Retrospective Analysis

Full Endoscopic Decompression Surgery for Far-Out Syndrome Via Pseudoarthrosis Formed by L5 Transverse Process and Sacral Ala: A Preliminary Outcome

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Background: Far-out syndrome (FOS) refers to the compression of the L5 nerve root in the extraforaminal region by a pseudoarthrosis formed between the L5 transverse process and the sacral ala. If conservative treatment for this condition fails, surgical intervention should be considered.

Objectives: This study aims to introduce a minimally invasive endoscopic technique for treating FOS via the pseudoarthrosis approach.

Study Design: A technical note and preliminary outcome.

Methods: We retrospectively analyzed the medical history, physical examination, auxiliary examinations, and imaging data as well as the visual analog scale (VAS), Oswestry Disability Index (ODI), and Macnab scores of 5 FOS patients treated with minimally invasive endoscopic surgery at our hospital from April 2024 to July 2024. The implementation process of this surgical technique is illustrated through typical cases.

Results: We performed decompression surgery via the L5 transverse process-sacral ala pseudoarthrosis approach using full endoscopy, which successfully relieved the clinical symptoms in the 5 patients. The patients' postoperative VAS scores were significantly lower than the preoperative scores ($P = 0.041$). Similarly, the postoperative ODI scores were markedly decreased ($P = 0.043$), and the last follow-up showed a 100% excellent rate (Macnab score). Imaging examination indicated a sufficiently expanded extraforaminal outlet, and the nerve roots were adequately decompressed.

Limitations: The study involved a relatively small number of samples and a short follow-up period.

Conclusions: The full endoscopic decompression surgery via the L5 transverse process-sacral ala pseudoarthrosis approach can address the extraforaminal compression in FOS. This procedure is a feasible endoscopic surgical option that serves as a valuable supplement to the minimally invasive treatment for FOS.

Key words: Full endoscopy, far-out syndrome (FOS), pseudoarthrosis, spine surgery, minimally invasive surgery, nerve entrapment, low back pain, radiculopathy

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In 1984, Wiltse first reported far-out syndrome (FOS), defining it as the compression of the L5 nerve root in the extraforaminal region caused by a pseudoarthrosis formed by hypertrophic transverse processes and sacral ala overgrowth. FOS is commonly seen in elderly patients with degenerative scoliosis and in younger adults with cases of isthmic spondylolisthesis in which the slip distance is at least 20% relative to the vertebral body diameter. Wiltse also noted that computed tomography (CT) was the most effective tool for diagnosing FOS. In surgical procedures intended to treat FOS, the primary goal is to decompress the nerve sufficiently to the lateral side, which may, however, compromise spinal stability (1). Patients with FOS often have a condition known as lumbosacral transitional vertebra (LSTV), a relatively common congenital spinal anomaly, in which the transverse process of the last lumbar vertebra becomes widened on one or both sides or forms varying degrees of fusion with the sacral vertebra (2-4), The most commonly used classification for describing the morphological characteristics of LSTV is the Castellvi classification (5). In addition to potentially causing FOS, LSTV can also lead to a condition known as Bertolotti syndrome (BS), which results in pseudoarticulation-induced pain in the lower back. BS was first reported by Mario Bertolotti in 1917. The incidence of this syndrome varies greatly, ranging from 4% to 35%, according to the literature. Many patients may never receive an accurate diagnosis because LBP can be mistaken for other conditions that present with similar symptoms. Radiological findings and their correlation with clinical presentation form the foundation for diagnosing BS. In most cases, anteroposterior plain x-rays of the lumbosacral spine are sufficient for this purpose (6-11). If conservative treatment for FOS is ineffective, surgical intervention is often required. Although traditional surgical treatment for FOS has primarily involved open lumbar spine surgery (12,13), minimally invasive surgeries have gradually emerged in recent years as treatment options for FOS (6,13,14). Procedures that use full endoscopic technology are considered types of ultra-minimally invasive spinal surgeries (15). However, there are currently few reports about the use of full endoscopic surgery for the treatment of FOS.

Methods

We retrospectively analyzed the clinical data of 5 patients diagnosed with FOS at our hospital from April 2024 to July 2024. These patients exhibited typical L5 root symptoms, primarily as radiating pain in the lateral calf. After completing relevant auxiliary examinations such as lumbar x-ray and lumbar CT, magnetic resonance neurography of the lumbosacral plexus, ultrasound-guided nerve root block, it was confirmed that all these patients had significant pseudoarthrosis formation between the L5 transverse process and the sacral ala, suggesting compression of the L5 root. After the relevant contraindications were excluded, all patients underwent full endoscopic decompression surgery via the L5 transverse process-sacral ala pseudoarthrosis approach at our hospital.

