A novel visualized foraminoplasty technique in patients with lumbar disc herniation with lumbar foraminal stenosis

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Research Article

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Abstract

OBJECTIVE: To introduce a novel visualized foraminoplasty technique in patients with lumbar disc herniation with lumbar foraminal stenosis.

METHODS: We retrospectively analyzed patients who had undergone surgery in our hospital for lumbar disc herniation with foraminal stenosis. We enrolled 35 patients who received the traditional TESSYS technique and 70 who received the new technique. We compared the foraminalplasty time, fluoroscopy times, intraoperative blood loss, intraoperative dural and nerve root injuries, length of postoperative hospital stay, clinical outcome according with modified MacNab criteria, Visual Analog Scale (VAS) and Oswestry Disability Index (ODI)between the new technique group and the traditional TESSYS technique group.

RESULTS: The intraoperative VAS score(1.84±0.96) and fluoroscopic times(13.30±3.79) in the new technique group were significantly lower than those in the traditional TESSYS group (intraoperative VAS score,3.60±1.09,*P*=0.000;fluoroscopic times,20.00±4.24,*P*=0.000).The foraminalplasty time in the TESSYS group(17.60±3.46) was significantly shorter than that in the new technique group (22.81±4.86) (*P*=0.000).There were no significant differences in length of hospital stay after surge, postoperative VAS score and postoperative ODI score between the two groups (*P*=0.835, *P*=0.779, *P*=0.350). In addition, the amount of blood loss during foraminoplasty could not be calculated due to the presence of continuous saline irrigation in the new technique group. In the conventional TESSYS technique group, there was 1 patient with exiting nerve root injury who developed significant leg pain after surgery.

CONCLUTIONS: The novel visualized foraminoplasty technique is a safe and effective surgical method. Compared with traditional surgical methods, it has obvious advantages in reducing intraoperative pain and radiation exposure.

Introduction

In 1970s, Hijikata et al. [1] developed the technique of percutaneous discectomy. Subsequently, Kambin and Sampson [2] proposed percutaneous endoscopic lumber discectomy (PELD).In recent years, with the development of minimally invasive spinal endoscopy and the continuous development of surgical instruments, PELD has gradually become a mature technique for the treatment of lumbar disc herniation(LDH).Compared with traditional open surgery, PELD has the advantages of less intraoperative blood loss, more anatomical structure of spinal and surrounding tissues preserved, shorter hospital stay, lowest postoperative movement restriction, faster recovery, smaller probability of iatrogenic injury, and relatively less postoperative pain [3, 4, 5].Therefore, many scholars believe that PELD is a better choice for treating LDH [6, 7, 8].There are two kinds of surgical approaches for PELD surgery, namely, the intervertebral approach and the transforaminal approach. In patients with foraminal stenosis, it is difficult to completely remove the dissected disc using the traditional transforaminal percutaneous endoscopic lumber discectomy (TF-PELD) approach, resulting in disc residue and even secondary open surgery. And if the cannula is inserted into the narrow foramen, the cannula may compress the exiting nerve root, causing postoperative dysesthesia. To prevent this complication, foraminoplastic TF-PELD was established [9, 10]. Foraminoplasty is defined as “the ventral partial excision of the foraminal ligament through the superior articular process (SAP), with the use of a bone trephines or endoscopic drill and a side-firing laser to enlarge the foramina to reveal the anterior epidural space and its contents” [11].

With the traditional TESSYS technique, the foramina was enlarged by isocentric reamers to remove part of the SAP after positioning with a puncture needle [12]. Puncture and foraminalplasty using reamers can be a very dangerous procedure because nerve roots also exist in the limited volume of the foraminal space. The traditional TESSYS technique has a steep learning curve [13, 14]. Inappropriate foraminoplasty can easily result in intraoperative nerve root injury, and the removal of excessive superior facet with reamers can affect the stability of the spine [15], the removal of too little will not be exposed nerve root enough cause disc herniation cannot be removed, which can be challenging for even experienced surgeons.

In order to perform foraminoplasty more safely and effectively, Knight et al. [16] performed endoscopic laser foraminoplasty for foraminal nerve root entrapment syndrome in the 1990s. In 2003, Ahn et al. [17] described an endoscopic reamer and laser foraminoplasty. In 2018, some scholars have proposed new instruments for foraminalplasty [18]. In this study, we proposed A novel visualized foraminoplasty technique. And we compared the foraminalplasty time, fluoroscopy times, intraoperative blood loss, intraoperative dural and nerve root injuries, length of postoperative hospital stay, clinical outcome according with modified MacNab criteria, Visual Analog Scale (VAS) and Oswestry Disability Index (ODI)between the new technique group and the traditional TESSYS technique group.

Materials And Methods

We retrospectively analyzed patients who were treated with TF-PELD at our hospital for symptomatic L4/5-disc herniation. Thirty-five patients underwent traditional TESSYS technique and 70 underwent the new foraminoplasty technique. Inclusion criteria were: (1) Chinese citizens; (2) typical symptoms of disc herniation; (3) L4/5 single-segment disc herniation demonstrated by CT or MRI; (4) diagnosis of lateral foraminal stenosis with LDH symptoms4mm or less for the posterior disc height and 15 mm or less for the foraminal height [19], and distance between posterior edge of the disc and ventral aspect of the facet joint was less than 8 mm [30]. Exclusion criteria included: (1) radio-graphic evidence of protrusion in the remaining segments, even if there were no symptoms; (2) spinal instability; (3) history of spinal surgery; (4) history of spinal trauma, tumor, tuberculosis, and infection.

Ethics statement

This study was conducted in accordance with the guidelines of the 1964 Helsinki declaration. Since it is a retrospective study, informed consent from patients is not required after the ethics committee of the First Affiliated Hospital of Wenzhou Medical University has been obtained.

