www.jkns.or.kr 10.3340/jkns.2008.44.1.19
J Korean Neurosurg Soc 44 : 19-25, 2008

Print ISSN 1225-8245 On-line ISSN 1598-7876

Clinical Article

Microdecompression for Extraforaminal L5-S1 Disc Herniation; The Significance of Concomitant Foraminal Disc Herniation for Postoperative Leg Pain

Dong Yeob Lee, M.D., Sang-Ho Lee, M.D. Ph.D.
Department of Neurosurgery, Wooridul Spine Hospital, Seoul, Korea

Objective : To analyze the relationship of concomitant foraminal lumbar disc herniation (FLDH) with postoperative leg pain after microdecompression for extraforaminal lumbar disc herniation (EFLDH) at the L5-S1 level.

Methods : Sixty-five patients who underwent microdecompression for symptomatic EFLDH at the L5-S1 level were enrolled. According to the severity of accompanying FLDH, EFLDH was classified into four categories (Class I : no FLDH; Class II : mild to moderate FLDH confined within a lateral foraminal zone; Class III : severe FLDH extending to a medial foraminal zone; Class IV : Class III with intracanalicular disc herniation). The incidence of postoperative leg pain, dysesthesia, analgesic medication, epidural block, and requirement for revision surgery due to leg pain were evaluated and compared at three months after initial surgery.

Results : The incidences of postoperative leg pain and dysesthesia were 36.9% and 26.1%, respectively. Pain medication and epidural block was performed on 40% and 41.5%, respectively. Revision surgery was recommended in six patients (9.2%) due to persistent leg pain. The incidences of leg pain, dysesthesia, and requirement for epidural block were higher in Class III/IV, compared with Class I/II. The incidence of requirement for analgesic medication was significantly higher in Class III/IV, compared with Class I/II (p=0.02, odds ratio=9.82). All patients who required revision surgery due to persistent leg pain were included in Class III/IV.

Conclusion : Concomitant FLDH seems related to postoperative residual leg pain after microdecompression for EFLDH at the L5-S1 level.

KEY WORDS : Extraforaminal · Intervertebral disc · Lumbosacral spine.

INTRODUCTION

Extraforaminal lumbar disc herniation (EFLDH), a herniated disc outside the confines of the spinal canal, has been also named as far-lateral, extreme-lateral, and extracanalicular disc herniation[10,14,16,17,20]. Foraminal lumbar disc herniation (FLDH), a herniated disc inside the confines of neural foramen, has been generally considered as an isolated and different disease entity from EFLDH[2,3,9,15]. However, lumbar disc herniation can occur in simultaneous foraminal and extraforaminal locations in significant numbers of patients[15]. The presence of simultaneous FLDH is considered important because remnant FLDH has been suggested as one of the causes of persistent or recurrent leg pain after microdecompression for EFLDH[2]. The possibility of remnant FLDH after microdecompression for EFLDH seems, in particular, higher at the L5-S1 level due to the unique anatomy of lumbosacral junction : longer foraminal zone and more prominent foraminal crowding at the L5-S1 level than other lumbar levels[4,16].

Though numerous studies have been reported concerning surgical outcomes of EFLDH, no study has focused on the relationship on concomitant FLDH with postoperative leg pain after microdecompression for EFLDH at the L5-S1 level. The authors classified EFLDH into four categories according to the severity of accompanying FLDH based on preoperative radiological findings, and analyzed the short-term surgical results after microdecompression for EFLDH at the L5-S1 level in each class, focusing especially on postoperative leg pain.

MATERIALS AND METHODS

Patient Population

Clinical and radiological data of 108 consecutive adult patients aged 44 to 81 years (mean 64.6 years) with a male : female ratio of 33.3 : 76.7 who underwent microdecom-

• Received : May 6, 2008 • Accepted : July 7, 2008
• Address for reprints : Sang-Ho Lee, M.D., Ph.D.
Department of Neurosurgery, Wooridul Spine Hospital, 47-4 Cheongdam-dong, Gangnam-gu, Seoul 135-100, Korea
Tel : +82-2-513-8150, Fax : +82-2-513-8146
E-mail : shlee@wooridul.co.kr

pression for single-level EFLDH from January 2005 to October 2005 were retrospectively reviewed. Microdecompression was performed using a lateral transmuscular approach in all patients. The following were excluded ; 1) microdecompression for pure FLDH; 2) microdecompression for multi-level EFLDHs; 3) spondylolisthesis and/or instability; and 4) previous history of spine surgery. Of the 108 patients, 65 (60.2%) underwent microdecompression at the L5-S1 level, 34 (31.5%) at the L4-5 level, eight (7.4%) at the L3-4 level, and one patient (0.9%) at the L2-3 level.

