Bilateral Decompression via Microscopic Tubular Crossing Laminotomy (MTCL) for Lumbar Spinal Stenosis: Technique and Early Surgical Result

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Abstract

The purpose of this study was to determine the feasibility and efficacy of bilateral decompression procedure via microscopic tubular crossing laminotomy (MTCL) for treating lumbar spinal stenosis (LSS). Seventeen patients with LSS underwent bilateral decompression via an MTCL procedure in which tubular retractor was placed. The mean age was 72 (range 59–84) years and there were 10 men and 7 women. All patients underwent pre- and postoperative dynamic lumbar x-ray, magnetic resonance (MR) image, and computed tomography. To verify the efficacy of this technique, pre- and postoperative cross-sectional area (CSA) of thecal sac, facet resection, and fatty infiltration (FI) of multifidus were measured. Clinical results were evaluated using Oswestry Disability Index (ODI), back and leg visual analog scale (VAS). The mean follow-up period was 17.5 months (range 12.1–21.2). 70.5% of MTCL was performed at the level of L4–5 and one case of dural violation (5.8%) was noted at the level of L5–S1. The mean preoperative CSA was 70.5 mm^2 (range 25.1–87.6) and it increased to 198.8 mm^2 (range 177.3–219.2) postoperatively (p = 0.00). The mean facet resection rate was 18.4% (range 9.9–26.9) and no radiological instability was noted postoperatively. MR image showed no increase in FI of the multifidus after 12 months of follow-up (p = 0.53). Preoperative clinical symptoms improved significantly at postoperative 6 months and 12 months of follow-up. These results indicate that an MTCL with use of tubular retractor system can be an effective procedure to achieve neural decompression for the treatment of LSS and it may be beneficial in preserving both facet joint and multifidus muscle.

Key words: lumbar spinal stenosis, minimally invasive surgery, lumbar laminotomy, tubular retractor

Introduction

Lumbar spinal stenosis (LSS) is the most common reason for lumbar surgery in adults older than the age of 65 years.[1,2] Surgical options for LSS include laminectomy with or without fusion, laminoplasty, laminotomy with medial facetectomy, minimally invasive decompression, and placement of an interspinous device. Laminectomy remains the mainstay of surgical treatment for many years and has reportedly resulted in good outcomes,[3–6] however there have existed concerns about iatrogenic instability and listhesis,[7–9] resulted from excessive facetectomy and midline structure damages including spinous process and paraspinal muscles. To overcome these concerns, various minimally invasive spine (MIS) posterior lumbar decompression techniques were introduced and the clinical efficacy and safety have been assessed in multiple studies.[10–14]

Preservation of the multifidus tendon attachment to the spinous process is the guiding principle of MIS posterior lumbar surgery in that they are responsible for maintaining posture and stabilization.[15] This is accomplished by using paramedian approach rather than midline approach and with the use of tubular retractor system additional muscle crush injuries during retraction can be decreased.[16] In 2002, Palmer et al.[11,12] reported the feasibility and surgery-related efficacy of unilateral approach bilateral decompression and the utilization of tubular retractor system in patients with LSS. Although the unilateral approach can allow the preservation of the facet joints and neural arch of the contralateral side, it may be difficult to reach the ipsilateral recess without removing the ipsilateral facet joint. Moreover, approach from contralateral side provides more efficient access to lateral recess when performing a unilateral approach (Fig. 1).

Thus, bilateral crossover technique[16] is another good option to overcome the above-mentioned shortcomings, not only sparing the tendinous attachment
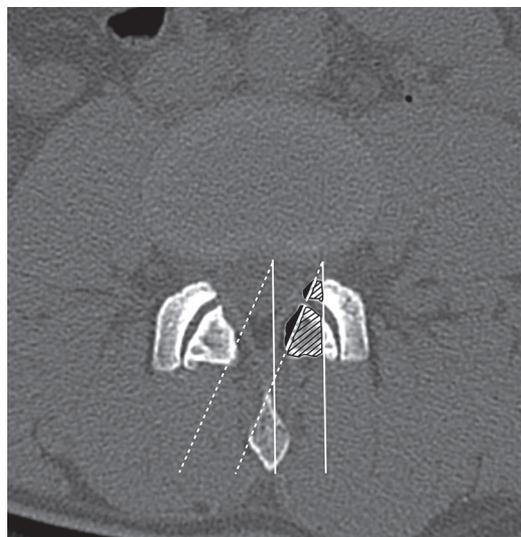
Fig. 1   **Comparison between contralateral (right; *dotted line*) and ipsilateral (left; *solid line*) approach for decompression of left lateral recess. The resected facet during decompression through the ipsilateral approach (*black* and *diagonal lined area*) is more remarkable than that (*black area*) of the contralateral approach.**

