Endoscopic Effort to Overcome Anatomical Barriers at L5/S1 Level

Ju-Wan Seuk, Hyun Jin Ma, and Junseok Bae

1 Preoperative Trajectory Evaluation and Foraminoplastic Ventral Epidural Approach

Ju-Wan Seuk

Abstract Transforaminal endoscopic lumbar discectomy (TELD) for L5-S1 disc herniation is regarded as challenging due to the unique anatomy of the iliac crest, large facet joint, and inclinatory disc space. Among these, the iliac crest is considered a major obstacle. In this chapter, we describe preoperative trajectory evaluation method avoiding high iliac crest and foraminoplasty for L5-S1 TELD.

Keywords Endoscopic discectomy; Transforaminal approach; L5S1; Iliac crest; Foraminoplasty

1.1 Introduction

L5-S1 TELD may sometimes be challenging and cannot be performed successfully in patients due to some factors. L5-S1 TELD is a demanding procedure because of the oblique trajectory created by the iliac crest and narrow foramen that is hindered by the L5 transverse process, the hypertrophic L5-S1 facet joint especially S1 superior articular process, and the sacral ala [1, 2]. Among these, the iliac crest is considered a major obstacle. So, in high and narrow iliac crest cases, interlaminar endoscopic lumbar discectomy or open lumbar microdiscectomy is considered to be a better surgical option. However, even in such a case, successful results can be obtained if proper trajectory evaluation and procedure are taken. In this chapter, we describe preoperative trajectory evaluation method avoiding high iliac crest and foraminoplasty for L5-S1 TELD.

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1.2 Indications

- Symptomatic soft disc herniation without calcification that does not respond to conservative treatment at L5S1 level.
- High and narrow iliac crest.
- Narrow foraminal dimension due to hypertrophied facet joint especially superior articular joint.

1.3 Evaluation

The skin entry point and trajectory of the endoscope were planned based on the axial images of MRI. In general, the entry point is located about 9–12 cm from the midline and the trajectory should pass cranial to the superior articular process and lateral to the isthmus. So, imagine a general trajectory on MRI and determine the approximate entry point location.

Eun et al. [3] introduced tilted axial images of the MRI or CT can help us determine whether or not the iliac crest blocks the working channel's trajectory. A new tilted axial and coronal MRI or CT scan is performed according to axis of L5-S1 transforaminal working channel, so the images show good relationship between working channel and iliac crest.

Bae et al. [4] introduced the isthmic approach in which the trajectory should pass cranial to the superior articular process and lateral to the isthmus. The isthmic approach offers a safe and effective anatomical corridor for performing endoscopic discectomy via transforaminal route, even in individuals with high iliac crest.

However, there can be the case that inability to place a working cannula ventral epidural space near the disc fragment because of an anatomic barrier can lead to surgical failure and revision open surgery. The superior articular process (SAP) should be the main obstacle in transforaminal endoscopic approach to the dural sac and nerve root in the spinal canal. To overcome this hurdle, foraminoplasty can be considered, allowing the working cannula access near the ruptured disc particle at epidural space. So, foraminal widening techniques, foraminoplasty, help surgeons access the epidural space, allowing visualization of hidden disc fragments and decompression of foraminal or lateral recess stenosis.

1.4 Surgical Technique

1.4.1 Foraminoplasty Using a Bone Reamer or Bone Cutter

The spinal needle was placed superior to the pedicle of the lower vertebra. A guide wire was located at the posterolateral margin of superior facet (Fig. 1). A tapered cannulated obturator was inserted along the guide wire (Fig. 2). A beveled working cannula was introduced along the obturator and then the obturator was leaned against the root, which is safe (Fig. 3). A reamer kit (TESSYS, Joimax GmbH, Karlsruhe, Germany) was advanced to the medial pedicle line serially, using large diameter reamers. Or with the bone cutter, 5-mm or 7-mm bone cutter (Arthro Kinetics PLC, Park Green, Macclesfield, U.K.) was inserted through the working cannula depending on the amount of bone to be removed. The endoscopic bone reamer and bone cutter could be advanced safely through the working cannula until the medial pedicular line was reached on the fluoroscopic anteroposterior view. After removing the superior facet and widening the intervertebral foramen, the working cannula was placed below the disc fragment.

1.4.2 Foraminoplasty Using an Endoscopic Drill

A tapered cannulated obturator was inserted along the guide wire. The cannula was placed outside of the foramen and the lateral border of the facet joint. An endoscopic drill (Primado2, Nakanishi Inc., Japan) was used to remove the part of the superior articular process. From the outside to the inside of the foramen, the facet joint and foraminal ligament were partially removed using a drill, cutting forceps, and an endoscopic Kerrison punch, while engaging the working cannula in the medial foraminal zone to undercut the superior facet.

