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ORIGINAL ARTICLE

Does the endoscopic keyhole technique have advantages over the microscopic keyhole technique for treating cervical radiculopathy?

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Abstract

Background: Both endoscopic keyhole and microscopic keyhole techniques are considered minimally invasive approaches. However, it is still unclear which is superior in treating cervical radiculopathy.
Aim: This study aimed to compare the clinical outcomes of the two methods for cervical radiculopathy.
Methods: Seventy-one patients with cervical radiculopathy caused by single-level disc herniation were retrospectively reviewed. These patients were treated with the endoscopic keyhole technique (EKT) (34 cases, classified as EKT group) or the microscopic keyhole technique (37 cases, classified as MKT group). Magnetic resonance imaging (MRI), neck disability index (NDI), and visual analog scores (VAS) were employed to assess clinical outcomes. All patients were followed up for at least 24 months.
Results: The average operative time (71.0 ± 15.2 min vs. 63.7 ± 18.9 min, $P = 0.131$), blood loss (56.1 ± 18.2 ml vs. 64.4 ± 13.5 ml, $P = 0.068$), and hospital stay (24.9 ± 5.6 h vs. 28.3 ± 7.1 h, $P = 0.061$) between the EKT and MKT groups were not significantly different. Postoperative MRI demonstrated that effective neural decompression was obtained in all cases after surgery. The NDI in both groups was significantly decreased from pre- to postoperatively (EKT group: 32.8 ± 9.4 vs. 9.2 ± 3.6, $P < 0.001$; MKT group: 36.2 ± 11.3 vs. 10.5 ± 4.1, $P < 0.001$), VAS (EKT group: 5.6 ± 2.3 vs. 1. 5 ± 1.0, $P < 0.001$; MKT group: 6.2 ± 2.1 vs. 1.9 ± 0.8, $P < 0.001$). Nine patients in the EKT group underwent revision surgery due to recurrent disc herniation compared with 2 patients in the MKT group ($P = 0.034$). The interval time from primary surgery to revisional surgery was shorter in the EKT group than in the MKT group (21 ± 5.8 weeks vs. 29 ± 7.2 weeks, $P < 0.001$). There were 2 patients with temporary nerve root irritation and 1 patient with cerebrospinal fluid leak that occurred in the EKT group versus 1 patient who suffered nerve root irritation in the MKT group ($P = 0.547$).
Conclusions: Both EKT keyhole and microscopic keyhole techniques are effective in treating cervical radiculopathy. However, compared with the microscopic keyhole technique, the EKT brings about a higher revision surgery rate with a shorter interval time from index surgery to revision surgery.
Relevance for Patients: These findings suggest that the microscopic keyhole technique seems to be a better way of treating cervical radiculopathy.

1. Introduction

Cervical radiculopathy is defined as a clinical syndrome of sensorimotor deficits due to compression on the cervical nerve root [1]. Facet joint spondylosis and herniation of the intervertebral disc are the most common causes of nerve root compression [2]. Patients present with pain, tingling, numbness, or even weakness in the upper extremity [2].

Surgical management for cervical radiculopathy mainly includes anterior cervical discectomy and fusion (ACDF), cervical foraminotomy via an anterior or posterior approach,

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and cervical arthroplasty with decompression [3-6]. ACDF has been widely performed and is considered the standard surgical treatment for cervical degenerative disc disease [7]. This procedure, however, usually results in the loss of motion at the operated level and accelerates adjacent segmental degeneration [8,9]. In addition to graft-site complications, dysphagia, esophageal perforation, and pseudoarthrosis may also occur in ACDF. Posterior cervical foraminotomy is an appropriate alternative since it is a motion-preserving and minimizing adjacent segmental degeneration technique. The posterior approach is especially feasible for patients whose soft disc herniation originates from the posterolateral location, lying lateral to the cord and compressing the nerve root. It is also appropriate for osteophytes originating from the facet joint, and arm symptoms are more severe than neck symptoms [10,11].

The importance of reducing damage, particularly to muscles that maintain segmental stability, has been widely recognized [12]. The concept that less invasive decompression could yield better results has given rise to the development of minimally invasive techniques, such as microscope-assisted keyhole discectomy and the recently developed percutaneous endoscopic keyhole discectomy. Both of them are considered minimally invasive approaches. However, no literature has reported which one is superior in treating cervical radiculopathy. This study aimed to compare the clinical outcomes of endoscopic keyhole and microscopic keyhole discectomy in treating cervical radiculopathy.