Fig. 2   **A: Intraoperative photograph showing tubular retractor in place for microscopic tubular crossing laminotomy using bilateral paramedian approach. B: Intraoperative C-arm image confirming proper position of tubular retractor at stenotic level.**

of multifidus muscle to spinous process but also providing minimal resection of facet joints during decompression of lateral recess. This bilateral decompression via microscopic tubular crossing laminotomy (MTCL) technique may already have been used by some surgeons, but it was not intuitive and not widely practiced. In this report, we described the surgical procedures of this technique and presented the results of our study with goals of sharing its pitfalls and increasing awareness.

Materials and Methods

I. Patient population

Between October 2012 and September 2013, 17 patients with LSS in whom a single surgeon performed MTCL and whose follow-up period was greater than 12 months were assessed for the present study. All patients were met for the following criteria of classic clinical LSS. These criteria included (1) low back pain, (2) neurologic claudication as defined by back and leg pain limiting ambulation, and (3) failure of conservative treatment after an appropriate length of management. The mean patient age was 72 (range 59–84) years, and there were 10 men and 7 women.

II. Operative techniques

Patients were prepared and positioned as in a standard laminectomy. The procedure is a modification of the bilateral decompression using tubular retractor
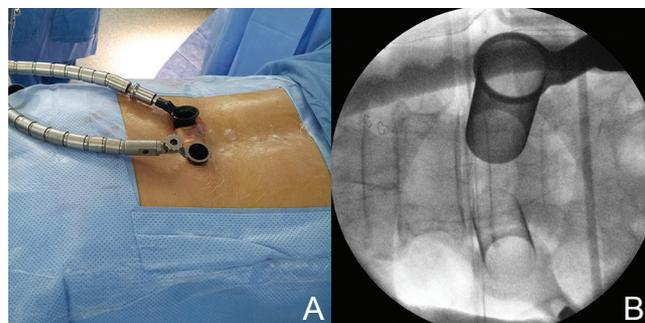
previously described in detail by Palmer et al.[11,12] The target level is verified using C-arm fluoroscopy, and 18 mm of paramedian skin incision is then made. Once the incision is made, longissmus and multifidus muscles are separated by finger dissection and the starting dilator is lodged on interlamina space sagittally and angled to spinolamina junction medially. Sequential dilators (METRx system, Medtronic Sofamor Danek, Memphis, Tennessee, USA or Insight system, DePuy Synthes, West Chester, Pennsylvania, USA) are used to expand a surgical field and 18 mm of tubular retractor is inserted and secured to a table-mounted bracket (Fig. 2A). Then, correct placement of tubular retractor is confirmed by using a C-arm fluoroscopy (Fig. 2B). The table is rotated away from the surgeon (in general, tilting angle depends on target pathology which is needed to be decompressed i.e., lateral recess and foraminal area need more tilted table than central spinal canal area) to gain direct visualization of contralateral structure. The operating microscope is moved into the field and is tilted paralleling the angulation of the tubular retractor.

