Am J Transl Res 2021;13(8):9356-9363
www.ajtr.org /ISSN:1943-8141/AJTR0131533

Original Article

Clinical efficacy of percutaneous transforaminal endoscopic TESSYS technique in the treatment of senile lumbar spinal stenosis

Bingquan Chen[1*], Shangzheng Li[2*], Zhaowei Wang[3]

[1]Department of Orthopedics, Panyu Hospital of Chinese Medicine, Guangzhou 511400, Guangdong, China; [2]Department of Orthopedics, Minzu Hosipital of Guangxi Zhuang Autonomous Region, Nanning 530000, Guangxi, China; [3]Department of Orthopedics, Laiyang Central Hospital of Yantai, Yantai 265200, Shandong, China. [*]Equal contributors and co-first authors.

Received February 6, 2021; Accepted April 1, 2021; Epub August 15, 2021; Published August 30, 2021

Abstract: Objective: To evaluate the clinical efficacy percutaneous transforaminal endoscopic TESSYS technique in the treatment of senile lumbar spinal stenosis. Methods: 157 senile with lumbar spinal stenosis were prospectively recruited at this study. The subjects in the experimental group received TESSYS operation, and the control group received traditional open surgery for posterior lumbar interbody fusion. The clinical pain relief, indexes of perioperative period, dysfunction of the lumbar spine and clinical effect of the two groups were measured. Results: The operation time of experimental group was (53.32±10.27) min, average blood loss in operation was (50.01±5.74) ml, and length of hospitalization was (6.73±3.21) d, which were all better than the control group (97.46±13.47) min, (172.23±8.61) ml, (13.94±2.15) d, with statistical significance ($P < 0.05$). The VAS scores at one day, one week, 1 month and 3 months were significantly lower than those before operation ($P < 0.05$). The VAS scores of the two groups were significantly lower than those of the open surgery group ($P < 0.05$). ODI scores of patients were significantly lower than those before operation ($P < 0.05$). The MACNAB scores of the two groups were significantly lower than those of the open surgery group ($P < 0.05$). Conclusion: Percutaneous transforaminal TESSYS technique is a safe and minimally invasive technique for the treatment of lumbar spinal stenosis in the elderly. Compared with traditional open surgery for posterior lumbar interbody fusion, percutaneous transforaminal endoscopic TESSYS technique has less trauma and does not damage the stability of the spine. It can significantly shorten the hospitalization and operation time, reduce intraoperative fluoroscopy and blood loss, reduce the degree of pain and postoperative complications, and quickly restore daily life function. and thus an effective and more advantageous scheme for the treatment of elderly lumbar spinal stenosis.

Keywords: Percutaneous transforaminal endoscopic, TESSYS technique, lumbar spinal stenosis, senile patients

Introduction

Lumbar spinal canal stenosis (LSS) and nerve root canal stenosis are chronic degenerative diseases. Their common causes are ossification of posterior longitudinal ligament and lumbar disc herniation [1]. The incidence rate of lumbar spinal stenosis in the elderly is increasing. It has become a common multiple spinal disease in the elderly [2]. The etiology of lumbar spinal canal stenosis is complex. It had much cause-off factors such as degeneration of bone and soft tissue, disc herniation, hypertrophy of facet and ligamentum flavum, and osteophyte formation, which lead to complex complications [3]. Lumbar spinal canal stenosis can occur in the central spinal canal, lateral recess or intervertebral foramen, The typical symptoms include lumbocrural pain, numbness or weakness of affected limb and intermittent claudication [4, 5]. Numbness can extend from the foot to the lower limbs, thighs, waist and sacral area. In severe cases, abdominal discomfort, banded feeling, abnormal defecation and even paraplegia appear. If the treatment is poor or progressive, surgical intervention is needed to improve motor function and quality of life [6].

Spinal endoscopy is a new minimally invasive spinal surgery technology, which evolves the traditional open surgery of discectomy [7]. At present, the innovative transforaminal endoscopic TESSYS technology uses special instruments to expand the intervertebral foramen [8]. TESSYS technology can extend the space into the spinal canal, decompress the nerve root under direct vision, change the previous indirect decompression into direct decompression, and it can effectively deal with lateral recess stenosis and spinal canal stenosis [9]. Percutaneous transforaminal endoscopic TESSYS technique has become a new treatment method for lumbar spinal canal stenosis. This study aims to investigate the clinical efficacy percutaneous transforaminal endoscopic TESSYS technique in the treatment of senile lumbar spinal stenosis.