Surgical techinal

All procedures were performed in lateral decubitus position on a radiolucent table using C-arm fluoroscopy under local anesthesia. Patients could communicate with the surgeon during the entire procedure, which enabled the surgeon to avoid damaging to the neural tissues. The skin puncture point was the intervertebral space plane tilted 15 degrees toward the patient's head. The distance from the skin entry point to midline was 2cm from the posterior axillary line。

The Traditional TESSYS Technique Group

After local anesthesia, a needle is inserted into the selected skin puncture point, just past the surface of the superior articular process tip, and further local anesthesia is performed. The final target points of the tip should be very accurate: the upper edge of the pedicle on the anteroposterior radiograph and the posterior upper edge of the vertebral body on the lateral radiograph. There are 3 grades of reamers: 5.0 mm, 6.5 mm, and 7.5 mm. The 5.0mm reamer was positioned using the puncture guide wire and rotated clockwise to extend the hole when in contact with the bone. The reamer was then replaced step by step to enlarge the foramina. In foraminoplasty, the depth of the reamer should be carefully controlled under fluoroscopy and the patient needs to be continually fluorinated anteroposterior and laterally. On anteroposterior radiographs, the depth of the reamer should not exceed the medial edge of the pedicle. (Figure1). Then put in the working cannula and the tip of the working cannula is placed directly into the spinal canal [12].

The New Technique Group

After local anesthesia, the puncture needle was pierced into the selected skin puncture point. During the operation, C-arm fluoroscopy was used to locate the puncture needle. The puncture needle just passes through the tip of the superior articular process. The tip of puncture needle is located outside the spinal canal and above and outside the pedicle on the anteroposterior radiograph and should be posterior and upper part of the vertebral body on the lateral radiograph. Subsequently, the patient was anesthetized further, and after soft tissue reaming, a working cannula was placed, and fluoroscopy was performed again. The cannula was found to be in the same position as the original puncture needle. The tip of the working cannula should be completely outside the foramina. (Figure 2)

The endoscopic system was then placed, followed by continuous irrigation with normal saline, and the external foraminal vessels, ligaments and soft tissues were gradually separated under the endoscope. At the same time, the bleeding vessels and soft tissues were stopped by radiofuncency electrodes, and the intersection points of the SAP, the intervertebral disc and the upper edge of the pedicle were searched (Figure 3, a). The foraminoplasty was subsequently performed under endoscopy with a bone chisel. The chisels included the ventral side of the SAP, the inner upper margin of the lower pedicle, and the posterior upper margin of the lower vertebral body, thereby increasing the width of the foramina and exposing the ventral epidural space. During the process, the soft tissue was carefully separated, and the chiseled bone was carefully removed to avoid damage to the exiting root and foraminal vessels (Figure 3, b). Under the endoscope, use a chisel to gradually enlarge the intervertebral foramen, slowly (Figure 3, c, d). The foramina is progressively enlarged to expose the junction of the superior articular process with the pedicle, or, when exposed to sufficient visual field, to remove the herniated disc (Figure 3, e). In this process, the nerve root is in our vision all the time, but our surgical instruments do not touch or squeeze the nerve root. Finally, we remove the disc (Figure 3, f).

Statistical annalysis

SPSS 17.0 software was used for statistical analysis. The independent sample t-test was used to compare the statistical differences in preoperative information, clinical outcomes, foraminalplasty time, number of fluoroscopic tests, and length of postoperative hospital stay between the two groups. Paired sample t-test was used to compare the differences in ODI scores and VAS scores between the groups before and after surgery. The full score of ODI was 45. Since many patients refused to score the item of sexual life, we removed this item. The foraminalplasty time in the traditional TESSYS technique group included the time of puncture and removal of the SAP with reamers and did not include the time of placement of the working cannulas. The foramination time in the new technique group included puncture fluoroscopy and bone chiseling under the working cannulas until sufficient field of view was exposed to remove the herniated disc.Statistical significant difference was established at $P<0.05$ in every analysis.

Results

Preoperative and Postoperative Clinical Assessments

Preoperative ODI score and VAS score were not significantly different between the two groups ($P=0.468$, $P=0.126$).Similarly, there was no significant difference in postoperative ODI and VAS scores between the two groups ($P=0.779$, $P=0.350$).The mean ODI score in the traditional TESSYS technique group decreased from 19.03±3.81 preoperatively to 4.31±1.55 postoperatively ($P < 0.001$), and the mean VAS score decreased from 7.46±4.04 preoperatively to 1.29±0.67 postoperatively ($P < 0.001$).The mean ODI score in the new technique group decreased from 19.51±2.89 preoperatively to 4.40±1.43 postoperatively ($P < 0.001$), and the mean VAS score decreased from 7.10±1.16 preoperatively to 1.14±0.77 postoperatively ($P < 0.001$).

As shown in Table 1, the intraoperative VAS score of the new technology group was significantly lower than that of the TESSYS group ($P=0.000$). Similarly, the number of intraoperative fluoroscopy in the new technology group was also significantly lower than that of the TESSYS group ($P=0.000$).However, the foraminalplasty time in the TESSYS group was significantly shorter than that in the new technique group (P=0.000).There were no significant differences in length of hospital stay after surge, postoperative VAS score and postoperative ODI score between the two groups ($P=0.835$, $P=0.779$, $P=0.350$).In addition, the amount of blood loss during foraminoplasty could not be calculated due to the presence of continuous saline irrigation in the new technique group.

Complications

As shown in Table 2, both techniques have good clinical outcomes. But in the conventional TESSYS technique group, there was 1 patient with exiting nerve root injury who developed significant leg pain after surgery. But the pain improved with medication.

