Orthopaedic Surgery

OPERATIVE TECHNIQUE

"Inside Disc Out" Discectomy for the Treatment of Discogenic Lumbar Spinal Canal Stenosis under the Intervertebral Foramen Endoscope

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Objective: Conventional posterior-approach decompression surgeries have a higher risk of nerve root injury and dura laceration. We explore the therapeutic strategy and effect of "inside disc out" discectomy under intervertebral foramen endoscope technique for discogenic lumbar spinal canal stenosis (DLSS) treatment.

Methods: Twenty-nine patients with DLSS in the responsible segment were treated with "inside disc out" discectomy under intervertebral foramen endoscope technique between October 2017 to October 2019. Lower limb and back pain were recorded before operation, and visual analogue scale (VAS) score and Oswestry disability index (ODI) were recorded for lower limb and back pain at 1, 3, 6, and 12 months postoperatively. The postoperative effects were evaluated using the modified MacNab method for all the patients.

Results: All 29 patients successfully completed the operation. The operation time was 75–120 min, with an average of 90 ± 17 min. Postoperative lumbar CT examinations of all the patients showed full decompression of the spinal cord with no residual pressure. The average follow-up time for all the patients was 13 ± 3.5 months (12–18 months). The VAS score for lower back and lower limb pain was 7.52 ± 1.25 before the operation, and 1.80 ± 0.63, 1.33 ± 0.88, 1.07 ± 0.89, and 0.81 ± 0.51 at 1, 3, 6, and 12 months after the surgery, respectively. The Oswestry dysfunction index was 59.43 ± 10.04 before surgery and 29.67 ± 10.35, 21.13 ± 9.32, 14.52 ± 5.98, and 9.84 ± 4.68 at 1, 3, 6, and 12 months after the surgery, respectively. The VAS score and ODI index of low back and lower limb pain at different time points after the surgery were significantly improved compared to those before the surgery ($P < 0.01$). The effect of the modified MacNab was excellent in 26 patients, good in two patients, and fair in one patient. The excellent and good rates were 91.4%. Among them, one patient had symptoms of hyperesthesia in the anterior aspect of the thigh and decreased quadriceps muscle strength after lumbar 4/5 segment endoscopic surgery. After symptomatic and conservative treatment, the symptoms disappeared 4 weeks postoperatively, and there were no other serious surgical complications.

Conclusions: Following the "inside disc out" discectomy under intervertebral foramen endoscope protocols, the risk of nerve injury can greatly be reduced, with good postoperative efficacy. Overall, the procedure is safe and feasible for DLSS treatment.

Key words: Discogenic lumbar spinal canal stenosis; Hard disc protrusion; "Inside disc out" discectomy; Intervertebral foramen Endoscope

Introduction

Lumbar spondylotic radiculopathy commonly occurs due to lumbar disc herniation or lumbar spinal stenosis (LSS). In contrast to lumbar disc herniation, in which ruptured fragments of disc tissue protrude into the spinal canal and are associated with the sudden onset of radiculopathy,

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LSS is one of the most commonly diagnosed spinal disorders, and is found to severely affect the quality of life.[1] The types of LSS included soft disc herniation (free from the main body of the disc) and hard disc protrusion (without free body). The most common type of LSS is hard disc protrusion (intervertebral disc degeneration). Hard disc protrusion without a free body is referred to as discogenic lumbar spinal canal stenosis (DLSS).[2]

Various approaches, such as percutaneous endoscopic interlaminar discectomy (PEID), percutaneous endoscopic transforaminal discectomy (PETD), unilateral biportal endoscopy (UBE), have been proposed for the treatment of DLSS.[2] The conventional surgical procedure is open laminectomy. Although conventional laminectomy is considered safe and effective for LSS, the overall success rate of this standard treatment is low, with reported secondary spinal instability as a consequence of surgical failure.[3,4] This may be attributed to the invasive nature of the open procedure, which may lead to detrimental consequences, including spinal muscle atrophy, nerve damage, and arteriolar blood supply disturbance. Furthermore, open laminectomy involves dissection of the supraspinous and interspinous ligaments, which normally provide spinal stability and ligamentous support. These structures were not preserved during the open laminectomy. All these processes may contribute to chronic pain and further exacerbate symptoms in patients with lumbar spine stenosis.[4]

