



Unilateral biportal endoscopic decompression for degenerative lumbar canal stenosis

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Background: Unilateral biportal endoscopic (UBE) decompression is a minimally invasive (MI) approach to treat degenerative lumbar canal stenosis (DLCS). Decompression can be performed in a clear and magnified surgical field with proper control of normal saline inflow and outflow.

Methods: Clinical and radiographic data of 81 consecutive patients of DLCS treated between July 2018 and Feb 2019 using UBE techniques were reviewed. They were 38 males and 43 females with an average age of 70.2. Sixty-nine had pure canal stenosis and 12 patients had associated spondylolisthesis. Bilateral decompression via unilateral laminotomy was performed from the side on patients with more severe neurological symptoms. This is a retrospective study from chart review and image analysis. Therefore, we don't have formal ethical information for this study, and it is not mandatory in our hospital.

Results: At the final follow-up, the mean VAS for low back pain was improved from 4.3 ± 3.0 to 1.2 ± 1.0 and the VAS for leg symptoms was improved from 7.3 ± 2.2 to 0.9 ± 0.7 . The mean JOA score and ODI was significantly improved from 13.3 ± 7.9 to 25.3 ± 5.0 and from 54.6 ± 16.9 to 14.6 ± 12.6 , respectively. Modified Macnab criteria were excellent in 47 patients (58.0%), good in 29 (35.8%), fair in 5 (6.2%). The average hospital stay was 3.6 ± 2.4 days. MRI before and after the operation showed the cross-sectional dural area (CSDA) was significantly increased from 71.4 ± 36.5 to 177.3 ± 59.2 mm², corresponding to a $201.9\% \pm 188.0\%$ increase. The percentage of facet joint preservation was 84.2% on the approach side and 92.9% on the contralateral side. Complications included 4 dural tears, 1 transient motor weakness, 1 inadequate decompression, and 1 epidural hematoma.

Conclusions: With UBE techniques, decompression for DLCS can be performed safely and effectively. The soft tissue and facet joint destruction are minimized; therefore, it is possible to avoid spinal fusion as well as to preserve the segmental stability.

Keywords: Minimally invasive surgery; biportal endoscopic spine surgery; lumbar canal stenosis

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Introduction

Degenerative lumbar canal stenosis (DLCS) is the most common indication for spinal surgery in the elderly population (1). Wide laminectomy with or without concomitant fusion procedures were considered as the

standard surgical procedures for decades (2-4). This classical approach usually involves extensive soft tissue dissection, which would result in fatty degeneration, atrophy, and weakness of paraspinal muscles and lead to failed back surgery syndrome (5,6). Randomized controlled trials showed that fusion adds little value to decompression for

DLCS (7,8). Considering the complications of spinal fusion and instrumentation, simple but adequate decompression is a more reasonable approach for patients who do not have the absolute indications for additional stabilization procedures (9).

For more than 20 years, minimally invasive (MI) spine surgeries have successfully treated patients with various lumbar spinal diseases (10-13). With the advancement of surgical instruments and endoscopic technology, MI spine surgeries have evolved rapidly from mini-open to tubular or percutaneous endoscopic approaches. Other than the potential benefits of MI approach (smaller wounds, diminished local pain, less blood loss, less postoperative wound pain, and shorter hospital stays), biomechanical studies have demonstrated the importance of the posterior column, including the interspinous ligaments, the facet joints, and the capsules, in maintaining spinal stability (14,15). Therefore, to minimize injury to the paraspinal muscles and the posterior stabilizing structures is the most critical concern for the long-term results (16).

Unilateral biportal endoscopic (UBE) decompression techniques is a percutaneous full endoscopic technique. It is performed through two separated small surgical wounds on either side of the spinous process. Unlike other endoscopic approaches, UBE is not confined by the working tube or the working channel. With continuous high-pressure normal saline irrigation and high-definition arthroscope, the surgeon can do very precise decompression in a clear and magnified surgical field.