2. Materials and Methods

2.1. Patients

From September 2018 to November 2022, 71 consecutive patients aged 29–75 years with single-level cervical radiculopathy were reviewed in four hospitals. A retrospective study was performed in patients treated with endoscopic keyhole discectomy (n = 34) and microscopic keyhole discectomy (n = 37). The inclusion criteria for this study were (1) unilateral posterolateral soft disc herniation demonstrated by magnetic resonance imaging (MRI), (2) unilateral radicular symptoms with or without neck pain consistent with MRI findings, and (3) failure of conservative treatment for at least 6 weeks. The exclusion criteria were as follows: previous cervical surgical history, myelopathic symptoms, segmental instability, cervical kyphosis, massive, sequestered disc prolapse, cervical axial pain, and discitis. This study was designed in conformity with the Declaration of Helsinki, and informed consent was obtained from eligible patients. The demographic data of the patients are shown in Table 1.

2.2. Surgical procedures

In the microscopic keyhole group, the patient's head was fixed by the Mayfield frame in the Concorde position after general anesthesia. The incision level was determined by fluorography. First, a longitudinal initial incision approximately 10 mm lateral to the midline was made on the pathologic side. Under fluoroscopic guidance, a K-wire was advanced from the incision and was docked at the inferomedial portion of the lateral mass of the surgical level. The incision was elongated to 20 mm, followed by muscular blunt dissection with tubular dilators (Figure 1A). An 18- or 20-mm tubular retractor was placed around the dilator and fixed on the laminofacet junction with a table-mounted flexible arm (Figure 1B). Next, the dilator was removed, and the surgical field was amplified and focused under the microscope. Bipolar cautery and pituitary rongeurs were used to conduct hemostasis and clear the remaining soft tissue off the lateral mass and lamina (Figure 1C). Then, a high-speed burr was utilized to resect the medial one-third of the inferior articular process of the cephalad vertebra until the superior articular process of the caudal vertebrae could be visualized (Figure 1D). After that, a small upangled curette was used to gently detach the ligamentum flavum from the undersurface of the inferior edge of the lamina, and a Kerrison rongeur was used to resect the medial one-third of the exposed superior articular process of the caudad vertebra. Finally, the herniated disc fragment was exposed and removed by a pituitary rongeur after slightly retracting away the dura and nerve root (Figure 1E). The target nerve root could be completely decompressed and checked under microscopic visualization (Figure 1F). A typical case treated by microscopic keyhole discectomy is presented on MRI (Figure 2).

Table 1. Patient demographics

Parameter	EKT (n=34)	MKT (n=37)	P-value
Age (year)	56.5±12.8	61.7±14.2	0.172
Gender (M/F)	15/19	20/17	0.549
Follow-up time (month)	31.8±6.3	29.5±5.1	0.154
Operative time (min)	71.0±15.2	63.7±18.9	0.131
blood loss (ml)	56.1±18.2	64.4±13.5	0.068
hospital stay (h)	24.9±5.6	28.3±7.1	0.061
Operative level			
C3/4	3	1	
C4/5	8	9	
C5/6	13	17	
C6/7	10	8	
C7/T1	0	2	

EKT: Endoscopic keyhole technique; M: Male; F: Female

Compared with the microscopic keyhole technique, the procedures of the endoscopic keyhole technique (EKT) were different as follows: the patient laid in the same position as mentioned above after general anesthesia. First, under fluoroscopic guidance, a K-wire was advanced from a 7 mm incision and docked at the inferomedial portion of the lateral mass of the surgical level. Tubular dilators were used to bluntly dissect muscles, and then the dilator was removed after a working channel was established. Second, a 5.9 mm endoscope was inserted through the working channel to obtain the vision of the margin of the superior lamina, inferior lamina, and medial facet joint after clearing off the attached soft tissue. Third, a keyhole foraminotomy was performed at the lamina-facet junction by using a 3 mm diamond burr and a bone punch. Then, the lateral edge of the dura and the nerve root was identified, and discectomy was performed using micropituitary forceps (Figure 3). A typical case treated by endoscopic keyhole discectomy is presented in Figure 4.