In 2002, Yeung and Tsou initiated PEID to treat lumbar spondylotic radiculopathy caused by LDH.[5,6] Percutaneous endoscopic interlaminar discectomy uses a posterior approach, passing through the lamina and ligamentum flavum to the disc. Owing to its wide space, it can be easily converted to open conventional surgery. The surgical outcomes of PEID are comparable to those of traditional open discectomies. Currently, PEID technologies are well accepted for the treatment of LDH with radiculopathy; however, PEID requires thecal sac traction and SAP resection to deal with disc fragments, which may consequently cause dural laceration, destruction of spinal stability, and other complications. Percutaneous endoscopic interlaminar discectomy for decompression of radiculopathy from DLSS remains controversial. Percutaneous endoscopic transforaminal discectomy employs a lateral approach that passes through the foramina to the disc; it can be performed under simple local anesthesia because the dural sac manipulation and irritation symptoms are minimal. Concurrent decompression of the foraminal and lateral recess zones is another important benefit of this approach. However, the transforaminal approach cannot effectively decompress central stenosis because of limitations in the surgical field. Traditional PETD is mainly applied to the resection of soft herniation disc fragments (free body); in the resection of the degenerated disc (no free body), the surgery is more challenging.[5,7]

Unilateral biportal endoscopic decompression is a percutaneous, full endoscopic technique. Bilateral decompression via unilateral laminotomy was the main feature. A clear and magnified surgical field was the most striking advantage. However, hemorrhage is a major problem for patients with severe stenosis or a degenerated disc (no free body). The spinous process and articular processes usually become hypertrophic and deformed, making the space between the spinous process and articular process very narrow. Once bleeding occurs, the narrow field of the surgery would be worse, hemostasis would be difficult, and the operation would be difficult to proceed smoothly.[8,9]

The PLDD method is a technique in which laser energy is transmitted by a fiber to the nucleus pulposus. However, PLDD lacks safety, has a poor therapeutic effect for LSS, and has many complications. Currently, this method is rarely used in clinical practice.

Although conventional posterior-approach decompression surgeries (open laminectomy, PEID, PETD, UBE, etc.) can theoretically achieve wide decompression of neural structures and relieve symptoms of nerve compression, they can also result in extensive destruction of the posterior anatomical structures. Indirect decompression was achieved by removing the dorsal vertebral laminae and articular processes of the pressed nerve when they were applied to the DLSS. The ventral nerve root could not be monitored under direct vision when reaming the SAP. Nerve root injury and dura laceration greatly increased; this is a common challenge for all posterior approaches.

With the assistance of various MI devices, calcified intervertebral disc protrusion is not a contraindication for spinal endoscopy.[10,11] Based on the concepts of TESSYS technique, the "inside disc out" discectomy technique was proposed in 2017,[7] as an MI surgical technique for the treatment of DLSS.

The aim of the present study was to illustrate *the feasibility, security and effect* of "inside disc out" discectomy under the intervertebral foramen endoscope procedure for the treatment of DLSS.

Methods

Patient Demographics

The clinical data of 29 patients with DLSS admitted to our hospital from October 2017 to October 2019 were retrospectively analyzed to explore the surgical technique and clinical practice of the treatment of DLSS under the intervertebral foramen endoscope "inside disc out" discectomy. The mean age of the 29 patients was 26–75 years (49 ± 3.3 years). There was L1/2 hard disc protrusion segment in three patients; L2/3 in four patients; L3/4 in five patients; L4/5 in eight patients; and L5/S1 in nine patients.

The inclusion criteria were as follows: (1) patients with lumbar spondylotic radiculopathy; (2) patients with disc protrusion and calcification; and (3) patients who failed to conservative treatment. The exclusion criteria included: (1) local segmental spinal instability or slippage; (2) spinal tumor or myelopathy; (3). coagulation dysfunction; and (4) patients with complicated mental disorders that cannot undergo surgery.