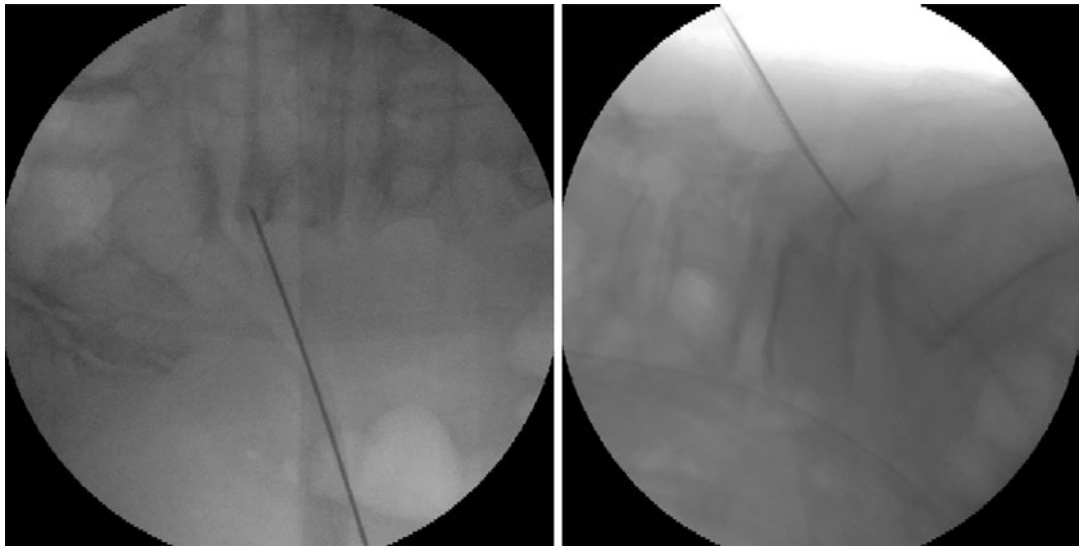

Fig. 1 Guide wire was located at the posterolateral margin of superior facet

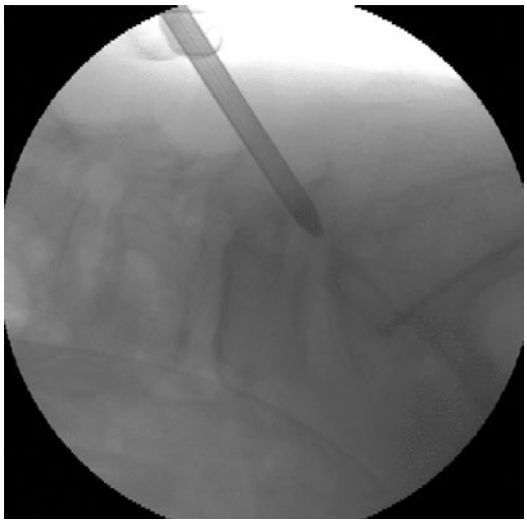

Fig. 2 A tapered cannula obturator was slid over the guide wire

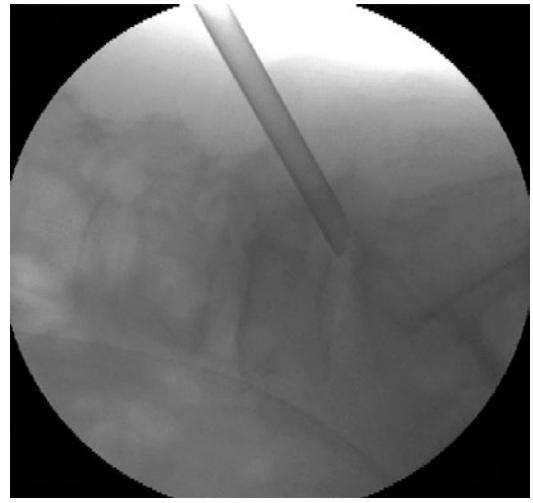

Fig. 3 A beveled working cannula was introduced along the obturator, surrounding the superior facet and leaning against the root, which is safe

1.5 Summary

TELD has several advantages compared to open surgery, such as less injury to the normal structure and more rapid recovery. However, TELD may be difficult to perform in the presence of anatomical limitations such as narrow foramen, high iliac crest, large facet joint, and inclinatory disc space at the L5S1 level [5, 6]. Such anatomical constraints may dictate preference for interlaminar technique or open surgery [7, 8]. However, the foraminoplasty technique allows expansion of the foramen and easy access to the accurate target. Finally, as the working space becomes wider, the possibility of nerve damage is reduced and access to the epidural space becomes possible.

2 Transiliac Approach

Hyun Jin Ma

Abstract Percutaneous endoscopic lumbar discectomy for L5–S1 pathology is sometimes challenging due to the complex anatomy of the iliac crest, large facet joint, large transverse process, sacral ala, narrow foramen, and inclination of disc space. Out of these, the high iliac crest can be a major obstacle. If the iliac crest is high in L5–S1, sometimes L4–5, they cannot be accessed by suprailiac approach because disc space is located deep in the pelvis.

Endoscopic transiliac approach can be a good approach for patients with high iliac crest.

Keywords Transiliac; Transforaminal; Lumbar endoscopic discectomy; Iliac crest

2.1 Introduction

Percutaneous posterolateral endoscopic lumbar disc decompression was first introduced in 1983 by Kambin. Since then, endoscopic techniques have rapidly evolved with development of instruments such as endoscope, laser, working cannula, and radiofrequency probe. Percutaneous posterolateral endoscopic surgery has several advantages compared to open surgery, such as less injury to paraspinal muscle, normal tissue, preservation of bony structure, more rapid recovery, and encounter pathology before meeting neural structures that makes less complication [9]. In contrast to other lumbar vertebral levels, L5-S1 level has unique anatomical features as follows: high iliac crest, sacral ala, large facet joint, large transverse process, inclination of disc space, and narrow foramen. The high iliac crest is one of the most challenging aspects of the transforaminal approach to the L5-S1 level and some patients at the L4-5 level [10]. And many authors suggest that high iliac crest can be a major obstacle in transforaminal endoscope at the L5-S1 level and even at the L4–5 level [11–13]. because iliac crest blocks optimal endoscopic pathway.

In the conventional suprailiac transforaminal approach, high iliac crest compels more medial and cephalad skin entry point. Medial skin entry point, medial to the medial border of the iliac crest, makes it difficult to approach the central pathology. The more cranial skin entry point increases the risk of the exiting nerve root injury due to its downward trajectory and needs excessive foraminoplasty to approach centrally located pathology.

