Chapter 5
Minimally Invasive Percutaneous Endoscopic Discectomy: Transdiscal Approach

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Since Kambin performed the first endoscopic discectomy in 1983 [1], various minimally invasive surgical techniques have been developed to mitigate the deleterious effects of disc herniation and nerve root compression. The current minimally invasive discectomy approaches are interlaminar, transforaminal, and transdiscal. Regardless of the approach, the goal is the resection of a herniated disc under direct endoscopic visualization. Compared with open discectomy, minimally invasive methods have been shown to eliminate cutting of muscles, reduce the rate of infection, shorten operating time, minimize blood loss, and decrease the incidence of cerebral spinal fluid leak and other major complications [2–5]. Although the routine use of endoscopic discectomy for the lumbar and cervical spine remains controversial [6–13], future high-quality research will help to delineate optimal treatment algorithms. This chapter presents the current concepts of the most commonly performed endoscopic spinal surgery [14–17]—the transdiscal approach. Relevant spinal anatomy, patient selection, clinical considerations, and the detailed surgical techniques are discussed.

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5.1 Spinal Anatomy

Intervertebral discs consist of a slightly posteriorly positioned nucleus pulposus enclosed by the annulus fibrosus on the periphery. The nucleus pulposus contains crisscrossing collagenous and elastin fibers immersed in mucoid polysaccharides. The annulus fibrosus is made of fibrocartilaginous laminas that are subdivided into outermost, middle, and innermost layers. These layers are arranged in a concentric fashion. The annulus fibrosus firmly attaches to epiphyseal rings of the adjacent vertebral bodies. The discs attenuate the axial force in the vertebral column and allow flexion and extension motions. The discs account for 25% of the total spinal column height.

Even though the intervertebral discs are avascular, each disc is innervated by multiple nerves. Sinuvertebral nerves innervate the posterior lumbar disc and posterior longitudinal ligament (PLL). The posterolateral disc is supplied by the adjacent ventral primary rami and the grey rami communicantes. The lateral portion of the disc receives fibers from the rami communicantes [18]. Following acute disc injuries, pro-inflammatory interleukins and nerve growth factors are released; these have been linked to axial back pain and the degenerative process [19]. When the intradiscal material comes in contact with the dorsal root ganglion following an injury, radicular symptoms may be present without mechanical nerve root compression.

In addition to the strong anterior longitudinal ligament (ALL), the anterior and middle fibers of the annulus are most abundant anteriorly and laterally, which contribute to the anterior column stability. Posteriorly, the PLL is thin, and the annulus fibers are deficient. Therefore, the posterior region of a disc is most prone to mechanical deformation. A disc herniation is defined as a focal deformation of the disc (less than 25% of the circumference of the disc) extending beyond the normal intervertebral disc space. Herniated disc material may include nucleus pulposus, cartilage, fragmented apophyseal bone, or annulus fibrosus tissue [20]. The morphology of disc herniation usually presents as a narrow neck with a “mushroom” head of nucleus pulposus impinging the nerve roots. Herniated discs may be further grouped into contained and uncontained herniations. Containment is determined by the presence of disc materials held within an intact outermost annulus fibrosis and PLL. An uncontained herniation is defined by the absence of intact annulus fibrosis and/or PLL. A central disc herniation will cause compression of the traversing nerve root exiting the foramen at the level below, whereas a far lateral disc herniation is likely to affect the nerve root at the level of the herniated disc, with corresponding neural tension signs and dermatomal, myotomal, and reflex changes. Furcal nerves, primarily sensory, are found in roughly 15% of individuals at L4-5. These furcal nerves may traverse the L4 foramen far laterally and exit with the L5 nerve root, so that a far lateral disc herniation can cause L4-5 radicular symptoms.

Each foramen is made up of pedicles (cranial and caudal), the intervertebral body and disc (anterior), and the facet joint (posterior). The ligamentum flavum courses between the laminas and forms the posterior wall of the spinal canal. Spinal nerve root, radicular vasculatures, and meningeal nerves exit the foramen below the corresponding vertebral body in the lumbar spine. Kambin’s triangle delineates an area

Fig. 5.1 Kambin's triangle (shaded in *pink*)

in this region formed by the exiting nerve root (hypotenuse), the superior end plate of the caudal vertebra (base), and the superior articular process (height) (Fig. 5.1). Kambin's triangle serves as an important landmark in interventional spine procedures, but it is important to be mindful that when the disc herniation is more apical, the Kambin's triangle is reduced, as the nerve becomes displaced more inferiorly. A calcified annulus fibrosus, osteophytes, facet joint hypertrophy, and vertebral body osteochondrosis can all make disc access difficult. A thorough knowledge of Kambin's triangle prevents unnecessary complications.