Data and methods

Clinical data

157 senile in our hospital from January 2018 to December 2020 met the inclusion and exclusion criteria and were randomized allocated into two groups: the Experimental group (n=81 cases) and the control group (n=76 cases). The researchers explained the operation risks and postoperative complications to the patients and their relatives, and informed patients of anesthesia risks and accidents. The patients and their families voluntarily signed the informed consent form to participate in this study. This study was approved and recognized by the ethics committee of our hospital.

Inclusion and exclusion standard

Inclusive criteria: ① Age ≥ 65 years; ② The clinical symptoms of lumbocrural pain, numbness of lower limbs and intermittent claudication were consistent with that of degenerative lumbar spinal stenosis indicated by CT or MRI; ③ The anatomical classification of lumbar spinal canal stenosis is lateral recess stenosis or intervertebral foramen stenosis; ④ There was no obvious improvement after more than 3 months of conservative treatment; ⑤ The subjects were willing to cooperate and implement the experiment.

Exclusion criteria: ① Had a history of mental illness; ② Lumbar instability and spondylolisthesis; ③ Cauda equina syndrome; ④ Had serious cardiac disorder, severe liver malfunction or renal failure; ⑤ Coagulation dysfunction; ⑥ There were multi segmental lumbar spinal stenosis and central spinal stenosis; ⑦ Unwilling to participate our research; ⑧ Allergic to anesthetics; ⑨ Severe osteoporosis, metabolic bone disease, etc; ⑩ Had a history of lumbar surgery history, severe adhesion of dural sac and nerve root, and patients who are not suitable for surgery.

Method

The control group: The patient underwent traditional open surgery for posterior lumbar interbody fusion. After tracheal intubation and general anesthesia, the patient took the prone position routinely. Under X-ray fluoroscopy, the operation segment was confirmed. The operation mark line was marked with sterile marker pen. Under fluoroscopy, the pedicle screw was placed. Under C-arm X-ray fluoroscopy, the position of the pedicle screw was confirmed to be good, and the titanium rod 1 with uniform length was placed on both sides. The posterior lamina and ligamentum flavum were removed by bone biting scissors and nucleus pulposus forceps, and the superior articular process of the lower vertebral body was removed. The nucleus pulposus tissue and cartilage endplate were removed by curette to protect the subdural pressure and release the surrounding compressed tissue. Then the artificial bone and the resected spinous process and lamina were scraped. X-ray fluoroscopy confirmed whether the pedicle screw and interbody fusion cage were in good position. The head and tail screws were pressurized and locked. Sterile saline was used to wash the wound. After complete hemostasis, a drainage tube was placed, and subcutaneous tissue and skin were sutured.

The experimental group: The subjects were received TESSYS operation. The patients received local anesthesia, and underwent discography, used the puncture needle to put the guide wire into the diseased intervertebral disc, then withdrew the puncture needle, inserted the guide wire into the facet of the facet, and withdrew from the 2nd to 3rd stage. The blue trephine was inserted into the tip of the superior articular process, and the handle was used to

Table 1. Comparison of clinical data between the two groups

	Experimental group (n=81)	Control group (n=76)	t/X^2	*P*
Age (years)	64.4±2.56	63.7±2.67	3.25	0.41
Sex			4.49	0.43
Male (n%)	39 (48.1%)	37 (48.7%)		
Female (n%)	42 (51.9%)	39 (51.3%)		
BMI	22.5±3.16	23.35±2.43	1.39	0.34
Smoking	37 (45.7%)	34 (44.7%)	5.16	0.26
Operative segment			6.29	0.22
L3~L4	11 (13.6%)	8 (10.5%)		
L4~L5	65 (80.2%)	62 (81.6%)		
L5~S1	5 (6.2%)	6 (7.9%)		

Note: Compared with the control group, significant difference as P<0.05.