Surgery

Preoperative Preparation

Regular oral nonsteroidal anti-inflammatory analgesics (diclofenac sodium) and central skeletal muscle relaxants (tizanidine hydrochloride) were administered 48 h before the operation. All the patients underwent lateral positioning and surgery under G-arm fluoroscopy guidance.

Anesthesia

Local anesthesia (1% ropivacaine, 10 mL; 2% lidocaine, 30 mL; and 0.9% saline, 45 mL) was used in all the patients. The anesthesia levels were the skin and subcutaneous tissue, lumbar dorsal fascia, articular process, and hard disc surface.

Operating Procedure

Establishment of the Operative Approach Working Sleeve. All the patients with hard intervertebral disc were treated with the "inside disc out" discectomy technique using the intervertebral foramen endoscope. The specific method involved puncturing the basal part of the SAP of the target intervertebral space using an 18 G puncture needle. The positive-perspective needle tip is located at the inner edge of the SAP, and the lateral-perspective needle tip is located at the basal part of the SAP and lower edge of the protrusion disc. Place a guide wire, make a skin incision of about 7 mm, and place 2, 3.5, 4.5, 5.5-mm catheters to dilate the soft tissue step by step.

To the Tip of the Articular Process. All levels of the soft tissue dilated with the catheter were removed and placed the TOMshidi locator (Fig. 1) along the guide wire and fixed at the tip of the TOMshidi locator to the tip of the articular process under fluoroscopy (Fig. 2).

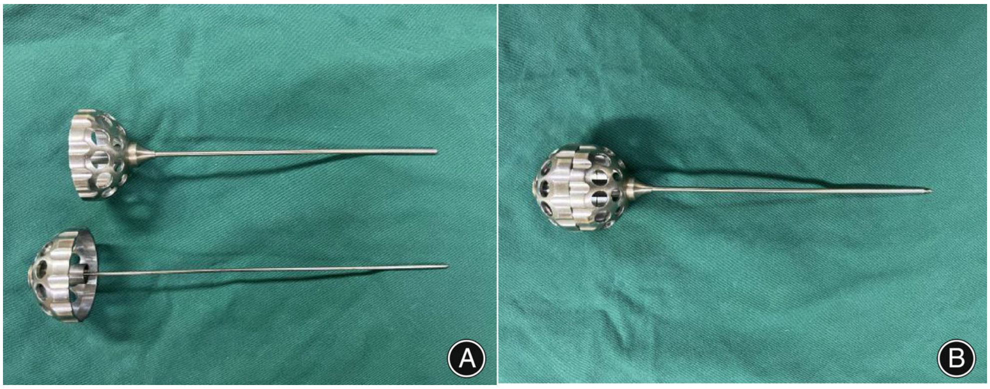
To the Surface of the Hard Disc. Point to the base of the SAP and lower edge of the disc using a G-arm fluoroscopy perspective to determine the position, and gently hammer through the articular process bone. Adjust the depth of the TOMshidi locator into the spinal canal, according to the disc protrusion position. As the tip of the TOMshidi locator reaches the surface of the hard disc (Fig. 3).

Entry into the Disc. Continue hammering the TOMshidi locator so that its tip breaks through the surface of the disc protrusion with the calcification and partial entry into the disc (Fig. 4).

Establishment of the Working Sleeve. The position of the TOMshidi locator tip was again confirmed by the positive and lateral perspectives of the G arm. After a successful positioning, the guide wire is replaced and the bone drill is inserted along the guide wire (Fig. 5) (diameter is 4.4, 6, 7, 8, and 9 mm). In order to form the intervertebral foramen, the opening along the TOM shidi locator in turn is drilled and ground, and the hard disc posterior lateral inferior is expanded, opening step by step. After completing the intervertebral foramen and breaking the hard disc, take out the bone drill, replace the guide wire, place the expansion guide rod, and place a 7.5 mm working sleeve along the guide rod. A G-arm fluoroscopy was used to confirm whether the working sleeve was directly attached to the target. After placing the spinal endoscope through the working sleeve and a 3.7-mm endoscopic central working sleeve under endoscopic surveillance, the nucleus pulposus forceps were used to clean the local soft tissue for bipolar radiofrequency local hemostasis.