Discussion

With the development of surgical instruments and surgical techniques, PELD has gradually become one of the mainstream operations for the treatment of lumbar disc herniation. In patients with lumbar degenerative disease, the nerve root outlet is often narrowed due to reduced disc height, osteoarthritic changes in the facet joints, cephalad subluxation of the SAP. Therefore, most of these patients are associated with foraminal stenosis. In this study, foraminal stenosis was defined as “4mm or less for the posterior disc height and 15 mm or less for the foraminal height [19], and distance between posterior edge of the disc and ventral aspect of the facet joint was less than 8 mm [20]”. For patients with foraminal stenosis, the diameter of the foraminal is often smaller than that of the diameter of our surgical endoscope. If the cannula is inserted into the narrow orifice, the cannula may compress the existing nerve root and cause postoperative dysesthesia. To prevent this complication, foraminal plasty is a routine procedure.

Hoogland et al. [12, 21, 22] established the existing TESSYS system, which is a technique for enlarging foramen by using staged reamers. The PELD technique has a very steep learning curve [5], and likewise the TESSYS technique has a very steep learning curve [23, 24]. Different from the YESS technique proposed by Yeung in 2002 [25], the TESSYS technique follows an "outside-in" approach, in which the disc herniation into the spinal canal is removed directly under the endoscope through an enlarged foramen. The decompression process looks directly into the nerve root. However, foraminal plasty should not be performed in the same way for different foraminal sites, and the desired foraminal procedure should be performed for each patient. In addition, there are disadvantages such as instability in the direction of the reamer when using it, such as improper operation, and the risk that the reamers may touch the soft tissue, dura and nerve roots at the edge of the foramina and cause unnecessary injury.

The intervertebral foramen and its adjacent area are the main areas of our surgical operation. However, there are a large number of ligaments and vessels in this area. Surgeons usually pay attention to whether the nerve root is hurt during the operation, thus neglecting the protection of blood vessels and ligaments. An anatomical study shows that, a large number of ligaments exist inside and outside the intervertebral foramen [26]. In these ligament spaces, there are many nerve branches and blood vessel branches. The traditional TESSTYS technology is to constantly adjust the angle and depth of the reamer under fluoroscopy. When the reamer reaches the desired position, the intervertebral foramoplasty is completed. But the whole process of this technique is blind, emphasizing the position of the bony and neglecting the protection of nerves, blood vessels and soft tissue. Some studies have shown that dysesthesia may occur after TESSYS surgery due to the irritation of nerve root associated with the approach [27]. Meanwhile, some scholars found that TESSYS was associated with a high probability of nerve root injury [28]. Wang et al. reported that 3 cases of nerve root injury in 207 cases of TF-PELD operation [29].

Another scholar reported a case of destruction of the radicular artery accompanied by the right L4 exiting nerve root during foramen plasty, followed by bleeding [30].

TF-PELD is operated through Kambin triangle, which is considered to be a safe operation [31]. This area is generally thought of as a blank area with no important organization. However, some scholars have found branches of ascending lumbar vein and intervertebral vein in Kambin triangle [32]. Therefore, blind foraminoplasty is dangerous because the inside and outside of the intervertebral foramen are filled with nerves and blood vessels. For these reasons, we proposed a novel visualized foraminoplasty technique.

Like the traditional TESSYS technique, our proposed new visual foramoplasty technique is a more thorough "outside-in" principle. Our puncture site and first placement of the working cannula were completely outside the spinal canal. After the working cannula was placed, the external foraminal vessels, ligaments and other tissues were clearly visible (Fig. 4). Careful dissection of these ligaments and blood vessels during foraminal plasty can achieve further hemostasis and preserve maximum anatomical integrity. Although the PELD procedure itself has the advantage of low blood loss, our surgical approach further reduces blood loss. The exact amount of blood loss cannot be calculated due to the presence of continuous irrigation with normal saline during the operation. Our technique greatly avoids the injury of large blood vessels and minimizes the possibility of postoperative epidural hematoma. The traditional TESSYS technique neglected the protection of soft tissues and blood vessels inside and outside the foramina due to its emphasis on preventing the reamers from entering too deep into the spinal canal through fluoroscopy in the process of foramina, which may increase the possibility of postoperative wound exudation and delay wound healing.

In our study, intraoperative pain scores were significantly reduced, and radiation exposure was significantly reduced in the new technique group compared to the traditional TESSYS group technique, suggesting that this technique is a good option for patients. Ideally, our new visual foramoplasty technique requires only four fluorograms to achieve our desired puncture location. However, the traditional TESSYS technique not only requires a large number of fluoroscopic positioning to reach the appropriate position of the puncture needle during the puncture process, but also requires continuous fluoroscopy in the anteroposterior and lateral position during the process of the reamers expanding the foramina to ensure that the reamers will not enter the spinal canal too deep and damage the nerve root and dural sac. In addition, a significant reduction in pain during foramoplasty also contributed to increased patient compliance. In the process of foraminal plasty, patients may change their position due to pain, which will affect the smooth progress of puncture positioning and even increase the number of fluoroscopies. Previously, some scholars have pointed out that repeated puncture will increase the risk of radiation exposure of patients and medical staff [33]. In order to reduce the number of fluoroscopy, some scholars have pointed out that the use of ultrasound-assisted needle insertion and foraminalplasty in TF-PELD can reduce the radiation exposure of medical personnel [34], while our technology can well reduce the radiation exposure without the assistance of external equipment.

Our technique allows individualized foraminalplasty according to the characteristics of the patient's foraminal stenosis, thereby reducing articular surface damage caused by excessive removal of bony tissue like the traditional TESSYS technique [35], and avoiding the failure to completely remove the herniated disc due to inadequate foraminalplasty. No nerve root or dural injury occurred in the 70 patients in our new technique group. Furthermore, none of the hundreds of patients who underwent the new technique but were not included in the study had any nerve root damage. In addition, our technique allows arbitrary adjustment of the position and orientation of the tip of the working cannula, using the surrounding skin and muscle tissue as elastic fulcrum, to perform foraminal shaping at the desired angle (Fig. 5). Therefore, for the high-grade migrated herniated discs and even contralateral herniated discs, the surgeon could lever the cannula to make it more horizontal, upward or downward tilting, even contralateral. In addition, one patient in the new technology group who had significant discomfort in the leg after the placement of the working cannula reported improved discomfort after changing the working cannula angle.