This study is aimed to describe the UBE decompression techniques for DLCS with emphasis on how to safely perform adequate decompression while preserving the facet joints via the posterior interlaminar approach. The radiological and clinical outcomes were examined to evaluate the efficacy of this MI technique.

Methods

Patient selection

From July 2018 to Feb 2019, 81 consecutive patients with DLCS treated by UBE decompression techniques were retrospectively reviewed for this study. The indications of surgery were persistent radicular leg pain, neurological deficits, or neurogenic intermittent claudication refractory to conservative treatment for at least 6 months due to moderate to severe canal stenosis demonstrated by MRI. Exclusion criteria included: (I) pre-existing degenerative

scoliosis with a Cobb's angle more than 20 degrees, or more than grade I degenerative spondylolisthesis; (II) segmental instability, which was defined as translation of more than 4 mm or 10 degrees of angular motion between flexion and extension on upright lateral radiographs, or lateral bending on upright anteroposterior radiographs; (III) history of prior lumbar spine surgery.

They were 38 males and 43 females with an average age of 70.2 ± 10.8 (range, 39–92). Of the 81 patients included in this study, 69 had canal stenosis and 12 patients had associated low grade spondylolisthesis. A total of 105 levels of decompression were done. Fifty-eight patients had 1-level decompression, 22 patients had 2-level decompression, and 1 patient had 3-level decompression. The decompression was performed at T11–T12 in 1 patient, L1–L2 in 1 patient, L2–L3 in 4 patients, L3–L4 in 28 patients, L4–L5 in 67 patients, and L5-S in 4 patients.

Surgical techniques

After induction of general anesthesia, the patient is placed prone with the abdomen free over the radiolucent Relton-Hall frame. The skin and the surgical field are prepared in the usual manners. UBE surgery is performed under continuous normal saline irrigation. It is critical to ensure that the final layer of draping is waterproof and a smooth drainage system for the saline outflow is properly set up. Without these precautions, the patient may be soaked by the cold normal saline and complicated with hypothermia.

In order to obtain a true anterior-posterior image, the fluoroscope should be tilted parallel to the disc space. The spinal levels of interest are determined using biplanar fluoroscope and marked on the skin. UBE decompression requires two small incisions through the deep fascia: a smaller one about 5–6 mm for insertion of arthroscope and continuous normal saline irrigation; a larger one about 8–10 mm for the outflow of normal saline, which is used as the instrument portal (*Figure 1*). An arthroscopic system with either a 0- or 30-degree scope is essential.

The initial target area for decompression is at the spino-laminar junction (the junction of spinous process and lower laminar margin of superior vertebra). The two skin incisions are usually located along the medial pedicle line, separated by 2–3 cm (*Figure 1*). We use serial dilators up to 10 mm to split the paraspinal muscles, enlarge the instrument portal, and gently detach the soft tissues off the interlaminar space. With the inflow of normal saline, a small space is created and ready to use. With meticulous

