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Microsurgical Medial Fenestration with an Ultrasonic Bone Curette for Lumbar Foraminal Stenosis

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Abstract

Background: Misdiagnosis and inadequate treatment of lumbar foraminal stenosis (LFS) are the most common causes of failed back surgery. Although several surgical procedures have been reported, the optimal surgical treatment remains controversial.

Aim: We describe our method of microsurgical medial fenestration using an ultrasonic bone curette (Sonopet, Stryker Corp., Kalamazoo, MI, USA) to treat patients with LFS and report our early results.

Patients and Methods: We followed up 26 patients who had undergone microsurgical medial fenestration at least 1 year earlier. The patients were 15 men and 11 women with a mean age at surgery of 59.5 years; the mean follow-up period was 30.6 months. The affected nerve root was at L4 in 1 patient and at L5 in 25. Evaluation of our clinical results was based on the Japanese Orthopedic Association score.

Results: There were no intraoperative surgery-related complications. After surgery, 1 patient had recurrence of L5 radiculopathy associated with iatrogenic spondylolysis. He was successfully treated with resection of the inferior articular process without fusion surgery; there was loss of disc height without obvious instability at the corresponding level. The Japanese Orthopedic Association scores showed significant improvement at 1 month after surgery and at final follow-up ($p<0.001$). No patient had spinal instability or malalignment postoperatively.

Conclusions: Microsurgical medial fenestration using Sonopet, a less-invasive surgical technique that does not result in spinal instability or malalignment, yielded excellent clinical outcomes.

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Key words: lumbar foraminal stenosis, microsurgical medial fenestration, ultrasonic bone curette, minimal invasive surgery, clinical outcome

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Introduction

Lumbar foraminal stenosis (LFS) is reported in 8% to 11% of patients operated on for lumbar degenerative disease[1–4]. Misdiagnosis and inadequate treatment of LFS are the most common causes of failed back surgery[5,6]. Although several surgical procedures have been reported, the optimal surgical treatment remains controversial. We perform microsurgical medial fenestration using an ultrasonic bone curette (Sonopet OST-2001; Stryker Corp., Kalamazoo, MI, USA) as a minimally invasive procedure in patients with LFS. Here we describe our surgical procedure and report our clinical outcomes.

Patients and Methods

From September 2008 through December 2009, 26 patients underwent microsurgical medial fenestration to treat LFS, a condition seen in 11.5% of 226 patients operated on for lumbar degenerative disease at our institution. They were 15 men and 11 women; their mean age was 59.5 years (range, 42 to 77 years). The mean follow-up period was 30.6 months (range, 25 to 36 months). Our diagnostic criteria for LFS are clinical symptoms, i.e. severe radicular symptoms (pain or paresthesia) of the affected nerve root area, presence of the Kemp sign[1,7], and radiological evidence. Patients in whom it was difficult to identify the affected nerve root on the basis of symptoms underwent selective nerve root block. Findings on magnetic resonance (MR), multiplanar reconstructive computed tomography

Table 1 Assessment Scale Proposed by the Japanese Orthopedic Association

	Score
1) Subjective Symptoms (9 points)	
1: Lower back pain	
None	3
Occasional mild pain	2
Occasional severe pain	1
Continuous severe pain	0
2: Leg pain and/or tingling	
None	3
Occasional slight symptoms	2
Occasional severe symptoms	1
Continuous severe symptoms	0
3: Gait	
Normal	3
Able to walk farther than 500 m, despite symptoms	2
Unable to walk farther than 500 m	1
Unable to walk farther than 100 m	0
2) Objective findings (6 points)	
1: Straight-leg-raising test	
Normal	2
30 to 70 degrees	1
<30 degrees	0
2: Sensory disturbance	
None	2
Slight disturbance (not subjective)	1
Marked disturbance	0
3: Motor disturbance	
Normal	2
Slight weakness (manual muscle test, 4)	1
Marked weakness (manual muscle test, 0 to 3)	0