Remove of the Protrusive Disc. The contour of the intervertebral foramen area was revealed using punch forceps to cut part of the ligamentum flavum layer by layer near the articular process. The disc-flava ligament space was exposed, and when the endoscope was landed on the surface of the hard disc, we could break the hard disc and pass through the opening with the nucleus pulposus and punch forceps by first conducting internal disc decompression. Remove the

Fig. 1 TOMshidi loc



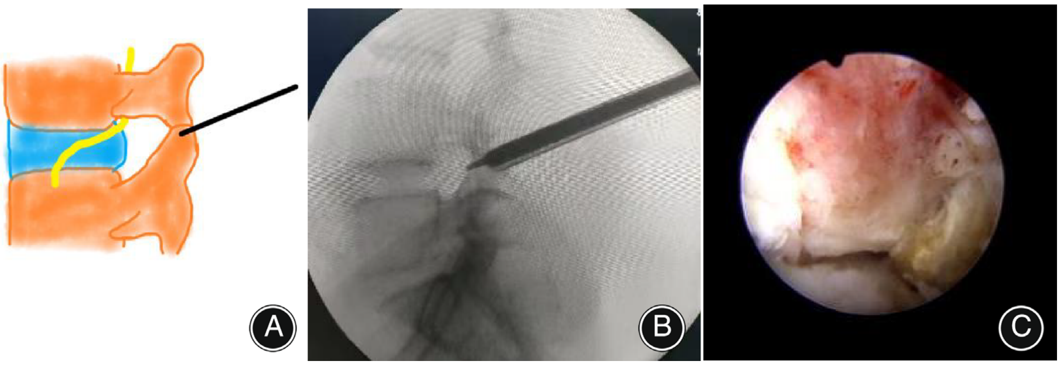


Fig. 2 Fix the tip of the TOMshidi locator to the tip of the articular process

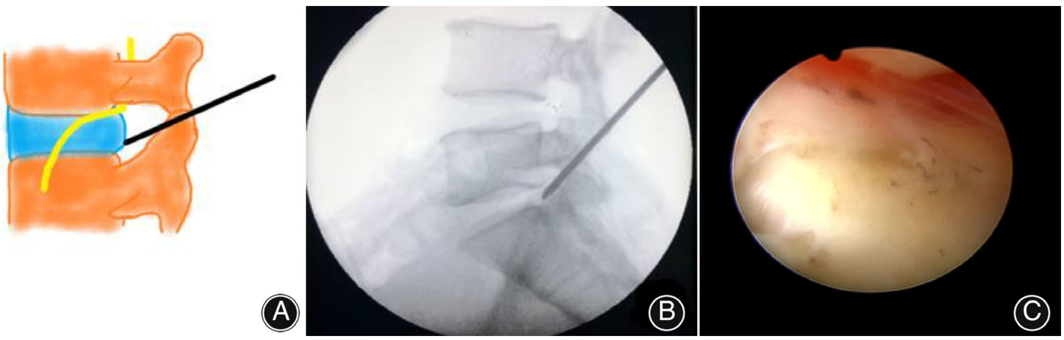


Fig. 3 The tip of the TOMshidi locator reaches the surface of the hard disc

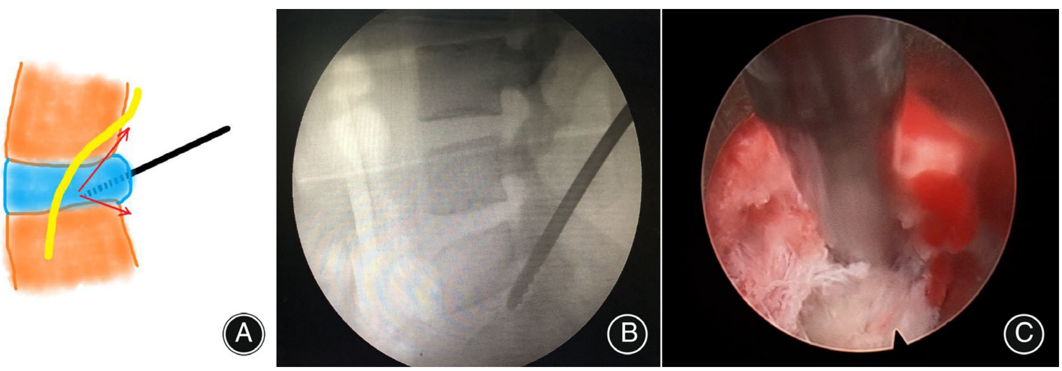


Fig. 4 The tip of the TOMshidi locator breaks through the surface of the disc protrusion

