Extraforaminal compression of the L-5 nerve root at the lumbosacral junction: clinical analysis, decompression technique, and outcome

Clinical article

Seungcheol Lee, M.D., Ph.D., Ji Hoon Kang, M.D., Umesh Srikantha, M.Ch., Il-Tae Jang, M.D., Ph.D., and Sung-Hun Oh, M.D., Ph.D.

Department of Neurosurgery, Nanoori Hospital, Bupyeong-gu, Incheon, South Korea; Department of Neurosurgery, M S Ramaiah Medical Teaching Hospital, Bangalore, India; and Department of Neurosurgery, Seoul Nanoori Hospital, Gangnam-gu, Seoul, South Korea

Object. Extraforaminal compression of the L-5 nerve encompasses multiple pathological entities and may result from disc herniations as well as bony (osteophytes or sacral ala) or ligamentous (sacroiliac ligament and lumbosacral band) compression. Several other factors, such as disc space collapse or coronal wedging, can also contribute to narrowing of the extraforaminal space. The extraforaminal space at L5–S1 has unique anatomical features compared with the upper lumbar levels, which makes surgical access to this region difficult. Minimally invasive techniques offer easier access to the region. The purpose of this study was to analyze the contributing factors for extraforaminal compression of the L-5 nerve and assess clinical outcome following surgical decompression.

Methods. Fifty-two consecutive patients who underwent a minimally invasive far-lateral approach for extraforaminal compression of the L-5 nerve were retrospectively analyzed for clinical data, outcomes, and imaging features (type of disc prolapse, coronal wedging, degree of disc and facet degeneration, facet tropism, foraminal stenosis, osteophytes, and adjacent-level disease). The authors describe the surgical technique used in this study.

Results. The mean age of the patient sample was 57 years. Sixteen patients each had an extraforaminal ruptured disc or contained protrusion, and the remaining 20 patients had disc protrusions extending into the foraminal region or the lateral recess. Associated foraminal stenosis was found in 38.5%, and adjacent-level stenosis was noted in 22 cases (42.3%) and spondylolisthesis in 4 (7.7%). Osteophytes were noted in 18 cases. A coronal wedging angle ≥ 3° was found in 46.2%, and the laterality of wedging corresponded to the symptomatic side in 91% of cases. Fifteen patients (28.8%) complained of postoperative dysesthesias, which completely resolved in all cases within 6 months. The incidence of dysesthesias was more common in the ruptured disc group. There were no differences in clinical outcome among the different types of disc prolapses. The mean preoperative and postoperative visual analog scale scores were 7.6 and 3.6, respectively. The mean preoperative and postoperative Japanese Orthopaedic Association (JOA) scores were 6.4 and 13.8, respectively. The mean JOA recovery rate was 86.1%. According to the Macnab functional grading system, 96% of the patients had excellent or good grades at follow-up.

Conclusions. A minimally invasive far-lateral approach to L5–S1 requires a good understanding of the regional anatomy and can provide good to excellent clinical results in properly selected cases. This approach is effective in de-compressing the far-lateral and foraminal zones. Adequate preoperative diagnosis and tailoring the surgical procedure to address the relevant compressive element in each case is essential to achieving good clinical results.

Key Words • far-lateral approach • minimally invasive spine surgery • extraforaminal compression/entrapment • far-lateral disc herniation • lumbosacral junction • lumbar

Extraforaminal or far-lateral disc herniations constitute an uncommon group in which the disc prolapse and nerve compression are found in the region lateral to the foraminal zone, in contrast to the classic posterolateral disc prolapse that occurs intraspinally medial to the foraminal zone.1,17,18,24,32 Extraforaminal or far-lateral disc herniations account for 2.6%–12% of all disc herniations in various patient series and are more commonly observed in upper lumbar levels, probably due to the narrow pedicle width at these levels accounting for increased disc compression.

Abbreviations used in this paper: JOA = Japanese Orthopaedic Association; VAS = visual analog scale.

