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*Original Article*

# Clinical outcomes of transarticular and lateral vertebral canal lumbar interbody fusion for lumbar spinal stenosis: a retrospective study of 124 cases

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**Abstract:** To explore the effectiveness and safety of transarticular and lateral vertebral canal lumbar interbody fusion (TLc-LIF) for the treatment of lumbar spinal stenosis. Clinical data from 124 patients with lumbar spinal stenosis who underwent transarticular and lateral vertebral canal lumbar interbody fusion operations from January 2011 to March 2014 were analyzed retrospectively. The operation duration, blood loss, and postoperative complications were recorded. The visual analog scale, Japanese Orthopedic Association score and Macnab criteria were used to evaluate the clinical efficacy. All patients were followed-up through outpatient review or telephone calls, and the mean follow-up interval was 36.2 months. The mean operative duration was 146.21±34.20 min. The mean blood loss was 496.85±114.74 ml. According to the Macnab scoring criteria, the clinical outcome was excellent in 69 patients (55.65%), good in 47 patients (37.90%), acceptable in 8 patients (6.45%), and worse in none of the patients. The rate of excellent or good patient outcomes was 93.55%. The score on the visual analog scale decreased significantly between pre-operative and post-operative measurements, and the Japanese orthopedic association score increased between the pre-operative stage and follow-up. The differences between pre- and postoperative scores for both scales were statistically significant ($P<0.05$). TLc-LIF has increased potential with broadly developing prospects; thus, it would be beneficial for these procedures to be applied on a more widespread basis due to their advantages in the treatment of lumbar spinal stenosis, including minimal trauma, decreased bleeding, and high satisfaction.

**Keywords:** Lumbar spinal stenosis, efficiency, safety, transarticular and lateral vertebral canal, lumbar interbody fusion

## Introduction

Symptoms such as intermittent claudication, low back and leg pain, and numbness that is caused by the oppression of related nerve roots or the cauda equina due to the degeneration of soft tissues and bone around the spinal canal are the main clinical manifestations of lumbar spinal stenosis [1]. As the population continues to age, the incidence of lumbar spinal stenosis is increasing, which has influenced the quality of life for middle-aged and older individuals. The current treatment programs, most patients benefit from conservative treatments. However, for patients who have received conservative treatments for more than six months, but have experienced a poor curative effect or who have a relatively long medical history and repeated symptoms, operative treatment is the most significant and effective intervention [2].

As biological materials and surgical procedures continue to undergo development, an increased number of lumbar spinal stenosis patients who have received conservative treatments have begun to seek operative treatment. Operative treatment has changed from an emphasis on the thoroughness of vertebral canal decompression to the improvement of quality of life and physiological function after the operation

**Table 1.** Patient demographics according to treatment group

| Groups | One level | Two levels | Three levels | Total |
|---|---|---|---|---|
| n | 45 | 53 | 26 | 124 |
| Sex (female/male) | 18/27 | 23/30 | 11/15 | 52/72 |
| Age at surgery (years) | 55.38±13.2 | 57.89±10.46 | 63.31±9.18 | 58.11±11.58 |
| Pain duration | | | | |
| <1 year | 11 | 13 | 3 | 27 |
| 1-3 years | 16 | 24 | 11 | 51 |
| >3 years | 18 | 16 | 12 | 46 |
| Other diseases | | | | |
| Hypertension | 15 | 18 | 7 | 40 |
| Diabetes | 7 | 9 | 3 | 19 |
| Cerebral infraction | 2 | 2 | 1 | 5 |
| Renal insufficiency | 1 | 2 | 1 | 4 |

Values are *number (%) or mean (range).*

[3]. Among the numerous methods that are used for surgical operation, posterior lumbar inter-body fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF) are the two most common methods for the treatment of lumbar spinal stenosis. Their clinical curative effect has been generally acknowledged by the field. However, as the number of operations increases and the follow-up time has become more prolonged, the application of these two surgical procedures has become controversial [4-6]. PLIF results in a high degree of trauma and increased bleeding, and its pressure relief position is internal. PLIF can also cause root symptoms postoperatively due to excessive stretching of the nerve root and spinal dura mater [7]. TLIF involves a small degree of trauma and minimal interference with the Canalis spineless. Its pressure relief position is exterior, which creates an increased probability of accessing the upper nerve root. Because some patients have clinical stenosis of the central spinal canal and nerve root canal, but the pressure relief range of the central spinal canal is inadequate, the application of TILF is partially restricted [8].

To determine the curative effect of lumbar interbody fusion and reduce the operation-related complications, we treated 124 lumbar spinal stenosis patients using transarticular and lateral vertebral canal lumbar interbody fusion (TLc-LIF) under the precondition of surgical proficiency of PLIF and TLIF according to the anatomical characteristics of the peripheral tissue of the spinal canal. Based on the retrospective analysis of the patients' clinical data, this operation was determined to be safe and effective, and it consequently provided guidance for clinical work.