The cephalad skin entry point also makes failure to access to the up-migrated herniated fragment. At that time, posterior decompression such as endoscopic interlaminar approach or open microscopic surgery is needed to access the pathology, but posterior approach encounters neural structure before the removal of pathology, so sometimes it needs excessive neural retraction and manipulation that can make nerve damage such as durotomy, cauda equina injury, and postoperative dysesthesia. To meet pathology before neural retraction, transforaminal approach is needed, and to access the pathology through optimal endoscopic pathway transforaminally, transiliac approach is needed. In the transiliac PELD, accurate placement of the transiliac channel is the most important part. During the preparation of the iliac channel, there is possibility of injury to the superior gluteal vessels, superior cluneal nerves, and sacroiliac joint [14, 15]. Osman and Marsolais studied a cadaver on the endoscopic transiliac approach for L5–S1 in 1997 and found it to be feasible and safe [15]. At L4–5 level, if pathology is up-migrated disc herniation, endoscopic trajectory needs caudocephalic angle. It makes the skin entry point more inferior that mandates a transiliac approach [16]. And at L5-S1 level, transiliac approach can make optimal pathway into the disc space in the line of inclination, and it allows easier direct targeting to the pathology. The only direct endoscopic approach for L5–S1 space is the transiliac approach. In patient with central or superiorly migrated herniations, transiliac approach can be the best way of approach [17–19].

2.2 Indications

In patients without instability, central canal stenosis, lateral recess stenosis, calcification of intervertebral disc, tumor, infection, severe lumbar deformity.

1. Unilateral radicular pain.
2. Failure of conservative treatment.
3. Intracanal L5-S1 disc herniation with high iliac crest.
   (The more disc located centrally, the more transiliac approach is mandated.)
4. Superiorly migrated herniations at L4-5 or L5-S1 with high iliac crest.

2.3 Surgical Technique

The major procedure is the same as TELD, but overcoming the iliac crest is the key to the surgical step. Accurate placement of the transiliac channel is the most important part during the whole procedure.

Under local anesthesia the patient is positioned prone over a radiolucent table with the guidance of C-arm fluoroscopy that anteroposterior (AP) and lateral images can be obtained. The skin entry point is generally 11–13 cm from the midline.

Sedate the patient with sedatives such as midazolam and fentanyl. The operator can communicate with the patient throughout the whole procedure that allows to notice damage to neural structures. Set C-arm fluoroscopy. If pathology is at L5-S1 centrally, to direct approach, determine the skin entry point in the line of inclination like iliac crest does not exist. The surgeon should not be overly concerned about the block of iliac crest as if there is no bone between the entry point to target point. If pathology is superiorly migrated at L4-5 or L5-S1, the entry point is caudal than the disc level while the target point is cephalic than the disc level in the AP view. This caudocephalic direction of the needle allows easy access to the superiorly migrated pathology. After infiltration of the entry point with local anesthetics, 6-in. 18-gauge needle is introduced posterolaterally down to the iliac bone (Fig. 4a). By rotating the needle with moderate pressure, the cortical bone of the ilium below the iliac crest can be perforated (Fig. 4b). The sclerotin of iliac crest is thin, so the resistance of puncture is small. The pressure of puncture should not be too much, so as to avoid excessive trauma like fracture [17]. Advance the needle into the epidural space. After withdrawing

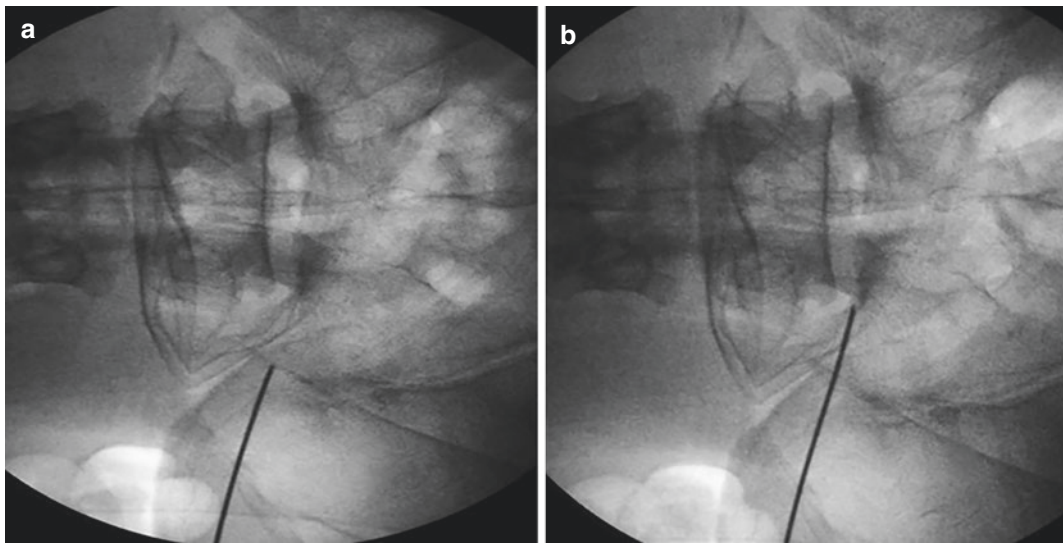

Fig. 4 (**a**) 18-gauge needle is introduced posterolaterally and touches iliac bone. (**b**) The cortical bone of the ilium is perforated and needle advanced to the facet joint