rotate the circular saw clockwise to remove the hyperplastic bone at the distal facet and the local superior articular process. Then exit the ring saw anticlockwise to ensure that the guide wire remains in place. According to the above methods, green, yellow and red circular saws were placed, the position of circular saw was determined by C-arm fluoroscopy, and the intervertebral foramen was expanded. To adjust the color effect, the intervertebral foramen mirror was connected with the light source and camera. Then the intervertebral foramen mirror was placed into the channel to regulate the water flow and pressure, and the blue stained nucleus pulposus tissue was removed through the nucleus pulposus forceps to expose the nerve roots. The relevant granulation tissue and nerve endings growing into the annulus fibrosus fissure were ablated with Ellman flexible bipolar radiofrequency electrode to make the opening shrink and form. After the operation, 7 mg compound betamethasone was injected into the intervertebral foramen. It should be avoided 3-6 weeks after operation. Patients with body torsion, weight-bearing exercise, guiding patients to carry out lumbar stability training.

All patients were treated with conventional antibiotics (Tianjin Pharmaceutical Group Jinkang Pharmaceutical Co., Ltd., Guoyao Zhunzi h20060932, specification: 100 mg) for 24 hours, detumescence, pain relief, nerve nutrition and other symptomatic treatment. The patients were guided to perform functional exercise of lumbar and dorsal muscles and raise their legs at the first day after operation.

Pain

Visual analogue scale (VAS) was used to evaluate the degree of pain before and after surgery, respectively [10]. The score range was 0-10, and the degree of pain increased with the increase of the score.

Clinical effect

According to macnab lumbar function standard [11], the clinical efficacy of the two groups was evaluated. The excellent and good rate was calculated according to the number of excellent and good cases. If the patient's symptoms was completely disappeared, this case was rated as excellent. If the patient's symptoms had mild limitation of activities, but it had no impact on work and life, this case was rated as good. If the patient's symptoms alleviates, however, the activity is limited, this case was rated as medium. If the patient's symptoms had no difference before and after treatment, this case was rated as poor.

The dysfunction of the lumbar spine

According to Oswestry disability index (ODI) [12], the degree of lumbar dysfunction was evaluated before operation and 1, 3, 6 months after operation.

Statistical analysis

All data were analyzed by SPSS 22.0. The statistical results are expressed by mean ± standard deviation (M ± s), the data comparison is conducted by t-test and the correlation analysis is conducted by person linear phase, $P < 0.05$ was the difference with statistical significance. Analyses were performed using Graph Pad Prism 7 Software (Graph Pad Prism, San Diego, CA).

Results

Clinical data

Table 1 shown characteristics of the participants. The research included 157 patients,

Table 2. Comparison of *VAS score* between the two groups before and after treatment (points, $\bar{x}\pm s$)

group	Number of cases	T0	T1	T2	T3	T4
Experimental group	81	7.43±0.86	2.11±0.94	1.69±0.75	1.49±0.68	1.35±0.68
Control group	76	7.94±0.89	7.15±1.14	6.78±1.23	6.44±0.78	4.37±0.87
t	-	0.168	19.797	20.235	20.415	16.742
P	-	0.843	0.0001	0.0002	0.0002	0.0004

Note: Compared with the control group, significant difference as P<0.05. T0: Before surgery; T1: one day after surgery; T2: one week after surgery; T3: four weeks after surgery; T4: 12 weeks after surgery.

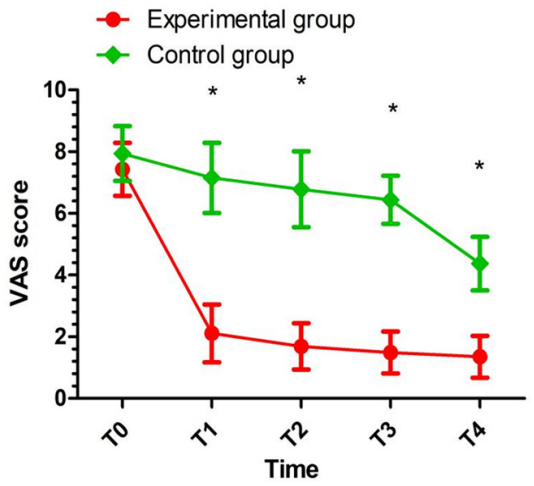

Figure 1. Comparison of *VAS score* between the two groups before and after treatment. Note: Compared with the control group, significant difference as P<0.05. T0: Before surgery; T1: one day after surgery; T2: one week after surgery; T3: four weeks after surgery; T4: 12 weeks after surgery.

