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"Tube in tube" interlaminar endoscopic decompression for the treatment of lumbar spinal stenosis

Technique notes and preliminary clinical outcomes of case series

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Abstract

To describe the Tube in Tube interlaminar endoscopic decompression method and investigate its efficacy and safety in treating lumbar spinal stenosis (LSS).

Utilizing the advantages of the micro-endoscopic decompression (MED) operation channel tube, we used a water-medium spinal endoscopy to perform trans-interlaminar canal decompression, that is, the "Tube in Tube" technique. A retrospective study was performed on 35 patients with LSS who were treated with the Tube in Tube technique. All patients were followed up to 12 months postoperatively. Visual analog scale (VAS), Japanese Orthopaedic Association (JOA) score, and Oswestry Disability Index (ODI) were collected preoperatively and at 3, 6, and 12 months postoperatively. Short-form (36) health survey (SF-36) score was used to examine the general health-related quality of life (HRQoL) of patients preoperatively and at 3 and 12 months postoperatively. Modified Macnab criteria were used to examine the clinical outcomes at 3 and 12 months post-surgery.

The clinical outcomes were satisfactory, with an improvement in all scoring systems. The VAS, JOA, and ODI scores improved from 6.46 ± 1.85, 12.03 ± 4.96, and 42.17 ± 12.22 preoperatively to 2.20 ± 1.14, 21.40 ± 5.86, and 13.14 ± 7.52 at 12 months postoperatively, respectively ($P<.001$). The Macnab excellent or good rates reached 65.7% and 77.1% at the 3 and 12 months follow-ups. No severe complications occurred.

The Tube in Tube technique had a positive clinical outcome in LSS patients and is safe, reliable, and efficacious. However, a larger number of cases and a multi-center research design will be needed further develop the technique.

Level of Evidence: IV.

Abbreviations: BDUF = Bilateral decompression via unilateral fenestration, CI = confidential interval, HRQoL = health-related quality of life, JOA = Japanese Orthopaedic Association, LSS = Lumber spinal stenosis, MED = microendoscopic discectomy, MFD = medial foraminal decompression, MIS = minimally invasive surgery, ODI = Oswestry Disability Index, SD = standard deviation, SF-36 = short-form (36) health survey, VAS = visual analog scale.

Keywords: endoscopy, lumbar spinal stenosis, minimally invasive surgery, quality of life, technique, tube in tube

1. Introduction

Lumber spinal stenosis (LSS) is the narrowing of the spinal canal with encroachment on the neural structures by surrounding bone and soft tissue.[1] A typical symptom of LSS is neurogenic intermittent claudication, which presents as increased pain in the legs when walking caused by congestion of blood outflow and edema of the nerve root.[2] LSS is one of the most common diseases involving the lumbar spine, with an incidence rate of

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Shiqi Cao and Hongpeng Cui contributed equally to this work.

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All procedures performed in this study involving human participants were approved by the Ethical Committee of Navy General Hospital (6th Medical Center of PLA General Hospital), which followed the ethical standards of the institutional and national research committee and the 1964 Helsinki Declaration and its later amendments (IRB No.: ECNGH-2014040).

Informed consent was obtained from all individual participants included in the study.

The datasets during and/or analyzed during the current study available from the corresponding author on reasonable request.

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approximately 5 per 100,000 people annually. It is often particularly found in middle-aged and elderly populations,[3] and is the most common cause for lumbar spinal surgery in individuals over 65 years of age.[4]

Traditional open lumbar surgery is effective in decompression of the neural elements and relieving the associated symptoms.[5] However, there are substantial complications and drawbacks to this procedure which have not been completely addressed. These include the risk of significant blood loss, wound infection, iatrogenic instability, perineural scarring, medical complications, and prolonged recovery.[6] In contrast, minimally invasive surgery (MIS) has been shown to reduce pain postoperatively, shorten the period of hospitalization, and contribute to faster functional recovery.[7–10] Bilateral decompression via unilateral fenestration (BDUF) can be achieved for LSS with micro-endoscopic discectomy (MED).[11] Despite the availability of this more efficacious MIS procedure, hemorrhage is still hard to control in MED, which complicates the surgical field. Additionally, the process of bone resection remains difficult and time-consuming to perform.

Given these substantial clinical challenges, we have developed a technique called the "Tube in Tube" approach. In this procedure, an interlaminar endoscope is inserted into the MED operation channel. This procedure is both easy to learn and convenient to perform during the decompression of the nerve root and dural sac. In this manuscript we describe the clinical efficacy and safety of the Tube in Tube procedure for the treatment of patients with LSS.