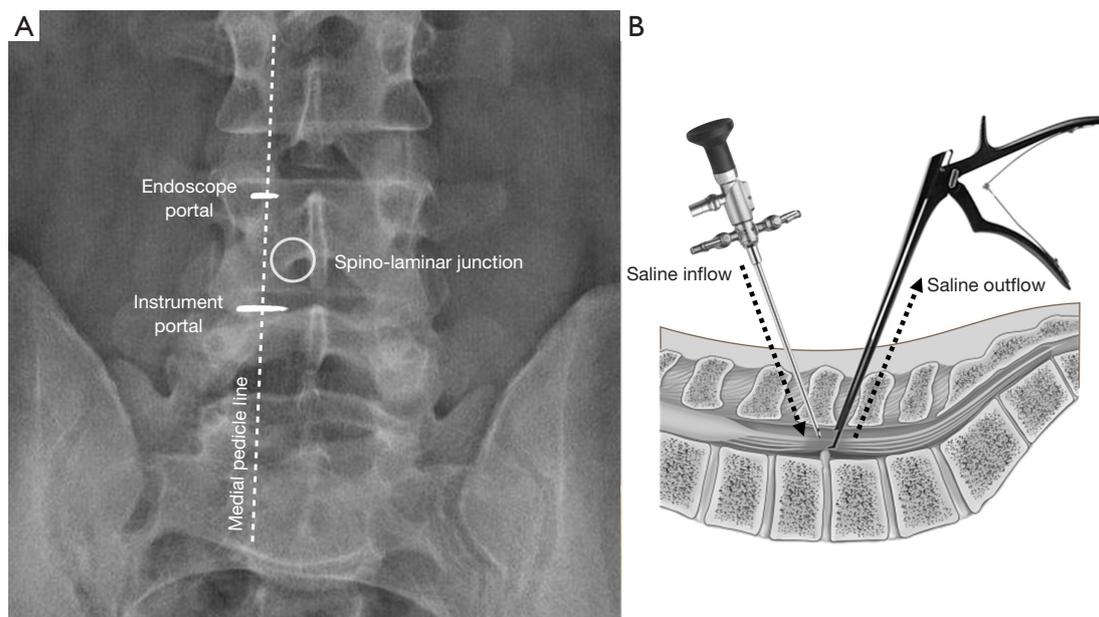


Figure 1 (A) The circle indicates the initial targeting area, the spino-laminar junction. The skin incisions are located along the medial pedicle line, separated by 2–3 cm; (B) the schematic drawing demonstrates the triangulation of the endoscope and instruments.

hemostasis, the whole surgical procedure can be performed in a clear and magnified surgical field (*Figure 2*). Hemostasis for bleeding from small epidural veins and oozing from bones can be achieved by adjusting the inflow hydrostatic pressure and control of outflow. Bleeding from soft tissues and larger epidural veins can be cauterized efficiently by a radiofrequency wand (ArthroCare, Austin, Texas, USA). Bone wax is useful for stopping more severe bleeding from cancellous bone.

We always start the decompression from the spino-laminar junction using an electric high-speed diamond bur of 3 or 4 mm in diameter (Primado 2, NSK, Fukushima, Japan). The decompression procedures are performed according to the following steps (*Figure 2*):

- (I) drill the ipsilateral lamina from its lower margin cranially until the origin of ligamentum flavum and underlying epidural fat are exposed (*Figure 2A*);
- (II) separate the ligamentum flavum from the undersurface of contralateral lamina using a blunt neural dissector;
- (III) drill the undersurface of contralateral lamina until the lateral recess is almost reached. Note that the ligamentum flavum must be preserved as a protector for underlying neural tissue. In the cases of severe stenosis, the spinous process and facet joints are usually hypertrophic and deformed. Removing more bone from the base of the spinous process would widen the laminotomy window and provide easier access to the contralateral lateral recess (*Figures 2B,3*);
- (IV) separate the contralateral ligamentum flavum from its attachment on the lamina, and decompress the contralateral lateral recess and foramen using small and curved Kerrison punches;
- (V) remove the superficial layer of ligamentum flavum and preserve the deep layer as a protector;
- (VI) drill the upper laminal margin of the lower vertebra and then detach the ligamentum flavum from its caudal attachment;
- (VII) remove the contralateral half of the ligamentum flavum and decompress the lower surface of the contralateral facet joint to free the contralateral traversing nerve root (*Figure 2C,D*);
- (VIII) perform ipsilateral decompression by drilling the medial margin of the ipsilateral lamina and facet joint. The facet drilling should be very conservative to preserve the facet joint as much as possible.
- (IX) remove the ipsilateral half of the ligamentum flavum, free the ipsilateral traversing nerve root, and check residual stenosis (*Figure 2E*);

