Retrospective Study

L5-S3 Compared to L5-S2 Full-Endoscopic Rhizotomy and Ablation Under a Navigation System for Sacroiliac Joint Pain: A Comparative Study

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Disclaimer: There was no external funding in the preparation of this manuscript.

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received: 11-22-2023
Revised manuscript received: 01-14-2024
Accepted for publication: 02-14-2024

Free full manuscript: www.painphysicianjournal.com

Background: Chronic low back pain (CLBP) with sacroiliac joint (SIJ) involvement is a prevalent issue in health care. Surgical intervention, employing an endoscopic technique with a navigation system, targets and ablates nociceptive nerve fibers associated with SIJ pain, although the clinical effect of omitting rhizotomy of the lateral sacral branch of S3 remains uncertain.

Objectives: This study aimed to compare the clinical outcomes of 2 full-endoscopic rhizotomy and ablation (FERA) techniques for SIJ pain and to determine the effect of omitting rhizotomy of the lateral sacral branch of S3 on patient outcomes.

Study Design: This study adopted a retrospective cohort study design.

Setting: This study was conducted at a single medical institution by a neurosurgeon.

Methods: From January 2018 through March 2021, the records of 73 patients undergoing L5–S3 or L5–S2 FERA for SIJ pain associated with CLBP were retrospectively reviewed. The patients were evaluated using the Visual Analog Scale (VAS) for pain, Oswestry Disability Index (ODI) for functional disability, and MacNab criteria for satisfaction. The procedures were guided by 3-D robotic C-arm navigation. The L5–S3 FERA group underwent rhizotomy and ablation of the L5–S3 lateral branches, whereas the L5–S2 FERA group did not undergo rhizotomy of the S3 lateral sacral branch.

Results: Both groups showed significant improvements at one year in VAS and ODI scores with similar trends. The L5–S2 FERA group had a shorter operative time, particularly bilaterally, without complications. Although the L5–S3 FERA group initially presented a slightly higher recurrence rate at 6 months, their recurrence rate was equal with that of the L5–S2 FERA group at one year. Furthermore, the MacNab criteria showed comparable satisfaction rates in both groups.

Limitation: This was a small retrospective study.

Conclusion: L5–S2 FERA demonstrated clinical outcomes similar to those of L5–S3 FERA for pain relief, functional improvement, and satisfaction. Omitting S3 lateral branch rhizotomy did not adversely affect the outcomes. Surgeons may consider omitting S3 lateral branch rhizotomy for SIJ pain treatment, thereby reducing operative time while maintaining patient benefits.

Key words: Low back pain, sacroiliac joint, rhizotomy, ablation, surgical navigation systems, robotics, minimally invasive surgical procedures

Pain Physician 2024: 27:E943-E951

Chronic low back pain (CLBP) affects millions of individuals worldwide; sacroiliac joint (SIJ) pain accounts for 15%–30% of all CLBP cases (1-3). The pain's effect on patients with CLBP with SIJ pain are significant in terms of lowering quality of life and functional status and increasing health care resources usage (2,3).

SIJ pain is difficult to determine because of its diagnostic complexity. Diagnosing SIJ pain includes detailed history taking, an elaborate physical examination, imaging studies, and diagnostic blocks (1,4-6).

The SIJ is a diarthrodial joint between the sacrum and ileum. It is supported by numerous ligaments, fibrous tissues, and muscles that provide stability and limit the motion for transferring the weight of the upper body to the lower extremities (7,8).

SIJ pain may arise from various factors, including, but not limited to, hypomobility or hypermobility, external compression or shearing forces, microfractures or macrofractures, soft tissue injuries, inflammation, pregnancy, adjacent segment disease, leg length discrepancy, and previous lumbar fusion (8,9). These factors activate the nociceptive sensory fibers that transmit pain to the brain (10).

Surgical intervention is considered when conservative treatment methods fail. Endoscopic radiofrequency ablation of the SIJ is a newly developed technique that has been reported to be able to successfully treat SIJ pain (11-15). Fluoroscopy-based guidance for this procedure is sometimes difficult because of the lack of anatomical landmarks. Therefore, at our institution, under endoscopic guidance, we use a 3-D robotic C-arm navigation system in order to precisely and accurately perform the "cut-and-ablation" technique over the nociceptive sensory nerve fibers just lateral to the sacral foramina that activate SIJ pain (13,14).