Our technology also has the following limitations. First, the new visualized foraminoplasty technique has a significantly longer foraminal shaping time than the traditional technique. Due to the continuous saline irrigation during the operation, too long operation time may have a certain impact on the intracranial pressure of the patients, and the patients may have symptoms of increased intracranial pressure such as headache after the operation. At the same time, prolonged placement of the working cannula increases the possibility of compression of the nerve root. Thirdly, in order to obtain a clearer field of vision, radiofrequency hemostasis will be performed on the bleeding bone surface during foraminoplasty, which will undoubtedly increase the risk of thermal injury in patients. Fourth, in the foraminal shaping process, we need an assistant to assist with the use of the dynamic system under the endoscope, which also has a certain test for the proficiency of the assistant. And finally, we have a very steep learning curve for this technique, which is very demanding for surgeons. However, the effects of both procedures on spinal stability still require many patients to be followed for a long time.

Conclusion

The novel visualized foraminoplasty technique is a safe and effective surgical method. Compared with traditional surgical methods, it has obvious advantages in reducing intraoperative pain and radiation exposure.

Abbreviations

VAS: Visual Analog Scale; ODI: Oswestry Disability Index; PELD: percutaneous endoscopic lumber discectomy; LDH: lumbar disc herniation; TF-PELD: traditional transforaminal percutaneous endoscopic lumber discectomy; SAP: superior articular process.

Declarations

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Authors’ contributions

Author Peng Zhang design the surgical plan, conceive and write the paper. Author Chao-wei Lin participates in surgery and paper writing. Author Minghang Chen, Yaozhi He, Xin Yan, Jiaxin Lai, Shikang Fan and Sheng Li collected the clinical data and analysis, interpretation of data. Author Honglin Teng accomplishes the operation and supervise and project administration. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This research was approved by the ethics committee of the First Affiliated Hospital of Wenzhou Medical University.

Consent for publication

Not applicable.

Competing interests

None declared

References

1. Hijikata S, Yamagishi M, Nakayama T, et al. Percutaneous discectomy: a new treatment method for lumbar disc herniation. J Toden Hosp. 1975; 5:5–13.
2. Kambin P, Sampson S. Posterolateral percutaneous suction-excision of herniated lumbar intervertebral discs. Report of interim results. Clin Orthop Relat Res. 1986;(207):37–43.
3. Cong L, Zhu Y, Tu G. A meta-analysis of endoscopic discectomy versus open discectomy for symptomatic lumbar disk herniation. Eur Spine J.2016; 25:134-143.

4. Rasouli MR, Rahimi-Movaghar V, Shokraneh F,Moradi-Lakeh M, Chou R. Minimally invasive discectomy versus microdiscectomy/open discectomy for symptomatic lumbar disc herniation. Cochrane Database Syst Rev. 2014:CD010328.

5. Wang H, Huang B, Li C, Zhang Z, Wang J,Zheng W, et al. Learning curve for percutaneous endoscopic lumbar discectomy depending on the surgeon's training level of minimally invasive spine surgery. Clin Neurol Neurosurg. 2013; 115:1987-1991.

6. Li Z, Zhang C, Chen W, Li S, Yu B, Zhao H, Shen J, Zhang J, Wang Y, Yu K. Percutaneous Endoscopic Transforaminal Discectomy versus Conventional Open Lumbar Discectomy for Upper Lumbar Disc Herniation: A Comparative Cohort Study. Biomed Res Int. 2020 Mar 2; 2020:1852070. doi: 10.1155/2020/1852070. PMID: 32190653; PMCID: PMC7072112.
7. Chen X, Chamoli U, Lapkin S, Castillo JV, Diwan AD. Complication rates of different discectomy techniques for the treatment of lumbar disc herniation: a network meta-analysis. Eur Spine J. 2019 Nov;28(11):2588-2601. doi: 10.1007/s00586-019-06142-7. Epub 2019 Sep 16. PMID: 31529215.
8. Percutaneous Endoscopic Lumbar Discectomy Versus Posterior Open Lumbar Microdiscectomy for the Treatment of Symptomatic Lumbar Disc Herniation:A Systemic Review and Meta-Analysis
9. Knight MT, Jago I, Norris C, Midwinter L, Boynes C. Transforaminal endoscopic lumbar decompression & foraminoplasty: a 10-year prospective survivability outcome study of the treatment of foraminal stenosis and failed back surgery. Int J Spine Surg. 2014; 1:8.

10. Choi G, Lee SH, Lokhande P, Kong BJ, Shim CS, Jung B, Kim JS. Percutaneous endoscopic approach for highly migrated intracanal disc herniations by foraminoplastic technique using rigid working channel endoscope. Spine 2008; 33: E508-E515.
11. Choi KC, Shim HK, Park CJ, Lee DC, Park CK.Usefulness of percutaneous endoscopic lumbar foraminoplasty for lumbar disc herniation. World Neurosurg. 2017; 106:484-492.
12. Schubert M, Hoogland T. Endoscopic trans-foraminal nucleotomy with foraminoplasty for lumbar disk herniation. Oper Orthop Traumatol.2005;17:641-661.
13. Hsu HT, Chang SJ, Yang SS, Chai CL. Learning curve of full-endoscopic lumbar discectomy. Eur Spine J. 2013; 22:727-733.