Classification and Outcome Assessment

Based on preoperative radiological findings, EFLDH at the L5-S1 level was classified into four categories according to the severity of accompanying FLDH. Combined with computed tomography (CT) and magnetic resonance (MR) images, coronal source images of MR myelography were performed to delineate the L5 pedicle, L5 ganglion, and the severity of concomitant FLDH before surgery in all patients (Fig. 1). Medial and lateral foraminal zone were subdivided at the mid-portion of L5 pedicle. EFLDH at the L5-S1 level was classified as follows : 1) Class I : no accompanying FLDH; 2) Class II : mild to moderate FLDH confined within a lateral foraminal zone; 3) Class III : severe FLDH extending to a medial foraminal zone; and 4) Class IV : Class III with intracanalicular disc herniation (Table 1, Fig. 2).

Parameters assessed included the incidence of patients who complained of postoperative residual leg pain (Visual Analogue Scale (VAS) score 5 or more) and dysesthesia within three months after initial surgery in each Class. The incidences of the requirement for analgesic medication, epidural block, and revision surgery due to postoperative leg pain within three months after initial surgery were also assessed in each Class. Then, first, the differences of each parameter among the four groups (Class I, II, III, and IV) were analyzed. Second, the differences of each parameter between two groups (Group I : Class I and II; Group II : Class III and IV) were analyzed.

Table 1. The classification of extraforaminal lumbar disc herniation based on the severity of accompanying foraminal lumbar disc herniation

Class	Definition
I	No accompanying FLDH
II	Mild to moderate FLDH confined within a lateral foraminal zone
III	Severe FLDH extending to a medial foraminal zone
IV	Class III with intracanalicular disc herniation

FLDH : foraminal lumbar disc herniation

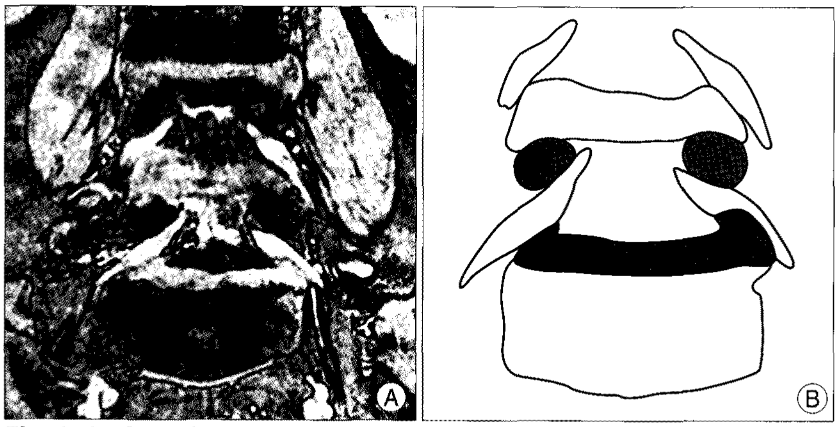

Fig. 1. A : Coronal source image of magnetic resonance myelography demonstrating extraforaminal lumbar disc herniation accompanied by foraminal lumbar disc herniation on the left side at the L5-S1 level. Concomitant foraminal disc herniation is confined in the lateral half of the foraminal zone. B : Schematic drawing of coronal source image of magnetic resonance myelography (black color : L5 pedicles, yellow color : L5 ganglions, brown color : intervertebral disc and herniated disc at the L5-S1 level).

Statistical Analysis

All of the statistical analyses were performed on a personal computer running commercially available software (SPSS, Inc). The differences of parameters among the four groups were assessed through a linear by linear association test. The differences of parameters between the two groups were assessed using Fisher's exact test. A p value of less than 0.05 was considered significant.