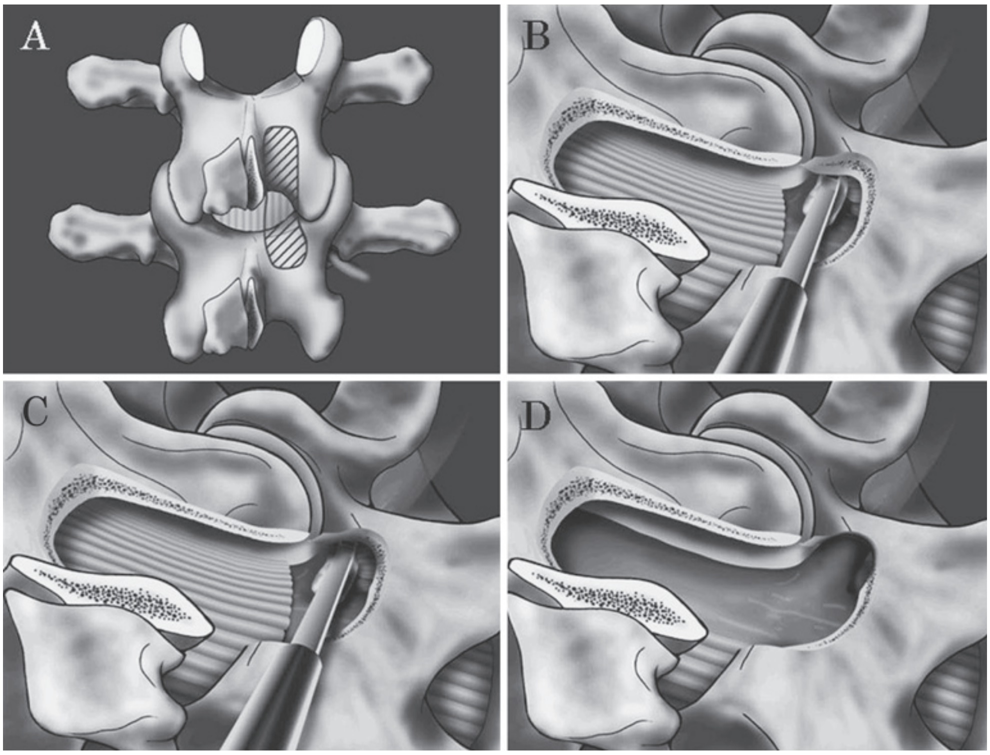

Fig. 1 Diagram of microsurgical medial fenestration on the right side using Sonopet.
A: Hemifenestration on the ipsilateral side was performed to confirm the affected nerve root in the lateral recess of the spinal canal.
B: After hemifenestration, medial resection of the pars interarticularis along the affected nerve root was performed. To prevent iatrogenic spondylolysis, the posterior cortex of the pars interarticularis was left intact at a distance of 8 mm from the lateral border.
C: To widen the foramen, the anterior cortex of the residual pars interarticularis was resected along the nerve root to the lateral border.
D: The ligamentum flavum in the foramen covering the nerve root dorsally was removed.

(MPR-CT), and plain radiography were used to diagnose LFS. On sagittal T2-weighted MR images we looked for the loss of a high-intensity area around the nerve root indicative of the loss of epidural fat surrounding the nerve root. In the evaluation of plain radiographs we looked for lumbar scoliosis on anteroposterior images and determined the range of motion (ROM), and the anterior and posterior disc height (mean of flexion and extension) at the corresponding level on lateral images. At our institution, spinal instability is defined as follows: the slip angle spreads over 5 degrees, or the percentage of slip of the L5 listhesis progresses more than 5% on a standing lateral flexion view[8].

Preoperatively, all patients had received unsuccessful conservative treatment and gave written informed consent. Excluded from this study were patients with extraforaminal entrapment at a level corresponding with the LFS, such as extraforaminal disc herniation and far-out syndrome. Symptoms were assessed with the Japanese Orthopedic Association (JOA) scoring system (maximum score=15) (**Table 1**) before surgery, 1 month after surgery, and at final follow-up. Data were subjected to statistical analysis with the paired *t*-test using the software program Statmate III (ATMS Co. Ltd., Tokyo, Japan); a value of $p<0.05$ was considered to indicate significance.