14. Yang J, Guo C, Kong Q, Zhang B, Wang Y, Zhang L, Wu H, Peng Z, Yan Y, Zhang D. Learning curve and clinical outcomes of percutaneous endoscopic transforaminal decompression for lumbar spinal stenosis. Int Orthop. 2020 Feb;44(2):309-317. doi: 10.1007/s00264-019-04448-1. Epub 2019 Nov 26. PMID: 31773186.
15. Fan Z, Zheng L, Bingqiang W, Yong Y, Dong L,Jisheng L, et al. Effects on single segmental lum- bar stability after graded facetectomy and lam-inectomy: a finite element study. Zhonghua Yi Xue Za Zhi. 2015; 95:973-977.

16. Knight MT, Vajda A, Jakab GV, Awan S. Endoscopic laser foraminoplasty on the lumbar spine–early experience. Minim Invasive Neurosurg. 1998 Mar;41(1):5-9. doi: 10.1055/s-2008-1052006. PMID: 9565957.
17. Ahn Y, Lee SH, Park WM, Lee HY. Posterolateral percutaneous endoscopic lumbar foraminotomy for L5-S1 foraminal or lateral exit zone stenosis. Technical note. J Neurosurg 2003, 99(3 Suppl):320-3.
18. Ao S, Wu J, Zheng W, Zhou Y. A Novel Targeted Foraminoplasty Device Improves the Efficacy and Safety of Foraminoplasty in Percutaneous Endoscopic Lumbar Discectomy: Preliminary Clinical Application of 70 Cases. World Neurosurg. 2018 Jul;115: e263-e271. doi: 10.1016/j.wneu.2018.04.032. Epub 2018 Apr 13. PMID: 29660553.
19. Inufusa A, An HS, Lim TH, Hasegawa T, Haughton VM, Nowicki BH. Anatomic changes of the spinal canal and intervertebral foramen associated with flexion-extension movement. Spine (Phila Pa 1976). 1996 Nov 1;21(21):2412-20. doi: 10.1097/00007632-199611010-00002. PMID: 8923625.
20. Henmi, T., Terai, T., Nagamachi, A., & Sairyo, K. (2017). Morphometric Changes of the Lumbar Intervertebral Foramen after Percutaneous Endoscopic Foraminoplasty under Local Anesthesia. Journal of Neurological Surgery Part A: Central European Neurosurgery, 79(01), 019–024. doi:10.1055/s-0037-1599059.
21. Hoogland T, Schubert M, Miklitz B, Ramirez A. Transforaminal posterolateral endoscopic discectomy with or without the combination of a low dose chymopapain: a prospective randomized study in 280 consecutive cases. Spine. 2006;31: E890-E897.
22. Hoogland T, van den Brekel-Dijkstra K, Schubert M, Miklitz B. Endoscopic transforaminal discectomy for recurrent lumbar disc herniation: a prospective, cohort evaluation of 262 consecutive cases. Spine (Phila Pa 1976). 2008; 33:973-978.
23. Wang B, Lu G, Patel AA, Ren P, Cheng I. An evaluation of the learning curve for a complex surgical technique: the full endoscopic interlam- inar approach for lumbar disc herniations. Spine J.2011; 11:122-130.
24. Fan G, Wang T, Hu S, Guan X, Gu X, He S. Iso-centric navigation of percutaneous endoscopic transforaminal discectomy at the L5/S1 level in difficult puncture cases: a technical note. Pain Physician. 2017;20: E531-E540.
25. Yeung AT, Tsou PM. Posterolateral endoscopic excision for lumbar disc herniation: Surgical technique, outcome, and complications in 307 consecutive cases. Spine (Phila Pa 1976) 27:722–731.
26. Yuan SG, Wen YL, Zhang P, Li YK. Ligament, nerve, and blood vessel anatomy of the lateral zone of the lumbar intervertebral foramina. Int Orthop. 2015 Nov;39(11):2135-41. doi: 10.1007/s00264-015-2831-6. Epub 2015 Jul 2.
27. Ahn Y. Transforaminal percutaneous endoscopic lumbar discectomy:technical tips to prevent complications. Expert Rev Med Devices.2012;9:361–366.
28. Xin G, Shi-Sheng H, Hai-Long Z. Morphometric analysis of the YESS and TESSYS techniques of percutaneous transforaminal endoscopic lumbar discectomy. Clin Anat. 2013 Sep;26(6):728-34. doi:

10.1002/ca.22286. Epub 2013 Jul 3.

29. Wang K, Hong X, Zhou BY, Bao JP, Xie XH, Wang F, Wu XT. Evaluation of transforaminal endoscopic lumbar discectomy in the treatment of lumbar disc herniation. Int Orthop. 2015 Aug;39(8):1599-604. doi: 10.1007/s00264-015-2747-1. Epub 2015 Apr 12.
30. Zhou C, Zhang G, Panchal RR, Ren X, Xiang H, Xuexiao M, Chen X, Tongtong G, Hong W, Dixson AD. Unique Complications of Percutaneous Endoscopic Lumbar Discectomy and Percutaneous Endoscopic Interlaminar Discectomy. Pain Physician. 2018 Mar;21(2):E105-E112.
31. Kambin P, Sampson S (1986) Posterolateral percutaneous suction-excision of herniated lumbar intervertebral discs: report of interim results. Clin Orthop Relat Res 207:37–43.
32. Yuan SG, Wen YL, Zhang P, Li YK. Ligament, nerve, and blood vessel anatomy of the lateral zone of the lumbar intervertebral foramina. Int Orthop. 2015 Nov;39(11):2135-41. doi: 10.1007/s00264-015-2831-6.
33. Srinivasan D, Then KD, Wang AC, La Marca F, Wang PI, Schermerhorn TC, et al. Radiation safety and spine surgery: systematic review of exposure limits and methods to minimize radiation exposure. World Neurosurg. 2014; 82:1337-1343.
34. Wu R, Liao X, Xia H. Radiation Exposure to the Surgeon During Ultrasound-Assisted Transforaminal Percutaneous Endoscopic Lumbar Discectomy: A Prospective Study. World Neurosurg. 2017 May; 101:658-665.e1. doi: 10.1016/j.wneu.2017.03.050.
35. Lee S, Kim SK, Lee SH, et al. Percutaneous endoscopic lumbar discectomy for migrated disc herniation: classification of disc migration and surgical approaches. Eur Spine J. 2007; 16:431–437.