Surgical Technique

All operations followed a standard pattern suggested by the senior author. A 3-cm vertical skin incision was made at 2.5 to 3.5 cm from the midline, which depended on the location of a triangular space bordered by the L5 transverse process, lateral margin of L5-S1 facet joint, and sacral ala on the CT and MR imaging. After the incision of fascia, fingertip dissection was performed to identify the triangular space. Then a self-retractor (Caper retractor combined with Papavero retractor) was applied and the table was tilted about 30 to 40 degrees toward the opposite side. Under microscopic view, the lower border of the L5 transverse process, upper border of sacral ala, and lateral L5-S1 facet joint, including lateral pars interarticularis (less than 50%) were carefully drilled with a high-speed diamond-tipped burr. Then the lumbosacral ligament in the triangular space was removed by the Kerrison punch to expose the L5 dorsal root ganglion and EFLDH. Before dissecting and retracting the L5 dorsal root ganglion, radicular arteries and veins were carefully dissected and cut after coagulation with bipolar cautery to prevent massive bleeding. After retracting the L5 dorsal root ganglion, EFLDH was removed by pituitary forceps. Foraminal widening was performed using a curved foraminal punch and then, accompanying FLDH were explored and removed. After identifying a thorough decompression of the L5 dorsal root ganglion, closure was performed in a conventional way after the insertion of Hemovac.

RESULTS

Of the 65 patients with EFLDH at L5-S1 level, there were 17 men and 48 women. The mean age of these patients at the time of operation was 64.1 years (range 44-81 years). All 65 patients complained of leg pain along L5 sensory dermatome and/or back pain before surgery. The mean duration of the symptom was 5.7 months (range 1.5-36 months). The mean operation time was 82.1 minutes (range 50-135 minutes). The mean estimated blood loss was 125.5 cc (range 55-450 cc). Transfusion was not performed in any case. Intraoperative complications such as ganglion injury did not occur in any case.

Twenty-four of the 65 patients (36.9%) suffered from postoperative leg pain (VAS score 5 or more) on the L5 sensory dermatome after surgery. Seventeen of the 65 patients (26.1%) complained of dysesthesia on L5 sensory dermatome. Fifteen of the 24 patients with postoperative leg pain also complained of dysesthesia on L5 sensory dermatome. Within three months after surgery, 26 of the 65 patients (40%) required analgesic medication, and 27 of the 65 (41.5%) required epidural block due to persistent leg pain. Leg pain was transient and improved after pain medication and/or epidural block in 18 of 24 patients with postoperative leg pain. However, leg pain did not improve with pain medication and/or epidural block in six patients (9.2%). Thus, revision surgery was recommended in all these six patients. Remnant FLDH was demonstrated on postoperative CT and/or MR images and was considered the cause of persistent leg pain in all the six patients (Fig. 3). Three patients underwent revision surgery (additional decompression of remnant FLDH in two and fusion surgery in one patient) and showed marked improvement of leg pain after the surgery. However, the other three patients refused a second surgery.

The most common type of EFLDH in the 65 patients included was Class III (45 patients, 69.2%), which was followed by Class IV (8 patients, 12.3%), Class II (7 patients, 10.8%), and Class I (5 patients, 7.7%). There was no significant difference in the incidence of postoperative leg pain among the four groups (20%, 28.6%, 37.8%, and 50% for Class I, II, III, and IV, respectively; p=0.24). There was a trend of an increasing incidence of dysesthesia with