Surgical Procedure

We performed full endoscopic decompression surgery via the L5 transverse process-sacral ala pseudoarthrosis approach. The patient was placed in a prone position on an arch frame and given intravenous anesthesia. The C-arm was used to locate the medial edge of the bony structure at the pseudoarthrosis. We then performed layered local anesthesia using 2% lidocaine, followed by an incision of 1 cm. A K-wire was used to penetrate to the medial edge of the L5 transverse process-sacral ala pseudoarthrosis. Afterward, intraoperative lumbar CT 3D reconstruction was used to confirm the accurate positioning of the K-wire, sequential dilators were inserted, and a guide rod was fixed to the junction area of the L5 transverse process and sacral ala. The placement of the endoscopic system then followed (Fig. 1). After thorough hemostasis with radiofrequency, adipose and other soft tissues were removed with rongeurs to fully expose the bony surface of the pseudoarthrosis, along with partial exposure of the transverse process and sacral ala, then we observed hypertrophy of the L5 transverse process and sacral ala, forming a pseudoarthrosis. We used a burr to grind down part of the pseudoarthrosis, transverse process, and sacral ala. The L5 nerve root and the radicular artery ran together at the pseudoarticulation between the L5 transverse process and the sacral ala, so, from an anatomical perspective, we could first locate the radicular artery during the removal of the pseudoarticulation, and by following the radicular artery, we could identify the accompanying L5 nerve root. Once the nerve root was identified, we could decompress the surrounding area along the L5 nerve root. The L5 nerve root was found adhering to surrounding tissues, with signs of congestion and edema. Subsequently, we used the burr to thoroughly remove the pseudoarthrosis and then exposed the L5 nerve root. We performed exten-

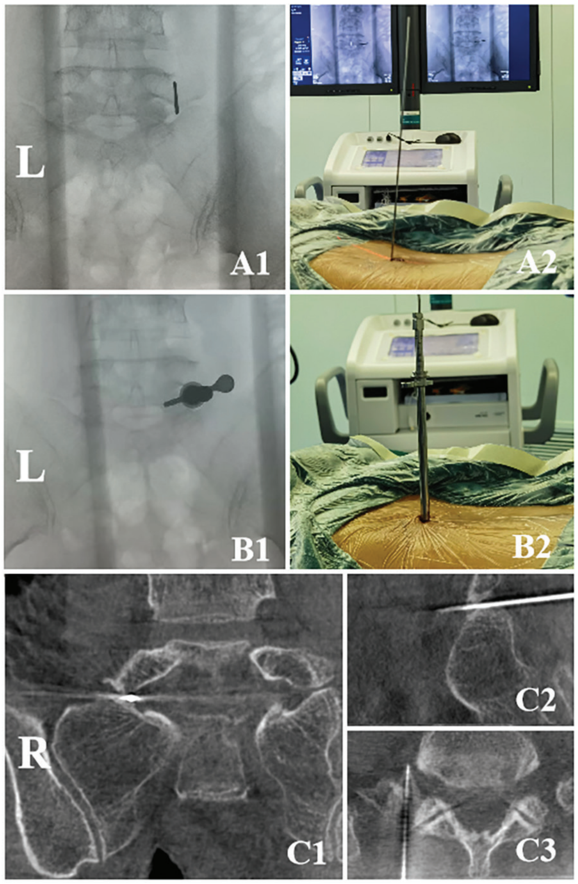

Fig. 1. *A1: The K-wire positioned at the pseudoarthrosis under x-ray guidance. A2: Schematic representation of the K-wire. B1: Illustration of the channel placement under X-ray fluoroscopy. B2: Schematic representation of the channel placement. C1, C2, and C3 were coronal, sagittal, and axial reconstructions guided by 3-dimensional CT, with the K-wire accurately positioned into the pseudoarthrosis.*