5.2 Patient Selection

Appropriate patient selection is imperative for favorable outcomes. Generally, the patient must demonstrate signs and symptoms consistent with mechanical impingement of a nerve root. The following are important considerations for planning endoscopic percutaneous discectomy procedure by the transdiscal approach:

- Contained herniated or bulging disc with radicular symptoms
- Positive neural tension signs (*eg*, positive straight leg raise test) accompanied by unrelenting monoradicular pain consistent with imaging findings (MRI, CT, discography)
- Radicular symptoms relieved by a diagnostic block of the suspected nerve root
- Unilateral radicular pain greater than low back pain
- Failure for at least 6 weeks of conservative management such as oral medications, physical therapy, and epidural steroid injections
- Confirmed electromyography studies
- Facet joint ruled out as a source of pain
- Greater than one half of disc height preserved

Evidence suggests that in the hands of an experienced surgeon, a large, uncontained herniated lumbar disc fragment (6–12 mm) and far lateral disc herniations can be sufficiently removed via an endoscopic discectomy procedure by a transforaminal approach [21].

5.3 Contraindications

The following conditions are considered contraindications for this type of procedure:

- Cauda equina syndrome
- Coagulopathy
- Herniation greater than one third the sagittal diameter of the spinal canal
- Calcified intervertebral disc herniation
- Concurrent spinal fracture, structural instability, tumor, pregnancy, or active infection
- Advanced degenerative joint disease, osteophytes, multilevel disc bulge, ligamentum flavum hypertrophy, or severe foraminal and spinal stenosis
- Psychiatric disorder, substance abuse, or lack of capacity to consent

5.4 Preoperative Planning and Patient Education

Thorough physical and neurological examination and diagnostic imaging are performed to establish the indication for the surgery. MRI is helpful to confirm the diagnosis. In equivocal situations, a diagnostic block is helpful to rule out other spinal conditions that mimic the symptoms of disc herniation. If other comorbidities are present, medical optimization should be achieved prior to surgery, such as the safe correction of anticoagulant status and evaluation for contrast allergy. Because the procedure is performed under local anesthesia with or without conscious sedation, the patient must be able to tolerate lying prone.

Patients must be educated on the benefits, risks, and alternatives to a percutaneous endoscopic discectomy (PED) procedure. Similar to open spinal surgeries, there are risks of infection, bleeding, nerve injury, paresthesia, disc collapse, dural tears, scar tissue formation, vertebral endplate damage, spinal instability, and damage to surrounding structures. Patients should understand that in the event of disc reherniation, future revision and open spinal surgery may be required. It is important to set realistic expectations, as long-term nerve compression with associated chronic swelling and perineural fibrosis may not have the same rapid improvement as acute disc herniation.

Postoperative plans and expectations should be discussed with the patient prior to the surgery. A comprehensive rehabilitation program will optimize functional mobility, core strengthening, and overall physical conditioning. The patient should be advised to adhere to a spinal mobility and strengthening routine to ensure long-term spine health.

5.5 The Transdiscal Approach

Because the PED procedure depends on proper positioning of the portal to ensure optimal access and sufficient visualization of the target disc and foramen, the success of the procedure is greatly influenced by the point of entry needle placement. During the transdiscal approach, the cannula normally is inserted similar to the discography approach. The entry point can be ipsilateral or contralateral, depending on the disc material to be removed, using an anteroposterior (AP) view with cranial-caudad adjustments to the fluoroscopic beam to square off the disc to be treated. The scope is then rotated to obtain an oblique view that clearly bisects the superior endplate with articular elements.

The skin entry point is marked just lateral to the superior articular process of the inferior vertebral body. Patients with body mass index greater than 40 present a unique challenge for the transdiscal approach. To reach the neural foramen at 45° in a morbidly obese patient, the needle length would have to be at least 21 cm (≥8 in.), which renders the transdiscal approach impractical. Similarly, in male patients with high iliac crests, approaching the L5-S1 foramen may pose a significant challenge, as the target foramen is embedded deeply in the pelvis, and the iliac crest obstructs the posterolateral trajectory to the disc space. The superior S1 endplate is at risk of injury if nonflexible instruments are used while adhering to the transdiscal approach. To create an optimal view at the L5-S1 level, the oblique fluoroscopic view requires the most amount of cranial tilt to place the superior articular process of S1 at the midpoint of the disc with clear visualization of the endplates. This oblique view will decrease the risk of injury by ensuring that the needle trajectory does not cross the nerve root.