According to cadaveric studies, the SIJ is predominantly innervated by the dorsal medial branch of L5 and the lateral sacral branch of S1, S2, and S3, forming the posterior sacral network over the joint (16,17). The treatment approach for SIJ pain is based on such anatomical structures, particularly the SIJ; its nerve supply originates from the aforementioned branches. However, the actual effect of each branch has not been discussed clinically; therefore, whether the lateral sacral branch of S3 is directly linked to improved clinical outcomes of SIJ pain treatment remains uncertain (16-18). This is the first article to address this issue.

Our study compared the clinical outcomes of 2 techniques for treating SIJ pain: one involves rhizotomy and ablation over the dorsal medial branch of L5 and the lateral sacral branches of S1, S2, and S3 (L5–S3 full-endoscopic rhizotomy and ablation; L5–S3 FERA). The other procedure involves rhizotomy and ablation over the dorsal medial branch of L5 and the lateral sacral branch of S1 and S2 (L5–S2 FERA). Both techniques were assisted with a navigation system.

Methods

Patient Enrollment

Our research project was approved by the Institutional Review Board of Changhua Christian Hospital (approval number: 220306). All patients who participated in this study provided informed consent. The surgical procedures were performed by the same experienced surgeon.

To conduct this study, we reviewed the medical records of 83 consecutive patients who underwent either L5–S3 or L5–S2 FERA under endoscopic guidance, assisted with the navigation system for SIJ pain associated with CLBP. The data collection period extended from January 2018 through March 2021.

The inclusion criteria were as follows: individuals with CLBP for > 6 months that did not respond well to conservative treatment, regardless of whether they had undergone spine surgery in the past; and pain felt in the inferomedial region of the posterior superior iliac spine (19). Furthermore, physical examinations required at least 3 positive results of 6 provocative tests, including compression, distraction, Gaenslen's test, thigh thrust, the drop test, and the sacral thrust test (20). SIJ pain was confirmed when ultrasound-guided SIJ diagnostic injections caused pain to improve > 50% (5). Furthermore, the image findings were used to rule out other pain sources. SIJ pain due to infection, inflammation, and malignancies were excluded from our study.

Surgical Procedures: L5–S3 and L5–S2 FERA Under a 3-D Robotic C-arm Navigation System

A 3-D robotic C-arm system (ARTIS pheno, Siemens Healthineers) in a hybrid operating room was used. The patients were instructed to lie down prone on a radiolucent table for the procedure, which was performed under local anesthesia. Before the start of the operation, the surgical steps were thoroughly explained to the patients, ensuring their understanding and cooperation. Following sterilization, sterile draping was

applied, and a reference frame was securely affixed to the skin using 2 layers of iodine-impregnated incision drapes, thus avoiding using the posterior iliac crest for fixation (Fig.1).

The 3-D robotic C-arm rotated around while the patient remained motionless. Real-time intraoperative images of the SIJ were captured and automatically registered in the image-guided surgical guidance platform (Buzz™ Digital O.R., Brainlab, Inc.). The accuracy of the matching was confirmed by placing the navigation pointer on the reference frame. Subsequently, registering a 5-mm obturator with tracking sensors was achieved by inserting a corresponding calibrating device of appropriate size.

Using the navigation system, an entry point was determined at the S1 foramen level, and local anesthesia was administered. A small incision was made using a No. 15 blade. An integrated obturator-working cannula composite with an inner diameter of 5.4 mm was introduced, and the tip landed at the lateral border of the S1 foramen (Fig. 2A). A 30° spinal endoscope with a 2.8-mm working channel and an outer diameter of 5.3 mm (SPINENDOS GmbH) was introduced after removing the obturator.