An electrocautery is used to clear away any residual soft tissue in the tubular retractor and the confirmation of the caudal portion of cranial lamina, base of spinous process and cranial portion of caudal lamina is done. Using a high-speed drill, the caudal portion of the base of the spinous process and the inferomedial portion of the cranial lamina are started to be drilled off (Fig. 3A). Next, undermining of the inner part of contralateral lamina is performed to separate the bone and ligamentum flavum until contralateral medial portion of facet joint is exposed. Occasionally, where the operative field is not adequately exposed, the undersurface of the spinous process could be drilled out with working channel angled more medially. During the use of high-speed drill, removal of
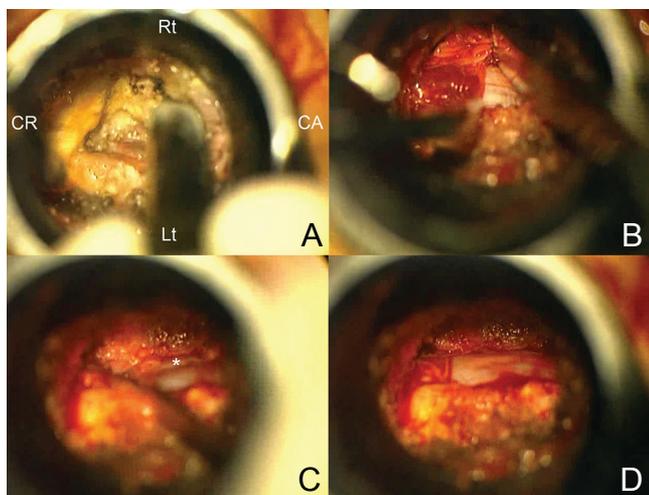
Fig. 3 Intraoperative photographs of the contralateral approach to the right side of L4–5 spinal stenosis. A: Caudal portion of spinous process and inferomedial portion of the cranial lamina are started to be drilled off. B: Excision of the contralateral ligamentum flauvum by using Kerrison punch. C: The paracentral portion of disc and the right L–5 nerve root (*) are observed with the dura retracted medially. D: Decompressed right dural sac. CA: caudal, CR: cranial, Lt: left, Rt: right.

ligamentum flavum should not be performed until sufficient medial facetectomy is carried out because it is useful for protecting dura mater and nerve root from dura tear or thermal injury (Fig. 3B). For this reason, it is recommended to remain ipsilateral ligamentum flavum intact as well for safe decompression at contralateral side. After removal of ligamentum flavum, the paracentral portion of the disc on the contralateral side could be easily visualized and palpated using ball-tipped probe with medially retracted dura mater (Fig. 3C). If paracentral disc protrusion and consequent root compression were detected, additional microdiscectomy can be performed carefully. In a situation of facet joint hypertrophy, it is necessary to resect anteromedial part of superior articular process of caudal vertebra to decompress the foramen and lateral recess. Tubular retractor needs to be angled caudally and in the state of ligamentum flavectomy, the Kerrison punch and high-speed drill should be used carefully with the dura mater protected by cottonoid. Finally, the nerve root is seen exiting freely toward the foramen. After confirmation of complete decompression by palpation of the pedicle and foramina plus direct inspection under a surgical microscope, thorough hemostasis and irrigation is obtained (Fig. 3D). Then, the surgeon changes his position to the opposite side and the same procedure is repeated for decompression of the other side. After complete decompression

on both sides is completed, the tubular retractor is withdrawn and skins are sutured closed.

III. Assessment for the effectiveness of decompression by MTCL procedure

To verify the expansion of spinal canal following an MTCL, the quantitative measurements of the cross-sectional area (CSA) of thecal sac at stenotic level from T_2-weighted axial images were performed using Image J software (version 1.40, US National Institutes of Health, Bethesda, Maryland, USA),[17] pre- and postoperatively. Preoperative and postoperative CT scan images were used to evaluate the degree of surgical invasion on facet joint. As described by Ikuta et al.,[18] the coronal dimension was defined as the distance between the medial edge and the posterolateral edge of the facet joint on axial CT scan image. The reduction rate was calculated as follows: (postoperative coronal dimension/preoperative coronal dimension) × 100%.

IV. Assessment for postoperative instability

To evaluate the radiologic instability, two variables of lateral radiographs on extension and flexion were used, sagittal translation and segmental angulation. This method was based on a report by White and Panjabi[19] and we regarded it as the presence of postoperative instability whether there was more than 3 mm of translation or more than 10° of angulation at the operative level.

V. Measurement of fatty infiltration (FI) rate of multifidus muscle

Image J software mentioned above was used to evaluate the FI area by converting the axial T_2 weighted magnetic resonance (MR) images into binary images, where discrimination between infiltrating fat and muscle was straightforward (the low signal intensity in the CSA as the FI and the high signal intensity in the CSA as muscle). The FI rate was calculated as a percentage of the number of pixels representing infiltrated fat among the total numbers of pixels in each CSA of the multifidus muscle.[20]

VI. Clinical assessment

For clinical assessment, preoperative 2 days, 6 months and 12 months of postoperative back VAS, leg VAS, and ODI were evaluated.