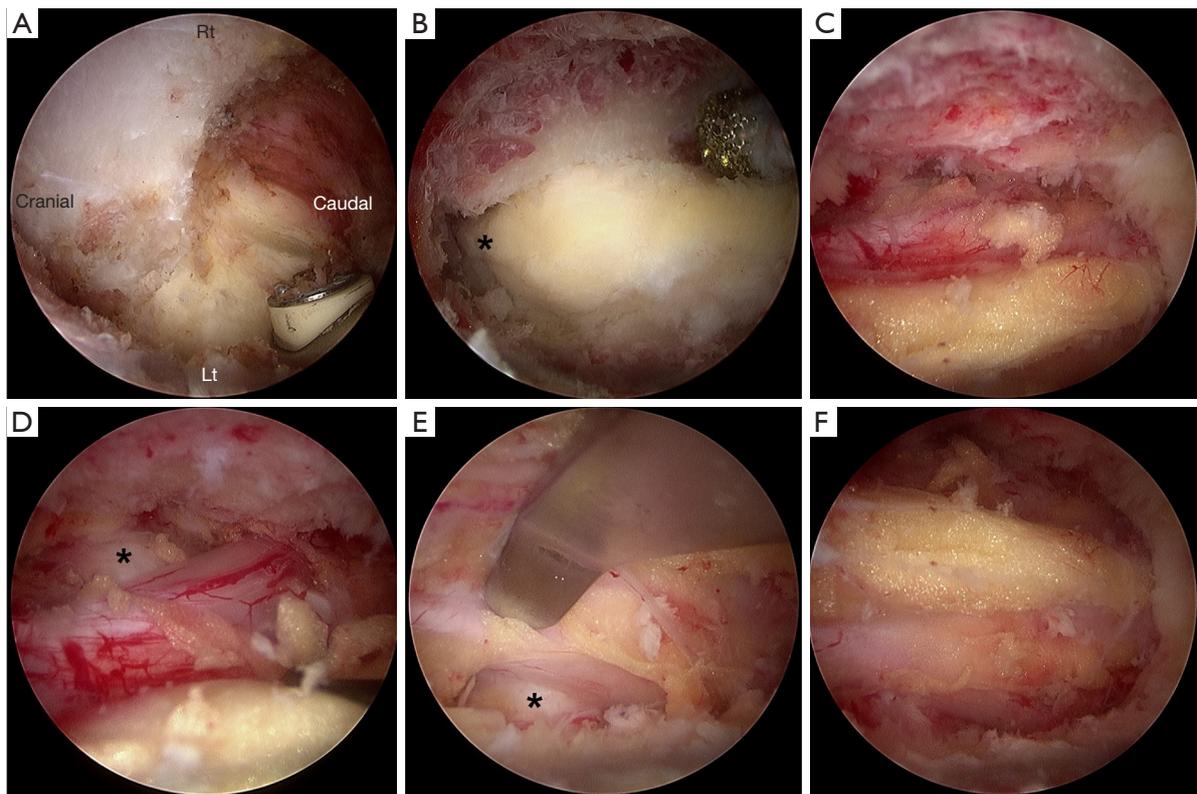


Figure 2 In this case, the UBE decompression was done with left side approach using a 0-degree arthroscope. (A) The spino-laminar junction as the starting point of decompression; (B) the origin of ligamentum flavum detached (*) and the base of spinous process removed using high-speed diamond bur; (C) the decompression of contralateral lateral recess; (D) the contralateral disc (*) and nerve root; (E) the ipsilateral disc (*) and nerve root; (F) the final result of decompression. The epidural fat was preserved.

- (X) insert a small caliber suction drain tube after hemostasis.

Outcomes evaluation

The pre-operative and final follow-up X-rays, including static and dynamic images, were reviewed to evaluate segmental instability. MRI studies of the lumbar spine was performed before surgery and 3 months after surgery. We measured the cross-sectional dural areas (CSDA) on the most stenotic axial MRI image to evaluate the decompression effect. Every measurement was repeated 3 times to get the mean value. Facet joint preservation was evaluated using the method described by Dohzono and Matsumura (17,18). However, MRI was used instead of CT scan (Figure 4).