During the endoscopic procedure, continuous saline irrigation was used. Hemostasis was maintained using a bipolar coagulation system (VANTAGE BIOTECH CO., LTD). The lateral sacral branch was identified using the tip of the bipolar coagulation system while monitoring the patient's pain response (Fig. 3A). Rhizotomy was performed using an endoscopic micropunch (Fig. 3B); further ablation was performed using the bipolar tip on the nerve stump and adjacent soft tissues (Fig. 3C). The "cut-and-ablation" procedure was performed repeatedly in the paraforaminal area until the provoked pain subsided.

The working channel was reassembled using the obturator after removing the endoscope. Shifting cephalad, the integrated obturator-working channel composite was landed at the junction of the sacral superior articular process, and the "cut-and-ablation" technique was applied to the medial branch of the L5 dorsal ramus (Fig. 2B).

Finally, the composite was shifted caudally and landed at the lateral border of S2 (Fig. 2C). The "cut-and-ablation" technique was performed in the same manner at the level of S3 for L5–S3 FERA. Immediate pain relief was confirmed by pressing upon the trigger point (21). The use of 4-0 polyglactin 910 closed the wound.

Clinical Assessment

Patient data were retrospectively recorded in a registry database by a research assistant. The data included detailed operative information, including the operation time, blood loss, and any complications encountered. Visual Analog Scale (VAS) scores for both the back and legs were evaluated to measure pain severity and outcomes. To assess functional disabilities, Oswestry Disability Index (ODI) scores were used. Furthermore, the MacNab criteria were evaluated to assess patient satisfaction. A clinical coresearcher performed patient-reported outcome assessments using questionnaires during patients' preoperative visits and follow-up appointments at postoperative one, 3, 6, and 12 months.

Statistical Analysis

The statistical analysis and graphical representations were generated using MedCalc 20.110 (MedCalc Software Ltd). Following the assessment of normal distribution and variances, comparisons between both groups were performed using either the χ^2 test, Mann–Whitney U test, or independent t test. Furthermore, the Friedman test was used to compare the median values at different time points within each group. P values < 0.05 denoted statistical significance.

Results

Of the 83 patients, 40 were allocated to the control group (L5–S3 FERA) from June 2019 through August 2020. Four patients in the control group were

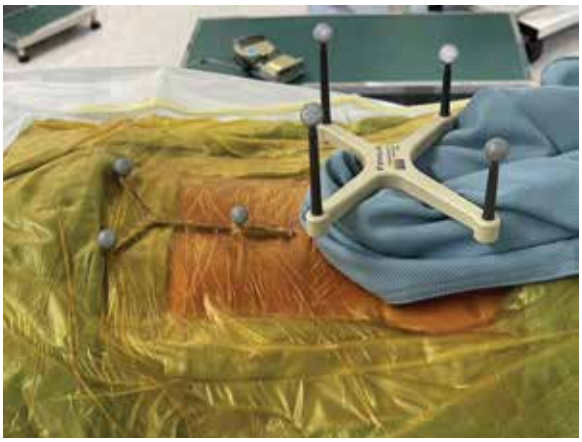

Fig. 1. *Registration and construction of a real-time 3-D surgical image. The reference frame is firmly affixed with an iodine-impregnated drape.*