Tables

TABLE1: Comparison of Clinical Outcomes in the TESSYS and NEW TECHONOLOGY Groups

	TESSYS GROUP	NEW TECHONOLOGY Group	P VALUE
VAS			
Preoperative	7.46±4.04	7.10±1.16	P=0.126
Intraoperative	3.60±1.09	1.84±0.96	P=0.000
Postoperative	1.29±0.67	1.14±0.77	P=0.350
ODI			
Preoperative	19.03±3.81	19.51±2.89	P=0.468
Postoperative	4.31±1.55	4.40±1.43	P=0.779
Foraminoplasty time(min)	17.60±3.46	22.81±4.86	P=0.000
Hospital stay after surge（day）	2.02±0.74	2.00±0.64	P=0.835
Radiation exposure times	20.00±4.24	13.30±3.79	P=0.000

TABLE2: Comparison of MacNab Evaluation, and Complications in the 2 Groups

	TESSYS GROUP	NEW TECHONOLOGY Group
MacNab evaluation		
Excellence	31	64
Good	2	3
Fair	1	3
Poor	1	0
Excellence/good rate	94.29%	95.71%
Nerve root injury	1	0

Figures

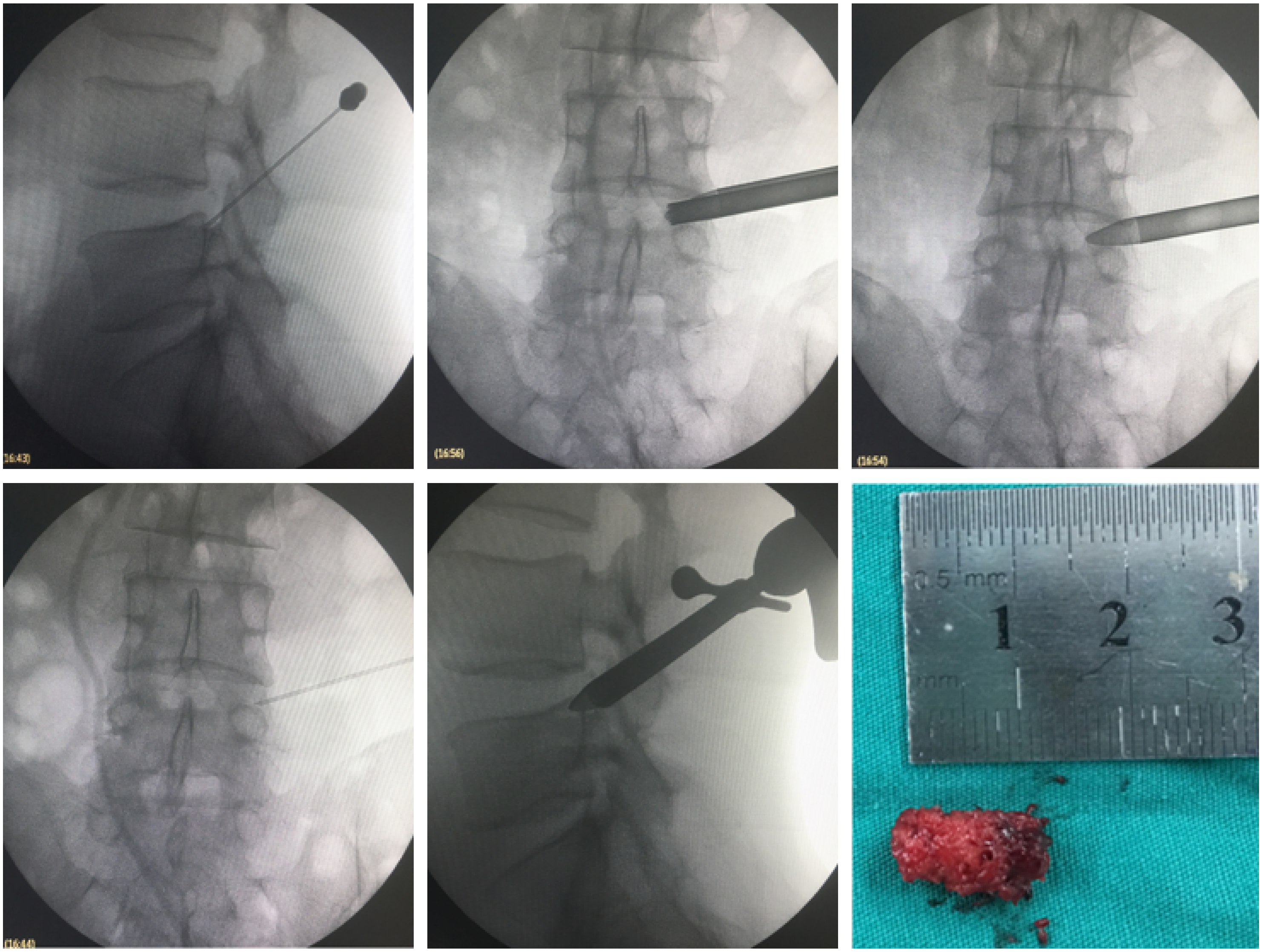

Figure 1

Intraoperative fluoroscopic images showing the traditional TESSYS technique.