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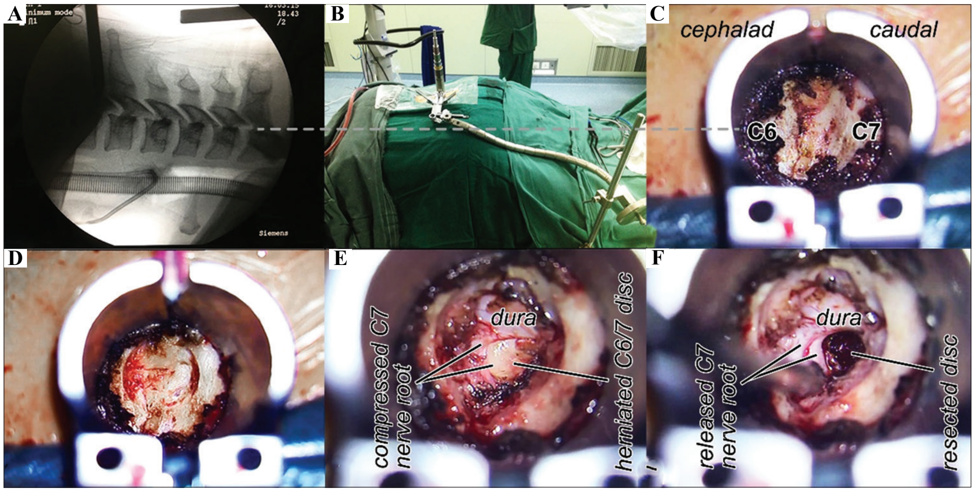

Figure 1. The procedure of the microscopic keyhole technique. (A) Lateral fluoroscopic image confirmed the interest level and demonstrated the starting dilator advancement over the target level. (B) The final 20-mm tubular retractor was placed over the dilators and fixed into place over the laminofacet junction with a table-mounted flexible retractor arm. (C) The surgical field was amplified and focused under the microscope, and the inferior articular process of C6 and the superior articular process of C7 were visualized. (D) After a high-speed burr was utilized to resect the medial third of the inferior articular process of C6 and the superior articular process C7, the yellow ligament was presented. (E) After detachment of the ligamentum flavum from the undersurface of the inferior edge of the lamina and resection of the medial third of the exposed facet joint of C6-C7, the herniated disc and compressed C7 nerve root were exposed. (F) The herniated disc fragment was removed by a pituitary rongeur, and then the C7 nerve root was completely decompressed.

2.3. Clinical evaluations and management

Preoperative and postoperative MRI was compared to evaluate neural decompression. The neck disability index (NDI) and visual analog scale (VAS) scores were recorded to assess intragroup and intergroup neurological functions. Operative time, blood loss, and hospital stay were documented. Surgery-related complications such as neurological deficits and leakage of cerebrospinal fluid (CSF) were recorded to evaluate surgical safety. All patients were followed up for at least 24 months.

Antimicrobials were intravenously administered half an hour before surgery in all patients just once. Analgetic acid was routinely administered for all patients for 72 h postoperatively. General activity was suggested on the 2nd day after surgery. A cervical collar was suggested for use for 2 weeks.

2.4. Statistical analysis

All statistical analyses were performed by IBM SPSS Statistics ver. 19.0 (IBM, Armonk, NY, USA). Preoperative and postoperative data were compared by paired t-tests. Independent samples t-tests were used to compare corresponding data between EKT and MKT groups. The revision surgery rate and complication rate were compared by the Chi-square test. Data are presented as mean ± standard deviation. A $P \leq 0.05$ was considered statistically significant.

3. Results

3.1. Operative outcomes

Seventy-one consecutive patients were retrospectively reviewed in this study. All patients' incisions were primarily healed. The average operative time was 71.0 ± 15.2 min in the EKT group and 63.7 ± 18.9 min in the MKT group ($P = 0.131$). The estimated blood loss was 56.1 ± 18.2 ml in the EKT group versus 64.4 ± 13.5 ml in the MKT group ($P = 0.068$). Additionally, the hospital stay (24.9 ± 5.6 h vs. 28.3 ± 7.1 h for EKT vs. MKT group, respectively, $P = 0.061$) was not significantly different.