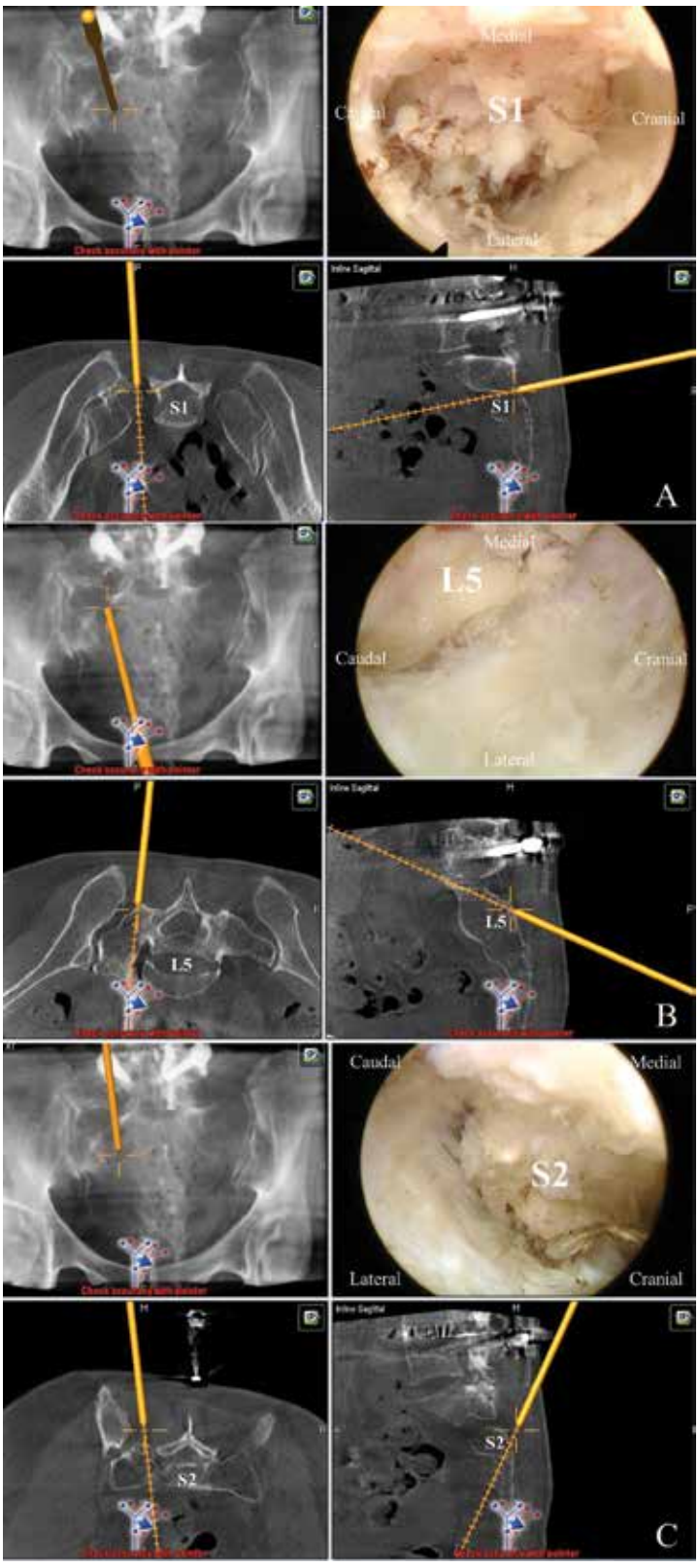

Fig. 2. *A real-time 3-D surgical image and the endoscopic views of the sacroiliac joint. The tip of the obturator with trackers lands at the lateral edge of the S1 foramen under virtual image guidance, and an endoscopic image of the S1 foramen after FERA. (A) Sequential FERA at the level of L5 (B) and the S2 foramen (C). S1, the dorsal sacral foramen of S1; S2, the dorsal sacral foramen of S2; L5, the dorsal medial branch of L5; FERA, full-endoscopic rhizotomy and ablation.*

excluded because of incomplete follow-up. A total of 43 consecutive patients underwent L5–S2 FERA from September 2020 through March 2021. Six patients in the L5–S2 FERA group were excluded because of incomplete follow-up. Most clinical manifestations were CLBP without leg pain, except for one patient from the L5–S3 FERA group who had coccyx pain. Furthermore, 59% (43 of 73 patients) had undergone previous lumbar surgery. No statistically significant differences in demographic data, including age, gender, height, weight, alcohol consumption, and smoking status were observed between the groups (Table 1).

The L5–S2 FERA group had a shorter operative time than the L5–S3 FERA group. Although the unilateral procedures did not show statistical significance in terms of operative time (L5–S2 FERA: 43.04 ± 12.22; L5–S3 FERA: 50.94 ± 17.32; P = 0.09), a time reduction of approximately 8 minutes was recorded. In

contrast, the bilateral procedures showed statistical significance in favor of the L5–S2 FERA group, shortening the overall procedure time by approximately 20 minutes (L5–S2 FERA: 51.79 ± 15.61; L5–S3 FERA: 72.89 ± 24.38; $P < 0.01$). Neither group experienced complications, such as hematoma, infections, or neurological deficits (Table 1).