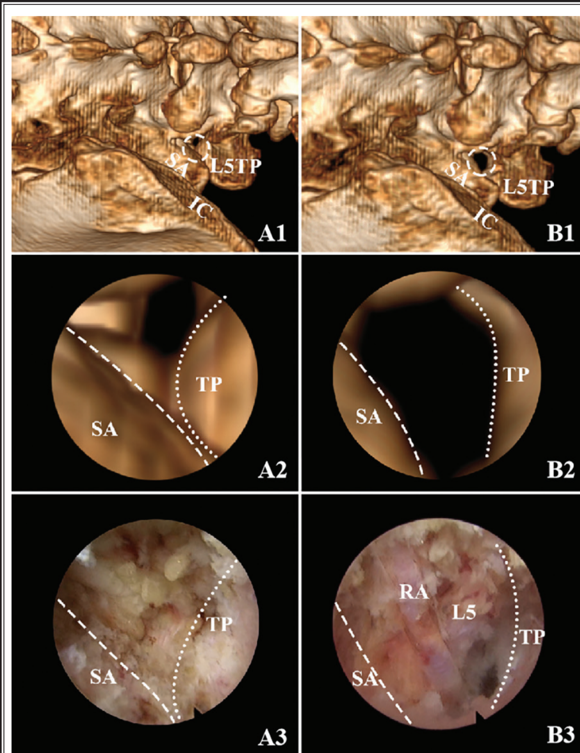

Fig. 2. *A1: Preoperative posterior view of 3D CT reconstruction of lumbar spine, with the dashed circle indicating the field of view of the endoscope. A2: Enlarged view of the dashed circle in A1, with white dashed lines indicating the course of the sacral ala edge and dotted lines indicating the course of the L5 transverse process edge. A3: Intraoperative endoscopic view before decompression, with dashed lines and dotted lines following the same definitions as in A2. B1: Postoperative posterior view of 3D CT reconstruction of lumbar spine. B2: Enlarged view of the dashed circle in B1. After the removal of the pseudoarthrosis between the L5 transverse process and the sacral ala, the gap between the L5 transverse process and the sacral ala increased significantly. B3: Intraoperative endoscopic view after decompression.*
SA: Sacral ala. TP: Transverse process. IC: Iliac crest.

sive decompression along the dorsal and lateral sides of the nerve root to relieve nerve compression (Fig. 2), and the incision site was locally disinfected with iodine and sutured with one stitch. The surgery proceeded smoothly, and postoperatively, the patients' lower limbs experienced significant pain relief and improvements to their sensation and motor function.

Case 1

A 54-year-old woman was admitted with "low back pain accompanied by right lower limb pain for one year." The pain was most severe in the posterior and lateral aspects of the right calf and the sole of the foot, VAS score: 6, ODI score: 25.6. The pain could be relieved by rest and worsened with walking. After the patient undergoing conservative treatment, her symptoms did not significantly improve. Physical examination revealed decreased sensation in the outer thigh area of the right side. Lumbar x-ray indicated a pseudoarthrosis between bilateral L5 transverse processes and the sacrum, with indistinct borders, more pronounced on the right side (Fig. 3). Meanwhile, preoperative magnetic resonance neurography of the lumbosacral plexus revealed a continuity interruption of the L5 root in the extraforaminal region near the pseudoarthrosis. Preoperative lumbar CT indicated pseudoarthrosis formation on the right side (Castellvi type IIa) (Fig. 4). We also performed a 3-dimensional reconstruction of the lumbar CT, which confirmed bony stenosis of the extraforaminal region of the right L5 root (Fig. 5). The hyperplastic pseudoarthrosis in the posterolateral region, combined with osteophytes or protruding annulus fibrosus from the medial vertebral body, compresses the L5 nerve root, causing radiating pain in the patient's lower limb. Additionally, the position of the pseudoarthrosis may compress the dorsal root ganglion, potentially contributing to the patient's lower back pain. Therefore, the surgery requires thorough decompression of the medial side of the pseudoarthrosis. After excluding relevant surgical contraindications, we performed full endoscopic decompression surgery via L5 transverse process-sacral ala pseudoarthrosis approach for this patient. Postoperatively, the patient reported significant relief of lower limb pain, with a VAS score of one and an ODI score of 1.6. The patient was discharged 3 days after surgery, and her last follow-up Macnab score was excellent.