5.6 Discography

Provocative discography is recommended to confirm the source of radicular symptoms. It is performed before or at the same time as the planned PED procedure. If planned at the time of the PED procedure, the water-soluble contrast is mixed with indigo carmine dye to provide visible radiopacity on the discography under fluoroscopy, and intraoperative light-blue chromatization of the disc tissue and annular tears. Depending on the disc pathology seen on the discogram, the transdiscal approach can be further subdivided into an inside-out technique [22] or outside-in technique [23]. The inside-out technique is appropriate for treating internal disc disruption, tears, and contained herniation in the foramen. The location of the disc herniation is of less concern with the inside-out technique, but this technique may remove too much normal disc tissue in minor disc herniation. For the outside-in technique, the opening of the access cannula is positioned in the foramen and does not enter the target disc space [23]. The outside-in technique is considered when treating foraminal disc herniation.

5.7 Uniportal Percutaneous Endoscopic Discectomy Technique

The patient is placed in the prone position on the operating room table, with pillows or a bolster placed beneath the lumbosacral area to reduce lumbar lordosis. Additionally, the knees are gently flexed, with pillows supporting the patient's ankles to improve positional comfort. The skin overlying the target area will be thoroughly cleaned and draped, with strict aseptic techniques. Intravenous administration of 1–2 g of cefazolin or 600 mg of clindamycin is recommended 30 min prior to the procedure.

The sterile draped C-arm is used to obtain an AP view of the spinous process centered between the pedicles of the target spinal segments. The fluoroscopic beam should be adjusted with an appropriate amount of cranial-caudal tilt until the target vertebral bodies and their end-plates are clearly in focus. Lines connecting the spinous processes and across the disc space are drawn. The C-arm is then repositioned to obtain a lateral view. Disc inclination angles are drawn and the cranial/caudal entry point is determined by the intersection of those lines. The skin and subcutaneous tissue are adequately anesthetized with 1% lidocaine infiltration. A 16-gauge, 6-inch-long spinal needle is then inserted into the skin, directed towards Kambin's triangle. The needle is usually angled 60° in the sagittal plane and advanced in the anteromedial direction towards the disc. In a larger patient, however, the needle entry point must be placed further laterally. Careful attention should focus on the needle trajectory, as the beveling of the needle may cause it to deviate away from the intended path as it pierces the soft tissues. Sufficient local anesthetic should be administered along the needle path down to Kambin's triangle to minimize intraoperative and postoperative pain. The safe annular entry point is confirmed on the AP and lateral view. On the AP view, the needle should be aligned with the posterior vertebral bodies at the inner pedicle line, with the tip nearly touching the posterior annulus (Fig. 5.2a). On the lateral view, the needle should be positioned on the posterior one third of the pedicle line (Fig. 5.2b). Under direct AP fluoroscopic visualization, the needle is carefully advanced until the tip is through the annular layer (Fig. 5.3). The final needle position is also confirmed on the lateral view. The lateral view confirms that an appropriate needle penetration depth is achieved, preventing over-penetration into the anterior nucleus or annulus. With the needle tip inside the disc, contrast (a combination of Omnipaque™ [iohexol] and indigo carmine dye) is introduced. This contrast mixture will aid in direct and fluoroscopic visualization of the diseased nucleus pulposus and annulus defects.

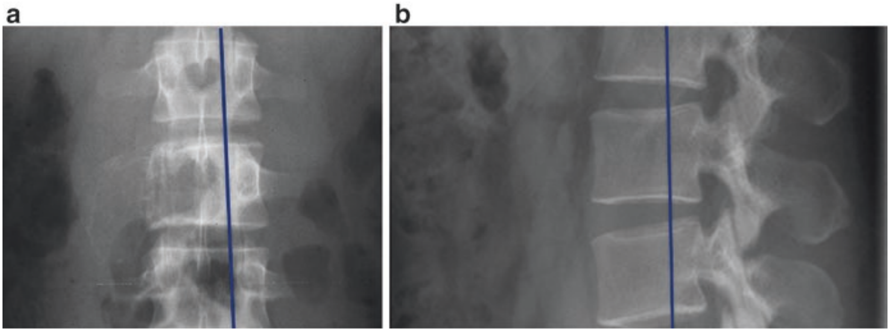

Fig. 5.2 (**a**) Anteroposterior (AP) fluoroscopic view with medial pedicle line drawn. (**b**) Posterior one third of the pedicle line on lateral view