VII. Statistical analysis

To compare the changes between before and after MTCL procedures paired t-test or Wilcoxon signed rank test were used depending on the result of normality test. A p-value less than or equal to 0.05 was considered to indicate statistical significance.

Results

The mean follow-up period was 17.5 (range 12.1–21.2) months. With regard to the level treated, 12 patients underwent MTCL at L4–5 level (70.5%), 3 at L5–S1 level (17.6%), 1 at L2–3 level (5.8%), and 1 at L3–4 level (5.8%). The operative time for a single-level MTCL procedure ranged from 55 minutes to 190 minutes with 89.11 minutes of median value. The operative blood loss was 108.4 ml (range 22.2–280.5) and no patients required intraoperative or postoperative transfusions. During the MTCL procedure at the level of L5–S1, one case of dural violation (5.8%) with difficulty of primary closure occurred and required intraoperative fibrin glue and 3 days of lumbar drain.

Table 1 shows the effectiveness of neural decompression by MTCL procedure. The mean CSA at stenotic level was 70.5 mm^2 (range 25.1–87.6) preoperatively and it showed significant increase of 198.8 mm^2 (range 177.3–219.2) postoperatively (p = 0.00). Coronal dimension of facet was significantly decreased after MTCL procedure (p = 0.00) and the resection rate was 18.4% (range 9.9–26.9).

With regard to the sagittal translation and segmental angulation, we could not find any evidence of postoperative instability on dynamic lumbar x-rays during the follow-up period. Postoperative T$_2$-weighted MR imaging showed increased median value of FI rate compared to preoperative findings; however it was insignificant (p = 0.11) and seemed to be due to the result of high signal intensity indicating postoperative edematous change. At 12 months of follow-up, the FI rate at corresponding multifidus muscle was similar with preoperative one (p = 0.53, Table 2).

Table 3 shows the clinical improvement of the patients with LSS following MTCL procedure. According to the postoperative back VAS, leg VAS, and ODI, MTCL procedure could lead to a significant improvement of symptoms and it lasted during the follow-up period.

Illustrative case

A 60-year-old man presented with a 29-month history of mild low back and persistent both buttock pain. The patient rated his back pain as a score of 7 and his buttock pain of 6 on a back and leg VAS; his ODI was 64.0%. Preoperative MR imaging revealed bilateral facet hypertrophy and thickening of ligamentum flavum at L4–5 resulting in central spinal canal stenosis with 57.9 cm^2 of CSA (Fig. 4A).

Table 1 The effectiveness of decompression by an MTCL procedure

	Preoperative	Postoperative	p
Cross-sectional area (mm^2)	70.5 (25.1–87.6)	198.8 (177.3–219.2)	0.00
Coronal dimension (mm)	8.8 (6.6–10.0)	1.5 (0.9–2.3)	0.00

Table 2 FI rate of multifidus following MTCL procedure

	Preoperative	Postoperative (hospitalization)	Postoperative 12 months
FI rate of multifidus (%)	12.3 (1.8–22.8)	14.23 (4.4–24.0)	12.94 (6.4–23.4)
P	NI	0.11	0.53

NI: not involved.

Table 3 Assessment for clinical outcomes

	Preoperative	Postoperative (hospitalization)	Postoperative 6 months	Postoperative 12 months
Back VAS	6 (4–8)	4 (3–5)	3 (1–5)	2 (0–3)
P	NI	0.01	0.01	0.00
Leg VAS	8 (6–9)	2 (0–4)	3 (1–4)	3 (1–5)
P	NI	0.00	0.01	0.01
ODI (%)	61.6 (50.4–72.5)	22.5 (12.1–33.1)	23.54 (9.7–37.3)	24.63 (13.2–38.4)
P	NI	0.00	0.00	0.00

NI: not involved, ODI: Oswestry Disability Index, VAS: visual analog scale.

All conservative treatment measures failed, and the patient underwent a successful spinal canal decompression using MTCL technique. Postoperatively, he experienced improvement in preoperative symptom and follow-up MR images showed widened spinal canal with 199.3 cm² of CSA (Fig. 4C). Postoperative computed tomography scan showed decompression of the right lateral recess via the left paramedian approach (vice versa) with minimal facet resection (Fig. 4D). At the time of his last follow-up of 14 months after surgery, his low back and buttock pain had resolved and his ODI improved from preoperatively to postoperatively.