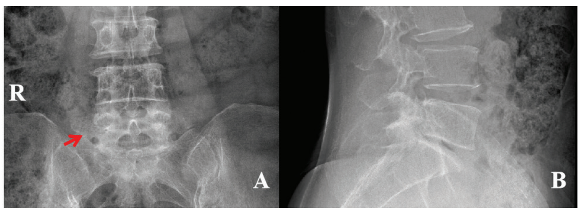

Fig. 3. *A: A pseudoarthrosis formed between the right transverse process and the right sacral ala (indicated by the red arrow). B: The collapse and narrowing of the L5/S1 intervertebral space.*

Case 2

The patient is a 60-year-old man presenting primarily with "lower back pain accompanied by left lower limb pain and numbness for 2 years, worsening over the past month." His lumbar x-ray showed a pseudoarthrosis between the left L5 transverse process and the sacral ala, and the L5/S1 intervertebral space showed collapse and narrowing (Fig. 6). The patient's lumbar CT with 3-dimensional reconstruction indicated impingement between the L5 transverse process and sacral ala (Castellvi Type IIa) (Fig. 7). Preoperative lumbar CT indicated bony stenosis between the L5 transverse process and the sacral ala. Postoperative images showed that this bony stenosis was resolved. We refined the examination further with lumbosacral plexus neuroimaging, which showed a discontinuity of the left L5 nerve root outside the intervertebral foramen. Full endoscopic decompression surgery via the L5 transverse process-sacral ala pseudoarthrosis approach was performed on the patient's left

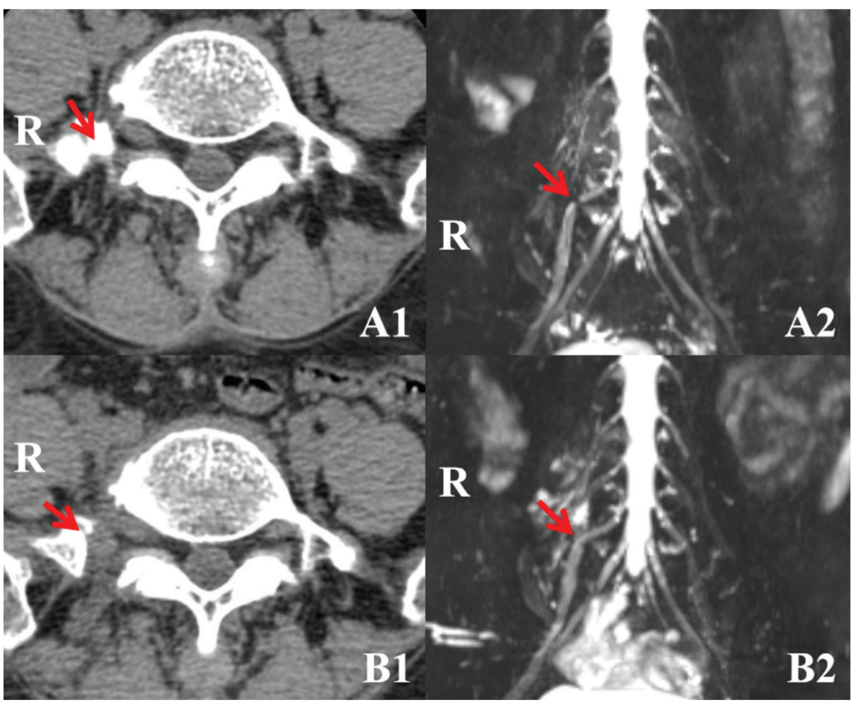

Fig. 4. *A1: Preoperative axial lumbar CT images of Case 1. B1: Postoperative axial lumbar CT images of Case 1. The red arrow in A1 indicates the pseudoarthrosis site before surgery, while the red arrow in B1 shows a significantly enlarged bony gap at the site where the pseudoarthrosis was excised. A2: Preoperative lumbosacral nerve hydrography illustration for Case 1, with the red arrow indicating the compression point of the right L5 nerve root, showing an interruption in nerve imaging continuity. B2: Postoperative lumbosacral nerve hydrography illustration for Case 1, with the red arrow indicating the restoration of continuity in the right L5 nerve root.*