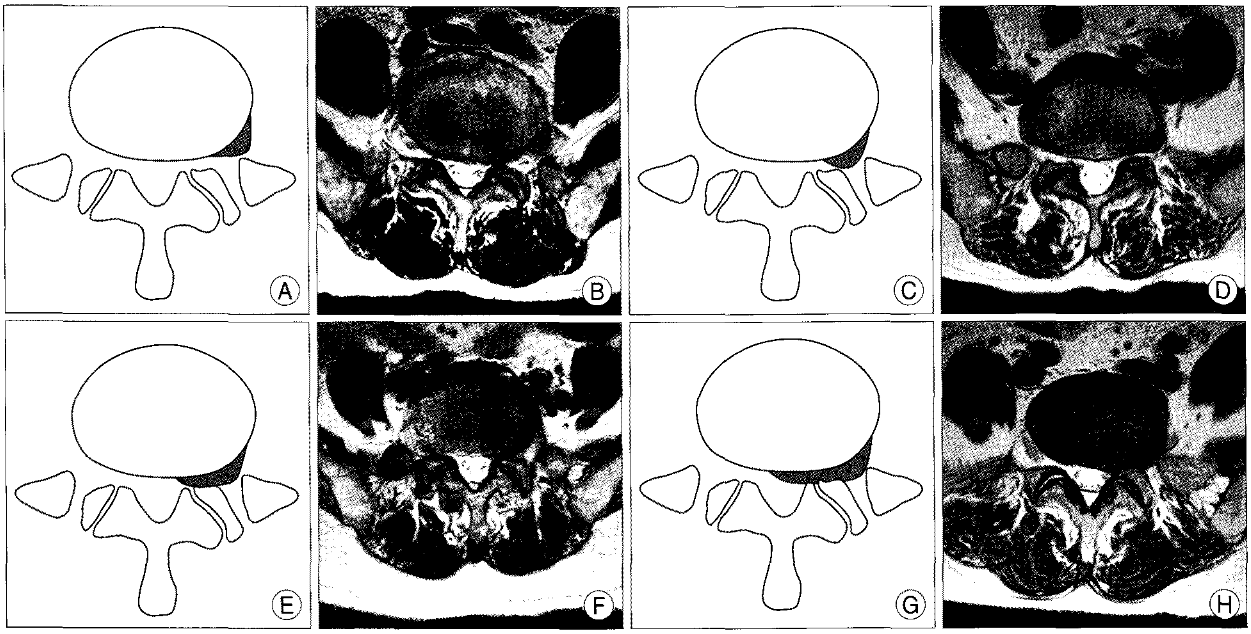

Fig. 2. Classifications of extraforaminal lumbar disc herniation at the L5-S1 level based on the severity of concomitant foraminal disc herniation. Schematic drawings and T2-weighted axial magnetic resonance images showing typical example of each Class. Class I (A, B), Class II (C, D), Class III (E, F), and Class IV (G, H).

increasing Class number, though statistically insignificant (0%, 14.3%, 28.9%, and 37.5% for Class I, II, III, and IV, respectively; p=0.09). There was no significant difference in the incidence of analgesic medication among the four groups (0%, 28.6%, 46.7%, and 37.5% for Class I, II, III, and IV, respectively; p=0.11). There was also no significant difference in the incidence of epidural block among four groups (20%, 28.6%, 44.4%, and 37.5% for Class I, II, III, and IV, respectively; p=0.37). There was a trend of an increasing incidence of requirement for revision surgery with increasing class number, though statistically insignificant (0%, 0%, 8.9%, and 25% for Class I, II, III, and IV, respectively; p=0.09) (Table 2). Considering the two-group analysis (Group I : Class I and II, Group II : Class III and IV), the incidences of leg pain and dysesthesia were higher in Group II than in Group I (39.6 vs. 25%, p=0.51 for leg pain; 30.1 vs. 8.3%, p=0.16 for dysesthesia). The requirement for analgesic medication was significantly higher in Group II than in Group I (47.1 vs. 8.3%, p=0.02, and odds ratio=9.82 (95% confidence interval : 1.18-81.6)). The incidence of epidural block was higher in Group II than in Group I (43.4 vs. 25%, p=0.33). All patients with persistent leg pain requiring revision surgery were included in Group II (11.3 vs. 0%, p=0.58) (Table 3).

Table 2. Summary of four-group analysis

	Class				p value†
	I	II	III	IV	
No. of patient (%)	5 (7.7)	7 (10.8)	45 (69.2)	8 (12.3)	
Parameter					
Residual leg pain (%)	1 (20)	2 (28.6)	17 (37.8)	4 (50)	0.24
Dysesthesia (%)	0 (0)	1 (14.3)	13 (28.9)	3 (37.5)	0.09
Analgesic medication (%)*	0 (0)	2 (28.6)	21 (46.7)	3 (37.5)	0.11
Epidural block (%)*	1 (20)	2 (28.6)	20 (44.4)	3 (37.5)	0.37
Revision surgery (%)*	0 (0)	0 (0)	4 (8.9)	2 (25)	0.09

