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Decompression Only by Unilateral Biportal Endoscopic Surgery for Adjacent Segment Degeneration: A Multi-Institution Retrospective Study

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Objective: Endoscopic surgery is gaining popularity as a minimally invasive option for adjacent segment degeneration (ASD). However, most of the previous literature has focused on transforaminal endoscopic techniques. This study aimed to assess the outcomes of decompressive laminectomy (unilateral laminectomy and bilateral decompression) with unilateral biportal endoscopic (UBE) in patients with lumbar ASD presenting with spinal stenosis.

Methods: Thirty-nine ASD patients presenting with spinal stenosis who underwent UBE decompressive surgery between June 2018 and November 2022 at 4 different institutions were enrolled. The postoperative decompression amount and spinal instability were assessed using magnetic resonance images and dynamic radiographs. All patients were followed for at least 1 year, and clinical outcomes were assessed.

Results: In the 39 patients, the cross-sectional area of the dural sac (0.55±0.21 cm^2 to 1.11±0.41 cm^2, $p<0.001$) indicated significant spinal decompression. Dynamic radiographs did not demonstrate significant occurrence of instability in operated segment. Three patients experienced complications, with one case each of hematoma, dural tear, and neurologic deficit. Visual analogue scale scores of the back (6.4±2.4 to 2.1±1.2, $p<0.001$) and leg (7.5±1.5 to 1.6±1.6, $p<0.001$), and Oswestry Disability Index scores (47.5±16.3 to 19.8±9.7, $p<0.001$) indicated significant clinical improvement that was sustained over 1 year. During the average follow-up period of 2 years, 2 patients underwent revision surgery due to failure and relapse.

Conclusion: UBE decompressive surgery had satisfactory outcomes in ASD patients, without significant failure or relapse.

Keywords: Adjacent segment degeneration, Minimally invasive surgery, Unilateral biportal endoscopy, Spinal stenosis

INTRODUCTION

Adjacent segment degeneration (ASD) is a common complication of spinal fusion surgery and is defined as the recurrence of symptoms related to new degenerative changes in the mobile segments above or below a fused spinal segment. It occurs

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with more mechanical stress induced upon the adjacent mobile segment due to the immobile state of the fused segments, and is more common in the lumbar segments [1-3]. The various pathological manifestations of ASD include spinal stenosis, mechanical instability, spondylolisthesis, and herniated intervertebral disc [4,5]. Symptomatic ASD presents with intractable back pain, radiating leg pain, or neurogenic intermittent claudication, often necessitating surgical treatment.

Traditionally, ASD has been treated using extended spinal fusion, which can completely decompress and stabilize the degenerated segment [6]. However, extended spinal fusion requires revision of the previous scar, which can induce various complications such as wound infection and dural tear, resulting in a longer surgery time and hospital stay [7]. Also, additional fusion surgery can induce yet another ASD in the new adjacent segment. Several minimally invasive techniques have been proposed for ASD revision, and endoscopic surgery is gaining popularity. Various studies have reported the efficacy of endoscopic surgery for ASD. However, most of the literature focus on transforaminal endoscopic techniques for herniated lumbar disc pathology [8-12]. Since ASD commonly presents as central canal stenosis due to overall degeneration of the segment, such as hypertrophy of the facet joint and ligamentum flavum4, an effective method for sufficient decompression without compromising stability is crucial.

Unilateral biportal endoscopic (UBE) decompression (unilateral laminectomy and bilateral decompression, ULBD) has been proven to be an effective tool for treating lumbar stenosis. Various studies have reported the efficacy of the interlaminar approach for UBE with bilateral decompression with good clinical outcome [13,14]. However, to our knowledge, no study has reported the efficacy of the UBE surgery in patients with ASD, other than one case series report [15]. We hereby present retrospective analysis of the radiological and clinical outcomes and complication rates in patients with ASD who underwent UBE surgery, with a minimum of 1-year follow-up.

MATERIALS AND METHODS

This retrospective study enrolled patients with ASD who underwent UBE decompression surgery at multiple institutions, with a minimum 1-year follow-up. This study was approved by Institutional Review Board of Gangnam Severance Hospital (IRB No. 3-2018-0361), which waived the requirement for informed consent.