Preoperative low back pain VAS scores were similar in both groups. Both groups showed significant improvement in VAS scores for lower back pain as well as ODI scores; both remained low for one year ($P < 0.001$). ODI scores at 6 months showed a statistical difference and were higher in the L5–S3 FERA group. The L5–S3 FERA group had a higher observed recurrence rate at 6 months. Both groups showed similar downward trends in VAS and ODI scores at > one year (Fig. 4A and Fig. 4B).

Meanwhile, the recurrence rate in the L5–S3 FERA group was higher than that in the L5–S2 FERA group (3 of the 36 patients in the L5–S3 FERA group vs one of the 37 patients in the L5–S2 group) (Tables 2 and 3). At the postoperative one-year follow-up, both groups had similar recurrence rates (4 of the 36 patients in the L5–S3 FERA group vs 4 of the 37 patients in the L5–S2 FERA group).

The MacNab criteria showed similar satisfaction rates in both groups (Fig. 5 and Table 4).

Discussion

The current surgical treatments for SIJ pain include SIJ denervation and fusion. Both treatment methods improve pain severity and functional outcomes (22).

SIJ denervation can provide immediate pain relief in percutaneous procedures without any implants (23,24). Furthermore, the anesthetic risk is lower for SIJ denervation, which can be performed using local anesthesia (25). Recently, SIJ denervation by radiofrequency ablation has evolved with promising clinical outcomes (16). However, determining which nerve branches are embedded within the ligaments at various depths and locations is challenging (26). This complexity makes it difficult to accurately and precisely ablate these nerve branches. Therefore, the common technique of SIJ denervation is ablation along the posterior sacroiliac ligaments (11,12).

A recent study has shown the efficacy of full-endoscopic rhizotomy using the "cut-and-ablation" technique assisted with navigation (13,14). With advanced technologies, locating and cutting sensory nerve branches exiting from the sacral foramina are feasible under endoscopic visualization (13,14). Based on cadaveric studies, the conventional SIJ denervation technique includes rhizotomy of the lateral branches