This article contains some figures that are displayed in color online but in black-and-white in the print edition.
area in the lateral zones. Extraforaminal disc herniations at L5–S1 are even more unusual, accounting for 2%–4% of all disc herniations. Extraforaminal or far-lateral disc herniations directly compress the dorsal root ganglion and thus produce severe clinical symptoms and a higher incidence of neurological deficits as compared with classic posterolateral herniations.

The extraforaminal zone at L5–S1 has several unique anatomical features. The broader pedicle width, coronally oriented and broader facet complex, narrow space between the L-5 transverse process and the sacral ala, and the sacroiliac part of the iliolumbar ligaments with its lumbosacral band, create a narrow “lumbosacral tunnel” through which the L-5 nerve courses. In addition, degenerative osteophytes at the lateral aspect of L-5 and S-1, disc space collapse, coronal wedging, and diffuse, even smaller disc bulges can further narrow this tunnel. Despite the rarity of extraforaminal “disc herniations” at the L-5–S1 level, the L-5 nerve is particularly prone to compression/entrapment in its extraforaminal zone due to these factors. It is not uncommon to misdiagnose or overlook extraforaminal pathology at L5–S1 and attribute L-5 radiculopathy to the presence of a milder pathology at the L4–5 disc level. This is particularly true as there are no definitive criteria, at present, to radiologically diagnose the lumbosacral tunnel as narrow, especially in the absence of significant disc pathology or osteophytes. Such situations can lead to persistent postoperative symptoms and/or failed back syndrome.

Surgical access to the L5–S1 extraforaminal zone is difficult, unlike at other lumbar levels. The wide interpedicular distance, broad pedicles, and facet complexes place the extraforaminal zone further laterally, making midline approach more invasive with longer incisions and extensive muscle dissection to access the region. On the other hand, the prominent iliac crest, the coronally oriented and broad facet joints, and the inclination of sacral ala narrow the operative corridor through a posterolateral muscle-splitting conventional microsurgical approach. Minimal access techniques using a tubular retractor overcome the limitations presented by both of the above approaches and can provide easy access to the region, but limit the extent of exposure. A thorough understanding of the regional anatomy is essential prior to adopting this technique.

Methods

Study Population and Data Collection

The study population consisted of 52 consecutive patients who underwent a far-lateral approach for extraforaminal pathology at L5–S1 in 2010 and 2011 at Nanoori Hospital in Incheon, South Korea. The records of these patients were retrospectively reviewed for demographic data, preoperative and postoperative clinical symptoms and signs and their laterality, duration of follow-up, and intraoperative details. Neurological assessment was conducted preoperatively, and postoperatively at the time of discharge. Visual analog scale (VAS) scores for back pain were collected preoperatively and on the first postoperative day. Japanese Orthopaedic Association (JOA) scores (range 0–15) were collected for all cases preoperatively and at the time of the latest follow-up. The JOA recovery rates were calculated according to the Hirabayashi method, the formula to calculate the recovery rate according to this method is: (postoperative JOA score – preoperative JOA score)/(15 – preoperative JOA score) × 100. Macnab's functional improvement grade for all patients (excellent, good, fair, or poor) was noted at the time of their last follow-up evaluation.

Imaging Data

Pre- and postoperative imaging studies were methodically assessed, including anteroposterior and lateral flexion-extension radiographs, axial CT scans, and sagittal and axial T1-weighted and T2-weighted MR images. The degree of disc degeneration was classified according to criteria suggested by Pfirrmann et al. The degree of facet degeneration was classified according to the criteria of Pathria et al. The degree of associated foraminal stenosis on the symptomatic side at L5–S1 was classified according to the study of Lee et al. The right and left facet angles were measured between a line parallel to the posteromedial surface of the superior articular process of S-1 and the midsagittal line, and the difference between them was noted as facet tropism. The laterality and degree of coronal wedging at L5–S1 were noted as the angle between the lines drawn through the superior endplates of L-5 and S-1. When the superior endplate of S-1 was not clear, a line joining the superior points on the sacral ala was used as a reference. The type of disc prolapse was noted and classified as one of the following: extraforaminal rupture, extraforaminal contained, extension of protrusion into the foraminal area, extension of protrusion into the lateral recess, or diffuse disc bulge causing bilateral compression. In addition, the presence or absence of osteophytes and any associated adjacent-level pathology was noted.