Surgical Technique

Our procedure for microsurgical medial fenestration with Sonopet at L5/S1 on the right side in patients who had not undergone failed previous attempts to address their condition surgically is illustrated (**Fig. 1**). After making a midline skin incision we performed hemifenestration on the

Table 2 Radiographic findings

		Preoperative	Final follow-up	*P*
Cobb angle of main curve (degrees)		6.3 ± 4.0	5.6 ± 4.1	0.28
Range of motion (degrees)		16.3 ± 6.9	16.2 ± 6.3	0.97
Disc height	anterior (mm)	13.1 ± 1.8	13.4 ± 1.6	0.45
	posterior (mm)	7.0 ± 1.7	7.0 ± 1.6	1.00

ipsilateral side at L4/L5 to confirm the affected nerve root in the lateral recess of the spinal canal. To obtain a better view of the foramen, the spinous process should be split at the base with a greenstick fracture and tilted in the opposite direction of the affected foramen. Additionally, to observe the outer region of the intraforaminal zone, the microscope needs to be tilted as far as possible to the opposite side of the affected foramen. Patients with radiographically confirmed L4/L5 canal stenosis underwent bilateral fenestration at L4/L5. To widen the lumbar foramen, the medial part of the pars interarticularis and the anterior cortex of the residual pars interarticularis were resected along the nerve root to the lateral border with Sonopet. During winding of the lumbar foramen, to decompress the nerve root safely, we select a HB-12S handpiece (Stryker Corp.) with a smaller and thinner tip. When the procedure involved the removal of structures near the nerve root, the insertion of cotton pads provided adequate protection. To prevent iatrogenic spondylolysis, the posterior cortex of the pars interarticularis was retained, as much as possible, at a distance of 8 mm or more from the lateral border. The upper attachment of the L5/S1 ligamentum flavum to the foramen covering the nerve root dorsally was removed with a Kerrison rongeur.

This method was used when the nerve root compression was localized to the intraforaminal zone or when spinal canal stenosis was identified radiologically and thought to be involved in the LFS symptoms.

Results

Clinical Presentation and Clinical Outcome

All patients presented with involvement of a single nerve root. The affected nerve root was at L4 in 1 patient (3.8%) and at L5 in the other 25 patients (96.2%). Of the 26 patients with LFS, 17 (65.4%) had undergone earlier lumbar decompression surgery for lumbar degenerative disease (lumbar canal stenosis, n=16; lumbar degenerative spondylolisthesis, n=1); 3 of the 17 patients presented with residual lower-limb symptoms after earlier lumbar decompression surgery (failed back surgery). In the other 9 patients medial microsurgical fenestration was the first attempt to address their condition surgically; in 3 of these 9 patients, spinal canal stenosis at the L4/L5 level was identified radiologically and thought to be involved in their LFS symptoms; therefore, they underwent simultaneous posterior decompression of the spinal canal.

There were no intraoperative complications, such as dural puncture and nerve root injury. One patient (3.8%) who had recurrence of L5 radiculopathy associated with iatrogenic spondylolysis within 1 month after surgery was successfully treated with resection of the inferior articular process without fusion surgery; there was loss of disc height without obvious instability at the corresponding level.

The JOA scores 1 month after surgery (mean, 12.0 ± 1.5; range, 8 to 14) and at final follow-up (mean, 11.5 ± 1.9; range, 8 to 14) were significantly higher ($p<.001$) than that before surgery (mean, 7.4 ± 2.8; range, 3 to 12).

Imaging Findings

Plain radiographs showed degenerative scoliosis in 5 patients (19.2%). The averaged Cobb angle, ROM, and disc height were maintained at final postoperative follow-up in all 26 patients ($p>0.05$) (**Table 2**). One patient presented with spondylolisthesis (L5 anterolisthesis at the L5/S1 level); however, neither progression of L5