involved 81 patients in the experimental group, a mean age (64.4±2.56) years, while in the control group, a mean age (63.7±2.67) years. The BMI in the experimental group was (22.5±3.16) kg/m^2, and in the control group was (23.35±2.43) kg/m^2, there was no statistical significance between two group (P=0.34). The number of smoking people in the experimental group was 37 (45.7%), and that in the control group was 34 (44.7%). The number of surgical segments in L3-L4, L4~L5 and L5~S1 in experimental group were 11 (13.6%), 65 (80.2%) and 5 (6.2%), respectively, and that in the control group were 8 (10.5%), 62 (81.6%) and 6 (7.9%), respectively. No statistical significance between two groups among mean age, BMI, smoking number and surgical segments.

Clinical relieve pain

As shown in **Table 2** and **Figure 1**, the score of VAS before surgery (T0) in the experimental group was (7.43±0.86) points, and that in the control group was (7.94±0.89) points; while the score of VAS at one day after surgery (T1), one week after surgery (T2), four weeks after surgery (T3) and 12 weeks after surgery (T4) in the experimental group respectively were (2.11±0.94) points, (1.69±0.75) points, (1.49±0.68) points and (1.35±0.68) points, and that in the control group respectively were (7.15±1.14) points, (6.78±1.23) points, (6.44±0.78) points and (4.37±0.87) points, there had statistical significance between two groups after surgery (P<0.05). The VAS was positively improvement with the treatment of TESSYS operation.

Indexes of perioperative period

The average operative time in the experimental group was (53.32±10.27) min, and that in the control group was (97.46±13.47) min. The average blood loss in operaton in the experimental group was obviously less than control group ((50.01±5.74) VS. (172.23±8.61) ml, P<0.05). Moreover, the length of hospitalization of experimental group was shorten than the control group ((6.73±3.21) VS. (13.94±2.15) d, P<0.05) (**Table 3** and **Figure 2**).

The dysfunction of the lumbar spine

The score of oswestry disability index (ODI) before surgery (T0) in the experimental group was (37.24±10.73) points, and that in the control group was (37.15±10.89) points; while the score of ODI at one day after surgery (T1), one week after surgery (T2), four weeks after

Table 3. Comparison of *Indexes of perioperative period* between the two groups ($\bar{x}\pm s$)

group	Number of cases	Operative time (min)	Average blood loss in operaton (ml)	Length of hospitalization (d)
Experimental group	81	53.32±10.27	50.01±5.74	6.73±3.21
Control group	76	97.46±13.47	172.23±8.61	13.94±2.15
t	-	13.571	23.694	10.154
P	-	0.0002	0.0001	0.0004

Note: Compared with the control group, significant difference as P<0.05.

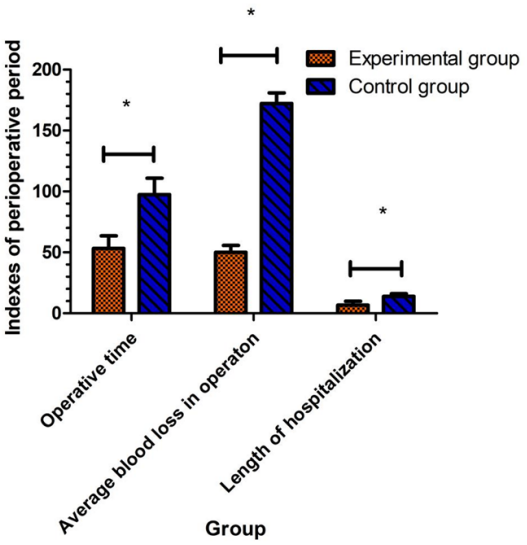

Figure 2. Comparison of Indexes of perioperative period between the two groups. Note: Compared with control group, *$^{*}P<0.05$*.

surgery (T3) and 12 weeks after surgery (T4) in the experimental group respectively were (20.51±5.12) points, (15.53±3.21) points, (14.17±3.48) points and (12.35±3.28) points, and that in the control group respectively were (27.15±8.14) points, (23.20±7.85) points, (18.36±4.87) points and (17.88±4.93) points, there had statistical significance between two groups after surgery (P<0.05). The dysfunction of the lumbar spine (ODI score) was positively improvement with the treatment of TESSYS operation (**Table 4** and **Figure 3**).