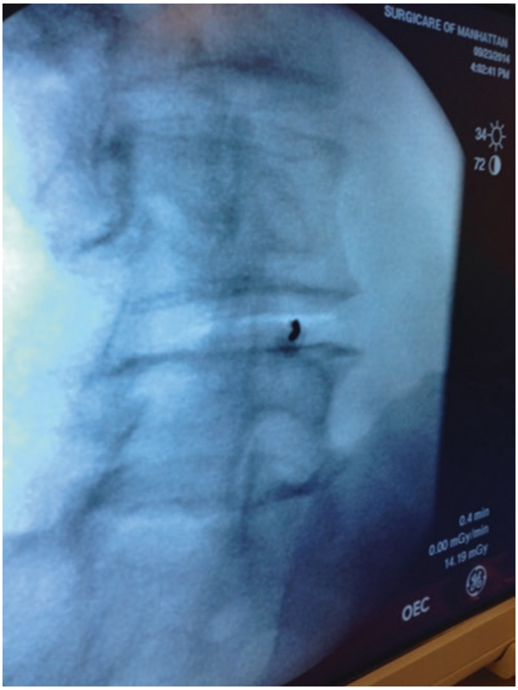

Fig. 5.3 AP fluoroscopic view of needle entry into the annular layer of the target disc

The next series of steps involve sequential inserting and retrieving of the needle, guide wire, blunt dilator, and beveled access cannula (Fig. 5.4). The guide wire is inserted through the spinal needle until it is 1–2 cm into the annulus. Once the guide wire is firmly held in place, the spinal needle is retrieved. The next step is to make a 2 cm skin incision with a #15 blade to allow the blunt dilator to be introduced over the

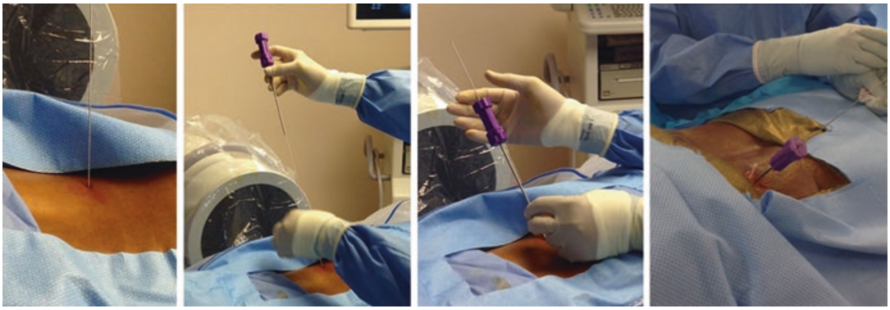

Fig. 5.4 Stepwise progression (*left* to *right*): Guide wire is in place; an access portal is inserted over the guide wire, toward the target disc space

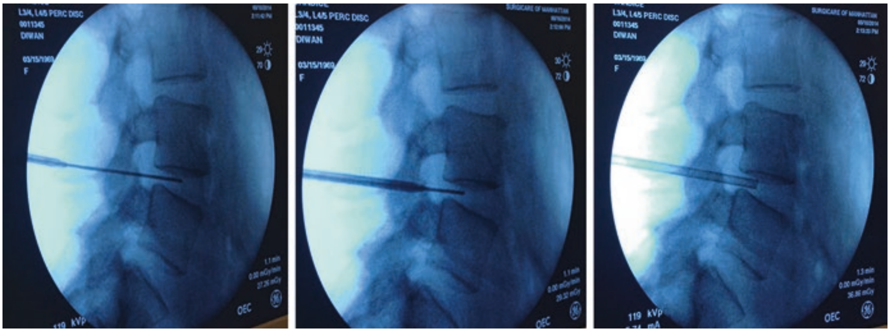

Fig. 5.5 Fluoroscopic views of accessory portal placement of the guide wire via the transdiscal approach (*left* to *right*). Note that the final portal tip is in line with the posterior one-third line

guide wire and securely engaged at the annular window. A mallet may be used to assist the annular fenestration process. After confirming that the dilator tip adequately embedded into the annulus on AP and lateral views, the access cannula is then slid over the dilator until the access cannula is deep in the annular window. At this point, the exiting nerve root is posterior to the access cannula. Care should be taken to secure the access cannula while the dilator is removed, because periannular bleeding will obscure endoscopic visualization. Finally, the trephine is inserted and then removed through the access cannula to perform an annulotomy. Under direct visualization, grasping forceps can be used to remove degenerated annular material in view.