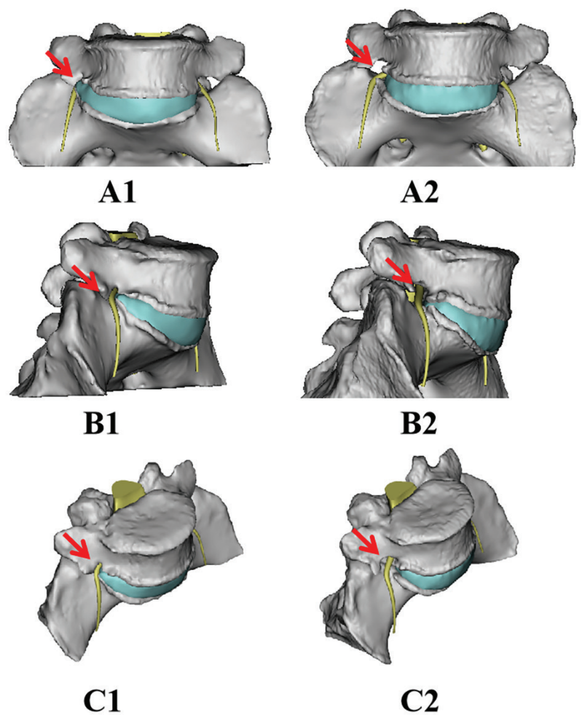

Fig. 5. *All the red arrows in these images indicate the areas around the nerve root before or after decompression. A1: Preoperative 3D reconstructed CT frontal view of the lumbar spine, showing the pseudoarthrosis formed between the L5 transverse process and the sacral ala. A2: Postoperative 3D reconstructed CT frontal view of the lumbar spine. B1: Preoperative 3D reconstructed CT right oblique view of the lumbar spine, showing the pseudoarthrosis that formed between the L5 transverse process and the sacral ala. B2: Postoperative 3D reconstructed CT oblique view of the lumbar spine. C1: Preoperative 3D reconstructed CT top view of the lumbar spine, showing the pseudoarthrosis that formed between the L5 transverse process and the sacral ala. C2: Postoperative 3D reconstructed CT top view of the lumbar spine.*

side. Postoperative magnetic resonance neurography of the lumbosacral plexus indicated the restoration of nerve continuity. Postoperatively, the patient experienced significant relief of pain in the left lower limb, with good motor and sensory function.

Statistical Analysis

In this study, SPSS® Version 26.0 (IBM® Corporation) was used for all statistical tests. The statistical analysis variables included preoperative and postoperative VAS scores and ODI scores. If the data followed a normal distribution, a paired t-test was used; if the data did not follow a normal distribution, a paired nonparametric test (Wilcoxon signed-rank test) was employed. *P*-values under 0.05 were regarded as significant.

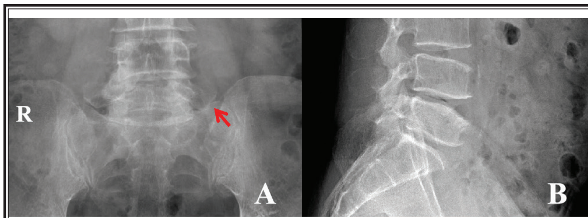

Fig. 6. *Preoperative x-ray examination of Case 2. A: A pseudoarthrosis formed between the left transverse process and the sacral ala (indicated by the red arrow). B: The collapse and narrowing of the L5/S1 intervertebral space.*

Results

From April 2024 to July 2024, 5 patients underwent full endoscopic decompression surgery via the L5 transverse process-sacral ala pseudoarthrosis approach at our hospital. Postoperatively, patients experienced significant relief of lower limb pain compared to preoperative levels, and their quality of life improved markedly (Table 1). One day after surgery, the VAS score was significantly lower than preoperative levels ($P = 0.041$), and the ODI score was also significantly reduced compared to preoperative levels ($P = 0.043$). Postoperative Macnab scores indicated an excellent and good rate of 100% (Table 2). Imaging examination indicated a sufficiently expanded extraforaminal outlet, adequately decompressed nerve roots, and restored continuity of L5 nerve roots.

Discussion

In our clinical practice, when encountering patients with low back pain accompanied by radiculopathy symptoms in the lower limbs, we initially consider the diagnosis of lumbar disc herniation. We consider this diagnosis because lumbar disc herniation that affects the L5 nerve root can present similar clinical symptoms to FOS. Therefore, it is crucial to differentiate carefully between the 2 conditions. The main distinguishing factor lies in the imaging findings, specifically in assessing whether hypertrophy of the fifth lumbar transverse process or sacral ala exists. Wiltse et al (1) recommend using CT scans to diagnose FOS accurately. The incidence of lumbar disc herniation is significantly higher than that of FOS. Therefore, an incomplete or insufficiently detailed imaging review may lead to missed or incorrect diagnoses for some FOS patients. Nakao et al suggest that 3D CT scans can effectively identify the