Surgical Approach

All cases in the present series underwent far-lateral decompression for extraforaminal pathology at L5–S1. In cases with associated foraminal extension, the far-lateral approach was chosen to additionally decompress the foraminal area. The technique for decompressing the foraminal area through the far-lateral approach is discussed below. In cases with disc protrusion extending into the lateral recess, a decision on the surgical approach was made based on the patient’s symptom. If symptoms were localized to the L-5 root alone, the far-lateral approach was used to decompress the foraminal and extraforaminal regions. If the patient also had S-1 root symptoms, a concomitant paramedian decompression was planned. In cases of diffuse disc bulges with bilateral lateral recess and foraminal stenosis, a fusion procedure (minimally invasive transfemoral lumbar interbody fusion) was performed. In the present series, the far-lateral approach was performed in 3 patients who had diffuse disc bulges because they were not ready for a fusion procedure and
had unilateral symptoms pertaining to the L-5 root alone. The cases in which a concomitant fusion procedure or paramedian decompression was performed at the same level (L5–S1) were not included in the present series. Patients with collapsed disc spaces and bilateral foraminal stenosis underwent a fusion procedure and disc space distraction and were not included in the present series.

**Surgical Technique**

All patients were operated while prone and under epidural analgesia supplemented with intravenous sedation. With the aid of anteroposterior fluoroscopy, a vertical 2-cm skin incision was marked approximately 1 cm lateral to the lateral margin of the L5–S1 facet complex, overlying and parallel to the disc interspace on lateral fluoroscopy. The incision was deepened as far as the thoracolumbar fascia and a puncture hole was made in the fascia. The initial dilator was passed through this fascial opening, through the paraspinal muscles, to sequentially palpate the lower part of the L-5 transverse process, lateral margin of the L5–S1 facet joint, and superior surface of the sacral ala to finally dock it just lateral to the facet complex. Care should be exercised to avoid accidental slippage of the initial dilator, which can injure the underlying L-5 nerve, especially while moving from the L-5 transverse process onto the facet joint. Once the initial dilator is positioned, larger sequential dilators are passed to finally place an 18-mm fixed tubular retractor and secure it in place with a table-mounted flexible arm assembly. The operating microscope is brought in and remnant muscles in the depth of the field are cleared using monopolar cautery, at the same time palpating for the bone landmarks described above. Once the soft tissue is cleared, one should be able to visualize the lateral part of the superior articular process of S-1 medially, superior surface of the sacral ala inferiorly, a thick ligamentous band laterally (representing the medial fibers of the dorsal band of the iliolumbar ligament), and inferior margin of the medial L-5 transverse process (Fig. 3). It is important to define these bone landmarks and note their inclinations before beginning to drill.

Drilling usually begins at the base of the superior articular process of S-1 (medial wall of the para-articular notch) and progresses superiorly. Because of the large and coronally oriented facet joints at L5–S1, the lateral third of the facet joint can be safely drilled without compromising joint stability. The next step is to drill the inferior margin of the medial L-5 transverse process to obtain a tangential view of the inferior surface of the L-5 pedicle. Both the above steps serve to widen the previously narrow L5–S1 intertransverse space (Fig. 4A). It is not always necessary to drill the posterior most portion of the superior surface of the sacral ala, as its overhanging edge can be adjusted for by cranially angulating the tubular retractor. In cases of severe narrowing of the L5–S1 intertransverse space, or a steep inclination of the ala, this portion of the sacral ala can be drilled to gain better access to the deeper part of the ala adjacent to the disc space and L-5 nerve root.