the stylet, infiltrate the epidural space with another anesthetics. Advance the needle further to the final target point on the disc. The final target point of the tip of spinal needle is the medial pedicular line on the AP view and the posterior vertebral line on the lateral view. If the targeted pathology is more centrally located, the tip of spinal needle can be targeted more medial to the medial pedicular line on AP view when the posterior vertebral line on lateral view. Advance the needle further into the disc space. Then perform discography with mixture of radio opaque contrast media, indigo carmine, and normal saline. Withdraw the stylet of the needle and insert blunt-tipped guide wire through the needle. Remove needle while guide wire is implanted. Insert sequential dilators to the ilium (Fig. 5). This sequential dilation enables muscle injury and neurovascular damage can be avoided. In the iliac bone, enlarge the channel by bone reamers along the guide wire (Fig. 6). Most of the working cannula have an outer diameter of 8 mm, so iliac channel diameter is needed up to 8 mm. But if diameter is same between outer diameter of working cannula and iliac channel, endoscope can be stuck into iliac channel, so cannot adjust to migrated pathology (Fig. 7a). If required a levering technique that lets the working cannula tilt, reaming can be done up to 10 mm or sometimes over 10 mm. The enlarged channel can facilitate levering technique of the endoscope to the cranial, caudal, ventral, dorsal direction (Fig. 7b) and axis shifting (Fig. 7c) that allows enough working space to reach the superiorly migrated fragment and perform foraminoplasty easily to approach the centrally located pathology. When the ala of the sacrum or large facet joint interferes with the transforaminal approach, an endoscopic reamer can be used to trim these anatomical barriers. And then blunt-tapered cannulated obturator is inserted along the guide wire. On the surface of annulus, obturator is inserted into the disc by hammering (Fig. 8). Guide wire is removed while obturator is implanted in the disc. A bevel-ended working cannula is inserted into the disc along the obturator (Fig. 9a, b). Remove the obturator and finally insert the endoscope through the working cannula. After these procedures, rest of the procedure is same as conventional transforaminal endoscopic discectomy. When operation is finished, bone bleeding in the iliac bone or gluteal muscles can be confirmed by withdrawing the endoscope. Drain catheter is positioned from the disc to the skin through the iliac channel.

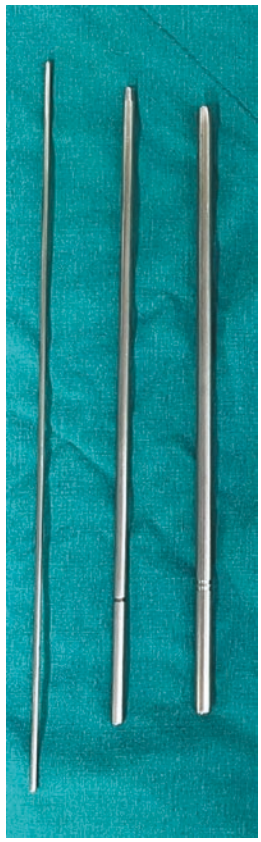

Fig. 5 Sequential dilators

2.4 Case Illustration

A 50-year-old male patient presented with radicular pain in the left gluteal area and posterior aspect of his leg. Positive straight leg raising sign was demonstrated on the left side. A plain radiograph showed the iliac crest at the

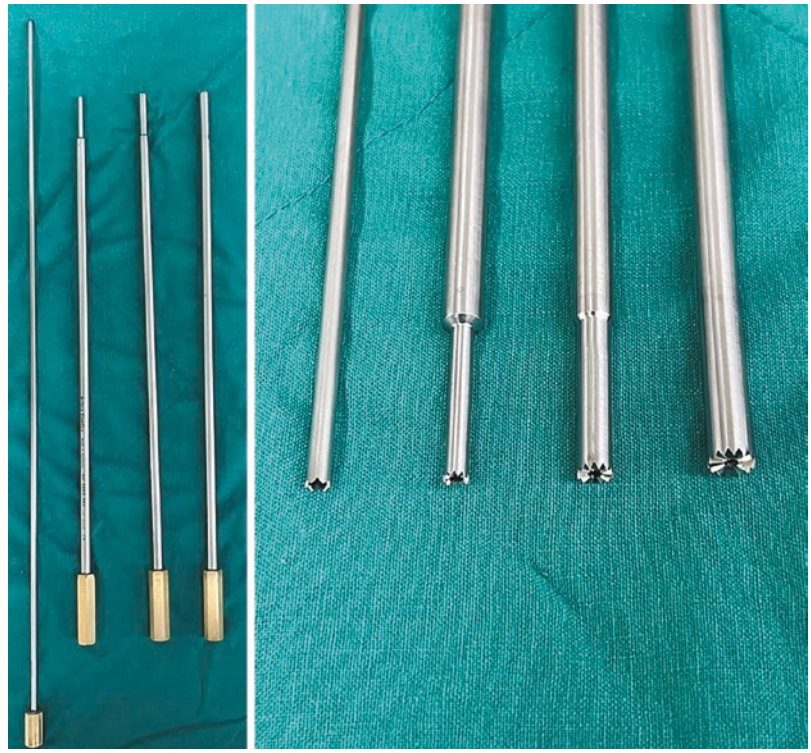

Fig. 6 Endoscopic bone cutters. These are cylindrical hollow instruments with sharp serrated ends for dilatating iliac channel