*Due to postoperative leg pain, †Calculated by linear by linear association test

Table 3. Summary of two-group analysis

Variable	Group†		p value‡
	I	II	
No. of patient (%)	12 (18.5)	53 (81.5)	
Parameter			
Residual leg pain (%)	3 (25)	21 (39.6)	0.51
Dysesthesia (%)	1 (8.3)	16 (30.1)	0.16
Analgesic medication (%)*	1 (8.3)	25 (47.1)	0.02
Epidural block (%)*	3 (25)	23 (43.4)	0.33
Revision surgery (%)*	0 (0)	6 (11.3)	0.58

*Due to postoperative leg pain, †Group I : Class I and II, Group II : Class III and IV, ‡Calculated by Fisher's exact test

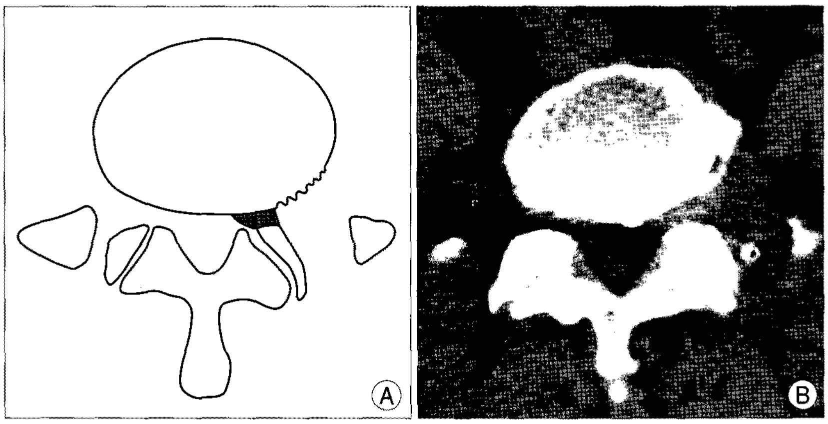

Fig. 3. A 60-year-old female underwent microdecompression for Class III extraforaminal lumbar disc herniation on the left side at the L5-S1 level. The patients underwent second surgery due to severe residual leg pain. Schematic drawing and postoperative CT scan showing remnant foraminal disc herniation (A, B). After additional decompression of remnant foraminal disc herniation, the patient showed marked improvement of leg pain.

DISCUSSION

EFLDHs occur more frequently in the upper lumbar levels and among elderly patients, with a peak incidence during the sixth decade of life[19]. EFLDHs at the L5-S1 level have been reported as a rare disease entity that constitutes approximately 2% to 4% of all lumbar disc herniations[8,18]. The results of the present study showed that symptomatic EFLDH requiring surgery occurred most commonly at the L5-S1 level, followed by L4-5 level, and EFLDHs at the upper lumbar levels were relatively uncommon. Due to the unique anatomical feature, such as ala, the iliolumbar ligament, and the broad pedicle at the L5-S1 level, the L5 root can be frequently compressed by herniated disc in the extraforaminal zone[7]. However, EFLDH at the L5-S1 level has been regarded sometimes difficult to diagnose even with CT and/or MR imaging, which has been considered as the frequent cause of persistent symptoms despite surgery[1,9]. There have been recent improvements in the diagnostic modalities for foraminal and/or extraforaminal pathologies. MR images using coronal plane was suggested as being useful in the assessment of extraforaminal pathologies in the lumbosacral spine, when sagittal and axial MR images were unable to clearly define the lesions[5]. In the present study, coronal source images of MR myelography were used to diagnose and classify the EFLDH at the L5-S1 level combined with CT and MR images. Coronal source images of MR myelography are the source MR images, which are used to extract conventional MR myelography images[11]. It can delineate the anatomical structures of foraminal and extraforaminal areas, such as pedicle, ganglion, and foraminal /extraforaminal disc, in the whole lumbar spine, thus being helpful to diagnose pathologic lesions in the foraminal and extraforaminal zone, when combined with CT and MR images[11]. Therefore, a high index of suspicion combined with multi-diagnostic modalities such as CT, MR, and MR myelography images might explain the different incidence of EFLDH at the L5-S1 level in the present study.