1. Patient Selection

Patients with ASD presenting with spinal stenosis who underwent UBE decompressive surgery between June 2018 and November 2022 at 4 different institutions were retrospectively enrolled. The inclusion criteria were: (1) history of lumbar fusion surgery, (2) diagnosis of spinal stenosis adjacent to previously fused segments, (3) intractable leg or back pain after >6 weeks of conservative treatment. For all patients enrolled in our study, the strict indications had been applied when selecting UBE decompressive surgery. First, there should have been no radiologic instability observed in preoperative radiographic images. The radiological instability was determined with baseline dynamic x-rays that showed excessive angle or transition motion of the segment. Secondly, no severe foraminal stenosis or collapsed disc space should have been observed. Since these patients also require effective restoration of disc height additional to decompression, fusion extension surgery was preferred over decompressive-only surgery. Lastly, the upper lamina of upmost vertebrae of previously fused segments should have been preserved. Because total laminectomy sacrifices the ligamentum flavum in the upper adjacent segment, it induces adhesive tissues around dural sac, making the UBE surgery challenging to perform.

2. Surgical Procedure

The decompression was performed using an interlaminar UBE approach with a ULBD technique. The following standardized technique was used in all 4 institutions participated in this study. The detailed surgical illustration of UBE surgery for patient with ASD is shown in Figure 1. All patients were administered general anesthesia and placed in the prone position on a Wilson frame. A paramedian vertical skin incision of approximately 1 cm was made at the medial pedicle line at 2 independent sites near the targeted lumbar disc level. Right-handed surgeons usually preferred a left-sided paramedian incision. An endoscope was inserted at the upper incision site, and a working channel was inserted at the lower incision site. After confirming the level with intraoperative C-arm radiography, the dissection of muscle and soft tissues around lower lamina were performed. At this stage, adhesion of muscle layers from previous surgery were noted, but were dissected with safety and ease by ablating the adhesive tissues above the bony surface. After identification of lower lamina, lower lamina was drilled out, and the ligamentum flavum was removed. The contralateral decompression was performed by tilting the endoscope

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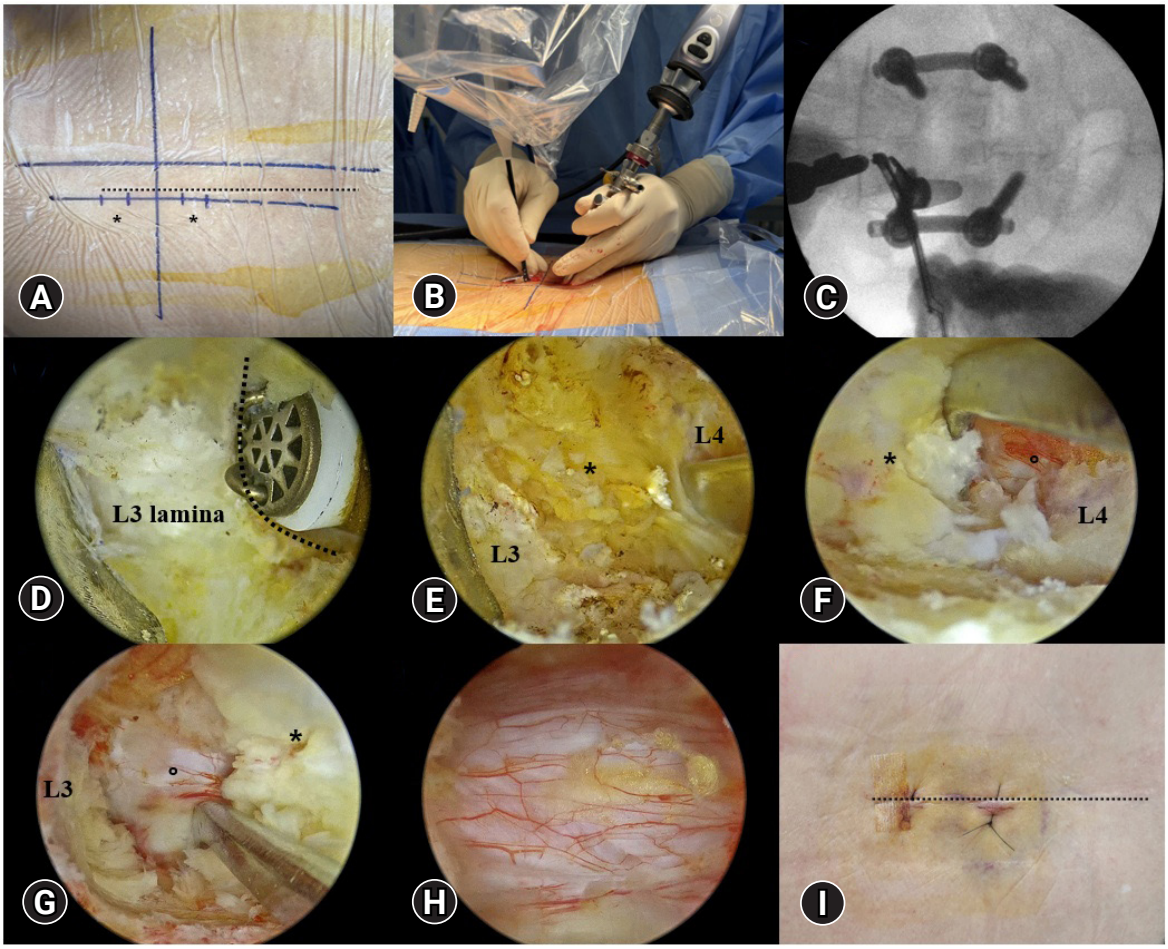