Drilling as described above gives access to the L-5

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**Fig. 1.** Axial CT scan showing the criteria for measuring the facet angle (A), and anteroposterior plain lumbosacral radiographs showing the criteria for measuring the coronal wedging angle (B and C). The right and left facet angles were measured between a line parallel to the posteromedial surface of the superior articular process of S-1 and the midsagittal line. The laterality and degree of coronal wedging at L5–S1 was noted as the angle between the lines drawn through the superior endplates of L-5 and S-1. When the superior endplate of S-1 was not clear, a line joining the superior points on the sacral ala was used as a reference.

**Fig. 2.** Axial T2-weighted MR images showing different types of disc prolapse: extraforaminal ruptured disc (A, single arrow), extraforaminal contained protrusion (B), extension of protrusion into the foraminal region (C), and extension of protrusion into the lateral recess (D). The outline of the L-5 nerve is indicated by double arrowheads in each image.
nerve root just inferior to the L-5 pedicle and proximal transverse process and the disc annulus at the deeper part of the para-articular notch. However, before clearly visualizing these structures, it is necessary to dissect the overlying fat and resect the medial longitudinal fibers of the sacroiliac part of the iliolumbar ligament (Fig. 4B). It is not uncommon for a novice to confuse some anterior and medial fibers of the iliolumbar ligament with the nerve root, as both structures course in the same direction. It is more practical in such cases to trace the nerve from its medial end just below the L-5 pedicle using a blunt probe to do so. Care should also be taken while clearing the foraminal fat as undue traction on the foraminal ligament bands that attach to the root sleeve can result in inadvertent dural or nerve root injury. Thus, a wide and clear access to the extraforaminal portion of the L-5 root is obtained.

Further steps are tailored according to the pathology to be addressed. In a ruptured disc, the fragment is removed using a right-angled probe (Fig. 4C), the annular defect is widened, and the discectomy is completed. In contained disc protrusion, the bone decompression is sufficient in several cases to fully relieve the nerve compression, and discectomy may not be required. In the event of

**Fig. 3.** Illustrations on a lumbosacral sawbone model demonstrating the regional anatomy (A) and bone landmarks and nerve outlines viewed through a tubular retractor (B). The narrow extraforaminal space at L5–S1 in comparison with L4–5 can be observed in panel A. d = extruded fragment of the disc; IAP = inferior articular process; inf = inferior; l = ligament; lat = lateral; med = medial; n = L-5 nerve; SAP = superior articular process; sup = superior; trans. proc = transverse process.

**Fig. 4.** Intraoperative photographs showing the sequential steps of exposure and decompression in a case of a ruptured disc on the left side. **A:** Image taken after initial drilling of the lateral facet. **B:** After drilling the lower transverse process, partial ligament resection, and dissection of perineural fat, the outline of the nerve and the bulging annulus is visualized. **C:** Extruded disc fragment being removed. **D:** Image obtained after discectomy. d = extruded fragment of the disc; inf = inferior; l = ligament; lat = lateral; med = medial; n = L-5 nerve; sup = superior.
Extraforaminal compression of the L-5 nerve

persistent nerve compression or significant annular bulge, the annulus is resected over the sacral ala, after which osteophytes located ventral (or deeper) to the nerve can be drilled by passing the drill inferior to the nerve. After completing these steps, the laxity of the lumbosacral tunnel is assessed by passing a blunt probe caudally and laterally along the nerve (Fig. 4D). Decompression of this area is achieved by drilling the anterior portion of the superior surface of the sacral ala, releasing the lumbosacral band of the iliolumbar ligament that forms the lateral margin in the depth of the lumbosacral tunnel, and drilling any residual osteophytes to ascertain easy passage of a blunt probe along the anterior margin of the sacral ala toward the pelvic cavity. Care should be exercised in minimizing retraction and manipulation of the L-5 nerve during these steps. Decompression is considered complete when the L-5 nerve is free from the foraminal portion down to the depth of the lumbosacral tunnel where it enters the pelvic cavity. In cases of associated foraminal stenosis, decompression will require slightly larger lateral facet resection and a curved Kerrison rongeur to undercut the articular processes and pars. Planning a more lateral to medial trajectory in such cases also facilitates foraminal decompression with no extra lateral facet resection. Once decompression is complete, adequate hemostasis is achieved, the tubular retractor is removed, and the fascial opening and skin are separately closed with interrupted sutures. Patients are mobilized on the first postoperative day with a soft lumbar support, which they are advised to wear for 2 weeks.