EFLDHs at the L5-S1 level have been considered particularly different from those at upper lumbar levels due to the unique anatomy of the lumbosacral junction[8,12,16]. Microdecompression via lateral transmuscular route, introduced by Reulen et al.[17] and Wiltse and Spencer[21], has been performed as one of the effective surgical techniques for EFLDH, which can preserve facet joints and avoid postoperative instability requiring fusion surgery. Until now, few studies have focused on the microdecompression of EFLDH at the L5-S1 level and concluded that microdecompression of this area was extremely difficult due to the narrow operative window despite relatively good surgical outcomes[7,8,12]. Although the present study focused on the postoperative residual leg pain during three months after initial surgery the result was disappointing and worse than those previously reported for EFLDH at the L5-S1 level, i.e., 36.9% of patients suffered from residual leg pain, 40% of the patients required analgesic medication due to residual leg pain, and 41.5% of patients required epidural block due to residual leg pain. Furthermore, second surgery was recommended in 9.2% of the patient due to persistent leg pain within three months after initial surgery. The etiology of persistent leg pain after microdecompression for EFLDH is still unclear. Chang et al.[2] suggested double disc herniation as a risk factor for an unfavorable outcome after foraminal and far lateral microdecompression. In their study not only patients with persistent leg pain, but also patients with recurrent leg pain were classified into those with unfavorable outcome. The disappointing and painfully obvious results of the present study seem attributable to both an incorrect understanding of the anatomical nature of EFLDH at the L5-S1 level and the technical limitation of microdecompression at the L5-S1 level, especially in terms of concomitant FLDH. EFLDH can be commonly accompanied by simultaneous FLDH[15]. In a clinical series of 202 patients reported by Porchet et al.[15], 41.1% were EFLDH, 32.7% were FLDH, and 26.2% were simultaneous FLDH and EFLDH. The pars interarticularis at the L5 is wider than upper lumbar levels, which represent a longer foraminal zone at the L5-S1 level, than those at other lumbar levels[16]. For example, the pars interarticularis at L5 is 70% wider than L1. Therefore, it seems that the possibility of the presence of concomitant FLDH is especially higher at the L5-S1 level than other lumbar levels. In the present study, most patients (92.3%) with EFLDH at the L5-S1 level had concomitant FLDH, and moreover 81.5% of patients were classified into EFLDH with severe concomitant FLDH (Class III or IV). Whereas only 7.7% of the patients were classified into pure EFLDH with no accompanying FLDH, i.e., Class I. Considering microdecompression, the lateral part of the L5-S1 facet joint and pars interarticularis were tried to remove less than 50% in all patients, because the removal of pars interarticularis 50% or more might cause significant postoperative back pain and/or instability[6]. Therefore, in cases of Class III and IV EFLDHs, it was usually time-consuming and troublesome to perform a thorough decompression of concomitant FLDH in the medial foraminal zone due to limited exposure during surgery. In addition, the cause of persistent leg pain requiring revision surgery was an incomplete decompression of concomitant FLDH in all cases in Class III and IV. Thus, the poor surgical results of the present study seem attributable to the high incidence of Class III and IV EFLDHs at the L5-S1 level and the possible incomplete decompression of concomitant FLDH in these Classes.

Until now, no studies have analyzed the relationship between the severity of concomitant FLDH and the surgical results of microdecompression for EFLHD. The classification system used in the present study consists of four categories based on the preoperative radiological findings such as CT, MR, and MR myelography, especially focusing on the severity of concomitant FLDH, and seems helpful in predicting the incidence of postoperative leg pain after microdecompression at the L5-S1 level. In four-group analysis, there was a trend of increasing incidences of postoperative dysesthesia and requirement for revision surgery due to persistent leg pain with increasing Class number, though statistically insignificant. In the two-group analysis, the incidences of all parameters assessed were higher in Class III and IV when compared with Class I and II. The two-group analysis also demonstrated a significantly higher incidence of analgesic medication due to residual leg pain in Class III and IV than Class I and II and the odds ratio was 9.82 (95% confidence interval : 1.18-81.6). Moreover, all patients recommended for a second surgery due to persistent leg pain were included in Class III and IV. The results of the present study suggest that the severity of concomitant FLDH were related with the incidence of parameters concerning postoperative leg pain after microdecompression for EFLDH at the L5-S1 level.