Figure 1. Surgical illustration of an adjacent segment degeneration (ASD) patient who underwent unilateral biportal endoscopic (UBE) surgery. A 73-year-old woman presented with both leg radiating pain after L4–5 fusion surgery 20 years ago. (A and B) Two paramedian skin incisions (*) next to the previous wound (dotted line) were made for the portals at the medial pedicle line near the L3–4 disc. (C and D) Initial docking of the scope and ablator was performed at the lower margin of the L3 lamina (dotted line). (E) Extensive adhesion tissue covering the interlaminar space was observed (*) (F and G) After releasing the lower and upper margin of the ligamentum flavum (*), the dural sac (°) was exposed without significant adhesion. (H) The thecal sac and both traversing roots were decompressed completely. (I) The patient was discharged 3 days later with only minimal scar adjacent to the previous wound (dotted line).

[16]. Since all of the patients in our cohort had a preserved ligamentum flavum in the ASD segment, the decompression of thecal sac could be performed without the need for dissection of adhesive tissues. Discectomy was additionally performed in patients with herniated disc pathologies. A representative case of a patient with ASD who underwent UBE is shown in Figure 2.

3. Data Collection and Analysis

Baseline demographic factors such as age, height, weight, body mass index (BMI), and bone mineral density were measured. Operation levels and interval periods from the prior fusion surgery were also collected. Surgery-related factors included the total surgery time, total estimated blood loss, and total hospital stay. Various postoperative surgery-related complications, such as epidural hematoma, dural tear, and neurological deterioration, were also recorded.

Lumbar radiographs were taken before, immediately after, and 1-year postsurgery. Lumbar radiographs included anteroposterior (AP) and lateral views in flexion and extension position. The largest lumbar Cobb angle was measured from the AP view, and the segmental rotation angle and transition at the operated disc level were measured from the flexion/extension lateral view (Figure 3). The difference in the rotation angle and transition between the flexion and extension positions was measured to analyze the development of lumbar instabil-