nucleus pulposus "inside disc out," then free the protrusive disc from the intervertebral foramen to the inferior pedicle and from the intervertebral foramen to the superior pedicle. The whole protrusive disc was removed completely and the ventral nerve root was decompressed fully. Resection of the articular process can be conducted safely, and the dorsal nerve root can also be fully decompressed. When the nerve root surface was filled with blood vessels, autonomic pulsation occurred. The ventral and dorsal spaces were adequate, and the patient's subjective symptoms were alleviated.

Postoperative Management and Observation Index

Postoperative routine administration of infection prevention, dehydration and detumescence, neurotrophic, and corresponding symptomatic treatment was to get out of bed properly under the protection of waist orthosis or support on the first day after the operation (waist orthosis or support protection for 3 weeks and get out of bed step by step). Patients were guided to perform lumbar dorsal muscle function exercise, straight leg raising (SLR) exercise, and lumbar spine health care program daily; regular follow-up assessed the patient's postoperative neurological improvement by the preoperative and postoperative different time points of back and lower extremity pain VAS score, dysfunction index (ODI), and at the last follow-up using improved Macnab criteria by telephone consultation at 1, 3, 6, and 12 months after the surgery to evaluate the final clinical efficacy.

Statistical Analysis

The mean ± standard deviation ($x \pm s$) was used to represent all measurement data in this study, and the counting data were expressed as absolute numbers or rates (%). The data are expressed as absolute numbers or rates. The measured data were compared using the *t*-test, and statistical significance was set at $P < 0.05$. The Data were analyzed using SPSS22.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Clinical Outcomes

The 29 patients in this group successfully completed the operation. The operation time was 75–120 min, and the average duration was 90 ± 17 min. The postoperative CT showed that the hard protrusion was removed thoroughly. The average follow-up time for all the patients was 13 ± 3.5 months (12–18 months). The VAS for low back and lower limb pain was 7.52 ± 1.25 before the surgery and 1.80 ± 0.63, 1.33 ± 0.88, 1.07 ± 0.89, and 0.81 ± 0.51 at 1, 3, 6, and 12 months after the surgery, respectively. The Oswsetry dysfunction index was 59.43 ± 10.04 before the surgery, 29.67 ± 10.35%, 21.13 ± 9.32, 14.52 ± 5.98, and 9.84 ± 4.68 at 1, 3, 6, and 12 months after the surgery, respectively. The VAS scores for low back and lower extremity pain and ODI significantly improved at different time points after the surgery ($P < 0.01$) (Table 1). For the improved MacNab, 26 patients were excellent, two patients were good, and one patient was fair. The excellent and good rate was 91.4%.

Fig. 5 Combination of bone drill and guide wire

Complications

One patient with anterior thigh hypersensitivity and decreased muscle strength of the quadriceps femoris at the second day after 4/5 segment endoscopy was treated with neurotrophic, acupuncture physiotherapy, and functional exercise conservative treatment. The symptoms disappeared 4 weeks after the operation, and no permanent nerve injury, discitis, or other serious surgical complications occurred.

Discussion

Our study demonstrates a significantly better outcome in safety, trauma, cost and recovery after operation using the "inside disc out" Discectomy protocol compared to conventional open surgery.

Challenges for Discectomy under the Intervertebral Foramen Endoscope

The difficulty of inside-out discectomy under the intervertebral foramen endoscope is that the protruding tissue is hard, the ventral nerve compression is heavy, the dural sac and nerve root are in obvious compression state, so treatment of hard protrusive discs under endoscopy is relatively difficult. And endoscopic operation space is limited compared with open surgery, complete removal of hard protrusive disc is relatively difficult, not only increase the operation time, but also the increase in the probability of accidental nerve injury. Therefore, the surgeon is required to have careful manipulation, extensive skill and experience.