Results

Patient Characteristics

The mean age of the 52 patients was 57.2 ± 11.3 years (range 21–77 years). There were 18 males (34.6%) and 34 females (65.4%). All patients presented with moderate (n = 22, 42.3%) or severe (n = 30, 57.7%) radicular pain in the distribution of the L-5 nerve localized to 1 side (n = 18 right, 34.6%; n = 34 left, 65.4%). The majority of patients also complained of mild (n = 18, 34.6%) or moderate (n = 26, 50%) back pain. The mean duration of aggravation of radicular pain was 3.2 ± 2.2 weeks (range 1–12 weeks), although many patients complained of intermittent low-back pain or an occasional mild degree of radicular pain prior to the aggravation. Almost all patients experienced sensory disturbances (paresthesias or numbness) at presentation. Preoperatively, motor deficits were noted in 17 patients (32.7%). None of the patients had sphincteric involvement.

Imaging Findings

On imaging findings, 32 patients (61.5%) had purely extraforaminal compression and the remaining 20 patients (38.5%) had associated foraminal stenosis. Among these 20 patients, Grades 1, 2, and 3 foraminal stenosis were found in 2 (3.8%), 13 (25%), and 5 (9.6%) patients, respectively. Four (7.7%) among these patients had additional ipsilateral lateral recess stenosis. Among the 32 patients with purely extraforaminal compression, 16 each (30.8%) had a ruptured disc or a contained protrusion. Disc protrusion extending into the foramen was observed in 16 cases (30.8%), and into the ipsilateral lateral recess in 1 patient. Three patients had diffuse disc protrusions causing bilateral lateral recess stenosis. All 4 patients with lateral recess stenosis (including the 3 cases with bilateral lateral recess stenosis) underwent a far-lateral approach as their symptoms were confined unilaterally to L-5 alone and none had symptoms pertaining to S-1 radicular distribution. As described earlier, patients with S-1 radicular symptoms in addition to those of L-5 underwent concomitant paramedian decompression or fusion and were not selected for the present study.

A large proportion of cases in the present study had significant imaging findings at the L4–5 level in addition to extraforaminal pathology at L5–S1. Adjacent-level stenosis was noted in 22 patients (42.3%) and spondylolisthesis in 4 (7.7%). Although the degree of stenosis was significant enough to warrant additional decompression at L4–5 in these cases, the stenosis was bilateral and did not explain the severe nature of unilateral radicular pain that these patients presented with. Moreover, none of these patients had a prolapsed or extruded disc, which could explain the nature of the radicular pain, even if the extraforaminal pathology at L5–S1 was overlooked, for example.

At surgery, microdecompression with partial hemilaminectomy and bilateral foraminoectomy was performed via a unilateral paramedian approach using a tubular retractor in the 22 cases with stenosis and minimally invasive transforaminal lumbar interbody fusion was performed in the 4 cases with spondylolisthesis. Apart from these cases, 3 patients had stable Grade 1 degenerative listhesis at L5–S1. None of them had worsened at follow-up.

Presence of Osteophytes, Disc Degeneration, and Facet Degeneration

The presence of osteophytes in the foraminal and extraforaminal region was noted in 18 cases (34.6%); in the majority (n = 13, 25%) they were small (< 3 mm). Only in the other 5 cases were the osteophytes large enough to be individually responsible for the patient’s symptoms. Focal osteophytes were more often noted in the extraforaminal region. Those osteophytes extending to the foraminal area were more often broad-based or diffuse (Fig. 5). Grade 2, 3, and 4 disc degeneration was observed in 2 (3.8%), 24 (46.2), and 26 (50%) of the cases. There was more variation in the degree of facet degeneration. Grade 0, 1, 2, 3, and 4 facet degeneration was noted in 8 (15.4%), 6 (11.5%), 25 (48.1%), 7 (13.5%), and 6 (11.5%) cases, respectively. There was no correlation between facet or disc degeneration and type of disc prolapse or postoperative outcome. The mean facet tropism angle was 6.4° (range 0.4°–27.2°). There was no correlation between the degree of facet tropism and type of disc prolapse.