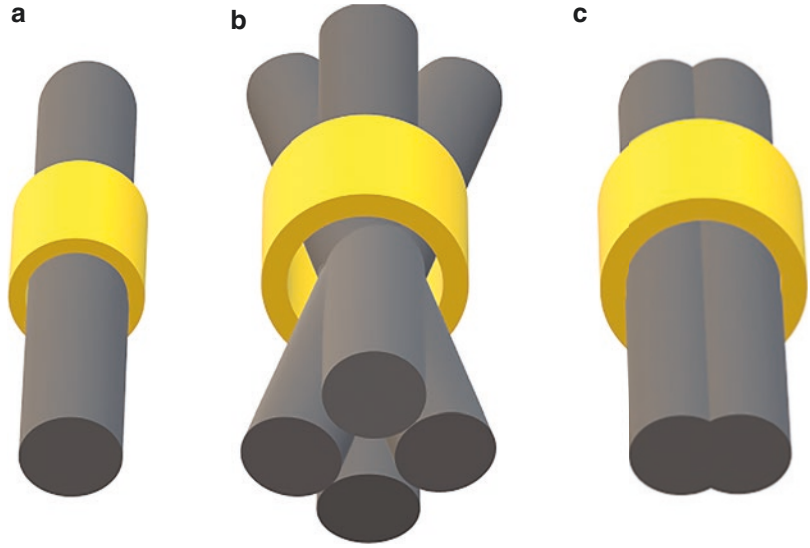

Fig. 7 (**a**) If diameter is same between outer diameter of working cannula and iliac channel, endoscope is stuck in the iliac channel, so cannot adjust directions. (**b**) The enlarged channel allows levering technique of the endoscope to the cranial, caudal, ventral, dorsal direction. (**c**) The enlarged channel allows axis shifting of the endoscope

level of the L4–L5 disc space (Fig. 10). Magnetic resonance imaging (MRI) of the lumbar spine showed left central inferiorly down-migrated disc herniation (Fig. 11). A computed tomography scan showed soft disc herniation. We performed a transforaminal percutaneous endoscopic lumbar discectomy via transiliac approach. Postoperative MRI showed the Lt. S1 root was successfully decompressed (Fig. 12). One slide above, channel made through the ilium and drain inserted through channel could be seen (Fig. 13).

2.5 Summary

Transforaminal posterolateral endoscopic surgery is a very safe procedure, because it allows to meet pathology before neural retraction. But in L5-S1 level, sometimes L4-5 level, high iliac crest is a major obstacle. In patients with high iliac crest, transiliac approach is a best way because it can overcome the blocking of iliac crest and approach the pathology directly and safely.

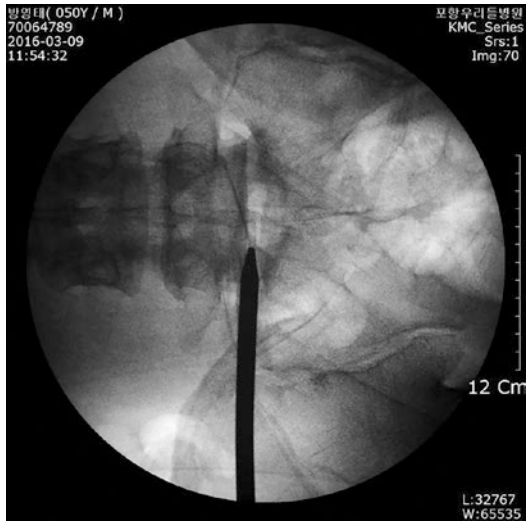

Fig. 8 Obturator is inserted into the disc

Fig. 10 A plain radiograph showed the iliac crest at the level of the L4–L5 disc space

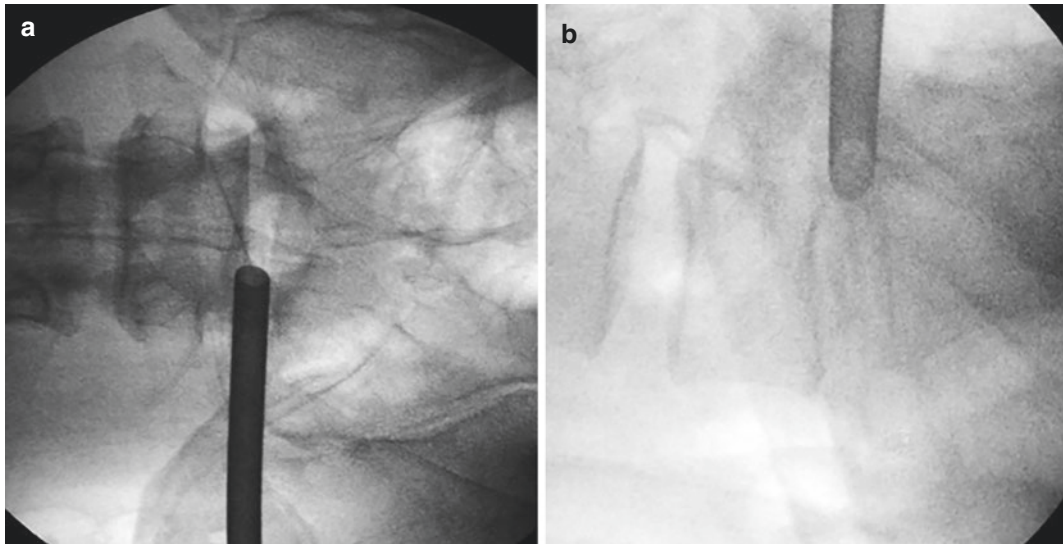

Fig. 9 (**a**) Anteroposterior view of working cannula inserted into the disc. (**b**) Lateral view of working cannula inserted into the disc