Postoperative dysesthesia has been considered to be caused by manipulation of the dorsal root ganglion, including thermal or mechanical trauma[2,8]. It is usually transient and most commonly occurring at the L5-S1 level in patients with a ruptured disc. Careful and minimal manipulation of the dorsal root ganglion has been recommended during microdecompression to avoid postoperative dysesthesia[8]. In the present study, of the 17 patients with postoperative dysesthesia, 15 patients (88.2%) also complained of significant postoperative leg pain. As already mentioned, there was a trend of increasing incidences of postoperative dysesthesia with increasing number in the four-group analysis. Thus, it seems that postoperative dysesthesia occurring after microdecompression for EFLDH at the L5-S1 level is partially related with the severity of concomitant FLDH.

The results of the present study suggest that preoperative evaluation of the severity of concomitant FLDH is especially important and should be considered for the surgical planning of EFLDH at the L5-S1 level. Based on the result of the present study, microdecompression seems more preferable for Class I or II EFLDH, because concomitant FLDH in the lateral foraminal zone can usually be exposed by microdecompression technique. For effective exposure and decompression of concomitant FLDH while preserving pars interarticularis, the operating table should be tilted toward the contralateral side by about 30 to 40 degrees. Curved Kerrison punch, or the so called "foraminal punch", is also useful for the removal of ligamentum flavum and tip of superior articular process in the foramen, which results in additional widening of the foramen and makes decompression of concomitant FLDH easier. However, for Class III or IV EFLDH at the L5-S1 level, microdecompression technique is limited to exposing concomitant FLDH in the medial foraminal zone, thus total facetectomy and fusion are recommended first for such cases. Combined midline and paraspinal approach has been performed as one of the surgical options for foraminal and/or far lateral lumbar disc herniation. Ozveren et al. reported the surgical outcomes of combined approach for far-lateral lumbar disc herniation[13]. They performed combined approach for 18 patients with far-lateral disc herniation and reported that all patients were excellent and no patients showed instability in the follow-up period. However, Ducati A and Ducker TB insisted in their commentary to this report that without combined intracanalicular disc herniation, there was no need to perform an interlaminar disc evacuation, which was in fact detrimental. They considered combined approach was mandatory for posterolateral intracanal herniation in addition to a far-lateral disc herniation. The opinion of the present authors for combined approach is nearly same as that of Ducati A and Ducker TB. Therefore, the authors consider that for Class IV EFLDH, which is defined as EFLDH combined with both FLDH and intacanalicular disc herniation, combined midline and paraspinal approach might be an effective surgical option as an alternative for spinal fusion.

The limitations of the present study are as follows : 1) study being retrospectively designed; 2) very short follow-up period; and 3) focusing on the postoperative leg pain only, thus any meaningful assessment for postoperative back pain and functional status were not performed. In the present study, the authors only focused on FLDH combined with EFLDH at the L5-S1 level. However, in real practice, foraminal bony stenosis can be combined with FLDH at the L5-S1 level in significant number of patients. When foraminal bony stenosis is very severe and predominant compared with FLDH, lumbar interbody fusion might be considered first, regardless of severity of accompanying FLDH. The authors believe this study demonstrates the significance of concomitant FLDH for surgical outcomes of EFLDH at the L5-S1 level, and can suggest meaningful guidelines for the operative planning of EFLDH at the L5-S1 level, despite the limitations.

CONCLUSION

Concomitant FLDH seems related with postoperative residual leg pain after microdecompression for EFLDH at the L5-S1 level. Though microdecompression is an effective less invasive surgical technique for EFLDH, the presence and severity of concomitant FLDH should be considered for the surgical planning of EFLDH at the L5-S1 level.

Acknowledgement This study was supported by a grant from the wooridul Spine Roundation.

• Acknowledgement
This study was supported by a grant from the Wooridul Spine Foundation.