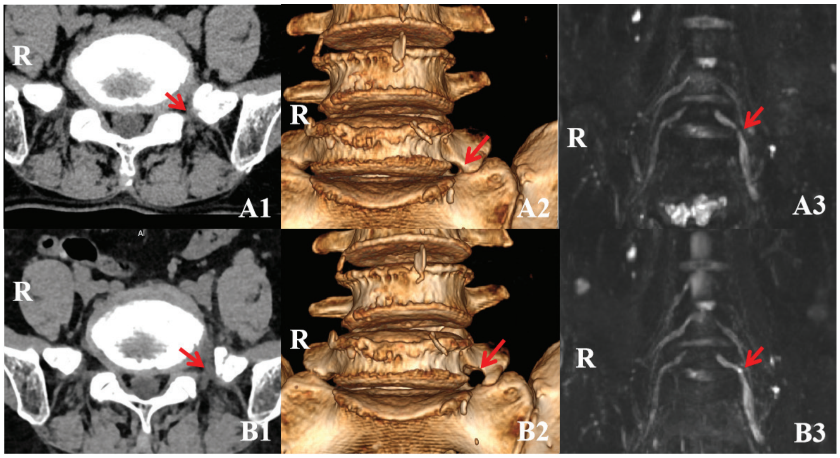

Fig. 7. *A1: preoperative axial CT images of the lumbar spine, respectively. B1: postoperative axial CT images of the lumbar spine, respectively. The red arrow in A1 indicates the pseudoarthrosis site preoperatively, while the red arrow in B1 shows the significantly enlarged bony gap after the pseudoarthrosis was removed. A2: Preoperative 3D reconstructed CT frontal view of the lumbar spine for Case 2. B2: Postoperative 3D reconstructed CT frontal view of the lumbar spine for Case 2. The red arrow indicates the significantly increased gap between the L5 transverse process and the sacral ala after the pseudoarthrosis removal. A3: Preoperative magnetic resonance neurography of the lumbosacral plexus for Case 2, with the red arrow indicating the compression point on the left L5 nerve root, showing an interruption in nerve continuity. B3: Postoperative magnetic resonance neurography of the lumbosacral plexus for Case 2, with the red arrow indicating the restored continuity of the left L5 nerve root, with minor local tissue edema.*

pseudoarthrosis formed between the L5 transverse process and the sacral ala (16). Byun et al (17) indicate that 3D magnetic resonance imaging (MRI) is more effective at detecting the indentations caused by compression of the L5 nerve root. Meanwhile, Takeuchi et al (18) have proposed an oblique MRI imaging method that uses clinical observation and analysis and may better identify conditions related to extraforaminal nerve root compression. Through a controlled study, Iwasaki et al pointed out that in addition to conventional imaging examinations, distal motor latency (DML) testing could be used to assess L5 nerve root compression from an electrophysiological perspective (19).

When conservative treatment fails, FOS often requires surgical intervention. The main surgical options are minimally invasive endoscopic surgery and open surgery. Matsumoto et al (13,21) successfully alleviated lower limb pain in 3 patients by using a microscope to excise part of the sacrum along the L5 nerve. Additionally, in another study, Sasaki et al (20) mentioned that for elderly patients with extraforaminal stenosis at the lumbosacral junction, nonfusion decompression surgery was a feasible and less invasive option that could provide good midterm outcomes (13,20,21). Park et al (14,22) evaluated patients' VAS and ODI scores and concluded that for FOS and other cases of L5/S1 extraforaminal stenosis, unilateral biportal endoscopic (UBE) surgery was an effective option. In 1991, Hambly et al (23) performed unilateral lumbar transverse process fusion on 13 patients, effectively relieving the clinical symptoms of FOS. The contributors to the study concluded that unilateral lumbar transverse process fusion was essential when decompression was needed for FOS treatment or when tumor compression caused neurological symptoms (23). For some patients with severe lumbar degeneration, a combination of lumbar interbody fusion and treatment of the pseudoarthrosis associated with FOS may result in better clinical outcomes. Ise et al reported a case in which transforaminal lumbar interbody fusion (TLIF) was performed to treat FOS as well as correct lumbar deformity. They excised the L5 transverse process to decompress the extraforaminal stenosis and subsequently installed pedicle screws, successfully alleviating the patient's symptoms (12). Due to the formation of pseudarthrosis, FOS may also involve the aforementioned condition of BS, which primarily manifests as low back pain (6,8,24). Desai et al (25) suggest that the pseudarthrosis itself could be the source of pain in BS. Therefore, addressing the pseudarthrosis is crucial when performing a surgical intervention for FOS.