3.2. NDI and VAS assessments

The NDI in the EKT group was significantly decreased from 32.8 ± 9.4 preoperatively to 9.2 ± 3.6 ($P < 0.001$) 2 years postoperatively. The NDI in the MKT group decreased from 36.2 ± 11.3 preoperatively to 10.5 ± 4.1 2 years postoperatively ($P < 0.001$). VAS in the EKT group decreased from preoperative 5.6 ± 2.3 to postoperative 2 years 1.5 ± 1.0 ($P < 0.001$), while in the MKT group, VAS decreased from 6.2 ± 2.1 to 1.9 ± 0.8 after surgery 2 years ($P < 0.001$). The improvement in NDI in the EKT group and that in the MKT group were not significantly different (23.4 ± 5.7 vs. 25.3 ± 7.6, $P = 0.313$). The same was true for the improvements in VAS between the two groups (4.1 ± 1.2 vs. 4.3 ± 1.4, $P = 0.583$). Comparing with the EKT group, the VAS and NDI were similarly ameliorated in the MKT group at 3 months and 2 years postoperatively (Table 2).

3.3. Surgery-related complications and revision surgery

MRI demonstrated that effective neural decompression was observed in all cases after primary surgery. Nine patients in the EKT group underwent revision surgery because of recurrent disc herniation versus 2 patients in the MKT group ($P = 0.034$). The interval time from primary surgery to revision surgery was shorter in the EKT group than in the MKT group (Table 3). There were 2 patients with temporary nerve root irritation and 1 patient with

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Figure 2. Preoperative and postoperative magnetic resonance imaging (MRI) preoperative cervical MRI showed the herniated fragment located lateral to the cord and compressing the nerve root of C7 (axial view in (A) and sagittal view in (B), white arrow). Postoperative cervical MRI demonstrated that the herniated fragment was completely resected by microscopic keyhole discectomy, and the nerve root of C7 was decompressed (sagittal view in (C) and axial view in (D)).

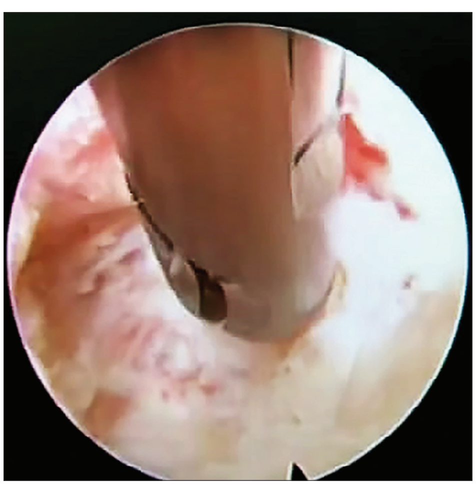

Figure 3. Endoscopic keyhole discectomy was performed by using micropituitary forceps.

CSF leakage due to a dural tear that occurred in the EKT group versus 1 patient who suffered nerve root temporary irritation in the MKT group. There was no significant difference in surgery-related complications between the EKT and the microscopic keyhole technique ($P = 0.547$).