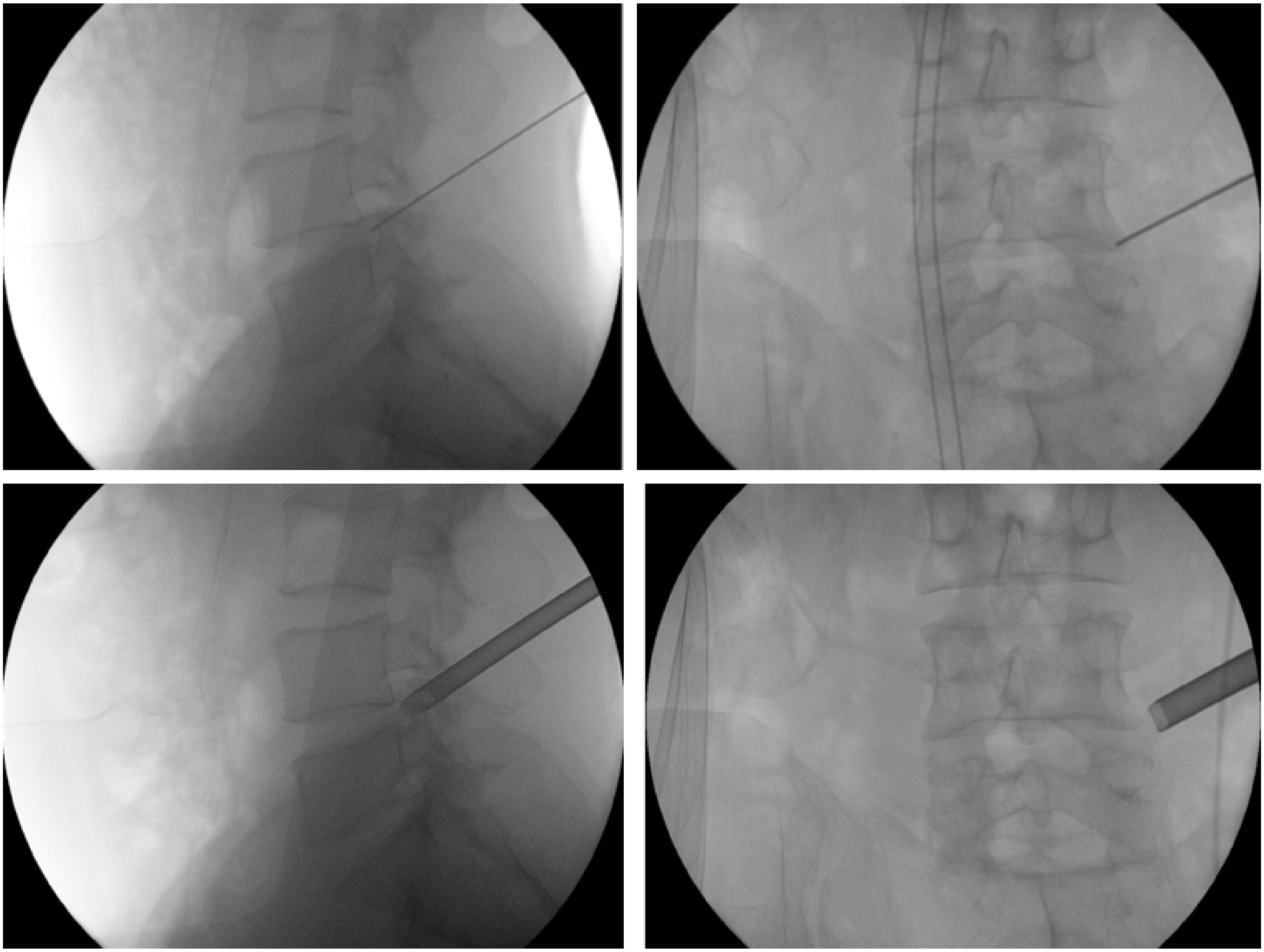

Figure 2

Intraoperative fluoroscopic images showing the new technique.