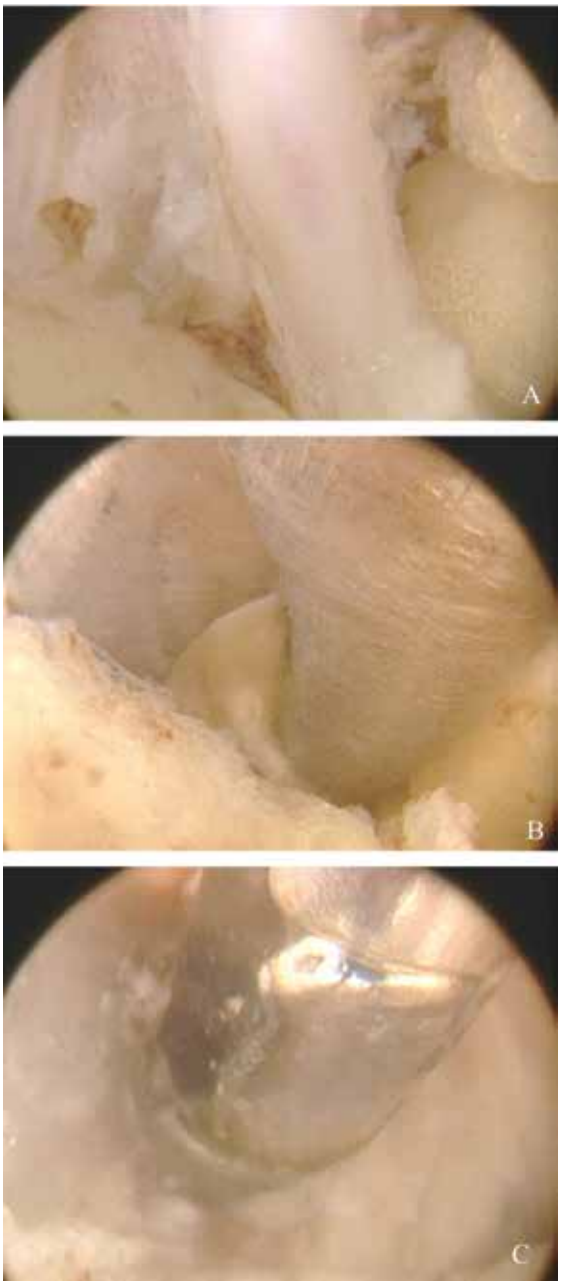

Fig. 3. *FERA of the sacral lateral branch that penetrates through the ligament complex. (A) The lateral sacral branch of S1 under endoscopic view. (B) Rhizotomy with a micropunch. (C) Postablation of the surrounding soft tissues and the nerve stump by bipolar electrocautery. FERA, full-endoscopic rhizotomy and ablation.*

Table 1. *Patient characteristics and operative information.*

Variable	L5-S2 FERA Group (n = 37)	L5-S3 FERA Group (n = 36)	*P* Value
Age (yrs)	62.95 ± 2.47	62.27 ± 2.37	0.846
Sex			
Men	15 (40.5)	13 (36.1)	0.090
Women	22 (59.5)	23 (63.9)	
Height (cm)	159.35 ± 1.48	158.54 ± 1.42	0.78
Weight (kg)	66.42 ± 2.13	63.92 ± 1.99	0.626
BMI (kg/m^2)	26.14 ± 4.49	25.68 ± 4.19	0.683
Smoker	0 (0)	1(2.8)	0.493
Alcohol User	0 (0)	1(2.8)	0.493
Unilateral LBP	23(62)	18 (50.0)	0.430
Bilateral LBP	14(38)	17 (47.2)	
Coccyx Pain	0	1 (2.8)	
SIJ pain followed by spine surgery	24 (64.9)	19(52.8)	0.346
Operation time (min)			
Unilateral	43.04 ± 12.22	50.94 ± 17.32	0.09
Bilateral	51.79 ± 15.61	75.89 ± 24.38	0.01
Complication	0	0	1.000

The data are represented as number (%) or mean ± standard deviation.
BMI: body mass index, LBP: low back pain, SIJ: sacroiliac joint.

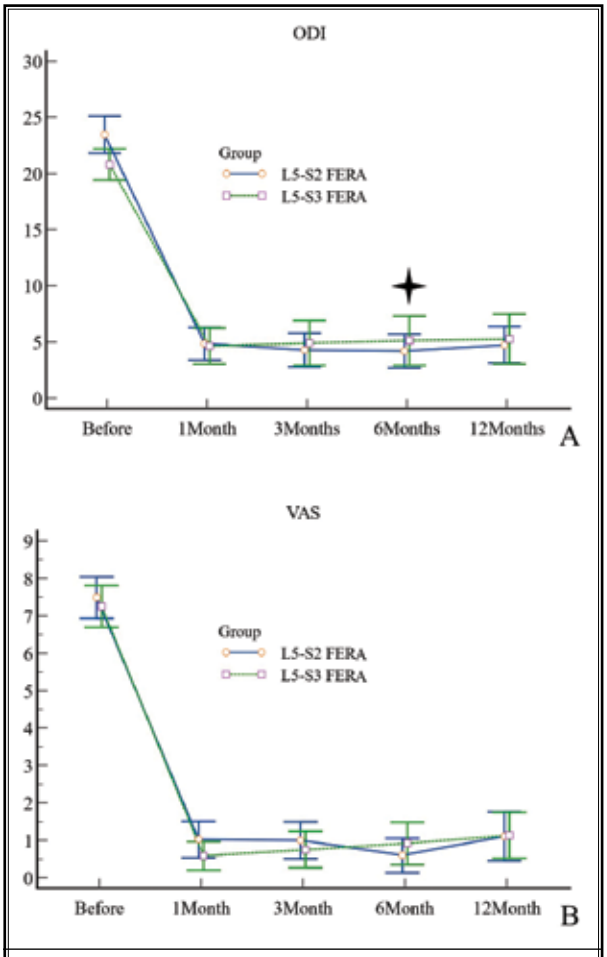

Fig. 4. *The clinical results of L5–S2 FERA and L5–S3 FERA preprocedure, and postprocedure one month, 3 months, 6 months, and 12 months. The values are shown as mean. Oswestry Disability Index (ODI). (A) Visual Analog Scale (VAS) scores. (B) Statistical significance (star). FERA, full-endoscopic rhizotomy and ablation.*