Following sufficient annulotomy, the guide wire, dilator, and cannula are sequentially re-inserted and exchanged until the cannula is positioned in the center of the nucleus pulposus under fluoroscopic control (Fig. 5.5). Tissue debulking graspers are inserted through the access cannula to perform nucleotomy (Fig. 5.6). The annulotomy is expanded medially to the base of the herniation via cutting forceps to release the annular layer and allow extruded disc material to be removed adequately. A large amount of nucleus with blue dye is usually visible directly under the herniation.

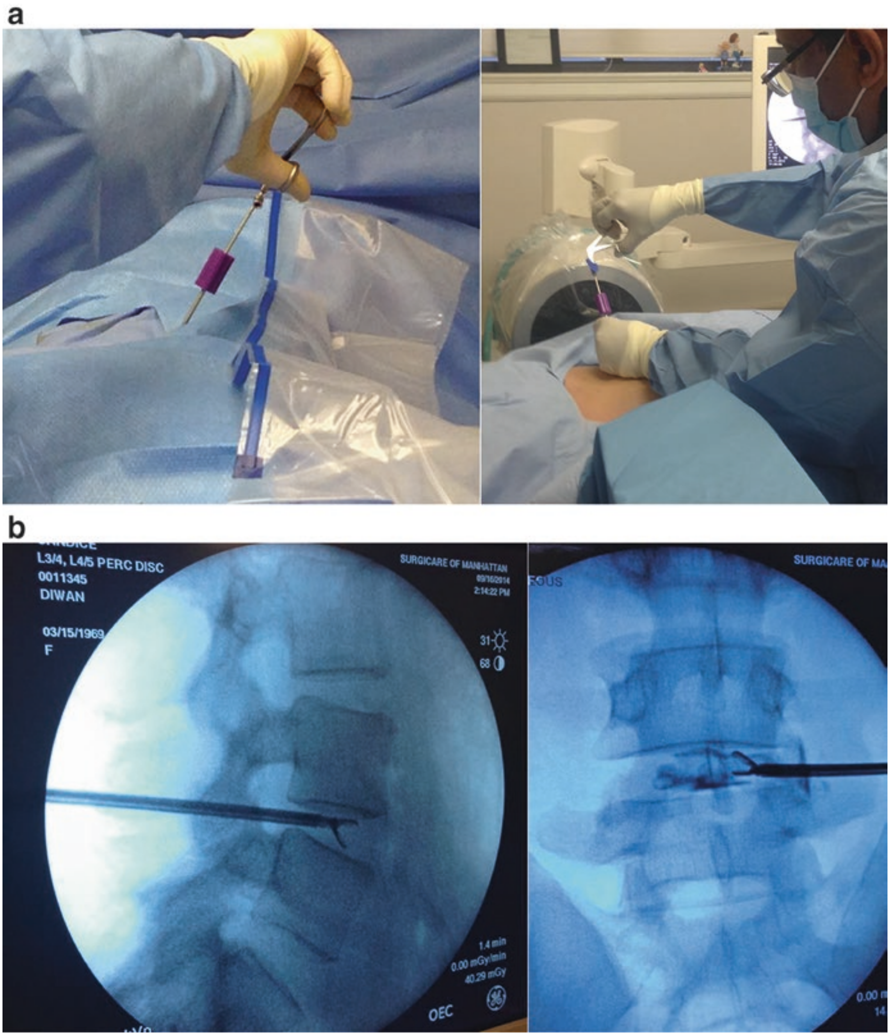

Fig. 5.6 (**a**) Nuclear debulking forceps are used to remove herniated disc material. (**b**) Fluoroscopic lateral view (*left*) and AP view (*right*) of the debulking forceps in the desired intradiscal space

5.8 Annulus Modulation

Once the herniated disc materials have been removed, the flexible steerable bipolar radiofrequency (RF) probe is used to shrink and thicken the herniation site (Fig. 5.7). The flexible RF probe is advanced towards the posterior or posterolateral aspect of the nucleus pulposus and positioned adjacent to the annular tears. AP and lateral fluoroscopic views should be obtained as needed for safety and efficacy. Small bleeding vessels are cauterized with the RF probe to achieve sufficient hemostasis. Optional endoscopic visualization is performed inside the newly created disc cavity.