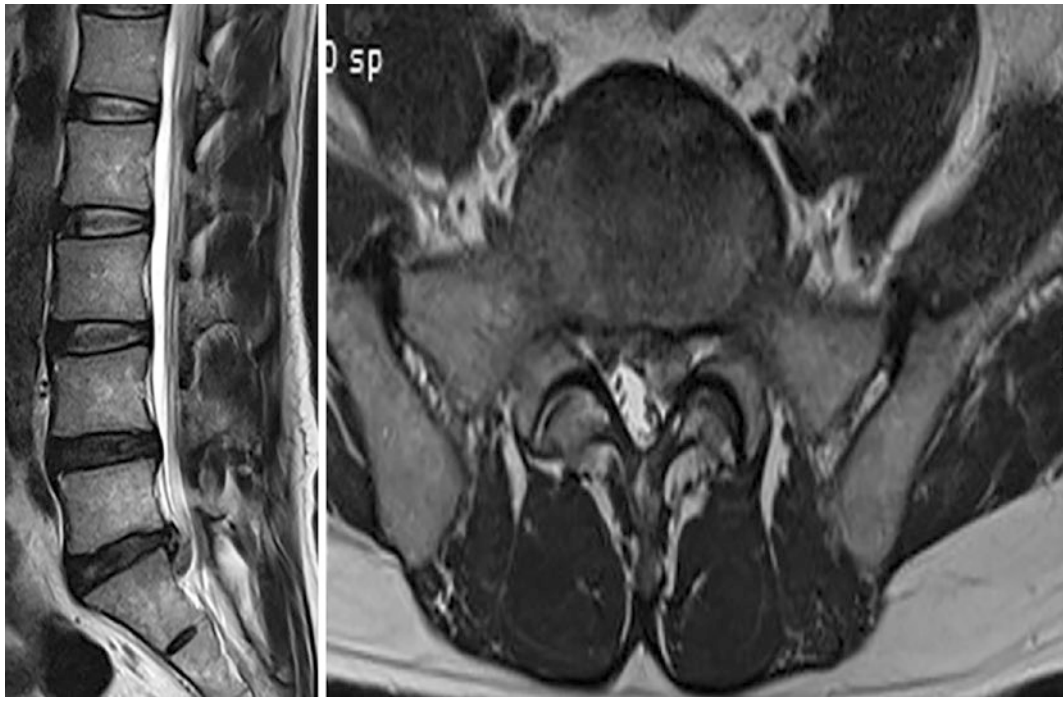

Fig. 11 Preoperative T2-weighted MR image shows left central inferiorly down-migrated disc herniation

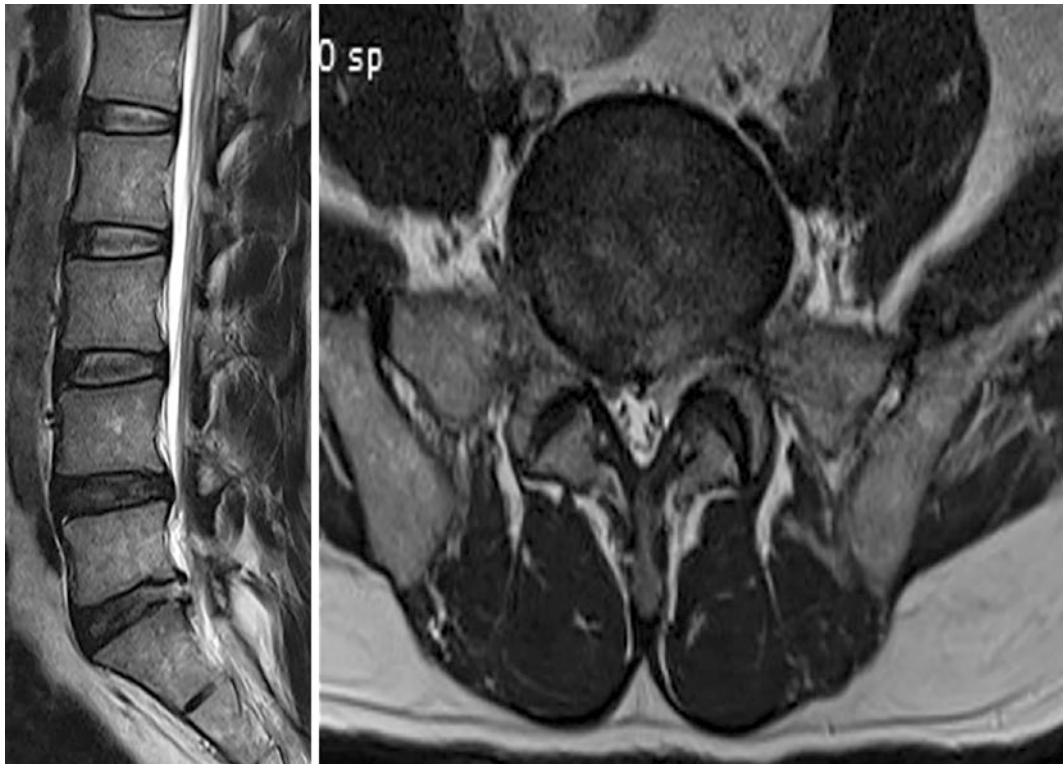

Fig. 12 Postoperative T2-weighted MR image shows that ruptured disc has been removed and the Lt. S1 root was successfully decompressed

Fig. 13 This postoperative T2-weighted MR image shows the channel made through the ilium and drain inserted through channel

3 Anatomical Approach Using the Isthmic Corridor

Junseok Bae

Abstract Anatomical constrains like high iliac crest, big transverse process, and hypertrophied alar joint may interfere the transforaminal approach. The upper part of intervertebral foramen, i.e., lateral to isthmus and cranial to the superior articular process, is an alternative way into the Kambin's triangle. In this chapter, the authors describe the transforaminal approach via isthmic corridor for the L5-S1 level.