Clinical effect

There were statistical differences between the two groups in the clinical effect (P<0.05). After treatment, there were increased in score of Comprehensive evaluation among the two groups. The excellent and good rate in the experimental group was 86.4% (70/81), and that in the control group was 71.1% (54/76), there existed significant difference in clinical effect between the two groups (P<0.05) (**Table 5**).

Preoperative and post-operative CT scan and MRI

As shown in the **Figure 4**, CT scan and MRI of patient with lumbar stenosis treated with TESSYS technique. The patient with treatment of TESSYS technique reduce intraoperative fluoroscopy.

Discussion

Lumbar spinal stenosis is a spinal canal disease. Combined with osteoporosis in the elderly, it is easy to lead fracture disease, and it even causes limb and motor dysfunction, affecting the quality of life [13]. Percutaneous transforaminal endoscopic TESSYS technique uses multi angle bipolar radiofrequency electrode, which can directly ablate nucleus pulposus at low temperature and repair the ruptured annulus fibrosus [14, 15]. It is widely used in clinical practice.

In our study, the VAS score of the experimental group after operation was significantly lower than that of the control group, and the ODI score was significantly higher than that of the control group. The results demonstrated that patients treated with percutaneous transforaminal endoscopic TESSYS technique have faster pain relief, earlier recovery of activity ability and more stable curative effect. Furthermore, intraoperative blood loss and the excellent and good rate of treatment in the experimental group were better than those in the control group, suggesting that percutaneous transforaminal endoscopic TESSYS technique has the advantages of less trauma, less intraoperative blood loss, shorter opera-

Table 4. Comparison of *ODI score* between the two groups before and after treatment (points, $\bar{x}\pm s$)

group	Number of cases	T0	T1	T2	T3	T4
Experimental group	81	37.24±10.73	20.51±5.12	15.53±3.21	14.17±3.48	12.35±3.28
Control group	76	37.15±10.89	27.15±8.14	23.20±7.85	18.36±4.87	17.88±4.93
t	-	0.334	6.997	7.698	3.972	4.649
P	-	0.794	0.0003	0.0002	0.0003	0.0004

Note: Compared with the control group, significant difference as P<0.05. T0: Before surgery; T1: one day after surgery; T2: one week after surgery; T3: four weeks after surgery; T4: 12 weeks after surgery.

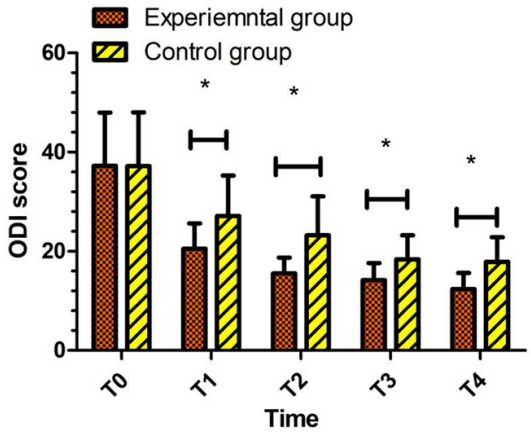

Figure 3. Comparison of ODI score between the two groups before and after treatment. Note: Compared with the control group, significant difference as P<0.05. T0: Before surgery; T1: one day after surgery; T2: one week after surgery; T3: four weeks after surgery; T4: 12 weeks after surgery.

tion time and fewer complications, and its clinical effect and safety are better than those of traditional surgery, which is related to the clear observation of diseased tissue and the improvement of operation safety.