In our clinical experience, we have found that some patients with FOS have collapsed L5/S1 discs and narrowed intervertebral spaces. We strongly suspect that these conditions are triggering factors for FOS. We also believe that in some patients with FOS, the presence of lumbosacral transitional vertebrae in their youth leads to a tendency for the L5 transverse process and sacral ala to form a pseudoarthrosis. However, due to the strong load-bearing capacity of the disc and vertebral body during youth, the load between the L5 transverse process and the sacral ala is relatively small, preventing hypertrophy, pseudoarthrosis formation, and L5 nerve compression. As these individuals age, the intervertebral disc gradually degenerates, leading to a decrease in disc height. Excessive load shifts from the vertebral body and intervertebral disc to the L5 transverse process and sacral ala, causing reactive hypertrophy and the formation of a pseudoarthrosis, which compresses the nerve. Therefore, a characteristic often seen in patients with FOS is an onset of chronic symptoms that coincide with the development of the hypertrophic pseudoarthrosis and primarily affect elderly individuals with degenerative changes in the lumbar spine.

In some patients with FOS, L5/S1 or L4/5 lumbar disc herniation may also be clearly present. It is essential to note that FOS manifests as L5 nerve root symptoms, primarily affecting the lateral thigh and calf, whereas L5/S1 lumbar disc herniation generally presents with S1 nerve root symptoms, affecting the posterior thigh and calf. We can differentiate these conditions based on clinical presentation and imaging results. However, some patients may give vague or atypical descriptions of their pain location. In such cases, we need to rely more heavily on imaging diagnostics. Ultrasound or x-ray-guided nerve root blocks of L5 or S1 can be performed to identify the affected segment accurately. When FOS is combined with L4/5 lumbar disc herniation, the clinical manifestations of both conditions are similar, and a nerve root block can alleviate pain effectively in both cases. Therefore, we must rely primarily on the results of imaging examinations, including x-rays and CT and MRI scans, to determine the site of nerve compression with accuracy. It is crucial to communicate the surgical risks with patients and their families thoroughly before the procedure. We especially need to be cautious when a patient has a combination of lumbar disc herniation (L4/5) and FOS. In these cases, addressing only one condition may not completely relieve the symptoms in the patients' lower limbs. Careful evaluation of the disc herniation and pseudoarthrosis compression is required, and the area with the most severe compression must be prioritized. Our goal is for the initial surgery to alleviate most of the lower-limb symptoms experienced by the patient. If both compression sites are significantly severe, an open surgery or 2 minimally invasive endoscopic surgeries may be necessary, depending on the situation.

In Figures 4 A2 and B2, we utilized magnetic resonance (MR) hydrography, a general term for static fluid imaging, which is a derivative of RARE fast T2-weighted

Table 1. ***Basic and surgical information of 5 cases and changes in those patients' VAS, ODI, and Macnab scores before surgery, one day after surgery, one week after surgery, one month after surgery, and at the last follow-up.***
"/" indicates that the patient had not yet reached one month after the operation at the last follow-up. VAS: Visual Analog Scale. ODI: Oswestry Disability Index. 1 d postop: one day postoperation; 1 w postop: one week postoperation; 1 m postop: one month postoperation.

Case	Gender	Age	Underlying Disease	Symptomatic Side	Surgery Duration	Blood Loss	Postoperative Hospital Stay	Postoperative Complications	VAS				ODI				Macnab			
									Preop	1 d Postop	1 w Postop	1 m Postop	Preop	1 d Postop	1 w Postop	1 m Postop	1 d Postop	1 w Postop	1 m Postop	Last Follow-Up
Case 1	F	54	None	R	90	10	3	None	7	1	0	0	27.2	1.6	0	0	excellent	excellent	excellent	excellent
Case 2	M	60	None	L	95	10	3	None	6	1	1	0	25.6	1.6	1.6	0	excellent	excellent	excellent	excellent
Case 3	F	49	None	L	120	20	3	None	6	2	0	0	25.6	1.5	0	0	excellent	excellent	excellent	excellent
Case 4	M	57	None	L	64	20	4	None	7	1	3	0	38.4	19.2	22.4	4.8	good	fair	excellent	excellent
Case 5	F	91	Coronary heart disease - hypertension	L	135	10	4	None	5	1	1	/	22.4	4.8	4.8	/	excellent	excellent	excellent	excellent

Table 2. *Comparison of VAS and ODI scores of 5 patients at one day, one week, and one month post-surgery to those patients' re-surgery scores (nonparametric Wilcoxon signed rank sum test for 2 paired samples).*