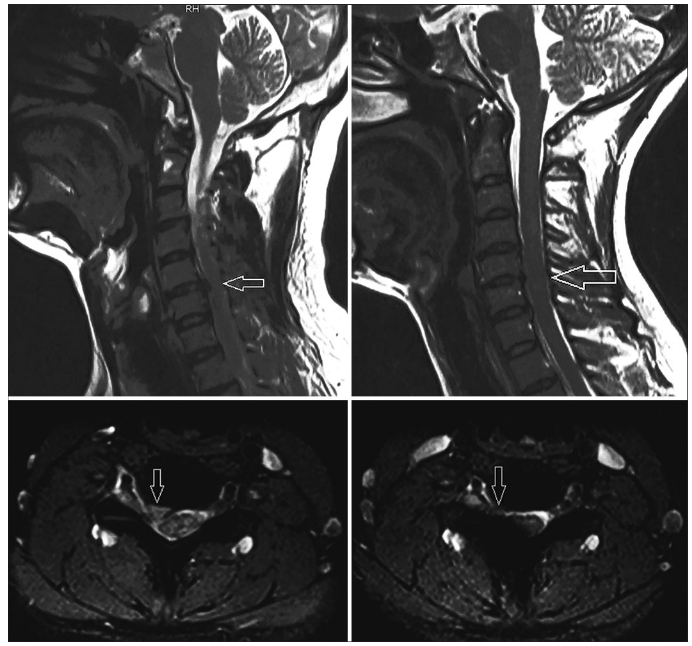

Figure 4. Preoperative and postoperative magnetic resonance imaging (MRI) in the endoscopic keyhole group. Preoperative cervical MRI showed the herniated fragment located lateral to the cord and compressing the nerve root of C6 (A and C, white arrow). Postoperative cervical MRI demonstrated that the herniated fragment was completely resected by endoscopic keyhole discectomy, and the nerve root of C6 was decompressed (B and D, white arrow).

4. Discussion

The posterior approach has distinct advantages in patients with posterolateral disc herniation [13,14], including direct decompression of the involved nerve root without much disruption of the disc and preservation of spinal segmental mobility [15]. In addition, it avoids the risk of injuring the front vital structures of the cervical spine. However, conventional posterior cervical approaches have some drawbacks, such as C5 palsy, kyphosis, and neck pain associated with extensor muscle detachment and atrophy [16,17]. Minimally invasive cervical spinal surgeries were developed to overcome the aforementioned shortcomings. Of those, the keyhole technique is an effective method for treating posterolateral cervical disc herniation which results in cervical radiculopathy. In this study, we compared the clinical outcomes of endoscopic keyhole and microscopic keyhole discectomy in treating cervical radiculopathy and found that both endoscopic keyhole and microscopic keyhole techniques were effective in treating cervical radiculopathy, but the latter had advantages in reducing the revision surgery rate and complications.

Adamson reported that endoscopic posterior lamino-foraminotomy was an effective alternative for treating unilateral cervical radiculopathy secondary to lateral or foraminal disc herniations or spondylosis [18]. In a cadaveric and clinical

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Table 2. NDI and VAS in the EKT group and MKT group

Variable	EKT (*n*=34)	MKT (*n*=37)	*P*-value
VAS			
Preoperative	5.6±2.3	6.2±2.1	0.331
Postoperative 3 months	2.4±1.2	2.7±1.0	0.332
Postoperative 2 years	1.5±1.0	1.9±0.8	0.118
P-value	<0.001	<0.001	
Δ Pre- and post operative	4.1±1.2	4.3±1.4	0.583
NDI			
Preoperative	32.8±9.4	36.2±11.3	0.244
Postoperative 3 month	19.2±6.0	16.8±5.4	0.136
Postoperative 2 years	9.2±3.6	10.5±4.1	0.230
P-value	<0.001	<0.001	
*Δ Pre- and post operative	23.4±5.7	25.3±7.6	0.313

*Δpre- and post operative indicates the difference between preoperative VAS/NDI and VAS/NDI at 2 years postoperatively. NDI: Neck disability index; VAS: Visual analog scores; EKT: Endoscopic keyhole technique

Table 3. Surgery-related complications and revision surgery

Item	EKT (*n*=34)	MKT group (*n*=37)	*P*-value
Complications			
Nerve root irritation	2	1	0.547
Cerebrospinal fluid	1	0	
Revision surgery	9	2	0.034
*Interval time (week)	21.0±6	29.0±7	<0.001

*Interval time means the interval time from primary surgery to revisional surgery.
EKT: Endoscopic keyhole technique

combined study, it was demonstrated that a viable, minimally invasive technique could provide exceptional visualization and an improvement in postoperative recovery time [19]. In this study, the NDI and VAS were also significantly decreased after endoscopic keyhole surgery, which confirmed the effectiveness of this minimally invasive surgery (MIS) method. Theoretically, endoscopic keyhole surgery is less invasive than microscopic keyhole surgery. However, we found that both keyhole techniques had similar MIS characteristics regarding operative time, estimated blood loss, and hospital stay. In the MKT group, a slightly longer incision and involved dissection might not affect the abovementioned aspects. Xu *et al.* considered that the tubular retractor system used in the MKT group was fixed by a free arm, so the traction force on posterior extensors was evenly dispersed, and excessive muscular traction could be avoided [20]. Hence, there was no severe postoperative muscle atrophy that occurred in the MKT group. The limited surgery time might be another explanation for the similar invasiveness between the two groups.