References

1. Burton CV, Kirkaldy-Willis WH, Yong-Hing K, Heithoff KB : Causes of failure of surgery on the lumbar spine. **Clin Orthop Relat Res 157** : 191-199, 1981
2. Chang SB, Lee SH, Ahn Y, Kim JM : Risk factor for unsatisfactory outcome after lumbar foraminal and far lateral microdecompression. **Spine 31** : 1163-1167, 2006
3. Epstein NE : Foraminal and far lateral lumbar disc herniations : surgical alternatives and outcome measures. **Spinal Cord 40** : 491-

500, 2002
4. Hasegawa T, Mikawa Y, Watanabe R, An HS : Morphometric analysis of the lumbosacral nerve roots and dorsal root ganglia by magnetic resonance imaging. **Spine 21** : 1005-1009, 1996
5. Hashimoto M, Watanabe O, Hirano H : Extraforaminal stenosis in the lumbosacral spine. Efficacy of MR imaging in the coronal plane. **Acta Radiol 37** : 610-613, 1996
6. Ivanov AA, Faizan A, Ebraheim NA, Yeasting R, Goel VK : The effect of removing the lateral part of the pars interarticularis on stress distribution at the neural arch in lumbar foraminal microdecompression at L3-L4 and L4-L5. Anatomic and finite element investigations. **Spine 32** : 2462-2466, 2007
7. Jang JS, An SH, Lee SH : Clinical analysis of extraforaminal entrapment of L5 in the lumbosacral spine. **J Korean Neurosurg Soc 36** : 383-387, 2004
8. Kotil K, Akcetin M, Bilge T : A minimally invasive transmuscular approach to far-lateral L5-S1 level disc herniations : a prospective study. **J Spinal Disord Tech 20** : 132-138, 2007
9. Kunogi J, Hause M : Diagnosis and operative treatment of intraforaminal and extraforaminal nerve root compression. **Spine 16** : 1312-1320, 1991
10. Kurobane Y, Takahashi T, Tajima T, Yamakawa H, Sakamoto T, Sawaumi A, et al : Extraforaminal disc herniation. **Spine 11** : 260-268, 1986
11. Lee DY, Lee SH, Lee HS : Unilateral isthmus resection for elderly foraminal stenosis. **J Korean Neurosurg Soc 41** : 207-209, 2007
12. O'Toole JE, Eichholz KM, Fessler RG : Minimally invasive far lateral microendoscopic discectomy for extraforaminal disc herniation at the lumbosacral junction : cadaveric dissection and technical case report. **Spine J 7** : 414-421, 2007
13. Ozveren MF, Bilge T, Barut S, Eras M : Combined approach for far-lateral lumbar disc herniation. **Neurol Med Chir (Tokyo) 44** : 118-122; discussion 123, 2004
14. Patrick BS : Extreme lateral ruptures of lumbar intervertebral discs. **Surg Neurol 3** : 301-304, 1975
15. Porchet F, Chollet-Bornand A, Tribolet N : Long-term follow up of patients surgically treated by the far-lateral approach for foraminal and extraforaminal lumbar disc herniations. **J Neurosurg 90** : 59-66, 1999
16. Reulen HJ, Muller A, Ebeling U : Microsurgical anatomy of the lateral approach to extraforaminal lumbar disc herniations. **Neurosurgery 39** : 345-350, 1996
17. Reulen HJ, Pfaundler S, Ebeling U : The lateral microsurgical approach to the "extracanalicular" lumbar disc herniation. I : A technical note. **Acta Neurochir (Wien) 84** : 64-67, 1987
18. Segnarbieux F, Van de Kelft E, Candon E, Bitoun J, Ferebeau P : Disco-computed tomography in extraforaminal and foraminal lumbar disc herniation : influence on surgical approaches. **Neurosurgery 34** : 643-647, 1994
19. Tessitore E, de Tribolet N : Far-lateral lumbar disc herniation : the microsurgical transmuscular approach. **Neurosurgery 54** : 939-942, 2004
20. Viswanathan R, Swamy NK, Tobler W, Greiner AL, Keller JT, Dunsker SB : Extraforaminal lumbar disc herniations : microsurgical anatomy and surgical approach. **J Neurosurg 96** : 206-211, 2002
21. Wiltse LL, Spencer CW : New uses and refinements of the paraspinal approach to the lumbar spine. **Spine 13** : 696-706, 1988