from L5 to S3 (16,17). Studies evaluating the S3's effect on SIJ pain are limited. Our study is the first to investigate the postprocedure clinical outcomes effect of denervating the lateral sacral branch of S3.

The proportion of SIJ innervation from the lateral branches of sacral nerves remains unclear and lacks clinical evidence. Anatomical studies on cadavers have shown that dorsal innervation of the SIJ occurs via the posterior sacral network, formed by the L5–S3 lateral branches (23,26). The lateral branches of S1–S2 consistently contribute to the formation of the posterior sacral network in all examined samples. However, the lateral sacral branch of S3 was observed occasionally, which suggests variation in each individual's innervation patterns (16-18).

The conventional SIJ denervation procedure is performed under fluoroscopic guidance (24,27,28). To ensure its effectiveness, the interventional range is usually from L5 to S3, either via radiofrequency ablation or endoscopic rhizotomy (12,14,15,23). Because it is a multilevel procedure, applying the fluoroscope during the operation takes time (14). Anatomical studies have suggested that ablation of the lateral branch of S3 is unnecessary (17,18). In our study, no significant difference in clinical outcomes was observed between the groups. The outcomes in the L5–S2 group remained favorable. Furthermore, the recurrence rates at the one-year follow-up in both groups were similar. Therefore, our results are concordant with the findings of previous anatomical studies. The S3 branch might contribute less than previously thought to SIJ innervation. Surgeons can omit rhizotomy of the lateral branch of S3 to decrease the surgical time.

Because full-endoscopic rhizotomy is a multilevel procedure, shifting the surgical field and finding the nerve branches takes time. A real-time surgical navigation system enables surgeons to deal with areas with complex anatomy, such as the SIJ, in a minimally invasive

Table 2. *Functional outcome at preprocedure, and at postoperative one month, 3 months, 6 months, and 12 months.*

Oswestry Disability Index	L5-S2 FERA Group (n = 37)	L5-S3 FERA Group (n = 36)	*P* Value
Preoperation	23.46 ± 4.92	20.8 ± 4.19	0.348
Post one month	4.84 ± 4.31	4.64 ± 4.71	0.600
Post 3 months	4.27 ± 4.51	4.89 ± 5.89	0.114
Post 6 months	4.19 ± 4.53	5.11 ± 6.51	0.033
Post 12 months	4.73 ± 4.85	5.25 ± 6.54	0.078
P value	< 0.001*	< 0.001*	

The data are represented as mean ± standard deviation.
FERA: Full-endoscopic rhizotomy and ablation.
**P*-value below 0.05 indicates a statistically significant difference.

Table 3. *Back pain Visual Analog Scale score at preprocedure, and at postoperative one month, 3 months, 6 months, and 12 months.*

	L5-S2 FERA Group (n = 37)	L5-S3 FERA Group (n = 36)	*P* Value
Preprocedure	7.49 ± 1.66	7.25 ± 1.66	0.992
Post one month	1.03 ± 1.46	0.58 ± 1.13	0.131
Post 3 months	1.00 ± 1.49	0.75 ± 1.44	0.845
Post 6 months	0.59 ± 1.38	0.92 ± 1.68	0.252
Post 12 months	1.11 ± 1.97	1.14 ± 1.82	0.650
	P < 0.001	*P* < 0.001	

The data are represented as mean ± standard deviation.
FERA: Full-endoscopic rhizotomy and ablation
**P*-value below 0.05 indicates a statistically significant difference.