Coronal Wedging

Twenty-four patients (46.2%) had coronal wedging (coronal wedging angle ≥ 3°) on anteroposterior standing radiographs (mean 6.3° ± 2.7°, range 3.1°–12.5°). Of these patients, the wedging angle was ≥ 3° in 14 cases (26.9%) and ≥ 10° in 3 cases (5.8%). There was no statistically
significant difference between the means of the wedging angles or the proportion of cases with angles ≥ 3° among different types of disc prolapse. The laterality of the wedging angle corresponded to the side of symptoms in 22 (91.7%) of 24 patients with angles ≥ 3°. In the remaining 28 cases with wedging angles < 3°, the laterality corresponded to the symptomatic side in 22 cases (78.5%).

Operative and Postoperative Data

The mean duration of surgery was 75 minutes (range 45–200 minutes) and the mean intraoperative blood loss was 70 ml (range 25–300 ml). Accidental root sleeve or root injury was not encountered in any case. All patients underwent bone decompression of the L-5 extraforaminal region as described above. Discectomy was required in 29 cases (55.8%). All 16 cases of extraforaminal rupture underwent discectomy. Only 3 (19%) of the 16 cases with contained protrusion limited to the extraforaminal region necessitated discectomy, while 10 (50%) of the 20 cases with protrusion extending into the foraminal or lateral recess region underwent discectomy for adequate root decompression.

There were no cases of wound complications or postoperative fresh deficits. The mean duration of follow-up was 7 months (range 1–27 months). The mean preoperative and postoperative VAS scores, JOA scores, and recovery rates are shown in Table 1. There were no significant differences in the clinical scores among patients with different types of disc prolapse (Table 2).

Radicular symptoms improved in all but 2 cases. Of these 2 cases, 1 had an extraforaminal contained disc and the other had a protrusion extending into the foraminal area. Fifteen patients (28.8%; Table 3) complained of postoperative dysesthesias, but they were not severe in any case (mild in 9 [17.3%], moderate in 6 [11.5%]). The dysesthesia lasted for less than 1 week in 5 cases (9.6%) and more than 1 month in only 2 cases (3.8%). None of the patients suffered permanent dysesthesias. A significantly larger percentage of cases with extraforaminal rupture had postoperative dysesthiasias than cases in other groups (p = 0.01). Also, dysesthesias in this group resolved within a month in all cases, and both cases in the series with dysesthiasias lasting more than 1 month had extension of their disc into the foramen or lateral recess.

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Fig. 5. Preoperative anteroposterior standing radiographs (A and D) and axial CT scans (B, C, E, and F) showing osteophytes. The outline of the L-5 nerve has been marked with white arrowheads. A: Prominent, large, broad-based, beak-shaped osteophyte arising from the lower L-5 and upper S-1 bodies on the left side (arrows). B: Right-sided focal extraforaminal osteophyte (black arrow) from the lateral aspect of the upper S-1 body causing direct nerve root compression. C: Broad-based, small, extraforaminal osteophytes (black arrows) causing narrowing of the left extraforaminal space. D: Small focal osteophytes from the lower L-5 on the left side (arrow). E: Large broad-based osteophytes causing foraminal (single black arrow) and extraforaminal narrowing on the left side (double black arrows). F: Small foraminal osteophytes on the right side (black arrows).
Discussion