Although the incisions of both keyhole techniques were small, intraoperative neural decompression could be performed effectively. The current study showed that NDI and VAS in both groups were significantly decreased after surgery ($P < 0.001$ in both groups), which revealed valid neural decompression resulting from both MKT keyhole and EKTs. The improvements in VAS and NDI between the two groups were significant. Considering that we treated cervical radiculopathy rather than myelopathy in the current study, we did not employ the JOA score to assess clinical outcomes.

Interestingly, in this study, the occurrence rate of revision surgery because of recurrent disc herniation in the EKT group was significantly higher than that in the MKT group ($P = 0.034$). Although the endoscopic technique can provide a minimally invasive approach, it only provides two-dimensional visualization, and surgical vision is often blurred by bleeding or obscured by tissue fragments during operation. The microscopic keyhole technique could provide a three-dimensional and amplified visualization of the surgical field, in coordination with coaxial illumination, and the tubular retractor system also provided more space for performance, which allowed the surgeon to resect the herniated disc more thoroughly and minimized neurological injury. Furthermore, the interval time from primary surgery to revision surgery was longer in the MKT group than in the EKT group ($P < 0.001$). This might reveal that the residual fragments of the disc could reherniate in an earlier stage in the EKT group and that the effectiveness of the microscopic keyhole technique in treating cervical radiculopathy was more durable. This is also the case because of the steep learning curve of the EKT, which has been one of its disadvantages. Furthermore, unskilled operation in the early stage of the steep learning curve is also the reason for the higher recurrence rate in the EKT group. Concerning surgery-related complications, there was more but no significant difference in the EKT group versus the MKT group ($P = 0.547$). Therefore, both techniques could be considered safe methods in the treatment of cervical radiculopathy.

To master the endoscopic technique in clinical practice, surgeons need to know the anatomic landmarks under endoscopy and acquire a way to minimize bone resection. Bony resection of endoscopic keyhole laminoforaminotomy was limited as follows: 1. superior limit, inferior border of the superior facet; 2. inferior limit, superior border of the inferior facet; 3. lateral limit, the junction of the lamina and facet; and 4. medial limit, lateral aspect of the dural sac. To avoid confusion, we considered all superior and inferior anatomic structures of a superior vertebra as superior and all superior and inferior structures of an inferior vertebra as inferior. Hence, instead of using anatomic nomenclature, we identified the facets and laminae based on their relative surgical perspectives. Although the amount of bony resection depends on the patient's anatomy and surgeon's experience, facet resection is usually not more than 25% of the facet joint and very rarely 50% to avoid segmental disability.

After the nerve root has been exposed, it is vital to discern whether the dorsal sensory and ventral motor roots are combined in a single dural sleeve or if the ventral motor root has a separate, thinner, dusky dural mater. This identification is critical to avoid confusing a tethered ventral motor root surrounded by perineural adhesions with the disc herniation itself. Typically, a compressed nerve root is surrounded by an engorged epidural venous plexus that must be coagulated, where feasible, with bipolar forceps. Electrocoagulation should be precise, especially when it is used in the spinal canal, and the electrode should be turned down to reduce damage to the nerve. Surgeons who are just getting

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involved in this field can start with endoscopic lumbar discectomy in a transforaminal approach, which is easier for beginners.

There were some limitations in this study. First, the sample size in this study was limited, which may increase bias. Second, the proficiency of surgery influences the clinical outcomes. Third, this study was a retrospective cohort study. A randomized controlled trial (RCT) would be better to illuminate the clinical outcome difference between the two different posterior MIS techniques. However, to our knowledge, this is the first comparative study between these different keyhole surgeries despite the abovementioned limitations. In future, a multicenter RCT study with a larger number of cases will be required to clarify the effectiveness and safety of both techniques.

With similar surgical complication rates, both endoscopic keyhole and microscopic keyhole techniques are effective in treating cervical radiculopathy resulting from posterolateral disc herniation. However, compared with the microscopic keyhole technique, the EKT brings about a higher revision surgery rate with a shorter interval time from index surgery to revisional surgery.

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Conflicts of Interest

The authors have declared no conflicts of interest.

Ethics Approval and Consent to Participate

This study has been approved by The First Affiliated Hospital of Nanchang University.

Consent for Publication

All patients gave their oral and written consent.

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