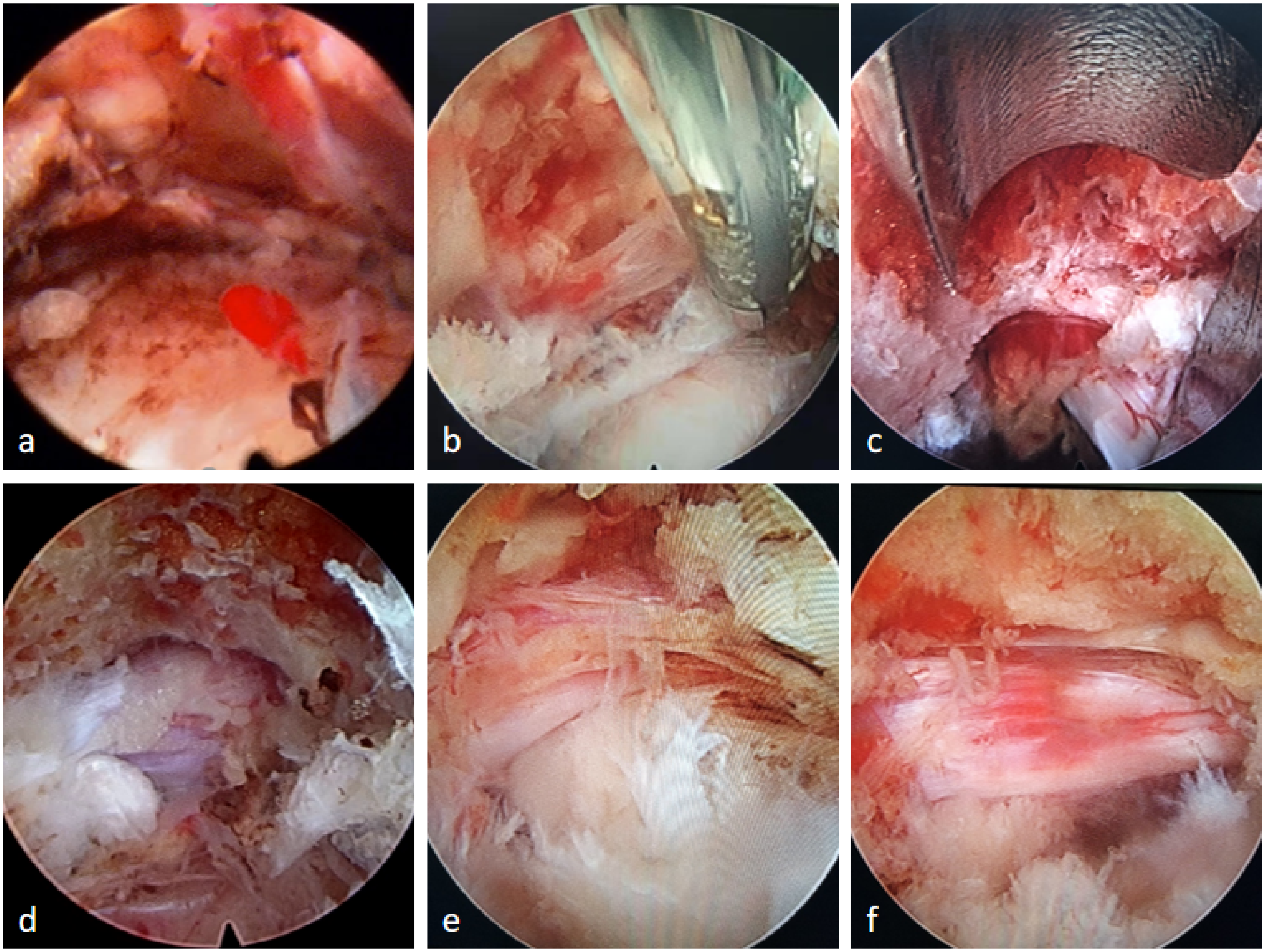

Figure 3

The picture shows the process of the new technique under the endoscope. Picture a shows lateral intervertebral foramen; b demonstrates the foraminal vessels and ligament; c and d show the process of foraminalplasty; e and f show before and after the removal of intervertebral disc.

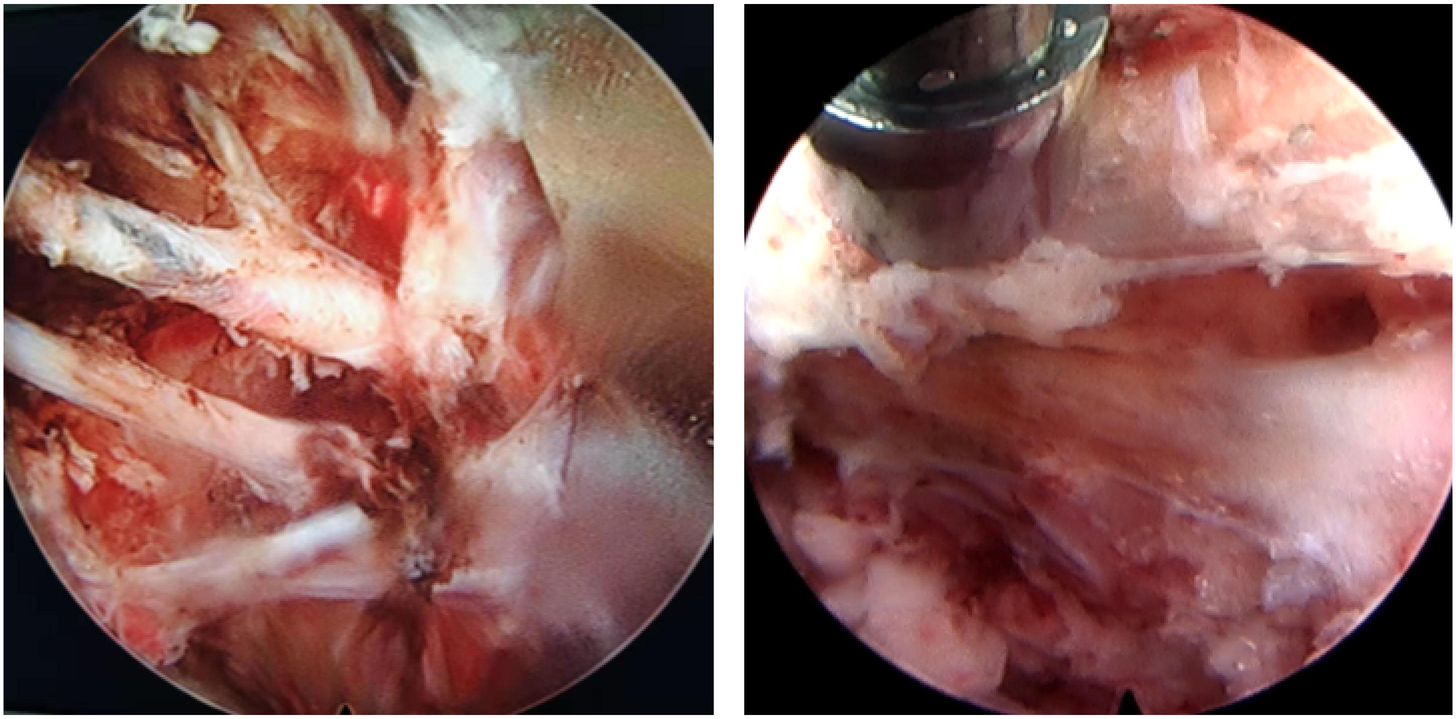

Figure 4

Foraminal vessels and ligament.

Figure 5

The working cannula can be adjusted according to the required angle.