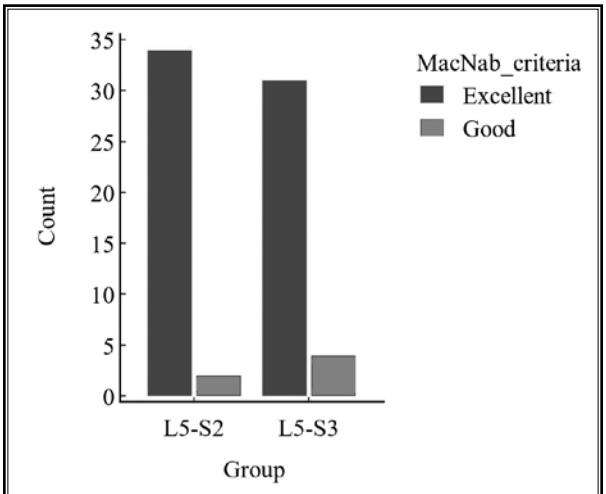

Fig. 5. *The MacNab criteria satisfaction rating at postoperative one-year follow-up. "Excellent" rating from 92% of the L5–S2 FERA group and 86% of the L5–S3 FERA group. "Good" rating from 8% of the L5–S2 FERA group and 11% of the L5–S3 FERA group. FERA, full-endoscopic rhizotomy and ablation.*

Table 4. *MacNab criteria satisfaction rating at postprocedure one year.*

	L5-S2 FERA Group (n = 37)	L5-S3 FERA Group (n = 36)	*P* Value
Excellent	34	31	0.406
Good	3	4	
Fair	0	1	
Poor	0	0	

FERA: Full-endoscopic rhizotomy and ablation.

way (29-31). Endoscopic procedures allow surgeons to visualize sensory nerve fibers that range from 0.21 mm to 1.52 mm in diameter (16). The "cut-and-ablation" technique can help achieve the maximum effect from the procedures by precisely targeting tiny nerve fibers (14). The navigation system not only allows all surgical members to be free from radiation exposure, but it also helps save time during the procedure, which helps in verifying the location of the surgical instruments without interruption by fluoroscopy. The surgical time difference between the 2 groups in our study was only statistically significant in the bilateral procedures. Although the unilateral procedures did not exhibit a statistically significant difference in operative time (L5–S2 FERA: 43.04 ± 12.22; L5–S3 FERA: 50.94 ± 17.32; $P < 0.09$), a noticeable reduction of approximately 8 minutes on average was observed. Although the surgical time could be shortened in experienced hands, we believe that the time-saving effect of omitting S3 lateral branch rhizotomy might be more significant if the procedure is conducted under fluoroscopic guidance.

Regarding postoperative outcomes, both groups showed similar trends in VAS and ODI scores (Fig. 4A and Fig. 4B). In addition, both groups had similar recurrence rates at postoperative one year (4 of the 36 patients in the L5–S3 group and 4 of the 37 patients in the L5–S2 group). The MacNab criteria also showed homogeneous satisfactory distributions (Fig. 5 and Table 4). No early recurrence or procedure failure was observed while omitting S3 lateral branch rhizotomy. The efficacy of L5–S2 FERA was sustained over the long term and the outcomes were favorable in most patients; However, recurrence may occur because of nerve branch regrowth (32). Patients with recurrence could get relief from repeated procedures. No correlation was found between recurrence and omission of S3 lateral branch rhizotomy in this study.

Limitations

This study has some limitations. First, this was a retrospective study with a limited number of patients and a short-term follow-up. Second, the heterogenous background and comorbidities of the patients could be confounders that may have affected the results. Third, the outcomes were based on patient reports; there was a lack of objective evidence to prove the procedure's efficacy. Further clinical studies are necessary to protocolize full-endoscopic rhizotomy for treating SIJ pain.

Conclusion

The L5–S2 FERA group had clinical outcomes similar to those in the L5–S3 FERA group, including pain, pain-associated disability, and satisfaction at the one-year follow-up. Our study suggests that the lateral sacral branch of S3 contributes less than previously thought to SIJ pain. Therefore, omitting S3 lateral branch rhizotomy is feasible and effective for shortening the operative time during full-endoscopic rhizotomy of the SIJ.

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