Unlike extraforaminal nerve compression at upper lumbar levels, which is almost always due to disc herniations, the origin of extraforaminal compression of the L-5 nerve at the lumbosacral junction is multifactorial. Although far-lateral disc herniations at L5–S1 are very rare, accounting for 2%–4% of all symptomatic lumbar disc herniations, the incidence of compression of the L-5 nerve at the extraforaminal region of L5–S1 is probably higher than that accounted for by disc herniations alone. This is due to the unique anatomical features of the L5–S1 extraforaminal region. The relatively large and coronally oriented facet joints, larger disc area of L5–S1, broader pedicles of L-5, and larger lordotic angle of the L5–S1 disc with a smaller posterior disc height relative to other levels together account for the narrow extraforaminal bone space. In addition, the prominent iliolumbar ligament, together with its extensions (the lumbosacral band and sacroiliac part of the iliolumbar ligament), form a ligamentous “lumbosacral tunnel” through which the L-5 nerve courses and is susceptible to entrapment. Because of these features, any added pathological change such as minor disc bulges, osteophytes, or coronal wedging, which would probably be asymptomatic at other levels, may cause symptomatic L-5 nerve compression warranting decompression.

A minimally invasive approach to address extraforaminal compression at L5–S1 has been described by several authors. An approach using a tubular retractor overcomes several limitations of conventional midline, as well as far-lateral, muscle-splitting approaches. One of the main limitations is the restricted field of view that makes it essential to have a thorough understanding of the regional anatomy. However, the inability to completely decompress the foraminal area has been considered a limitation of this approach. In the present series, all cases of foraminal stenosis were effectively decompressed, which was achieved by using a larger degree of facet resection and choosing a slightly more lateral approach in cases with concomitant foraminal stenosis.

The facet joints at L5–S1 are broad and oriented coronally, and we believe that resecting a slightly larger portion of the lateral aspect of the joint can provide a sufficient view to decompress the foramina without compromising joint stability.

Dysesthesias have been reported to be the most important postoperative patient complaint after this approach, and their incidence varies between 5% and 30%. The cause of the dysesthesias, although not definitively proven, has been attributed variously to the manipulation of the dorsal root ganglion, thermal injury due to use of cautery, and even avulsion of the dorsal ramus from the ganglion. The incidence of postoperative dysesthesias in the present series was 28.8%, which resolved in the majority of patients within a month. More interestingly, dysesthesias were more often a problem in ruptured extraforaminal discs than in contained protrusions. Other studies that reported the relation of the type of disc prolapse to postoperative dysesthesias reported mixed results, with 1 study observing an increasing trend of dysesthesias with prolapses extending into the foramen and lateral recess, and the other study reporting observations similar to ours. Considering the well-accepted hypothesis that postoperative dysesthesias are a result of dorsal ganglion manipulation, and because they are not observed with any increased frequency in intracanalicular disc herniations, it is reasonable to speculate that the origin of postoperative dysesthesias may not be related to the extent of extraforaminal disc prolapse. On the contrary, the exact reason for the present study’s finding of an increased incidence of postoperative dysesthesia in ruptured discs is also not clear. It would appear that this result can either be due to the more direct and focal mechanical compression of the root by the fragment, or to the exposed nuclear material causing a more intense inflammatory response around the nerve, or even due to the obviously increased nerve manipulation in removing the fragments in these cases.

The relationship of the degree of disc degeneration and facet tropism to far-lateral or posterolateral disc herniations is controversial, and no study has conclusively
Coronal wedging, more often an accompaniment of the degenerative process of the lumbar spine in the elderly, is probably a more significant finding at L5–S1 than at upper lumbar levels due to the narrow extraforaminal space. Unlike the upper levels, even smaller degrees of wedging can sufficiently narrow the extraforaminal space to compress the nerve and cause symptoms. A study comparing the laterality of coronal wedging to symptoms reported a positive correlation between the closing (narrower) side and symptomatic side. Twenty-four percent of the cases in the present study had a coronal wedging angle \( \geq 3^\circ \) on anteroposterior standing radiographs with a mean angle of 6.3\(^\circ\), and its laterality corresponded to the symptomatic side in 92% of the cases. Also, the laterality of the wedging angle corresponded to the symptomatic side in 78.5% of the cases with wedging angles \( < 3^\circ \); probably suggesting a contributory role.