2. Methods

2.1. Patients and data collection

Between March 2015 and November 2017, a total of 35 LSS patients treated with our novel approach (Tube in Tube) as case series at the authors' hospital were retrospectively reviewed. Protocol of this study was approved by the Ethics Committee of Navy General Hospital, PLA in 2014 (IRB No.: ECNGH-2014040). Informed consent was obtained from each patient. To determine sample size, we assumed that the difference in the Visual Analogue Scale (VAS) score between baseline level and 1 year postoperative follow up should be no less than 3, with a variance of 4. When setting the α value at 0.05, and 1-β value at 0.80, the sample size of N was calculated to be no less than 16 according to the sample size form and study design.[12]

The diagnosis of LSS was determined according to the criteria previously defined in the literature:[13]

(1) patients complained of neurogenic claudication which could be relieved by sitting and bending forward, and
(2) computed tomography (CT) or magnetic resonance imaging (MRI) characteristics were consistent with patients' symptoms.

The inclusion criteria were as follows:

(1) patients diagnosed with LSS according to the diagnostic criteria,
(2) overall patient health could tolerate the surgery, and,
(3) patients who had signed informed consent.

Exclusive criteria included:

(1) infection at the surgical site,
(2) history of minimally invasive spinal surgery,
(3) mental disorders, or other uncontrolled systematic disorders, such as diabetes mellitus, malignant tumor, or hepatitis and,
(4) patients who did not accept the potential prognosis of the treatment or those who would not sign the informed consent.

2.2. Health-related quality of life (HRQoL) assessments

HRQoL questionnaires are patient-based and contribute to a better understanding of the severity of the patient's disorder and the most appropriate therapeutic approach.[14,15]

All patients completed a VAS, JOA score, and Oswestry Disability Index (ODI) preoperatively and at 3, 6, and 12 months postoperatively. Further scores on the short-form (36) health survey (SF-36) were used to examine the general HRQoL of patients preoperatively, as well as at 3 and 12 months postoperatively. Modified Macnab criteria were used to examine the clinical outcomes at 3 and 12 months post-surgery. All data were obtained from patient-based outcome questionnaires or telephone interviews.

The VAS score evaluates the perception of pain in patients with a possible 0 to 10 score, in which 0 demonstrates no pain at all, and 10 corresponds to pain of highest level.[16]

JOA score consists of 6 subdomain scores (motor dysfunction in the upper extremities, motor dysfunction in the lower extremities, sensory function in the upper extremities, sensory function in the trunk, sensory function in the lower extremities, and bladder function), scaled from 0 to 4, 4, 2, 2, 2, and 3, respectively, with total scores ranging from 0 to 17.[17]

The ODI, developed by Fairbank et al,[18] consists of 10 items that assess the level of pain and interference with HRQoL activities, such as sleeping, self-care, sex life, social life, and travel.[19,20]

SF-36 is a comprehensive questionnaire measuring general quality of life. It is composed of 36 items in 8 subscales. Scores for each subscale range from 0 (worst) to 100 (best).[21–23]

2.3. Surgical techniques

The aim of the Tube in Tube Interlaminar Endoscopic Decompression technique is to thoroughly decompress the nerve root and dural sac in LSS with minimal trauma. To accomplish this aim, the following procedures were performed.

2.4. Portal placement and channel construction

Patients were placed prone on the table with their low back exposed. The operative segment and its surface projection were determined and marked under the guidance of G-arm fluoroscopic imaging. The surgical incision was marked in the longitudinal direction and 1 cm away from the median line at the affected side. After local anesthesia with 0.5% lidocaine, the incision was made through skin to deep fascia. The MED operation channel was inserted after the portals of different diameters for MED were placed at the level of the vertebral plate, in sequence (Fig. 1).

An interlaminar endoscope with the water medium was then inserted into the MED operation channel, which defines the "Tube in Tube" technique. This accomplished bilateral decompression within one surgical approach. A sodium chloride solution (0.9%) was irrigated continuously into the interlaminar endoscope to provide the water medium at the surgical site. Any overflowing solution with blood and dissociative tissue was removed with a vacuum aspirator.

When the casing tip was back to the dural sac, it was gently hammered at the casing to ensure it was stuck in the junction.