Clinical outcome was evaluated using the visual analog scale (VAS) for back pain and lower leg symptoms, the

Japanese Orthopedic Association (JOA) scores (18) for functional recovery, the Oswestry Disability Index (ODI) for degrees of disability, and modified MacNab criteria for overall treatment outcomes. These evaluations were performed before surgery and at the final follow-up. The medical charts were carefully reviewed to evaluate any complications, if existent.

Results

The average follow-up period was 8.6 months (range, 6–12 months). The operation time was 89 ± 56.9 minutes (range, 50–190 minutes) per level of decompression. Intra-operative blood loss was minimal. The average hospital stay was 3.6 ± 2.4 days (range, 3–6 days). Most of the patient got off the bed for ambulation on the 2nd post-operative day.

Significant improvement was obtained after the surgery. The VAS for leg pain was improved from 7.3 ± 2.2 to

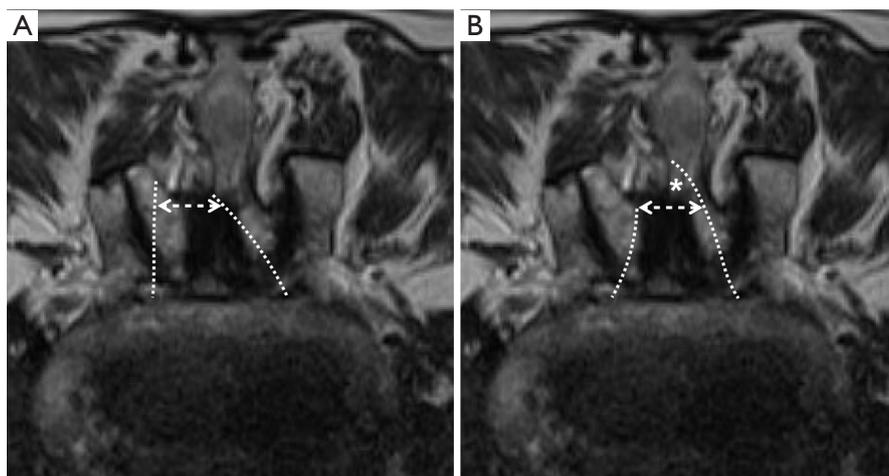


Figure 3 For patients with severe stenosis, bilateral decompression via unilateral laminotomy (dashed lines) may cause excessive destruction of the ipsilateral facet joint (A); removal of more bone from the base of the spinous process (*) shifts the laminotomy window (double arrow) contralaterally and preserves the ipsilateral facet joint (B).