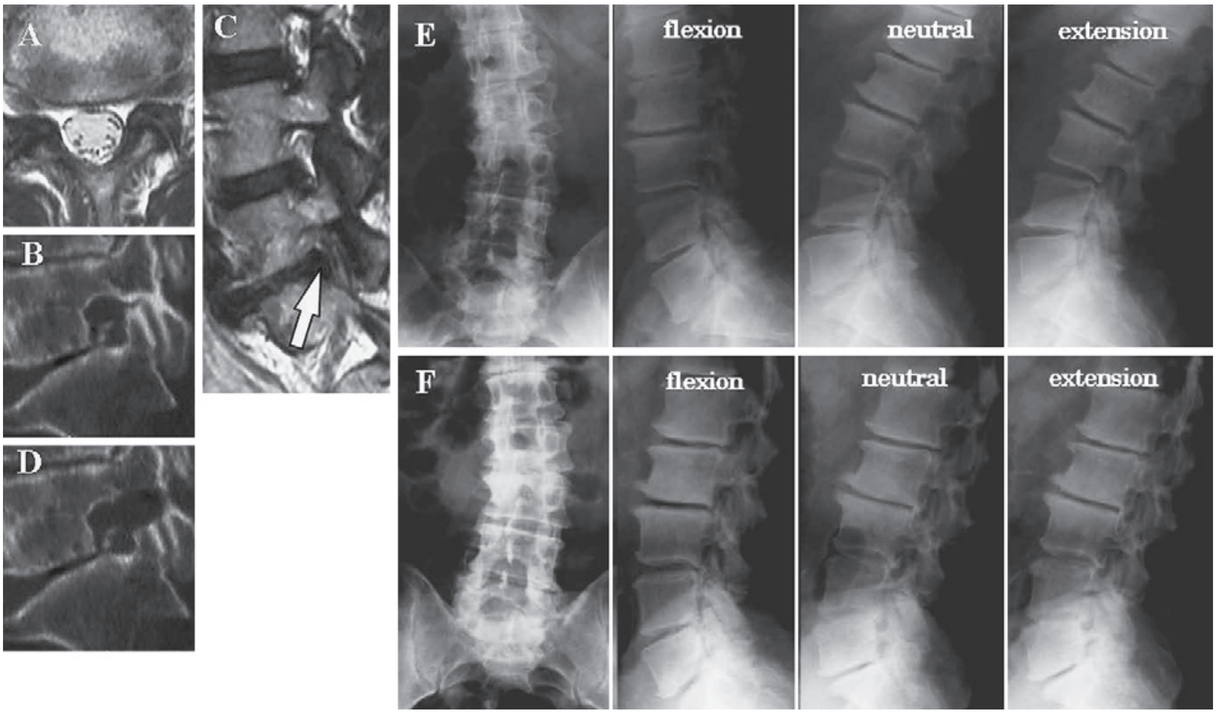

Fig. 2

A: MR image (axial view) showing adequate decompression of the spinal canal at the L4/L5 level.
B: Preoperative MPR-CT revealed that diminished disc height, a posterior osteophyte, and upward shift of the superior articular process were factors in the compression at the left L5/S1 level.
C: MR image (sagittal view) showing LFS (circumferential type) at the left L5/S1 level. The arrow indicates the left L5/S1foramen.
D: Postoperative MPR-CT showing foraminal widening with partial resection of the anterior cortex of the isthmus and the tip of the superior articular facet.
E: Preoperative plain radiographs showing lumbar degenerative scoliosis with a left curve (Cobb angle at L1–L4: 19.7°).
F: Plain radiographs acquired after surgery showing no significant change in the Cobb angle of the main scoliosis curve, the ROM, and the disc height. There was no instability at the corresponding level.

anterolisthesis nor obvious instability at the corresponding level, as defined by our radiological criteria, was noted after surgery.

Foraminal stenosis, as shown on parasagittal MR images, was classified as anteroposterior (n=5), cephalocaudal (n=1), or circumferential (n=20)[1,9]. The main factors involved in the manifestation of LFS as analyzed on parasagittal MPR-CT images were a thickened ligamentum flavum (n=2) and upward shift of the superior articular process (n=3) in anteroposterior foraminal stenosis; an osteophyte behind the vertebral body (n=1) in cephalocaudal foraminal stenosis; an osteophyte behind the vertebral body and upward shift of the superior articular process (n=18), an osteophyte behind the vertebral body and a thickened ligamentum flavum (n=1), or disc bulging (n=1) in circumferential foraminal stenosis.

Illustrative Cases

Case 1 **(Fig. 2)**

This 57-year-old man had undergone surgery (L4/L5 fenestration) 2 years earlier at our institution; he was subsequently symptom-free. However, at rest, lower back pain and severe pain in the L5 area of the left lower extremity recurred. The Kemp sign was present on the left side. Plain radiographs showed lumbar degenerative scoliosis with a left curve; the Cobb angle of the major curve at L1 to L4 was 16.3°, and the apical vertebra was at L2. MR revealed adequate decompression of the spinal canal at the L4/L5 level and circumferential LFS, and MPR-CT demonstrated loss of disc height and upward shift of the superior articular process at the