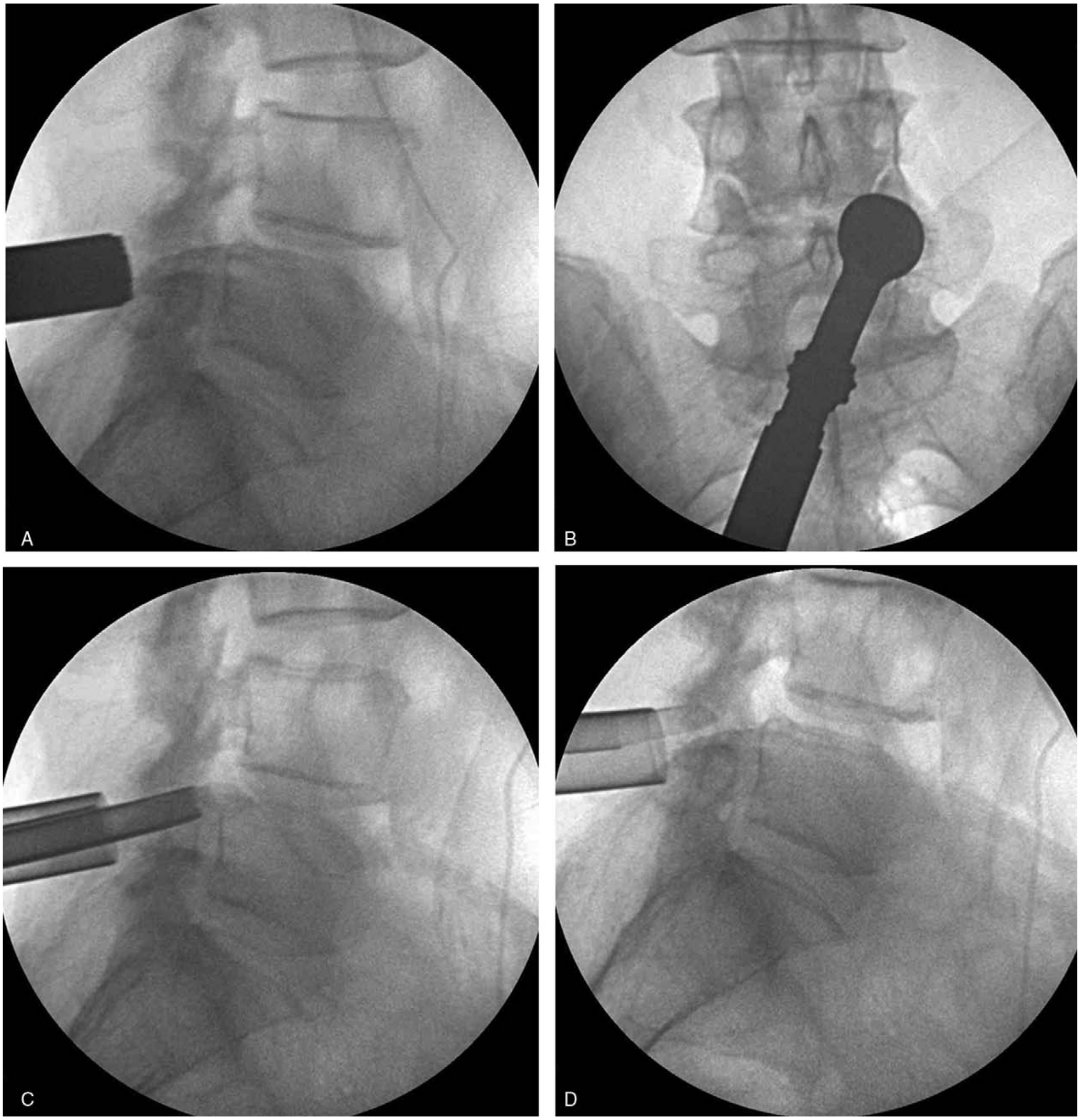

Figure 1. The localization of the Tube in Tube. (A and B) MED was placed to the level of vertebral plate. (C) Interlaminar endoscope placement: the tip margin of the sleeve was located at the intervertebral space margin or the posterior edge of the lower vertebra (lateral). (D) Decompression of lumbar spinal canal.

This was done to ensure the location of the endoscopic sleeve: the tip margin of the sleeve was located at the contralateral medial margin of the pedicle (anteroposterior), and the intervertebral margin or the posterior edge of the lower vertebra (lateral). Manual trephine could then be used to remove part of the lamina and zygopophysis joint (Fig. 1). Manual trephine should always be implemented carefully, and the surgeon should monitor the patient's ability to feel and respond periodically during the procedure.

2.5. Spinal canal decompression

In this process, the ipsilateral and contralateral spinal canals were decompressed with an interlaminar endoscope with water medium through the thin portal (Fig. 2). The surgical field was cleaned followed by yellow ligament resection and hyperplastic bone removal. After ipsilateral decompression, the tip of endoscopy was retreated posterior to dural sac, and pointed to the contralateral side. Yellow ligament and hyperplastic bone posterior to dural sac and contralateral nerve root were then removed. If necessary, secondary decompression of any herniated intervertebral disk detachment and removal should also be performed until free mobilization of the nerve root and dural sac is achieved. Finally, based upon the progression of the surgical course and outcomes, the inferior margin of upper lamina and superior margin of lower lamina can be removed easily. This results in an enlarged space in the spinal and nerve root canal at multiple levels (Fig. 3). This then completes the decompression.