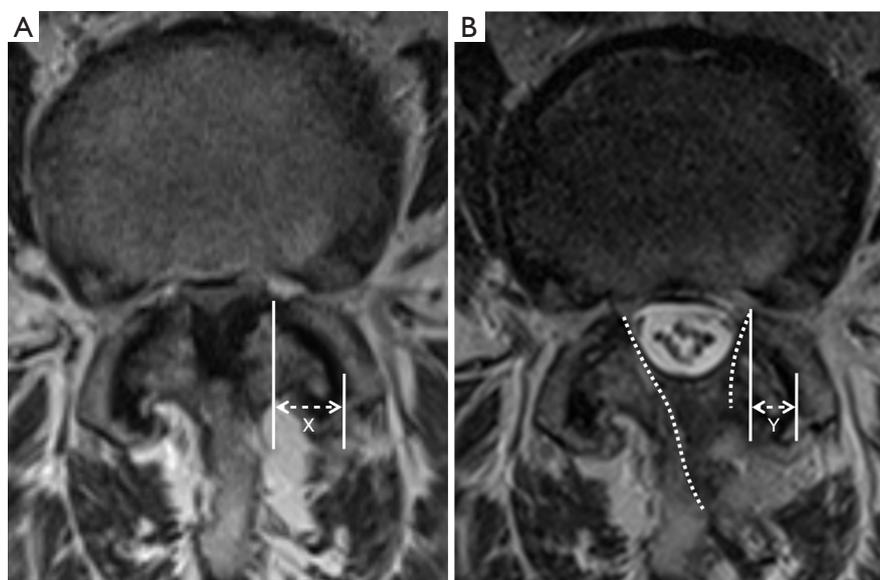


Figure 4 Measurement of facet joint preservation on the pre-operative (A) and the final follow-up (B) MRI. Dashed lines highlight the extent of the laminotomy. The percentage of facet preservation = $y/x \times 100\%$.

0.9 ± 0.7 ($P < 0.005$, paired t -test); VAS for back pain was also improved from 4.3 ± 3.0 to 1.2 ± 1.0 ($P = 0.013$, paired t -test) at the final follow-up. The JOA score was improved from 13.3 ± 7.9 to 25.3 ± 5.0 ($P < 0.005$, paired t -test) at the final follow-up. The average JOA improvement rate was $72.6\% \pm 40.0\%$. The ODI was improved from 54.6 ± 16.9 to 14.6 ± 12.6 ($P < 0.005$, paired t -test). According to the modified MacNab criteria, the final outcomes were

excellent in 47 patients (58.0%), good in 29 (35.8%), fair in 5 (6.2%), and poor in 0. That is, 92.6% of patients had good or excellent outcomes.

The stenotic spinal canal was significantly enlarged after UBE decompression. The measured CSDA at the most stenotic axial image on MRI was significantly increased from 71.4 ± 36.5 to 177.3 ± 59.2 mm^2 ($P < 0.005$, paired t -test). The average increment in CSDA was 105.9 ± 39.5 mm^2 ,

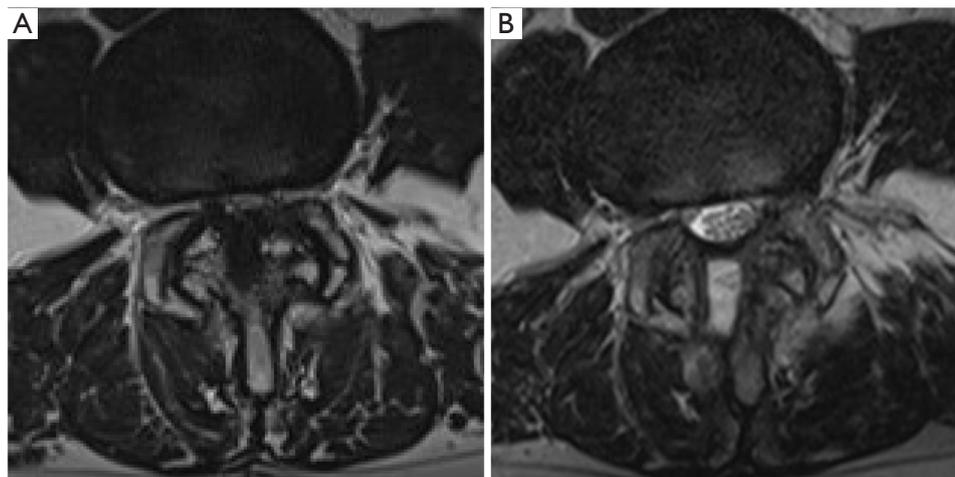


Figure 5 Comparison of the final follow-up MRI (A) and the pre-operative MRI after UBE decompression shows adequate decompression with a great improvement on cross-sectional dural area and preservation of bilateral facet joints in a patient with very severe degenerative lumbar canal stenosis.