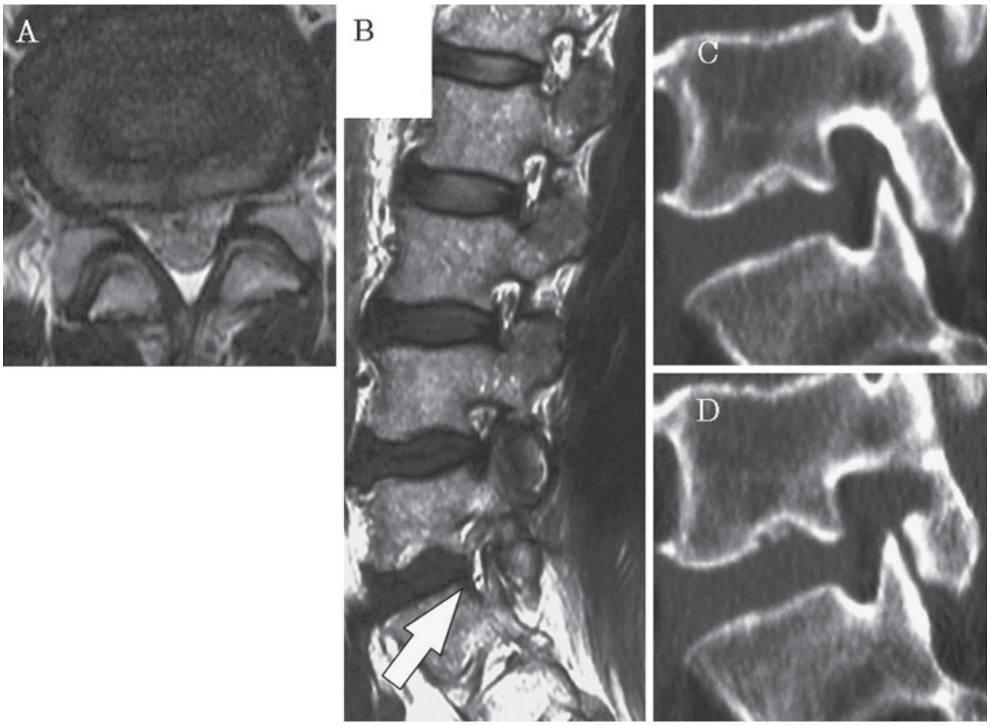

Fig. 3
A: MR image (axial view) showing moderate spinal canal stenosis at the L4/L5 level.
B: MR image (sagittal view) showing LFS (anteroposterior type) at the left L5/S1 level. The arrow indicates the left L5/S1foramen.
C: Preoperative MPR-CT demonstrated a thickened ligamentum flavum at the right L5/S1 level.
D: Postoperative MPR-CT showing foraminal widening with partial resection of the anterior cortex of the isthmus.

left L5/S1 level (**Fig. 2**). This patient underwent microsurgical medial fenestration at the left L5/S1 level. Immediately after surgery the symptoms resolved, and the Kemp sign was absent. He has had no symptoms in the 2 years after surgery.

Case 2 (**Fig. 3**)

This 59-year-old man had lower back pain and severe pain in the L5 area of the right lower extremity at rest. The Kemp sign was present on the right side. MR revealed mild spinal canal stenosis at the L4/L5 level and anteroposterior LFS, and MPR-CT demonstrated a thickened ligamentum flavum at the right L5/S1 level. He underwent microsurgical medial fenestration at the right L5/S1 level with hemifenestration on the ipsilateral side at the L4/L5 level. Immediately after surgery the symptoms resolved, and the Kemp sign was absent. He has had no symptom in the 22 months after surgery.

Discussion

Our diagnostic criteria for LFS are severe radicular symptoms and presence of the Kemp sign. Previous studies have found that the Kemp sign is present in 79% to 85% of patients with LFS[1,7]. These findings are useful for the diagnosis of LFS and for the postoperative assessment of surgical effectiveness, although LFS cannot be diagnosed on the basis of symptoms alone. While selective nerve root block is diagnostic of LFS, it carries the risks of infection, root injury, and adhesion, and distinguishing LFS from lateral recess or extraforaminal stenosis remains difficult. The adhesion of the nerve root to surrounding structures at the neural foramen raises the risk of iatrogenic nerve root injury. We tend to avoid this procedure unless we are unable to identify the affected nerve root on the basis of presenting symptoms. In 98% of patients with LFS, sagittal MR images show a smaller foramen and a loss of epidural fat surrounding the nerve root[10]. MPR-CT is extremely sensitive (90%) for LFS and is helpful for detecting posterior osteophytes and superior displacement of the superior articular process[2]. However, the incidence of asymptomatic foraminal stenosis is high[11], and because some imaging studies are of limited diagnostic value, the diagnosis of LFS requires comprehensive examination and the evaluation of both symptoms and imaging findings.