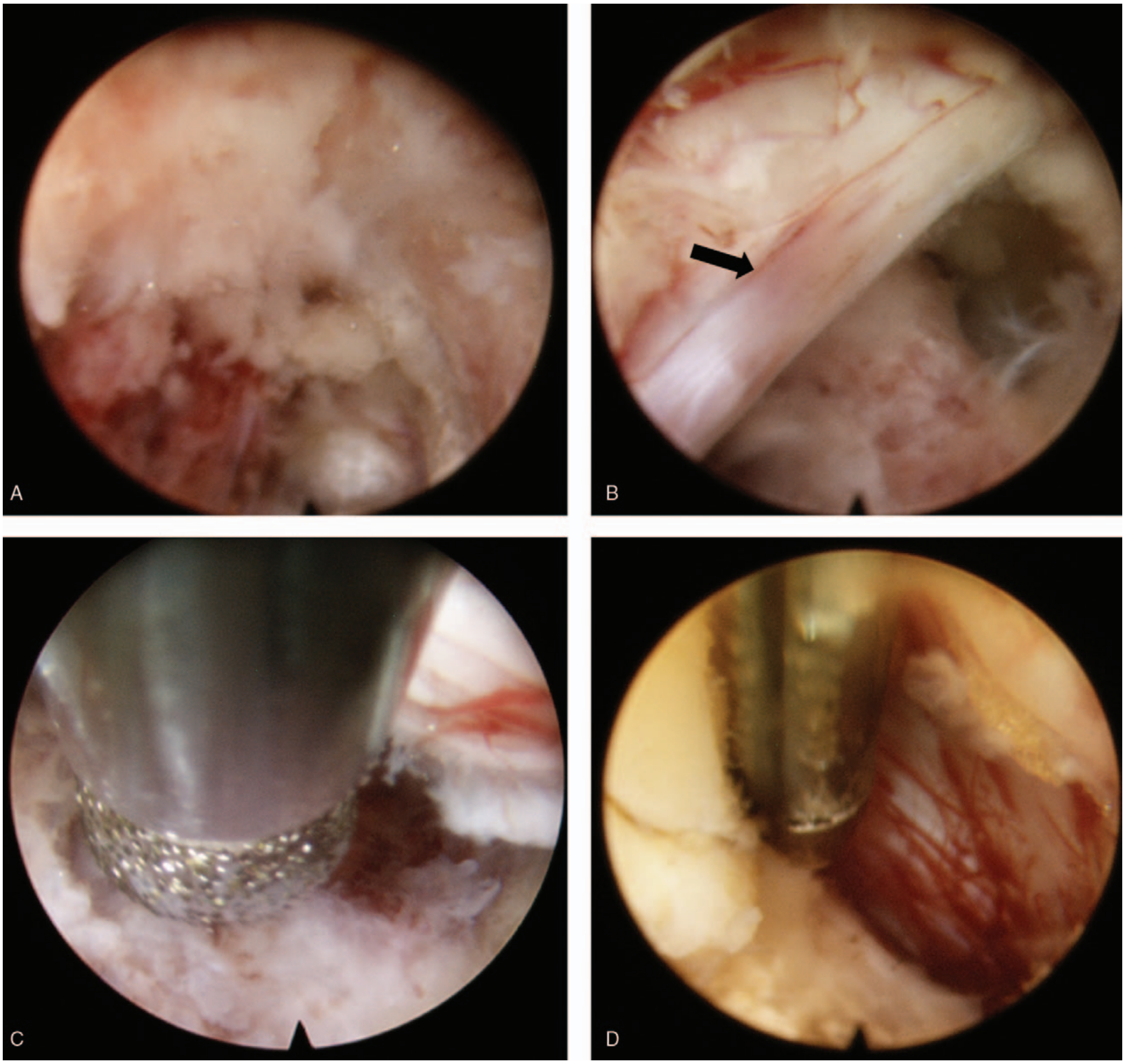

Figure 2. Surgical techniques. (A) The nerve root was compressed. (B) Compression was relieved and revascularization was shown on the surface of the nerve root (arrow). (C) Bony compression was relieved by endoscopic burr drill. (D) Hypertrophic yellow ligament was removed.

2.6. Closure

After adequate cleaning and hemostasis, 1 drainage tube was placed in the surgical area. The incision was sutured layer by layer, and a subcutaneous suture with absorbable material was performed at the last step.