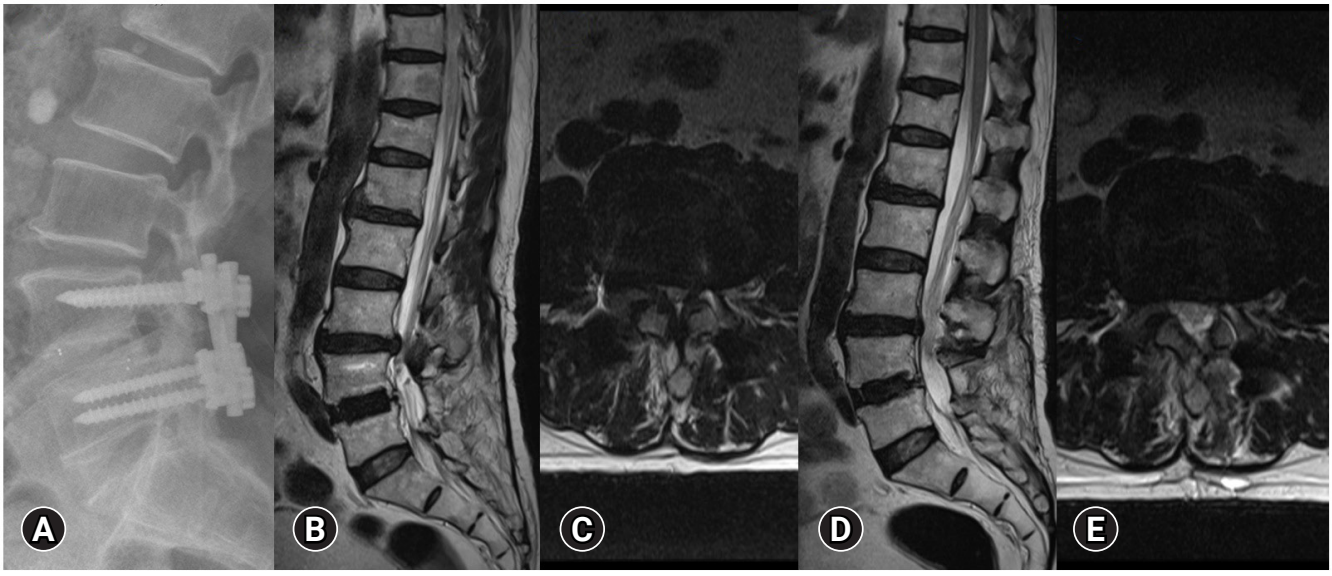

Figure 2. Representative case of adjacent segment degeneration (ASD) patient who underwent unilateral biportal endoscopic (UBE) surgery. (A) A 77-year-old man presented with persistent neurogenic intermittent claudication after L4–5 fusion surgery 13 years ago. (B and C) Magnetic resonance imaging (MRI) showed central canal stenosis at the adjacent L3–4 disc level. (D and E) After performing UBE surgery at L3–4 level, postoperative MRI showed decompression of the spinal canal, and the patient's symptoms were improved.

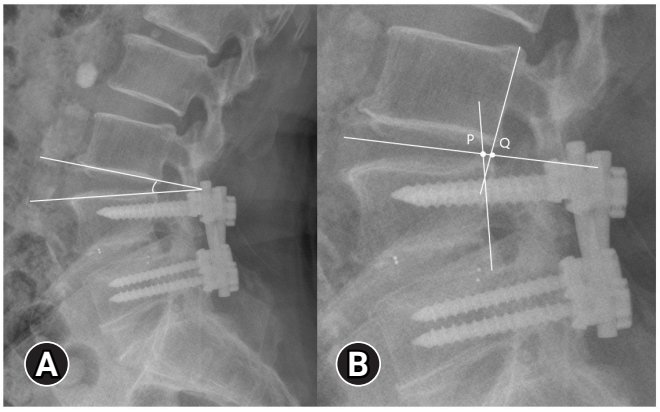

Figure 3. Illustration of x-ray parameter measurement. (A) Angle measurement: the angle between the upper endplate of the lower vertebrae and the lower endplate of the upper vertebrae was measured. (B) Translation measurement: the line bisecting the disc space was drawn. The distance between each intersection point (P, Q) and the posterior line of the lower and upper vertebrae was measured.

ity. Postoperative magnetic resonance imaging (MRI) images, taken approximately 2-day postoperation, were analyzed and compared with preoperative MRI images. For MRI parameters, the cross-sectional area (CSA) of the dural sac, AP and transverse diameter in the axial image, and sagittal AP diameter and disc height in the sagittal images were collected. The parameters of lumbar radiographs and MRI were measured by different individual neurosurgeon in each institution. Clinical outcomes were evaluated using the visual analoge scale (VAS) and Oswestry Disability Index (ODI). The VAS and ODI were taken from the patient before and immediately after the surgery during admission, and 1 year after the operation at the out-patient clinic.