Table 1 Summary of clinical and radiographic results

Measurement	Pre-operative	Post-operative	P value
VAS for leg pain	7.3±2.2	0.9±0.7	<0.005
VAS for back pain	4.3±3.0	1.2±1.0	0.013
JOA score	13.3±7.9	25.3±5.0	<0.005
ODI	54.6±16.9	14.6±12.6	<0.005
Modified MacNab			
Excellent		47 (58.0%)	
Good		29 (35.8%)	
Fair		5 (6.2%)	
Poor		0	
CSDA (mm ²)	71.4±36.5	177.3±59.2	
CSDA increase (mm ²)		105.9±39.5	
CSDA increase (%)		201.9±188.0	
Facet joint preservation			
Ipsilateral (%)		84.2±9.3	0.024
Contralateral (%)		92.9±6.2	

VAS, visual analog scale; JOA, Japanese Orthopedic Association; ODI, Oswestry Disability Index; CSDA, cross-sectional dural area.

corresponding to 201.9%±188.0% increase of pre-operative CSDA. The percentage of facet joint preservation was 84.2%±9.3% on the approach side and 92.9%±6.2% on the contralateral side. It was significantly higher on the

contralateral side ($P=0.024$, paired t -test) (Figure 5). No patients had post-decompression segmental instability or progression of pre-existing spondylolisthesis. Facet joint effusion was noted in 3 patients (Table 1).

A few surgical complications were noted. Four patients had small dural tears. Direct repair under endoscope was performed successfully in 1 patient. The other 3 were treated conservatively. No cerebrospinal fluid leakage was encountered. All the 4 dura tears occurred in the first 30 patients. The other complications included transient motor weakness in 1 patient, epidural hematoma in 1 patient, and inadequate decompression in 1 patient. There was no infection or wound related complications.

Discussion

For the surgical treatment of DLCS, adequate decompression is the most critical determining factor. To avoid destruction to the posterior stabilizing structures, bilateral decompression via unilateral laminotomy was the most frequently used decompression method. In a biomechanical cadaver study, this decompression method was demonstrated to maintain more than 80% stiffness of the intact spine, and it can preserve the facet joints better than other decompression methods (19). In order to enhance recovery after surgery, various MI approaches (open, microscopic, tubular retractor assisted, microendoscopic, endoscopic assisted, or full-endoscopic) have been proposed to further minimize the surgical wounds

and injury to the paraspinal muscles (10-13). However, the advantages of minimal invasiveness must be weighed against the drawbacks of limited visual field, limited working space, steep learning curve, radiation exposure, cost, compromised treatment results, and complications.

The concepts of the UBE decompression technique have been proposed since 2003 as an MI surgical technique for treatment of lumbar disc herniation and spinal canal stenosis. However, there was a paucity of development due to lack of handy instruments such as the radiofrequency wands for hemostasis and power motor drills for efficient removal of bony pathologies. With the advancement of endoscopic technology and surgical instruments in recent years, UBE techniques have been successfully applied on various disorders involving the cervical, thoracic, and lumbar spines (20-22). Because no tubular retractor is used to maintain the access portals, we can handle the instruments almost the same way as we do in the open surgeries (23). With meticulous hemostasis and proper control of hydrostatic pressure of normal saline, the surgical field is almost bloodless. The diameter of the endoscope is only 4 mm, which allows us to bring it very close to the pathology for a more precise decompression and delicate manipulation of the neural tissue.

Adequate decompression can be achieved with UBE decompression techniques. In our study, the average CSDA was increased from 71.4 to 177.3 mm² with an average increase of 201.9%. Our clinical data also showed great improvements after the operation. The most significant one was VAS for leg pain, which was improved from 7.3 to only 0.9. The patients also had significant improvement in the neurological symptoms as well as the disability status, which were reflected by the improvement in JOA scores and ODI. In addition, more than 90% of patients had good or excellent outcomes as evaluated using the modified MacNab criteria.