2.7. Statistical analysis

To assess efficacy of the Tube in Tube procedure in LSS patients, treatment effect was calculated based on the difference between the mean value of the questionnaire score at follow-up and the baseline value with a 95% confidence interval (CI). If the 95% CI included a 0, the difference of such a score between follow-up and baseline was determined to not be statistically significant.

We hypothesized that the treatment effect, as determined by VAS, JOA, ODI, and physical subscales of SF-36 (Physical Function, Role-Physical, Bodily Pain and General Health), would be both clinically and statistically significant during the follow-up period. We also hypothesized that the treatment responses would be weaker for the mental subscales of the SF-36 (Vitality, Social Function, Role-Emotional and Mental Health).

Statistical Package for the Social Sciences, version 20.0 (SPSS, Chicago, IL) was used to analyze all data. Mean values were reported with standard deviation (SD). For continuous variables, a paired *t* test was used for normally distributed data. *P* values $\leq .05$ or a 95% CI excluding a 0 for the mean difference were considered significant.

3. Results

3.1. Demographics and disease characteristics

The basic demographics and disease characteristics are listed in Table 1. A total of 14 male and 21 female patients were enrolled in our study with an average age of 62.1 years (range, 45–80

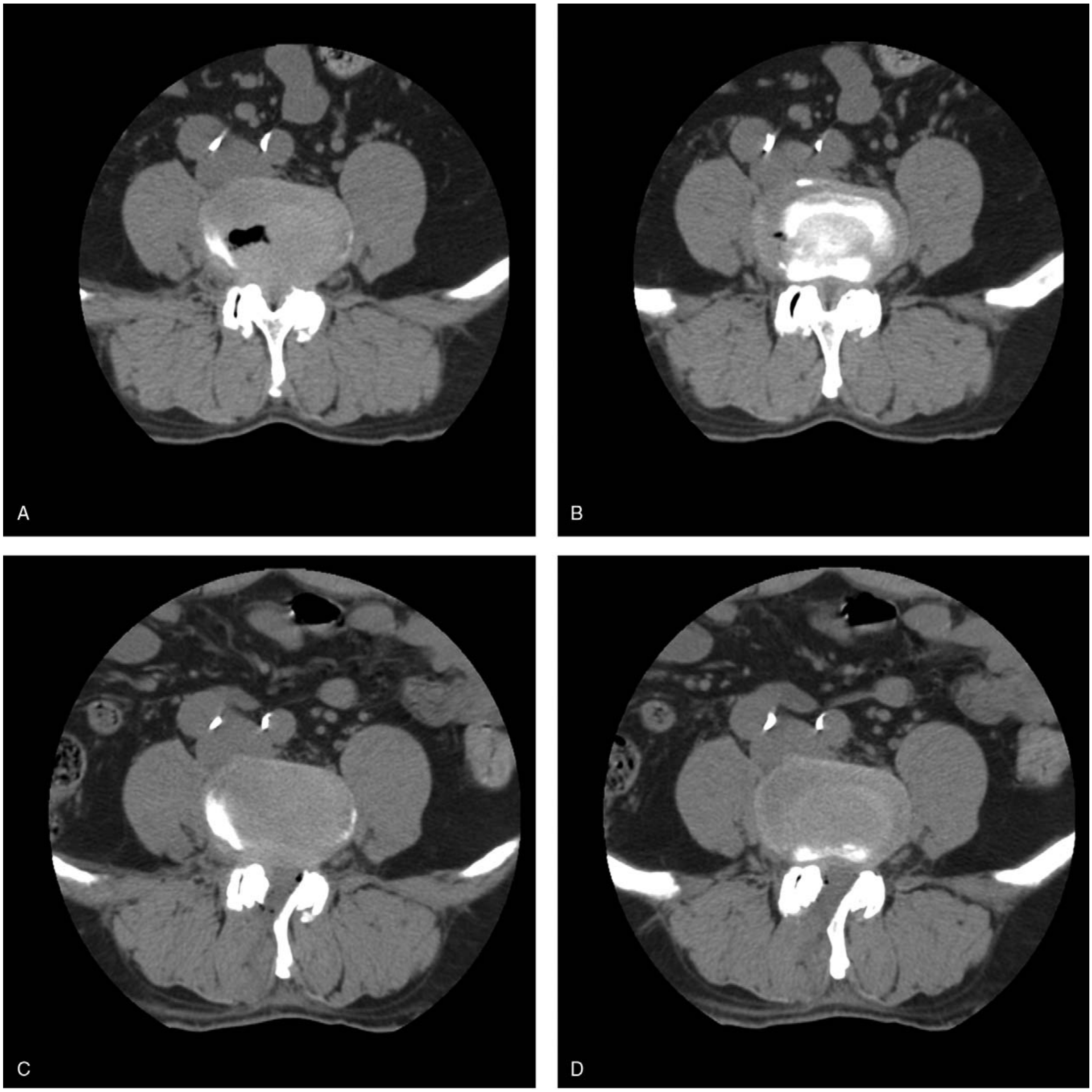

Figure 3. Preoperative and postoperative CT images of 1 patient with LSS. (A and B) preoperative CT scan showing the reduction of lumbar spinal canal volume; (C and D) postoperative CT scan showing the enlargement of lumbar spinal canal volume. CT=computed tomography, LSS=lumbar spinal stenosis.

Table 1

Demographic and clinical characteristics of participants.

Characteristics	Number	Mean ± SD
Age (years)	45–80	62.1 ± 11.0
Gender		
Female	21 (60%)	
Male	14 (40%)	
Duration of symptoms (months)	6–38	16.4 ± 7.4
Segment of LSS		
L3–4	5 (14.3%)	
L4–5	21 (60.0%)	
L5-S1	9 (25.7%)	

years; SD, 11.0 years). All patients in our study were followed for 1 year postoperatively, without withdrawal.