Statistical analyses were performed using Python ver. 3. Continuous variables are presented as the mean±standard deviation, and categorical variables are presented as the numbers and percentage. Various demographic and outcome data were compared using the Mann-Whitney test or repeated measures analysis of variance (ANOVA) for continuous variables and Fisher exact test or chi-square test for categorical variables.

RESULTS

A total of 39 patients were retrospectively enrolled in this study. The basic demographic data of the patients are listed in Table 1. The average age of the patients was 69.1±7.9 years old, and 22/39 of them were female. The average BMI of the patients was 25.0±2.8 kg/m^2. The average follow-up periods for the patients were 23.2±12.3 months, and the average interval period from previous fusion surgery to UBE decompressive surgery for ASD was 9.0±6.0 years. Regarding the number of fused segments in the previous surgery, 31 patients had a previously fused segment of a single level, 5 patients had 2 levels, and 3

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patients had 3 levels. ASD occurred in the cephalic, caudal, and both cephalic and caudal locations in 31, 6, and 2 patients. At the surgical level, there were 2 cases of L1–2, 2 cases of L2–3, 25 cases of L3–4, 8 cases of L4–5, and 4 cases of L5–S1.

The surgery-related data of the patients are listed in Table 2. The average total surgery time, estimated blood loss, and hospital stay were 86.5±33.1 min, 40.9±26.4 mL, and 6.9±3.5 days, respectively. Additional discectomy after bilateral decompression was performed in 9 patients. Complications were noted, with 1 case of epidural hematoma, 1 case of dural tear, and 1 case of neurological deficit of motor weakness. Two patients ultimately underwent revision surgery for fusion extension during the follow-up period because of persistent neurological pain.

Various radiologic and clinical outcome data are listed in Table 3. Of the MRI image, the CSA of the dural sac showed a significant improvement postoperatively from 0.55±0.21 cm^2 to 1.11±0.41 cm^2 (p<0.001). The AP diameter and transverse diameter of the axial cut, and the sagittal AP diameter of the sagittal cut also showed significant improvement postoperatively (6.1±2.0 mm to 9.7±2.9 mm, 10.4±3.4 mm to 13.9±2.3 mm, 5.4±1.8 mm to 8.1±2.6 mm; p<0.001). However, the disc height measured at sagittal view did not show significant difference (8.6±2.7 mm vs. 8.1±3.1 mm, p=0.244).

Regarding the radiograph data, the segmental angle difference was 4.5°±3.3°, 5.8°±3.4°, and 5.3°±4.3° at baseline, imme-

Table 1. Basic demographic data (n=39)

Demographic variable	Value
Follow-up period (mo)	23.2 ± 12.3
Age (yr)	69.1 ± 7.9
Female sex	22 (56.4)
Height (cm)	158.8 ± 8.0
Weight (kg)	63.1 ± 8.4
BMI (kg/m2)	25.0 ± 2.8
Interval to ASD operation (yr)	9.0 ± 6.0
No. of previously fused segments	
1	31 (79.5)
2	5 (12.8)
3	3 (7.7)
Operated ASD location	
Cephalic	31 (79.5)
Caudal	6 (15.4)
Cephalic and caudal	2 (5.1)
Operated ASD level	
L1–2	2 (5.1)
L2–3	2 (5.1)
L3–4	25 (64.1)
L4–5	8 (20.5)
L5–S1	4 (10.3)

Values are presented as mean±standard deviation or number (%).
BMI, body mass index; ASD, adjacent segment degeneration.

Table 2. Surgery-related data (n=39)

Variable	Value
Total surgery time (min)	86.5 ± 33.1
Total blood loss (mL)	40.9 ± 26.4
Hospital stay (day)	6.9 ± 3.5
Complications	3 (7.7)
Hematoma	1
Dural tear	1
Neurologic deficit	1
Revision surgery	2 (5.1)

Values are presented as mean±standard deviation or number (%).