Keywords Kambin's triangle; L5-S1; Transforaminal approach; Foraminoplasty; Endoscopic discectomy

3.1 Introduction

Lumbosacral junction (L5-S1) with its distinctive anatomical features presents a unique challenge to endoscopic spine surgeons [8, 10, 20]. Both interlaminar and transforaminal routes have been well established for L5-S1 endoscopic discectomy. Transforaminal corridor is particularly advantageous in terms of applicability to all types of disc herniations and avoidance of significant neural complications. However, anatomical constraints like a high iliac crest, thickened L5 transverse process, or hypertrophied L5-S1 facet may dictate a preference for interlaminar technique [7, 8]. The upper part of the intervertebral foramen, lateral to the pars and cranial to superior articular process (SAP), can offer an alternate safe way into Kambin's triangle. The uniqueness of the current approach lies in the fact that it bypasses this major anatomical hurdle. The basis of this approach is the inverted tear-drop shape of neural foramen with wider and more flexible superior half [21]. By utilizing the isthmus trajectory and superior part of the neural foramen, chances of encountering the iliac crest are remarkably reduced and satisfactory decompression can be performed with good clinical outcomes. Utilizing an isthmic approach reduced the need for foraminoplasty and consequently increased the safety of this procedure [4]. The author group in the current technique exploits this unique anatomical property of neuroforamen to achieve optimal surgical outcomes. (Fig. 14) In this chapter, the authors describe in detail the endoscopic approach utilizing the above-mentioned anatomical corridor for transforaminal endoscopic lumbar discectomy (TELD) at the L5-S1 level.

3.2 Indications

Indicated patients are those who have symptomatic L5-S1 disc herniation with radiculopathy resistant to conservative measures (for at least 6 weeks), with or without associated axial back pain, a positive nerve root tension sign on physical examination, and MRI findings correlating with clinical findings. Cases with the presence of segmental instability, grade II or above spondylolisthesis, significant spinal stenosis, and neurogenic claudication were specifically excluded.

3.3 Surgical Technique

3.3.1 Surgical Technique (Fig. 15)

1. Patient position: Prone on radiolucent operating table with knees flexed.
2. Anesthesia: Conscious sedation with IV Fentanyl and Midazolam.
3. Surface marking: Operating level, midline and cranio-lateral extent of iliac crest under C-arm guidance.
4. Trajectory planning: An imaginary line is drawn from skin surface to the intended annular puncture site using AP and lateral C-arm views. The trajectory should pass cranial to the superior articular process and lateral to the isthmus.
5. The planned needle pathway is infiltrated with 8 mL to 10 mL of 1% lidocaine.
6. 18G spinal needle is inserted along the planned trajectory under fluoroscopic guidance.
7. Once the needle crosses the isthmic zone, an epidurogram is performed to confirm the location of nerve roots and the safe triangle.

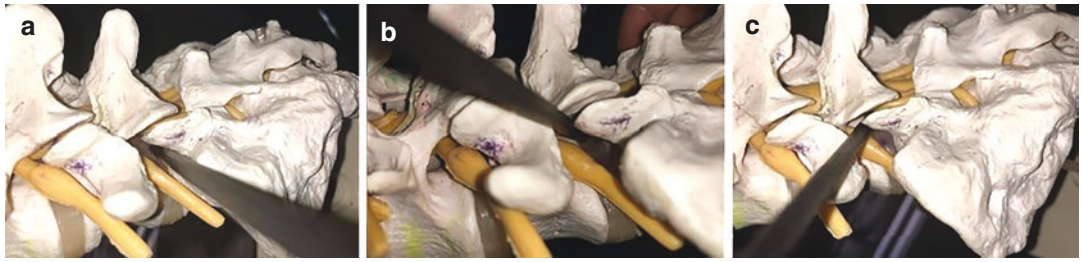

Fig. 14 Comparison of standard transforaminal approach and novel isthmic approach: (**a**) Standard transforaminal approach through the inferior part of neuroforamen and anterior to superior articular facet; (**b** and **c**) isthmic approach through the wider and flexible superior part of neuroforamen

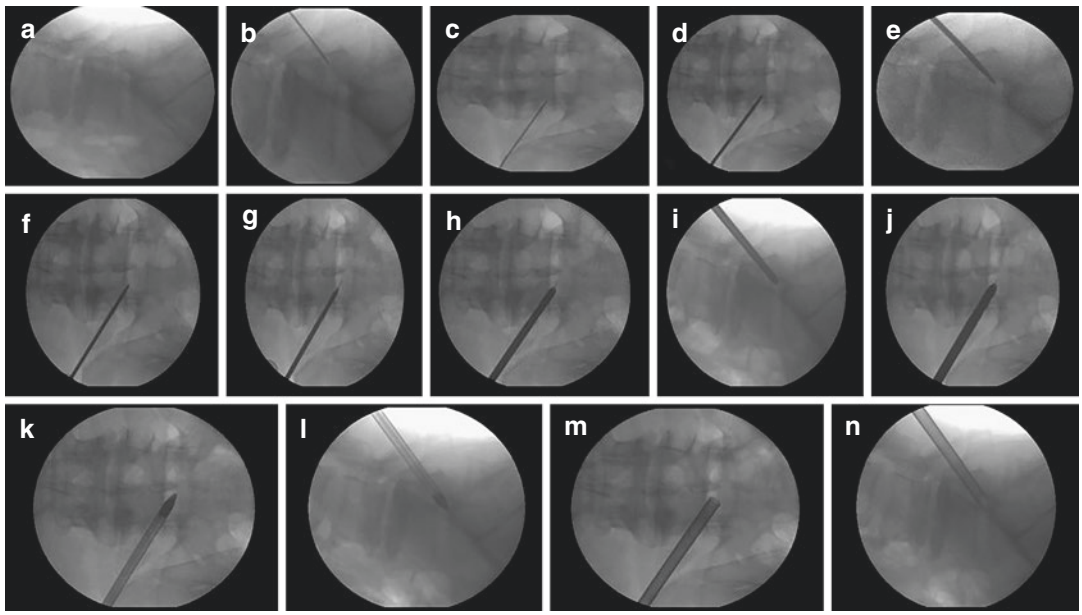

Fig. 15 Surgical technique: (**a**) Lateral fluoroscopy to plan trajectory; (**b** and **c**) insertion of 18G spinal needle along the planned trajectory under fluoroscopic guidance; (**d**–**g**) sequential dilation over guide wire; (**h**–**j**) use of bone drills to ream the tip of superior articular process; (**k** and **l**) introduction of obturator over guidewire; (**m** and **n**) final position of working cannula