Advantages of Inside-out Discectomy under the Intervertebral Foramen Endoscope

The advantage of inside-out discectomy under the intervertebral foramen endoscope is that we decompress the

TABLE 1 Visual analogue scale (VAS) and Oswestry disability index (ODI) scores preoperatively and at each time point postoperatively

	Preoperative	One month after operation	Three months after operation	Six months after operation	Twelve months after operation
VAS	7.52 ± 1.25	1.80 ± 0.63[a]	1.33 ± 0.88[a]	1.07 ± 0.89[a]	0.81 ± 0.51[a]
ODI	59.43 ± 10.04	29.67 ± 10.35[a]	21.13 ± 9.32[a]	14.52 ± 5.98[a]	9.84 ± 4.68[a]

[a] Compared with preoperative, $P < 0.0$.

internal of the disc inside-out, make the protrusive disc and the nerve root away from the ventral side of articular process. Compared with previous endoscopic operations this can avoid nerve root injury when the intervertebral foramen was enlarged. Compared with open surgery, it has the advantages of less trauma, less bleeding, quick recovery after operation, retention of spinal movement unit, protection of structure stability of spine, high safety and so on. And because of the previous comparative studies, compared with the interlaminar approach, the postoperative incidence of lower extremity sensory disorders was lower in the transforaminal approach.

The "inside disc out" discectomy under intervertebral foramen endoscope protocols is a safe and effective surgical technique for the treatment of thoracic vertebra and lumbar vertebra calcified intervertebral disc herniation, which can more safely and more conveniently reach the diseased area and remove the calcified tissue, more effectively separate the adhesion and further perform nerve root decompression.

Structure of Pedicle Ligament Flavum Tunnel

The intervertebral foramen can be divided into three parts: superior pedicle-ligamentum flavum tunnel (PEFT), SAP and inferior articular processes(IAP), and inferior PEFT. The top of the superior PEFT is the IAP and its junction with the pedicle. The outside aperture is the intervertebral foramen, and the inside aperture leads to the spinal canal. The anterolateral wall is the vertebral pedicle. The posteromedial wall is the ligamentum flavum, and the IAP is the capsular ligament. The top of the *inferior* PEFT is the SAP and its junction with the pedicle. The outside aperture is the intervertebral foramen, and the inside aperture leads to the spinal canal. The anteromedial wall is the ligamentum flavum, and the SAP is the capsular ligament. The posterolateral wall is the vertebral pedicle.

The "inside disc out" discectomy technique employs a lateroposterior approach, passing through the foramina to the inside disc. With mild symptoms of dural sac manipulation and irritation, direct decompression can be performed under local anesthesia. First, we performed a foraminoplasty per PEFT, then passed through the foramina to the inside disc and conducted an internal disc decompression. The DLSS cases are those with hard compression on the ventral dural and nerve root, but the posterior lower edge of the calcified disc, inferior pedicle, and dorsal ligament flavum channel area is no nerve area. This has appropriate operation space, so that the PEFT percutaneous endoscopic "inside disc out" discectomy technology for the treatment of DLSS can be safer and convenient to reach the lesion area and remove calcified tissue. By removing the nucleus pulposus "inside disc out," and freeing the protrusive disc from the intervertebral foramen to the inferior pedicle and from the intervertebral foramen to the superior pedicle, the whole protrusive disc was removed completely, and nerve root decompression was more effective and safer. Our clinical data showed significant