Table 3. Radiologic and clinical outcomes

Variable	Baseline	Immediate postoperative	1 Year postoperative	p-value
MRI				
Dural sac CSA (cm^2)	0.55 ± 0.21	1.11 ± 0.41	-	< 0.001
AP diameter (mm)	6.1 ± 2.0	9.7 ± 2.9	-	< 0.001
Transverse diameter (mm)	10.4 ± 3.4	13.9 ± 2.5	-	< 0.001
Sagittal anteroposterior diameter (mm)	5.4 ± 1.8	8.1 ± 2.6	-	< 0.001
Disc height (mm)	8.6 ± 2.7	8.1 ± 3.1	-	0.244
X-ray				
Flexion - extension angle Δ (°)	4.5 ± 3.3	5.8 ± 3.4	5.3 ± 4.3	0.310
Flexion - extension transition Δ (mm)	1.7 ± 1.3	1.5 ± 1.2	1.2 ± 1.9	0.400
Lumbar Cobb angle (°)	2.5 ± 3.3	2.1 ± 3.3	2.5 ± 3.5	0.547
VAS & ODI				
VAS-back	6.4 ± 2.4	2.1 ± 1.2	2.4 ± 1.7	< 0.001
VAS-leg	7.5 ± 1.5	1.6 ± 1.6	1.8 ± 1.9	< 0.001
ODI	47.5 ± 16.3	19.8 ± 9.7	19.8 ± 5.4	< 0.001

Values are presented as mean±standard deviation.
CSA, cross-sectional area; VAS, visual analogue scale; ODI, Oswestry Disability Index.

diately postoperative, and 1-year follow-up, respectively; No significant difference in this parameter was observed between the time intervals in the repeated measures-ANOVA analysis (p=0.310). The segmental transition difference was 1.7±1.3 mm, 1.5±1.2 mm, and 1.2±1.9 mm, at baseline, immediately postoperative, and 1-year follow-up, respectively. There were also no significant differences between the groups (p=0.400). The lumbar major Cobb angle was 2.5°±3.3°, 2.1°±3.3°, and 2.5°±3.5° at baseline, immediately postoperative, and 1-year follow-up, respectively, with no significant difference (p=0.547).

For the clinical outcomes, the VAS score of back pain reduced significantly throughout the postoperative period (6.4±2.4 vs. 2.1±1.2 vs. 2.4±1.7, p<0.001). The VAS score of leg pain also reduced significantly (7.5±1.5 vs. 1.6±1.6 vs. 1.8±1.9, p<0.001). The ODI score also reduced significantly throughout the postoperative period (47.5±16.3 vs. 19.8±9.7 vs. 19.8±5.4, p<0.001).

DISCUSSION

We hereby demonstrated that UBE decompressive surgery can be a promising surgical method for ASD with low rate of complications. Sufficient decompression of spinal stenosis and improvement of clinical symptoms were achieved and were sustained over an average period of 2 years, without significant incidence of failure or relapse.

The efficacy of UBE in decompressing the spinal canal is well proven in many previous literatures. In contrast to the traditional open microscopic surgery, endoscopic surgery has a wider surgical view owing to the free angulation of the endoscope, resulting in more advantages regarding contralateral decompression [17]. The surgical angle of traditional open microscopic surgery is restricted by the tension of muscle fascia, and the contralateral side is sometimes impossible to view in severely obese or muscular patients. However, in UBE surgery, efficient contralateral decompression can always be performed due to relatively free handling of the endoscope, regardless of patient's muscular or fatty structure. Also, since the ligamentum flavum was preserved in the operated segment for all patients in our cohort, the ULBD by UBE could be conducted without much difficulty. The procedure was similar with that of standard spinal stenosis, other than some adhesions in the muscular structure above the lamina. However, if the ligamentum flavum had been sacrificed in the previous surgery, adhesion around the dural sac should be expected. Since adhesiolysis by endoscopy is challenging to perform, UBE decompression should be considered with caution.