The mean duration of LSS symptoms, such as chronic pain and/or lower limb numbness, was 16.4 ± 7.4 months (range, 6–38 months). All patients included in our study suffered from a single-segment LSS, with a frequency of: L3–4, 14.3% (5 patients); L4–5, 60.0% (21 patients); L5-S1, 25.7% (9 patients).

3.2. Clinical outcomes

Clinical outcomes for all patients were evaluated by VAS, JOA, ODI, and SF-36 score preoperatively and postoperatively, which are listed in Table 2. The mean VAS score decreased from 6.46 ± 1.85 preoperatively to 2.20 ± 1.14 12 months postoperatively ($P < .001$), with a treatment effect of –4.26 (95% CI: –4.84 to –

Table 2

Primary outcomes and treatment effect of Tube in Tube.

Outcome	Baseline	At 3 Mo Mean/Value	At 3 Mo Treatment effect (95% CI)*	At 6 Mo Mean/value	At 6 Mo Treatment effect (95% CI)*	At 12 Mo Mean/Value	At 12 Mo Treatment effect (95% CI)*
VAS	6.46±1.85	3.03±1.10	−3.43 (−3.87, −2.99)	2.37±1.14	−4.09 (−4.60, −3.58)	2.20±1.14	−4.26 (−4.84, −3.67)
JOA	12.03±4.96	18.80±6.09	6.77 (5.71, 7.84)	20.09±5.99	8.06 (6.84, 9.28)	21.40±5.86	9.37 (7.92, 10.82)
ODI	42.17±12.22	19.60±8.48	−22.57 (−25.33, −19.81)	15.66±8.42	−26.51 (−29.97, −23.06)	13.14±7.52	−29.03 (−32.73, −25.33)
SF-36 subscales							
Physical function	34.86±14.06	45.29±20.07	10.43 (7.88, 12.98)	NA	NA	53.00±23.05	18.14 (14.44, 21.85)
Role-physical	33.57±17.09	45.71±26.77	12.14 (7.32, 16.97)	NA	NA	55.00±32.54	21.43 (13.88, 28.98)
Bodily pain	33.23±14.32	48.34±20.49	15.11 (8.40, 21.83)	NA	NA	50.77±18.16	17.54 (10.88, 24.20)
General health	30.97±12.51	37.82±17.74	6.86 (3.52, 10.20)	NA	NA	46.06±23.11	15.09 (9.44, 20.73)
Vitality	36.00±23.23	40.86±25.48	4.86 (0.94, 8.78)	NA	NA	42.57±26.41	6.57 (1.66, 11.48)
Social function	42.86±16.96	52.14±19.53	9.29 (6.28, 12.29)	NA	NA	58.93±23.20	16.07 (12.23, 19.91)
Role-emotional	43.81±19.42	51.43±26.00	7.62 (2.01, 13.23)	NA	NA	49.52±28.44	5.71 (−2.84, 14.27)
Mental health	44.11±21.55	42.97±22.04	−1.14 (−2.17, −0.11)	NA	NA	43.43±22.23	−0.69 (−1.95, 0.58)
Macnab criteria							
Excellent	NA	8 (22.9%)	NA	NA	NA	9 (25.7%)	NA
Good	NA	15 (42.9%)	NA	NA	NA	18 (51.4%)	NA
Fair	NA	10 (28.6%)	NA	NA	NA	7 (20.0%)	NA
Poor	NA	2 (5.9%)	NA	NA	NA	1 (2.9%)	NA

* The treatment effect is the difference in the mean change from baseline to the follow-up point of 3 mo, 6 mo or 12 mo postoperatively.