TESSYS surgery method was performed through the lateral approach. A special circular saw was used to expand the intervertebral foramen and remove the diseased articular process. Some hyperplastic osteophytes and thickened ligamentum flavum in the lateral recess can further remove or repair the ventral tissue causing lateral recess stenosis [16, 17]. This operation can be used as the first choice for minimally invasive treatment of lumbar spinal canal stenosis combined with nerve root canal stenosis [18]. Compared with the traditional surgical treatment, percutaneous transforaminal endoscopic TESSYS technique has many advantages. Firstly, the incision is short, only 7 mm, which can effectively prevent postoperative complications caused by resection of articular process [19]. Secondly, during the recovery period, the patients can walk after 24 hours, which can reduce the adhesion between tissues. Thirdly, the postoperative pain was mild, the amount of bleeding was less and the trauma was small. Because of these advantages, it has been widely used in various medical units, and it has become the first choice for the treatment of elderly lumbar spinal stenosis.

In this study, percutaneous transforaminal endoscopic TESSYS technology can reduce the degree of lumbar pain, and actively promote the recovery of lumbar function. The reasons may be as follows: (1) Percutaneous transforaminal endoscopic TESSYS technique has a small incision to avoid physiological stress reaction and complications. (2) The patient was under local anesthesia, and they can get feedback in time, which can reduce the damage to the nerve root. Furthermore, it is conducive to the recovery of lumbar function [20]. (3) Percutaneous transforaminal endoscopic TESSYS technology uses the intervertebral foramen to directly insert the endoscopic working cannula into the spinal canal, and it magnifies the surgical target through the image system, so that the surgical field of vision is clearer. (4) During the operation, the special circular saw was used to expand the intervertebral foramen and place the operation channel, which almost did not damage the lamina, articular process, muscle, etc., it did not affect the anatomical structure of the lumbar spine, maintained biomechanical stability and recovered quickly after operation. (5) There is no need to pull the nerve root during the operation. (6) The use of bipolar radiofrequency ablation during the operation can realize the denervation of the nerve fibers in the annulus fibrosus, which is helpful to relieve the pain quickly.

Table 5. Comparison of *Macnab classification* between the two groups after treatment

group	Number of cases	Excellent	Good	Medium	Poor	Excellent and good rate
Experimental group	81	52 (64.2%)	18 (22.2%)	8 (9.9%)	3 (3.7%)	70 (86.4%)
Control group	76	41 (53.9%)	13 (17.1%)	15 (19.7%)	7 (9.2%)	54 (71.1%)
t	-	7.172	4.533	8.323	3.967	12.243
P	-	0.013	0.023	0.006	0.038	0.0003

Note: Compared with the control group, significant difference as P<0.05.