In a cohort of patients with ASD in our study, the spinal canal was also sufficiently decompressed, as was proven in postoperative MRI image (CSA of the dural sac: 0.55±0.21 cm^2 to 1.11±0.41 cm^2, p<0.001). Although there is yet no absolute radiologic criteria for sufficient decompression, many previous studies regarding lumbar decompression provided similar results in dural CSA. A dataset from NORDSTEN study which includes 437 patients of lumbar decompression reported that the spinal canal CSA increased from 52.0 mm^2 from 117.2 mm^2 postoperatively [18]. Another study form Japanese population which included 105 patients who received lumbar decompression surgery also reported dural sac expansion from 71.2 mm^2 to 102.2 mm^2 in the early postoperative period [19]. All of these previous studies reported similar results with our study, indicating that sufficient decompression was achieved.

The average surgical time and operative blood loss reported in our study were generally consistent with those of previous reports on standard UBE decompression surgery [20-22], with approximately 90 minutes of surgery time and 40 mL of blood loss. However, the hospital stay was longer, with an average period of 1 week compared with other studies. The surgery time and operative blood loss were also somewhat longer than those in previous studies of endoscopic treatment for ASD [8,11]. However, most previous studies used the transforaminal endoscopic approach, which were performed under local anesthesia. All cases in our study were performed under general anesthesia, which may have led to longer hospital stays. The unique medical insurance system in South Korea should have also contributed, which allows patients for longer hospital stay until postoperative discomfort is completely alleviated.

The patients in our cohort showed a significant reduction in all VAS-leg, VAS-back, and ODI scores. The VAS-leg score seemed to reduce in larger amount compared with the VAS-back score (7.5±1.5 to 1.6±1.6 vs. 6.4±2.4 to 2.1±1.2). These results align with previous findings that decompression of spinal stenosis is usually more effective for leg pain than for back pain [23,24]. Moreover, our 1-year follow-up results prove that UBE surgery was not only temporarily effective but also maintained a significant reduction in pain for a minimum of 1 year. Although long-term follow-up MRI had not been performed because of cost-effective matters, the favorable parameters of immediate postoperative MRI images along with favorable results of 1-year clinical outcome demonstrates that we achieved significant surgical decompression.

A major concern regarding decompressive treatments without fusion for ASD is lack of sustainability and failure. Since ASD is a progressive disease, there are concerns that minimally invasive decompression might only be temporary and will

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ultimately require revision with fusion extension during long-term follow-up. In a case series analysis of patients with ASD who underwent transforaminal endoscopic surgery, Telfeian [9] reported a 33 % failure rate over a 2-year follow-up. Although favorable outcome was achieved and sustained for an average period of 2 years in our cohort of patients, whether it can be sustained for a longer period of time needs to be confirmed.

Iatrogenic instability after endoscopic treatment is one of the risk factors for failure and relapse that requires revision by fusion [25]. In this study, we performed an additional analysis of the occurrence of instability in the operated segment as a predictor for failure. We used the most common radiologic criteria for the incidence of radiologic lumbar instability: the dynamic translation distance and rotation angle of the neighboring vertebrae (Figure 3). The reference value for lumbar instability is traditionally defined as a translation of > 4.5 mm at L1–2 to L5–S1 and a rotation angle of >15° at L1–2 to L3–4, >20° at L4–5, and >25° at L5–S1, respectively [26,27]. Other authors proposed a more strict definition of lumbar instability as ≥3-mm dynamic sagittal translation and >10° dynamic angulation [28,29]. Accordingly, we confirmed that there was no definite radiologic instability at the operating segment at baseline. Postoperative radiography showed no significant new instability, both immediately after and at 1-year follow-up. Rotation angle parameters suggested mild increase of instability at immediate postoperation compared with baseline that seemed to restabilize again at 1-year follow-up (4.5°±3.3° vs. 5.8°±3.4° vs. 5.3°±4.4°), although not statistically significant. Thus, we concluded that a well-performed UBE technique without facet violation and muscle preservation does not significantly induce instability in the ASD segment. This in turn should lower the risk of failure or relapse in the future.