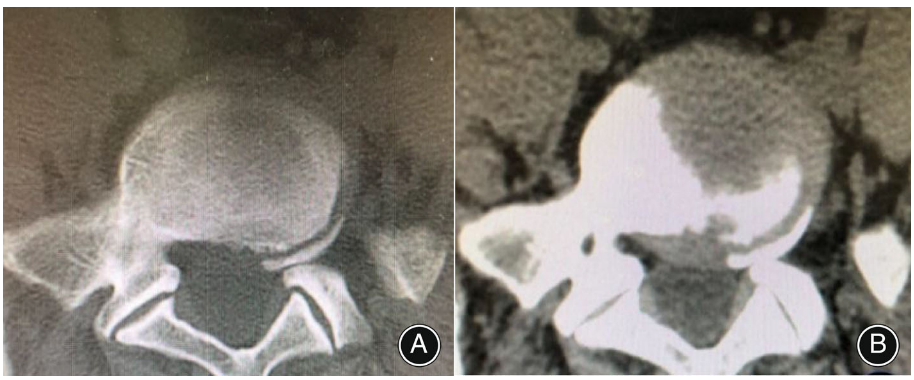


Fig. 6 Preoperative computed tomography (CT) showing lumbar disc protrusion and calcification with lateral recess stenosis

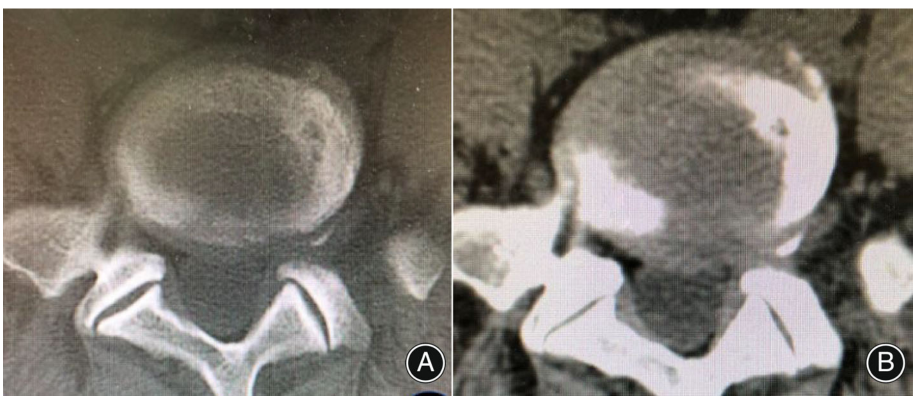


Fig. 7 Postoperative CT revealed adequate removal of the calcified tissue

postoperative improvements. The most significant one was the VAS for leg pain, which improved from 7.52 ± 1.25 (preoperative) to only 0.81 ± 0.51 (12 months after operation) (Table 1). The patients also showed significant improvements in neurological symptoms and disability status, which was reflected by the improvement in ODI (Table 1). Additionally, for the improved MacNab, 26 patients were excellent, two patients were good, and one patient was fair. The excellent and good rate was 91.4%. Imaging also showed significant improvement. Preoperative CT showed calcified lumbar disc protrusion with lateral crypt stenosis (Fig. 6), and postoperative CT revealed adequate removal of the calcified tissue (Fig. 7).

Limitations and Strengths

The sample size of this study was small, and the conclusions would be more reliable if enough patient data were collected. This surgical technique is only tried in the lumbar spine. If it can be applied to the thoracic spine, we believe the conclusion will be more comprehensive.

The surgeon needs to be careful and have rich skills and experience, and the learning curve for the "inside disc out" discectomy protocol is relatively long. Calcified intervertebral disc is very hard with no plasticity, and heavy adhesion with nerve root and dural. The endoscopic management of the calcified protruding discs is relatively difficult due to the limited surgical manipulation space. In terms of high-speed microscopic dynamic system, the risk rate of intraoperative nerve injury is still relatively high.

As the indications and applications of this technique have broadened, the method of approach can be further evolved and modified. The goal of all surgical procedures is to decompress the spinal canal without compromising the stability of the motion segment.[12] When compared with the conventional open surgery, the MI technique can be a cost-effective procedure due to short operation time and rapid return to work with comparable clinical outcomes.[13,14]

Conclusion

The current study demonstrates that per PEFT "inside disc out" discectomy under the intervertebral foramen endoscope is a safe and effective surgical technique for the treatment of DLSS. This technique can reach the diseased area and remove calcified tissue more safely and conveniently; it can separate adhesions more effectively with further nerve root decompression.

Author Contributions

Yuan Xue and Lu Wang conceived and designed the experiments and performed the experiments. Lu Wang and Shunqiang Sun analyzed the data. Shunqiang Sun wrote the paper.

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