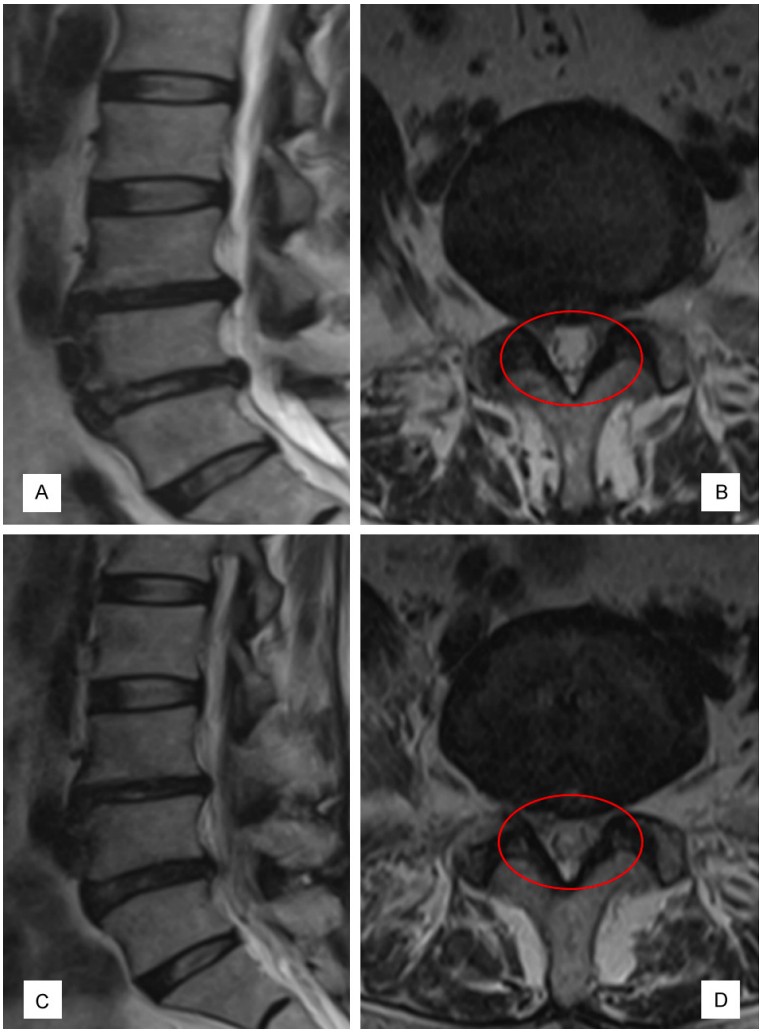

Figure 4. CT scan and MRI of patient with lumbar stenosis treated with TESSYS technique. (A, B) Preoperative MRI. (C, D) Post-operative MRI. The stenosis was indicated by red circle in (B), and the removal ventral osteophyte of articular process was indicated by red circle in (D). MRI Magnetic Resonance Imaging.

There had some weakness in our study. Firstly, the sample size of our study is limit, the reason maybe relate to many patients are elderly, and they are unwilling to receive surgery. Secondly, the follow-up time was short. Thirdly, the case population is the elderly, and the limitation of the population also leads to the limitations of the study. The findings of the current study needed more longitudinal studies on the clinical effect of percutaneous transforaminal endoscopic TESSYS technology in treatment of patients with lumbar spinal stenosis.

In summary, Percutaneous transforaminal tessys is a safe and minimally invasive technique for the treatment of lumbar spinal stenosis in the elderly. Compared with traditional open surgery for posterior lumbar interbody fusion, percutaneous transforaminal endoscopic TESSYS technique has less trauma and does not damage the stability of the spine. It can significantly shorten the hospitalization and operation time, reduce intraoperative fluoroscopy and blood loss and reduce the degree of pain and postoperative complications. It is an effective and more advantageous scheme for the treatment of elderly lumbar spinal stenosis.

Disclosure of conflict of interest

None.

Address correspondence to: Zhaowei Wang, Department of Orthopedics, Laiyang Central Hospital of Yantai City, No. 111 Changshan Road, Laiyang 265200, Shandong, China. Tel: +86-13793587675; E-mail: lwangzw@163.com

References

[1] Schatlo B, Horanin M, Hernandez-Durán S, Solomiichuk V and Rohde V. Shape of the spinal canal is not associated with success rates of microsurgical unilateral laminotomy and bilateral decompression for lumbar spinal canal stenosis. World Neurosurg 2018; 116: e42-e47.

[2] Fujita N, Michikawa T, Miyamoto A, Sakurai A, Otaka Y, Suzuki S, Tsuji O, Nagoshi N, Okada E, Yagi M, Tsuji T, Kono H, Ishii K, Nakamura M, Matsumoto M and Watanabe K. Lumbar spinal surgery improves locomotive syndrome in elderly patients with lumbar spinal canal stenosis: a multicenter prospective study. J Orthop Sci 2020; 25: 213-218.

[3] Tanishima S, Fukada S, Ishii H, Dokai T, Morio Y and Nagashima H. Comparison between walking test and treadmill test for intermittent claudication associated with lumbar spinal canal stenosis. Eur Spine J 2015; 24: 327-32.

[4] Lawal YZ, Maitama MI, Ejagwulu FS and Lawal A. Open laminectomy for lumbar spinal canal stenosis due to prolapsed lumbar intervertebral discs. West Afr J Med 2019; 36: 83-87.

[5] Choi WS, Oh CH, Ji GY, Shin SC, Lee JB, Park DH and Cho TH. Spinal canal morphology and clinical outcomes of microsurgical bilateral decompression via a unilateral approach for lumbar spinal canal stenosis. Eur Spine J 2014; 23: 991-8.