The Sonopet ultrasonic bone curette has recently been introduced for use in spinal surgery[12–15]. The use of a high speed drill raises temperatures in the operative field in the absence of adequate irrigation and can damage the surrounding structures, such as the dura mater and the affected nerve root; therefore, the use of a high speed drill is not recommended for such widening of the foramen. While the Sonopet is being operated, the handpiece tip is cooled with continuous irrigation. In conventional medial fenestration without Sonopet, a bone curette or Kerrison rongeur is used to resect the anterior cortex of the pars interarticularis and expand the foramen. However, if the affected nerve root is compressed severely in the stenotic foramen, insertion of these instruments and the motion, the scratching of the bone curette or the gnawing of the Kerrison rongeur, can result in irritation and damage of the nerve root. The vibration by which Sonopet destroys tissue is composed of both longitudinal and torsional motions; this vibration facilitates the safe removal of bone in a narrow field and provides for the safe and reliable widening of the foramen along the nerve root[13]. Nonetheless, while the Sonopet is being used, care must be taken to avoid iatrogenic dural tears and epidural venous plexus damage resulting from tissue being sucked into the aspirator attachment[12–15]. Therefore, cotton pads must be placed between the tip of the Sonopet and structures that must be protected. In this series, we encountered no intraoperative complications associated with the used of Sonopet.

Several surgical procedures, including medial foraminotomy[16,17], total facetectomy with fusion[18], lateral foraminotomy with muscle splitting[19], microsurgical nerve root canal winding[20], unilateral resection of the pars interarticularis[21], and intrapedicular partial pediculectomy[1], have yielded favorable outcomes in patients with LFS.

Spinal fusion surgery is an effective option for treating LFS because, in combination with total facetectomy, it results in complete, stable, and prolonged nerve root decompression in the foramen and restoration of the disc height[7,22]. However, spinal fusion surgery has a high complication rate (e.g., infection and nerve injury) and may result in degenerative changes at levels adjacent to the fusion site[23]. Lateral foraminotomy with muscle splitting is useful for patients in whom nerve root compression is limited to the outer region of the intraforaminal zone or the extraforaminal zone or both[1] and may be less invasive; however, the surgeon can become disoriented during the approach to the nerve and foramen. Medial fenestration is recommended for patients in whom concomitant compressive pathology is present in the central canal (stenosis or posterolateral disc herniation) or the lateral recess in addition to the foramen[2]. In contrast to lateral foraminotomy, medial fenestration is familiar to most surgeons and is less likely to cause intraoperative disorientation. The aim of our microsurgical medial fenestration is anteroposterior decompression of nerve roots in the foramen; it is achieved by resection of the anterior cortex of the pars interarticularis and ligamentum flavum in the foramen. We found that microsurgical medial fenestration with Sonopet addresses all types of LFS and all factors contributing to its manifestation. In this procedure, the pars interarticularis is left intact more than 8 mm from the lateral border to maintain the continuity of the bony arch. The pars interarticularis should be left intact at a distance of 8 mm or more from the lateral border, if possible, if the outer region of the intraforaminal zone can be observed through the microscope, which is tilted to the opposite side of the affected foramen. The removal of more than one-quarter of the lateral part of the pars interarticularis significantly increases mechanical stress in the remaining neural arches[24]. In all but 1 of our patients the bony continuity of the pars interarticularis was retained postoperatively.

The other patient had iatrogenic spondylolysis. Plain radiographs obtained in the follow-up period showed that this procedure did not affect the severity of lumbar scoliosis, the ROM, or the anterior or posterior disc height at the corresponding level. During the operation, calculating how much of the pars interarticularis should be preserved can be difficult. However, our experience indicates that the pars interarticularis should be preserved at a distance of 8 mm or more from the lateral border.

Our study had several limitations. Our study population was small, and the follow-up period (mean, 30.6 months) was short. Nonetheless, our findings suggest that microsurgical medial fenestration with Sonopet is a less-invasive and safer surgical technique for the treatment of LFS.

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