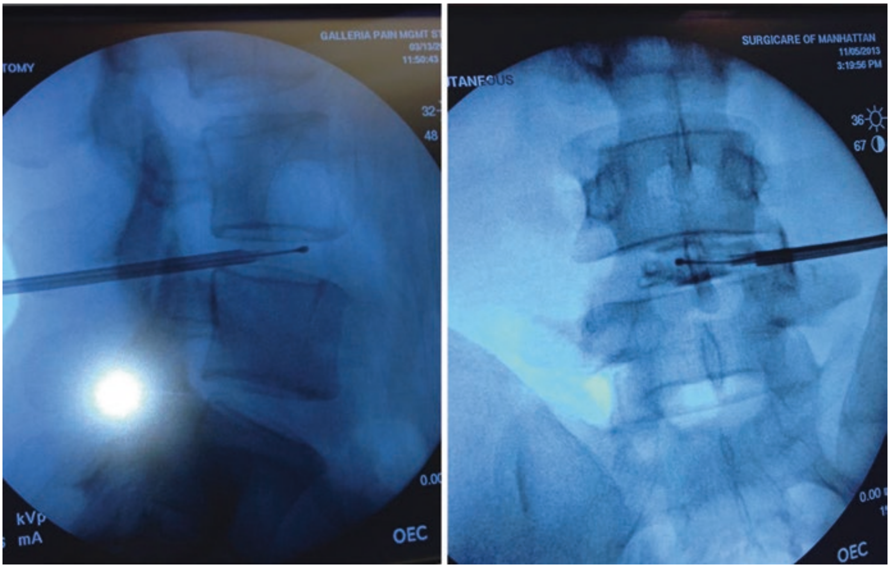

Fig. 5.7 Lateral (*left*) and AP (*right*) views of transdiscal radiofrequency (RF) probe

The access cannula and the endoscope can be retracted 2–3 mm to inspect the exiting nerve in the epidural space. The procedure site is irrigated before retrieving the endoscope and the blunt nerve retractor. An adhesive dressing is applied to close the skin stab wound.

5.9 Postoperative Care and Rehabilitation

Minimally invasive endoscopic discectomy is an outpatient procedure. The patient is discharged home on the same day with analgesics and anti-inflammatory medications. A follow-up visit is scheduled in 7–10 days. Signs of infection and bleeding should be closely monitored. The patient should be advised to minimize activities that increase intradiscal pressure. Postures such as sitting, slouching, and lifting should be avoided during the initial recovery period. If the patient shows improvement, a progressive rehabilitation protocol and neuromuscular re-education can be initiated under physical therapy supervision. A post-procedure back brace may be prescribed for a week or two to aid with instability and provide posterolateral support. The orthosis decreases axial loading and helps to improve functional status. The patient is encouraged to participate in aquatic exercises followed by progressive lumbar and core strengthening exercises, and to integrate good body mechanics and postural awareness into activities of daily living.

Even if the patient does not report significant improvement, the procedure should not be considered a failure until at least 6 weeks from the date of the procedure. If the patient shows signs and symptoms consistent with an inflamed nerve root, an image-guided selective nerve block may be considered.

5.10 Discussion

Current evidence supports the use of PED as a method for treating radicular pain caused by disc herniation [24–28]. Because this technology requires only local anesthesia with conscious sedation, it provides an opportunity for patients who are unable to tolerate general anesthesia to undergo open surgical discectomy. Thorough knowledge of Kambin's triangle and the surrounding neurovasculature is a cornerstone of the procedure. Appropriate patient selection, coupled with skilled access cannula placement and surgical techniques, drive the safety and effectiveness of this surgical procedure. Minimally invasive endoscopic discectomy offers the advantages at the cost of the surgeon's commitment to mastering the skills of negotiating instruments with a two-dimensional field of view. Future technical advancement through continued effort in research will improve our understanding and ability to treat disc herniation and other spinal disorders via minimally invasive endoscopic techniques.

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