[6] Wang Y, Dou QY, Yang J, Zhang LF, Yan YQ, Peng ZY, Guo C and Kong QQ. Percutaneous endoscopic lumbar decompression for lumbar lateral spinal canal stenosis: classification of lateral region of lumbar spinal canal and surgical approaches. World Neurosurg 2018; 119: e276-e283.

[7] Komatsu J, Muta T, Nagura N, Iwabuchi M, Fukuda H, Kaneko K and Shirado O. Tubular surgery with the assistance of endoscopic surgery via a paramedian or midline approach for lumbar spinal canal stenosis at the L4/5 level. J Orthop Surg (Hong Kong) 2018; 26: 46-52.

[8] Sun FL, Liang QC, Yan M, Wang HQ, Liu ZY, Li F, Dong J and Liu TJ. Unilateral laminectomy by endoscopy in central lumbar canal spinal stenosis: technical note and early outcomes. Spine (Phila Pa 1976) 2020; 45: E871-E877.

[9] Xiong CJ, Li T, Kang H, Hu H, Han J and Xu F. Early outcomes of 270-degree spinal canal decompression by using TESSYS-ISEE technique in patients with lumbar spinal stenosis combined with disk herniation. Eur Spine J 2019; 28: 78-86.

[10] Downie WW, Leatham PA, Rhind VM, Pickup ME and Wright V. The visual analogue scale in the assessment of grip strength. Ann Rheum Dis 1978; 37: 382-4.

[11] Daltroy LH, Cats-Baril WL, Katz JN, Fossel AH and Liang MH. The North American spine society lumbar spine outcome assessment Instrument: reliability and validity tests. Spine (Phila Pa 1976) 1996; 21: 741-9.

[12] Macnab I. Negative disc exploration. An analysis of the causes of nerve-root involvement in sixty-eight patients. J Bone Joint Surg Am 1971; 53: 891-903.

[13] Cook CJ, Cook CE, Reiman MP, Joshi AB, Richardson W and Garcia AN. Systematic review of diagnostic accuracy of patient history, clinical findings, and physical tests in the diagnosis of lumbar spinal stenosis. Eur Spine J 2020; 29: 93-112.

[14] Yüce İ, Kahyaoğlu O, Çavuşoğlu HA, Çavuşoğlu H and Aydın Y. Long-term clinical outcome and reoperation rate for microsurgical bilateral decompression via unilateral approach of lumbar spinal stenosis. World Neurosurg 2019; 125: e465-e472.

[15] Cheng XK and Chen B. Percutaneous transforaminal endoscopic decompression for geriatric patients with central spinal stenosis and degenerative lumbar spondylolisthesis: a novel surgical technique and clinical outcomes. Clin Interv Aging 2020; 15: 1213-1219.

[16] Song QP, Hai B, Zhao WK, Huang X, Liu KX, Zhu B and Liu XG. Full-endoscopic foraminotomy with a novel large endoscopic trephine for severe degenerative lumbar foraminal stenosis at l s level: an advanced surgical technique. Orthop Surg 2021; 13: 659-668.

[17] Li L, Chang F, Hai Y, Yang J, Xu C, Yuan J, Sun J, Wang Q, Ding S and Yang X. Clinical effect evaluation and correlation between preoperative imaging parameters and clinical effect of endoscopic Transforaminal decompression for lumbar spinal stenosis. BMC Musculoskelet Disord 2020; 21: 68.

[18] Hasan Saqib, McGrath Lynn B, Sen Rajeev D, Barber Jason K and Hofstetter Christoph P. Comparison of full-endoscopic and minimally invasive decompression for lumbar spinal stenosis in the setting of degenerative scoliosis and spondylolisthesis. Neurosurg Focus 2019; 46: E16.

[19] Lee CH, Choi M, Ryu DS, Choi I, Kim CH, Kim HS and Sohn MJ. Efficacy and safety of full-endoscopic decompression via interlaminar approach for central or lateral recess spinal stenosis of the lumbar spine: a meta-analysis. Spine (Phila Pa 1976) 2018; 43: 1756-1764.

[20] Youn MS, Shin JK, Goh TS, Son SM and Lee JS. Endoscopic posterior decompression under local anesthesia for degenerative lumbar spinal stenosis. J Neurosurg Spine 2018; 29: 661-666.