3.67). The mean JOA score improved from 12.03±4.96 preoperatively to 21.40±5.86 12 months postoperatively ($P < .001$), with a treatment effect of 9.37 (95% CI: 7.92–10.82). The mean ODI score improved from 42.17±12.22 preoperatively to 13.14±7.52 at the last follow-up postoperatively ($P < .001$), with a treatment effect of –29.03 (95% CI: –32.73 to –25.33). The HRQoL for patients measured by SF-36 showed similar results in physical function, role physical, bodily pain, general health, and social function subscales ($P < .001$, Table 2). The clinical outcomes displayed by the different scoring systems maintained a stable level at 3, 6, and 12 months post-surgery, which suggests a relief in clinical symptoms and an improved quality of life and social adaptability.

The outcomes according to the modified Macnab criteria (Table 2) were excellent in 8 (22.9%) and 9 (25.7%) patients, good in 15 (42.9%) and 18 (51.4%) patients, fair in 10 (28.6%) and 7 (20.0%) patients, and poor in 2 (5.9%) and 1 (2.9%) patients, 3 and 12 months postoperatively, respectively. Excellent or good response rates reached as high as 65.7% and 77.1% at the above 2 follow-ups (3 and 12 months).

3.3. Complications

A total of 4 complications were presented in this study. Elevated radicular pain occurred in 2 patients 3 days postoperatively, due to nerve root disturbance or inflammatory stimulation during the operation. This was relieved utilizing local block therapy. One patient complained of a sore lumbosacral region and decreased strength during excretion postoperatively, which may have been caused by the cauda equina stimulation. These symptoms disappeared after 4 weeks of rehabilitation therapy. Spinal cord hypertension appeared in 1 elderly patient just before the end of the surgery. The surgery for this patient was completed as quickly as possible, and relative symptoms were relieved in 45 minutes. There were no severe complications, such as large dural tears or nerve injuries.

4. Discussion

Lumbar spine degeneration due to hyperostosis and narrowing of disc spaces is quite common in the elderly population.[3,24] The basic pathological changes of LSS include narrowing and bulging of the intervertebral disk, hypertrophy of the facet joints, thickening and buckling of the ligamentum flavum, and/or degenerative spondylolisthesis.[25] The narrowing of the spinal canal could cause elevated pressure on the nerve and its venous circulation, which could then induce tissue edema, adhesion, cauda equina ischemia, and radicular neuritis. These resultant outcomes are difficult to alleviate utilizing conservative treatment. Laminectomy through a posterior approach is the classical surgical method of treatment, and can be efficacious in treating yellow ligament hypertrophy, inner concentrated facet joint, and nerve root compression due to a herniated intervertebral disc with good mid- to long-term clinical outcomes.[26,27] The technique of PTED can avoid the negative effects associated with open surgery, such as iatrogenic segmental instability, loss of mobility in the fusion segment, adjacent segmental degeneration, implant loosening or fracture, and foreign-body reaction and infection. However, it is still challenging to achieve the necessary 360-degree decompression of the dural sac and nerve root. Further, PTED is not optimal when treating LSS, except in cases with lateral recess stenosis. Using an endoscopic technique with a large channel utilizing the posterior interlaminar approach is more effective in opening the lamina, and resolves the extensive of central or lateral canal stenosis, while accomplishing nerve root decompression for the contralateral stenosis.

While MED is an established technique in the spine, its effectiveness in treating LSS has been challenging.[28,29] The imaging medium for the MED technique is air, and as such intraoperative hemorrhage can be difficult to clear. This results in anatomical structures in the surgical field being hard to identify. Further, there is a steep learning curve associated with this procedure, which restricts its large-scale application. The large-channel surgical technique Tube in Tube described here addresses the limitations of MED. First, the imaging medium in the procedure is water, which contributes to a clearer surgical field and more thorough decompression. Second, it is a simpler MIS, which results in rare resection of bone structures or resultant negative impacts on segment stability.

Based on our experience with open partial laminectomy, and to accomplish a better decompression in LSS patients utilizing MIS, we developed the surgical approach of medial foraminal decompression (MFD).[30] In MFD, decompression is performed from the lateral side of the interlaminar space, upper laterally to the inner space of the foramina at the intervertebral level. Decompression of the lateral recess can also be achieved utilizing this procedure, which then in turn can be used to effectively treat stenosis at the lateral recess. In essence, the MFD approach combines the advantages of MIS and open surgery together. However, due to the limited scale of decompression at the level of the upper and lower lamina, it is not an efficacious treatment for severe LSS patients. The approach stated in this article, Tube in Tube, is a spinal decompression approach targeted at the inner space of the foramina utilizing the large channel of MED. The surgical field can easily be exposed with MED, which makes the utilization of a thinner endoscope possible while achieving decompression at multiple levels. This is particularly true for the inner space of the foramina and the hyperplastic inferior articular process. Further, the channel used in MED isolates the tissue from the water medium, which could potentially prevent tissue swelling and contribute to a faster postoperative rehabilitation.