	VAS			ODI		
	1 d Postop	1 w Postop	1 m Postop	1 d Postop	1 w Postop	1 m Postop
P value	0.041	0.042	/	0.043	0.043	/

"/" indicates that the patient had not yet reached one month after the operation at the last follow-up. VAS: Visual Analog Scale. ODI: Oswestry Disability Index. 1 d postop: one day postoperation, 1 w postop: one week postoperation; one m postop: one month postoperation.

imaging, whereby stagnant or slowly flowing bodily fluids are represented as high-bright, high-contrast structures against a dark background. Magnetic resonance cholangio-pancreatography (MRCP), the best known example of MR hydrography, has been rapidly and widely employed as a primary method for imaging the biliary and pancreatic ducts and has become competitive with endoscopic retrograde cholangio-cancreatography (ERCP) (26,27). Through our review of the literature, we found that studies on the sensitivity and specificity of lumbar plexus MR hydrography are limited, suggesting that this subject represents a promising area for further research.

Full endoscopy surgery is one of the least invasive procedures in spine surgery (15), characterized by significantly smaller incisions and less soft tissue distribution than in traditional open surgery and UBE surgery. Whereas the latter 2 methods require general anesthesia, full endoscopic surgery can be performed under intravenous anesthesia. Therefore, this approach carries a lower anesthesia risk and allows for intraoperative neurophysiological monitoring to prevent nerve injury. For example, in the present study, Case 5 was a 91-year-old woman with underlying conditions of hypertension and coronary heart disease. After an assessment by the anesthesiology department, it was determined that the patient could not tolerate general anesthesia. Before performing the procedure, we administered intravenous anesthesia to the patient, and her symptoms improved significantly after the operation. By excising the pseudoarthrosis precisely and performing limited bone removal, spinal stability was maintained. Moreover, compared to conventional open spine surgery, patients undergoing full endoscopic decompression Surgery experience shorter hospital stays and fewer postoperative complications, such as deep vein thrombosis and pneumonia.

In our previous cervical spine surgery, we proposed a technique called vertical anchoring technique (VAT) (28). In FOS surgery, we also used this technique. By anchoring the Kirschner wire (K-wire) on the bone surface of the pseudoarthrosis, we could effectively reduce the displacement of the K-wire and prevent the K-wire from sliding deep into the nerve. When we inserted the endoscope, we could also find the anchor point on the bone surface easily. Despite the advantages of this surgical method, we believe it still has limitations and room for improvement. One major challenge is the difficulty of positioning the puncture and inserting the K-wire. Sometimes the puncture position is poor, requiring the K-wire needs to be fixed repeatedly. During the procedure, repeated fluoroscopy may be necessary to adjust the wire's position and establish an optimal surgical approach; during the puncture, there is still a risk that the K-wire may slip deep to the anterior surface of the pseudoarthrosis and injure the nerve. Therefore, this technology places significant demands on the surgeon's fundamental skills in spinal puncture and positioning, resulting in a steep learning curve. For the future, we are considering robot-assisted guidance for puncture positioning. This approach would not only reduce the frequency of punctures, thereby minimizing both mechanical and radiation-related risks to patients, but also shorten the duration of the surgery and enhance overall surgical efficiency.

Conclusion

Full endoscopic decompression surgery via the L5 transverse process-sacral ala pseudoarthrosis approach demonstrates efficacy in removing the pseudoarthrosis and decompressing the L5 nerve root, leading to significant relief of lower limb symptoms in patients with FOS. Compared to traditional open surgical approaches, this minimally invasive technique offers reduced anesthesia risk and faster postoperative recovery. While this study demonstrates promising results, larger, long-term studies are needed to establish the durability of this approach to full endoscopic decompression surgery and to compare its outcomes with other minimally invasive techniques.

Author Contributions

Hao Hu and Fu-Kuan Zhu are responsible for the conception and writing of the entire article. Xi-Zi Miao is responsible for the data collection and analysis in the article, Rui Deng and Ya-Feng Wen are responsible for English grammar correction and formatting adjustments. Lei Shi and Xiao-Min Sheng are responsible for the arrangement and implementation of the surgeries and provided guidance in writing the surgical procedure. Zhen-Yong Ke is responsible for supervising the standardization of the article-writing process. Zhong-Liang Deng and Lei Chu conducted literature retrieval, summarized relevant previous work, and finally made revisions to the article. All authors read and approved the final manuscript.

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