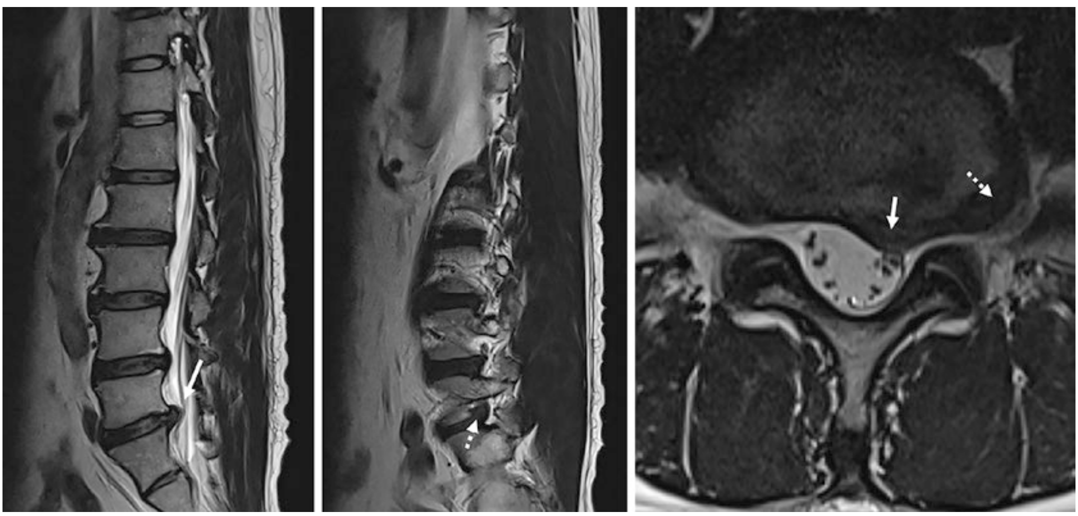

Fig. 19 Pre-operative MRI images show para-central disc protrusion (white arrow) and extra-foraminal disc protrusion (white dot arrow) on L5-S1 level

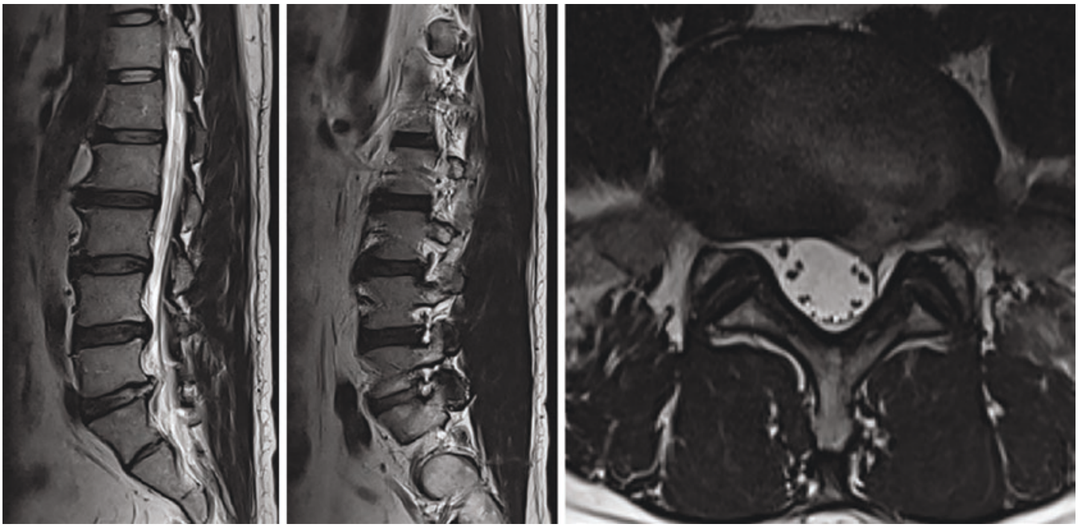

Fig. 20 Post-operative MRI images show that both the para-central and extra-foraminal protrusion disc are well removed

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