Spinal MIS results in less trauma and surgical complications, which ultimately results in the patient having fewer adverse reactions in any subsequent surgery. For elderly patients, it is important to balance the benefits and risks of any treatment. As such, it is also important to treat LSS in a controllable scale with less surgical trauma and complications. This could effectively improve the quality of life and may prolong life-span, especially in elderly or longevous patients. The creativity of the Tube in Tube procedure is a testament to the feasibility of combining a large channel and water imaging medium in a spinal endoscopic surgery. This novel procedure subsequently made the decompression of LSS in the intermediate and posterior column easy to perform.

In comparison to traditional open surgery, the Tube in Tube approach has further additional advantages. First, the incision of less than 2 cm is smaller than open surgery. Blunt dissection decreases denervation and devascularization of the paravertebral muscles, such as psoas major, musculi multifidi, and semispinalis, which is conducive to postoperative rehabilitation. Second, the surgical view is much clearer when compared to open surgery due to the surgical imaging system. With the addition of effective communication between the patient and surgeon during local anesthesia, nerve damage can be significantly avoided. Finally, irrigation with the water medium can remove blood more effectively for a cleaner surgical field, which decreases the risk of postoperative infection.

Compared with the results from all other HRQoL assessments, the treatment effects on the mental subscales of the SF-36 were weaker during the follow-up period. This is consistent with our hypothesis. This may be due to the fact that Tube in Tube technique could completely achieve decompression and relieve patients' physical symptoms, such as neurologic claudication, which are measured more clearly by the scores on the VAS, JOA, ODI, and physical subscales of the SF-36. Additionally, the treatment effects had already reached a satisfactory level at 3-month post-surgery on most scales. However, they progressed more slowly for the next 9 months of follow-up. This indicates that the first 3 months postoperatively is the key period for recovery of the nerve and surgical trauma, and the recovery period for the nerve is continuous up to 1 year post-operation.

At the final 12-month postoperative follow-up, the excellent and good rates on the modified Macnab criteria were 77.1% in the LSS patients who underwent Tube in Tube decompression. This is slightly lower than the rate of 86.5% to 92% reported by previous studies utilizing a percutaneous interlaminar approach.[31–33] This is likely due to several reasons. First, all patients included in our study were LSS patients who complained of neurological claudication for an extended period, and most patients were elderly. Second, although Tube in Tube is a MIS for LSS, the associated incision and trauma are still larger than full endoscopic spinal surgery, which may cause more residual symptoms on paraspinal muscles. Finally, follow-up time for our study was 1 year, which is a relatively short time for spinal surgery. The recovery time required for the nerve in some patients could be greater than 1 year.

The occurrence of complications for the Tube in Tube procedure was also acceptable. A total of 4 mild complications presented in this study, without any severe adverse event. However, these complications are a reminder to surgeons that caution during surgery is always necessary. This is despite the Tube in Tube procedure being a MIS. All of these prior points suggest that the Tube in Tube surgical procedure is an efficacious and safe method for treating LSS.

However, there are also some limitations for this study which could impact our conclusions. First and most importantly, a control group was not set, and the sample size was relatively small. However, despite the absence of a control group, we noted a shorter recovery time and days of hospitalization in the Tube in Tube patients when compared to patients receiving open surgery in the same period. Further, there were compelling clinical outcomes in all Tube in Tube patients. These points suggest the procedure was efficacious despite the absence of the control group. Second, the follow-up period was short in our study and the outcomes and efficacy of the technique needs to be assessed in long-term follow-ups. Finally, we only used the Tube in Tube procedure to treat patients with LSS. Theoretically, it could also be effective in other lumbar diseases, such as, lumbar disk herniation; however, its efficacy and safety in other conditions was not tested in this study.

In conclusion, the technique of Tube in Tube is effective and safe in treating LSS, with low surgical trauma and good preservation of the natural structure. However, examination of a larger number of cases and a multi-center research design with a better level of evidence will need to be conducted to verify these results.

Author contributions

Data curation: Shiqi Cao, Hongpeng Cui, Zhengcao Lu, Kai Zhu, Bensheng Fu, Wen Li, Jianjun Zhang, Yu Ding.
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