The role of osteophytes in extraforaminal entrapment of the L-5 nerve is well established in several studies and has been implicated as a cause of symptoms in as many as 74% of the cases.\(^{11,19–21}\) In the present study, osteophytes were noted in 34.6% of the cases and the majority of them were small. In only 5 cases did we believe that osteophytes could have individually explained the patient’s symptoms. Nevertheless, the presence of osteophytes in other cases was important, and together with reduced disc height and coronal wedging, could contribute to narrowing of the extraforaminal space, thus resulting in patient symptoms even in the absence of a significant disc protrusion. This is also corroborated by the fact that, in 44% of patients in the present study, we did not believe the disc bulge to be significant enough to warrant a discectomy, and decompression of the nerve was achieved by bone and ligamentous resection alone.

Lee and Lee\(^4\) classified the extraforaminal disc herniations into 4 classes based solely on the medial extension of the disc herniation. We preferred to classify extraforaminal disc herniations additionally into ruptured discs and contained protrusions. We believe that these 2 classes are pathologically different as evidenced by the significant difference in the incidence of postoperative dysesthesias between the 2 groups in our study.

The reported rates of clinical improvement in the present series are comparable to those described in the literature.\(^5,12,18,19,21,30,32,33\) However, this clinical benefit is achieved despite a significant proportion of the cases (38.5%) having associated foraminal stenosis. It is surprising that very little mention is made of the incidence of associated foraminal stenosis in several prominent studies, despite the incidence of extraforaminal disc prolapse being common in the older age group, who are more likely to have associated degenerative changes. Earlier reports have demonstrated a poor clinical outcome in the presence of associated foraminal stenosis.\(^4,14\) The technique of additional lateral facet resection and choosing a more lateral trajectory in cases of foraminal stenosis used in this study achieves adequate foraminal decompression and good clinical outcomes. Another factor to be noted in the present study is the higher incidence of associated adjacent-level disease. Almost half of the cases had either adjacent-level stenosis (43%) or spondylolisthesis (7%), which needed to be decompressed or fused. Although the degree of stenosis was significant enough to warrant additional decompression at L4–5 in these cases, the stenosis was bilateral and did not explain the severe nature of unilateral radicular pain that these patients presented with. Moreover, none of these patients had a prolapsed or extruded disc, which could explain the severe nature of radicular pain, even if the extraforaminal pathology at L5–S1 was overlooked, for example. The exact cause for improvement in back pain scores could not be explained by a decompressive procedure alone, which could be the effect of intraoperative epidural analgesia, or better postoperative physiotherapy.

Another possible reason for the better clinical results in our study, despite the high incidence of associated foraminal stenosis and adjacent-level disease, is the method of case selection, as outlined above. Symptoms attributable to S-1 compression cannot be treated by a far-lateral approach and require additional paramedian decompression or a fusion procedure. Those patients with bilateral symptoms inevitably require a fusion procedure, wherein bilateral facetectomy and disc height restoration using an interbody cage can achieve adequate decompression without any alar resection.

The major limitation of the present study is the limited duration of follow-up. Several studies outlining the long-term clinical results of the far-lateral approach have described early recurrences or persistence of symptoms after surgery and have reported persistence of clinical benefit in the long-term as well.\(^4,5,18\) Recurrent symptoms may arise due to inadequate decompression, recurrent herniation, or development of foraminal stenosis.

**Conclusions**

A minimally invasive far-lateral approach to L5–S1 requires a good understanding of the regional anatomy and can provide good to excellent clinical results in properly selected cases. The approach is effective in decompressing the far-lateral and foraminal zones. The pathology of extraforaminal compression of the L-5 nerve is multifactorial and may be due to a herniated disc, ligamentous (sacroiliac ligament and lumbosacral band) or bone (osteophytes or sacral ala) compression, or to a variable combination of each of these factors. Adequate preoperative diagnosis and tailoring the surgical procedure to address relevant compressive element in each case is essential to achieve good clinical results.

**Disclosure**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Address correspondence to: Seungcheol Lee, M.D., Ph.D., Nanoori Hospital, 124-5, Bupyeong-dong, Bupyeong-gu, Incheon 403-010, South Korea. email: best spine@gmail.com.