8. After achieving a satisfactory epidurogram, the needle is further advanced to rest on the annulus.
9. The surface of annulus is infiltrated with 2–3 mL of 1% lidocaine before piercing it with a needle.
10. A stylet is removed and discography is performed using 2–3 mL of a 2:1:2 mixture of radio-opaque dye, indigo carmine, and normal saline.
11. After obtaining a satisfactory discogram, the needle is replaced with a 0.8 mm guide wire.
12. Skin is incised and a blunt cannulated obturator is passed over the guide wire under fluoroscopic control until its tip reaches the outer surface of the annulus.
13. In case of spondylotic foraminal stenosis, foraminoplasty can be performed at this point using bone drills (Joimax GmbH, Karlsruhe, Germany).
14. Finally a 7 mm beveled working cannula is placed over the obturator and endoscope is introduced (Tessys, Joimax GmbH, Karlsruhe, Germany).
15. Using standard endoscopic instruments (forces, side-firing Ho: YAG laser, radiofrequency probe, etc.), the rest of the procedure is performed as standard endoscopic discectomy.
16. Throughout the procedure, continuous feedback from the patient is utilized to avoid any neural injury.
17. Direct endoscopic visualization of a free nerve root and pulsatile dural sac is used to confirm adequate decompression.
18. Skin is closed in standard fashion.

3.4 Case Illustration

A 39-year-old male patient presented with left S1 radiculopathy. Conservative treatment failed to improve his pain. MRI showed downward migrated disc herniation at the L5-S1 level on the left side (Fig. 16c, d). Physical examination revealed a posi-

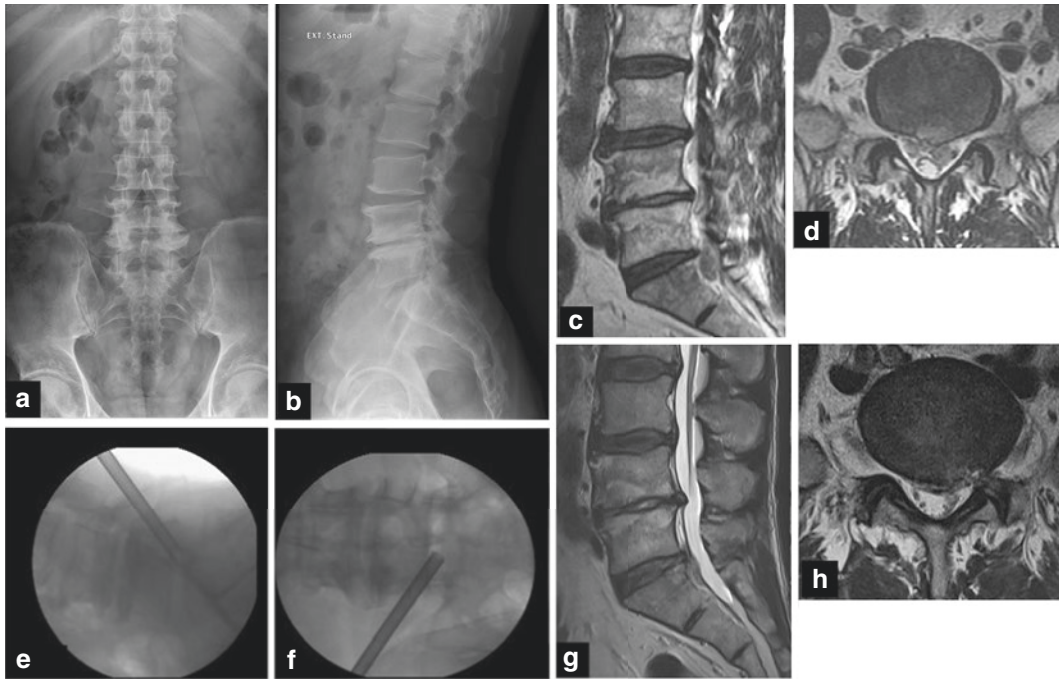

Fig. 16 Representative case of a 39-year-old male with symptomatic L5-S1 disc herniation: Preoperative x-ray AP and lateral (**a**, **b**) and MRI (**c**, **d**) showing narrow and high iliac crest with downward migrated disc fragment on the L5-S1 left. Transforaminal endoscopic discectomy was done with isthmic corridor (**e**, **f**) resulting in a good neural decompression on the postoperative MRI (**g**, **h**)

tive SLR sign with numbness on the S1 dermatome. A preoperative x-ray on the AP and lateral image shows a high and narrow iliac crest (Fig. 16a, b). The transforaminal approach via isthmic corridor was done to place the final working tube on the posterior and vertebral line on the lateral fluoroscopic view (Fig. 16e) and paramedian disc space close to the midline (Fig. 16f). Postoperative MRI shows a well-decompressed state (Fig. 16g, h).

3.5 Summary

Combining isthmic trajectory to L5-S1 transforaminal endoscopic discectomy adds to the applicability of this already well-established surgical procedure. The isthmic approach offers a safe and effective anatomical corridor for performing endoscopic discectomy via transforaminal route, even in individuals with high iliac crest.

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