Discussion

Generally, the neural compression of the patients with LSS results from a complex degenerative process including bulging or herniation of interverteral disc, osteophytes formation, ligamentum flavum hypertrophy, and facet joint thickening with arthropathy of the capsule soft tissues.[21] Based on these pathophysiologic perspective, the traditional surgical

Fig. 4 **Pre- and postoperative images of Case 4. Preoperative axial T₂-weighted MR (A) and CT scan (A) images demonstrating lumbar spinal stenosis at the level of L4–5. Postoperative axial MR image (C) demonstrates the extent of decompression afforded by the MTCL procedure. Note the preservation of tendinous attachment of the multifidus muscle at the spinous process. Postoperative CT scan image (D) with minimal facet resection. CT: computed tomography, MR: magnetic resonance, MTCL: microscopic tubular crossing laminotomy.**

treatment have focused on the decompression of neural elements through decompressive laminectomy, ligamentum flavectomy, medial facetectomy, or foraminotomy.[22] Although successful outcomes of the surgical treatments were well described in various reports,[23–26] there exist concerns about morbidity, a prolonged recovery period, postoperative instability, and need for additional arthrodesis because the traditional surgery typically entails extensive resection of posterior elements including supra- or interspinous ligament, spinous processes, bilateral laminae, portions of facet joints, and the ligamentum flavum.[22] In addition, wide muscular dissection and retraction were usually used to achieve an adequate surgical visualization. The posterior lumbar paraspinal muscles form a larger biomechanical system that is responsible for generating movements of the spine while maintaining its stability.[27] Especially, multifidus muscles which belong to the deep paramedian muscle group, is believed to be the major posterior stabilizing muscle of the spine through its bowstring mechanism that produces compressive forces on the vertebra interposed between its attachments.[28]

Efforts to overcome such potentially destabilizing surgery have been pursued via MIS surgery in which the key concepts are (1) decrease muscle crush injuries during retraction, (2) avoid detachment of the osteotendinous complex of the paraspinal muscles (especially, the multifidus attachment) to the spinous process and superior articular processes, and (3) maintain the dynamic stability of the spine while accomplishing the intended goal of surgery.[15] In 1999, Weiner et al.[10] devised a microsurgical bilateral decompression via a unilateral approach and in this technique, the spinal canal can be approached through a unilateral portal via a hemilaminectomy procedure without removal of the spinous process. Oertel et al.[29] investigated 102 patients who received unilateral laminotomy for bilateral decompression (ULBD) and reported 85% as excellent to fair results at a mean 5.6-year follow-up. Müslüman et al.[30] performed ULBD for 84 patients with Grade 1 lumbar degenerative spondylolisthesis or LSS and followed them for mean 4.4 ± 2.3 years. They reported significant spinal canal size increase from 50.6 ± 5.9 mm² to 102.8 ± 9.5 mm² without significant changes of slip percentage and 80% of patients (64 cases) showed good or excellent results in both the early and late follow-up evaluations.

With the development of tubular retractor which consists of a series of cylindrical, concentric tubes, the need for muscle stripping that may otherwise disrupt its tendinous attachment was decreased
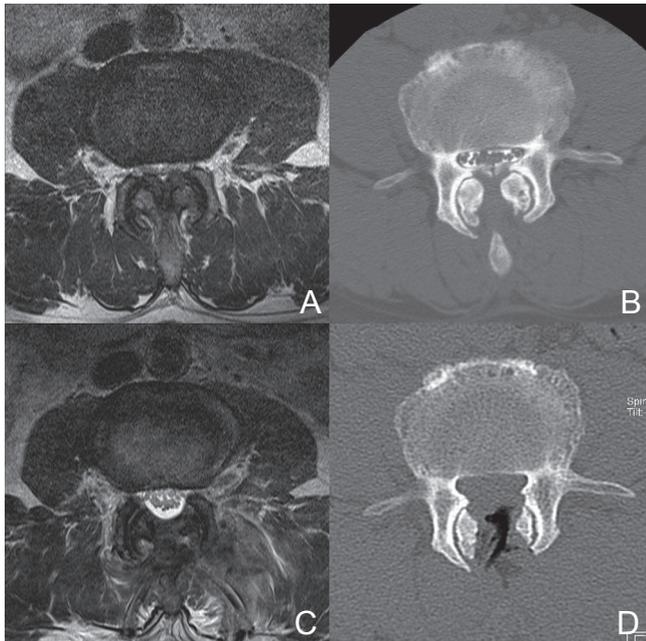
and intramuscular retraction pressure was also reduced, resulting in less muscle crush injury.[15] Anderson et al.[31] compared two matched cohort of patients undergoing decompression using a traditional midline approach versus a tubular retractor system. Both the tubular retractor and traditional midline approach groups achieved significant improvements in SF-12, ODI, and VAS for both back and leg pain at a mean follow-up of 20.2 months and 24.7 months, respectively. Ikuta et al. revealed that the patients who performed tubular microendoscopic posterior decompression (MEPD) showed significant decrease of morbidity including lesser use of postoperative analgesic medication, shorter days of postoperative fever, and lesser hospital stay than the patients of conventional laminotomy group. They assumed the results were led from the use of tubular retractor in that it could minimize the elevation and the retraction of paraspinal muscles. However despite these advantages, they pointed out that tubular MEPD technique had a high possibility of over-resection of the inferior articular process on the approach side. They analyzed that in MEPD, the approach was more lateral than that in the standard procedures because the shape of tubular retractor is cylindrical and the spinous processes disturbed the medialization of the retractor. Particularly in case with wide spinous processes or a developmentally narrow spinal canal, surgeons were likely to resect inferior articular process excessively.