The facet joints complex (including the synovial facet joint and the joint capsule) is the most important among the posterior stabilizing structures. Biomechanical tests have demonstrated that more than 50% of facet joint destruction can lead to segmental instability (24). All the MI approaches aim to obtain adequate decompression while preserving the integrity of the facet joint complex. When performing bilateral decompression through unilateral laminotomy, the approach side facet joint destruction was always a concern. Facet undercutting has been suggested to avoid excessive facet joint destruction. Using curved instruments including osteotomes, Kerrison punches, and high-speed

drills might help reduce facet destruction (25). However, such techniques were difficult for open, tubular retractor assisted or microendoscopic approaches, because the surgeon's visual point remained outside of the patient's body or outside of the lamina. With an endoscopic approach, especially UBE, the surgeon's visual point can be advanced inside of the lamina or into the contralateral lateral recess and the contralateral foramen. That feature enables precise check of the offending pathological structures without visual limitation. If a 30-degree endoscope is used, the visual field would be even wider.

In our study, the decompression was adequate, and the facet joints were preserved very well. Facet joint preservation was 92.9% on the contralateral side and 84.2% on the approach side. It is unavoidable that facet joint destruction is more severe on the approach side (17,18). For patients with severe stenosis, the spinous process and facet joints usually become hypertrophic and deformed. These deformities make the space between the spinous process and the facet joint very narrow. Bilateral decompression via unilateral laminotomy then becomes very difficult and may result in excessive destruction of the ipsilateral facet joint. Two modified approach techniques may solve these problems. First, do the contralateral side decompression first to create space for the neural tissue to mobilize contralaterally. Second, remove more bone at the base of the spinous process for easier sublaminar decompression and getting access to the contralateral recess. These modified techniques shift the laminotomy window contralaterally and minimize drilling on the ipsilateral lamina and facet joint (*Figure 3*).

The more facet joint is preserved, the less risk of instability after decompression. As compared with open laminectomy, the incidence of post-decompression segmental instability is significantly lower for MI decompression even in patients with pre-existing low-grade spondylolisthesis (26-28). In our study, there was no iatrogenic spondylolisthesis or progression of pre-existing spondylolisthesis in the very short follow up period. However, 3 patients developed facet joint effusion which was not noted in pre-operative MRI study. Because facet joint effusion is an indicator for segmental instability, longer follow-up is needed to reach a conclusion.

The learning curve for UBE decompression techniques is relatively shallow as compared with other MI decompression techniques, such as microendoscopic or percutaneous uniportal endoscopic techniques, estimated around 30 and 100 cases respectively (29-31). For a

surgeon familiar with open surgeries but no experience of endoscopic procedures, the learning curve for UBE decompression is about 30 cases. However, for a surgeon familiar with microendoscopic or percutaneous endoscopic procedures, the learning curve can be reduced to 10 or 15 cases. The key points are to be familiar with control of the hydrostatic pressure and hemostasis skills in the small space with continuous normal saline irrigation. Dural tear is the most encountered complication in UBE decompression surgeries. Nevertheless, most of the time the dural tear is very small and conservative treatment is enough. Direct dural repair under the endoscope is possible but technically demanding (32). We did not have dural tear after the first 30 cases. Using blunt neural dissectors and high-speed diamond bur is much safer than using sharp curettes and osteotomes. Most of all, the ligamentum flavum is a perfect protector for the underlying neural tissue; it should not be removed until all the bony procedures are done.

Conclusions

The UBE decompression technique for DLCS is a safe and effective MI technique. Soft tissue destruction and the facet joint destruction can be minimized. It is therefore possible to avoid spinal fusion as well as to preserve the segmental mobility and stability. Moreover, the learning curve is less steep than for other MI decompression techniques.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy

or integrity of any part of the work are appropriately investigated and resolved. This is a retrospective study from chart review and image analysis. Therefore, the authors don't have formal ethical information for this study, and it is not mandatory in Far-Eastern Memorial Hospital.

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