One of the obvious major advantages of UBE surgery for ASD over traditional fusion extension is that it can efficiently decompress the spinal canal while minimizing damage to the previous wound [13,14]. Although some scar tissue may cover the upper vertebral lamina of the previously fused segments, structures such as the ligamentum flavum under the lamina were preserved in our cohort of patients. Therefore, whereas the initial approach to the interlaminar space may be moderately hindered because of the scar tissue covering the lamina, the overall decompression procedure after drilling the lamina could be performed easily. In contrast, fusion extension requires full exposure of the previous wound, including previous instruments, which could induce more wound-related complications and require a longer surgery time [7].

Another advantage of UBE decompression is that it could be considered as a salvage treatment for frailty patients with ASD. Since the decompression itself could be sufficiently achieved by UBE, immediate postoperative improvement of symptoms could be expected. In addition, since UBE surgery is much more simple than fusion extension, it may be preferred for older patients with comorbid conditions despite the higher risk of future failure and relapse. Even if the patients relapse after UBE surgery, fusion extension surgery can be more simplified. Because the posterior compartment had been already decompressed by UBE, it should only require restoration of disc height which indirectly decompresses the foramen. This could be achieved by relatively less invasive procedure with anterior approach, without invasive surgical intervention of posterior compartment.

Although we established that UBE decompression can be a promising tool for treatment of ASD, we recognize that not all patients qualify for UBE decompression. We report 2 patients who ultimately required revision surgery with fusion extension. Both cases were due to newly formed foraminal stenosis within a short period after UBE surgery and persistent foraminal symptoms after conservative care. In many cases, evident instability or severe combined foraminal stenosis of the degenerated segment requires fusion extension surgery [8,9,30]. As we had already stated in Methods section, careful patient selection and strict indications are needed for the decision to perform UBE in patients with ASD, excluding those with definite mechanical instability or collapsed disc space. Total laminectomy-state of upmost vertebrae from previously operated segments with removed ligamentum flavum in the ASD segment can also make endoscopic surgery much more challenging since there should be adhesion around the dural sac, making surgeons opt for open surgeries. However, stable ASD with central canal stenosis and relatively spared disc height or foraminal space, and with a preserved ligamentum flavum can be a good indication for endoscopic decompressive surgery, especially in older patients who should avoid invasive surgery and longer surgery time.

Our study has some limitations. First, the data were retrospectively collected, and various biases could not be ruled out during data collection. The data were collected in 4 different institutions; therefore, the variance between the surgeons' technical skills and treatment protocols between institutions could have attributed to the heterogeneity of the data. Also, the UBE procedure in our study was only performed for strictly selected patients. A control group who received standard open decompression or fusion extension surgery and careful control of selection bias should be needed to accurately assess the benefit of UBE for patients with ASD. In addition, only a small amount

of data were analyzed during a relatively short follow-up period. The idea of incorporating the endoscopic technique for adjacent segment disease is relatively recent, thus the cumulative data with long-term follow-up is currently still lacking even with multicenter collection. Since relapse of symptoms due to ASD usually requires several years, a longer follow-up should be needed to accurately assess the long-term benefit. However, this was the first cohort analysis of patients with ASD who underwent UBE decompression. Future studies should be conducted in prospective manner with proper control group, and with larger amounts of patient data and long-term follow-up to accurately assess the efficacy of UBE surgery for patients with ASD.

CONCLUSION

UBE decompressive surgery for ASD presenting with spinal stenosis can achieve satisfactory clinical and radiological outcomes with low rate of failure. Since sufficient bilateral decompression of the spinal canal with minimal damage to the previous scar can be achieved with UBE surgery, it can be an effective alternative, especially for older patients who are at risk of additional fusion extension surgery. However, further studies performed in larger numbers are needed, and the indications for patient selection should be further discussed.

NOTES

Conflicts of interest

JYP, is member of the Editorial Board of *Journal of Minimally Invasive Spine Surgery & Technique*, is the author of this article. However, he played no role whatsoever in the editorial evaluation of this article or the decision to publish it. Except for that, no potential conflict of interest relevant to this article was reported.

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