Due to the major role of facet joints in maintaining lumbar spinal stability, various reports have been studied about the effect of facetectomy on motion segment flexibility.[32–34] Lee et al.[32] conducted *in vitro* experiment and revealed that unilateral facetectomy and resection on contralateral facet markedly altered the rotation motion, flexibilities, and coupled motion in extension. In another study by Haher et al.,[34] they reported that unilateral and bilateral facetectomies showed a significant change in the ability to support a load with extension moment applied. As mentioned, in performing ULBD, facet joint on approach side is likely to be over-resected to relieve compressed nerves. However, neural decompression on contralateral side can be done successfully because most of the lateral recess and intra-foraminal area can be accessed while requiring little or no resection of superior articular process, just by increasing medial angulation of the operative corridor. Based on this fact, we performed two contralateral decompressions on bilateral approach sides at single level using tubular retractor and demonstrated well-preserved bilateral facet joints postoperatively with sufficient

spinal canal enlargement. Following the MTCL procedure, the mean CSA of spinal canal increased to 198.84 ± 21.53 mm^2 and the resection rate by medial facetectomy was $18.45 \pm 8.53\%$. According to the Ikuta et al.[18]'s report about MEPD, resection rate on the approach side was 22.6 % while that on the contralateral side was 13.1% (p = 0.01). The resection rate of contralateral facet joint following MEPD is lower compared to MTCL in the current study. It can be postulated that the surgical view provided by endoscope could facilitate to do a more sophisticated drilling and usage of curve instruments was effective in neural decompression thus, excessive drilling was not necessary.

We believe the MTCL procedure is advantageous for not only the preservation of the facet joint but also convenient visualization of contralateral side because tubular retractor could provide handy tilt of the operative corridor with muscle retraction in all directions, not to speak of less muscle crush injury. In the current study, postoperative 12 months of FI rate was similar to preoperative one indicating that the atrophic change of multifidus could be minimized owing to tubular retractor.

As with other minimally invasive approaches, steep learning curve and longer operation time is a major concern to spine surgeon who begins to do an MTCL because surgical maneuver should be done in the small cavity and especially, operative view of MTCL is very different from and unfamiliar with that of the standard posterior approach. In addition, high chance of dural injury and difficulty in handling are other concerns of MTCL. Dural injury reported in the current study occurred at L5–S1 level, specifically in the proximal portion of the S1 root. Given that the L5 lamina is the widest, the instruments should be positioned deeply for neural decompression from contralateral side. Hence, it is reasonable to say that MTCL is suitable for LSS with narrow lamina.

Conclusion

Bilateral decompression via MTCL is a useful and an effective minimally invasive procedure for treating LSS. It preserves the facet joint integrity as much as possible while providing a sufficient neural decompression and causes less iatrogenic injury to the paraspinal musculature than classic laminectomy or laminotomy procedure. Although we obtained relatively good results in this study however, prospective studies with long-term follow-up will be needed to define the exact indications, advantages, and disadvantages of the MTCL procedure.

Conflicts of Interest Disclosure

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