## Material and methods

### *Patient population*

A total of 217 clinical cases were obtained from our hospital's electronic case system. These patients received TLc-LIF operations between January 2011 and March 2014. Among them, 93 patients were excluded due to incomplete clinical data. The clinical features and imaging results from 124 patients (72 males and 52 females) were consistent with the diagnostic criteria of LSS [9] established by the American Association of Spine Surgeons. All the patients were treated with normal conservative treatment for at least 6 months before their operation. The average age of patients was 58.11 years old, and the duration of the disease ranged from 2 to 144 months. Sixty-nine patients had other underlying diseases: 19 had diabetes mellitus, 40 had hypertension, 5 had cerebral infarction, 4 had renal insufficiency, and 9 patients had at least two underlying diseases. Before the operation, blood glucose, blood pressure, and other organ functions were monitored to determine the patient's response to surgery. Forty-five patients had single segmental spinal stenosis, 53 patients had double segmental lumbar canal stenosis, and 26 patients had triple spinal stenosis (**Table 1**). Patients with the following outcomes were excluded from this study: multiple causes of permanent disability, lesions caused by infectious disease, lumbar tumor accompanied by cervical and thoracic diseases leading to spinal cord or cauda equina lesions, serious medical diseases, lack of tolerance of surgery, and patients who could not attend scheduled appointments.

### *Surgical procedure*

The patients in this study underwent routine A-P and lateral plain film of lumbar vertebrae,

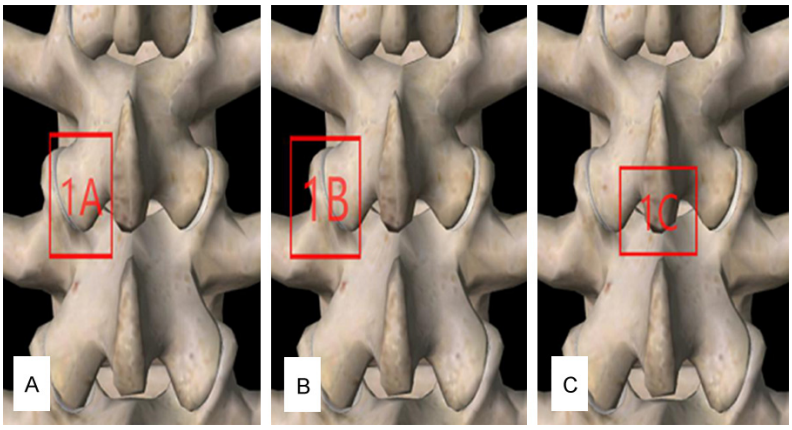


**Figure 1.** Diagram of TLc-LIF and common lumbar interbody fusion. (A-C) represent the procedures for TLc-LIF, TLIF, and PLIF, respectively.

hyperextension and hyperflexion on plain film, and lumbar spinal magnetic resonance. According to the patient's clinical manifestations, imaging findings, and the comprehensive judgment regarding the operative section, the appropriate implant materials were selected preoperatively. Preoperative education and skin preparation were performed by experienced nurses the day before the operation.

All surgeries were performed by the same experienced doctor. After general anesthesia, the patients were placed in a supine position, and the operative field was subjected to routine disinfection and covered by an aseptic wound towel. The following procedures were performed: a posterior median incision was made (retaining the ligamentum supraspinale and interspinalia), the flap along the two sides of the spinous process was removed by an electric knife, the symptomatic side of the lumbodorsal myofascial was incised, the paravertebral muscles to the edge of the articular process were removed, the intervertebral space was determined by X-ray, the lower extremity radicular symptoms (radicular symptoms of the lower limbs) due to unilateral or bilateral decompression were examined, the unilateral nerve root or bilateral nerve roots were decompressed depending on the status of the radicular symptoms of the lower limbs, the vertebral laminar soft tissue was cleaned with an electric knife, the articular process was exposed, the partial articular process was resected, the yellow ligament was resected to reveal the intervertebral foramen space in the operative field, part of the vertebral lamina was removed (the bone granule was retained for intervertebral fusion), the outer edge of the dura and the nerve root were exposed, the compression degree of the nerve root was examined, the presence or absence of prolapse of the nucleus pulposus in the nerve root canal or intraspinal canal was determined with a neural probe hook probe, and the nerve root tube along the nerve root was expanded by rongeurs if central spinal canal stenosis was observed. Then, the central spinal canal was expanded by undercutting decompression, the thick yellow ligament was excised to ensure that the central spinal canal was fully decompressed, and the dural sac and upper and lower nerve root were protected by laterally pulling the nerve root retractor toward the dural sac to expose the upper and the lower nerve root of the intervertebral disc in the safety triangle composed of the epidural space and the upper and lower nerve roots (via TLc-LIF) (**Figure 1**). The annulus fibrosis was incised with a sharp knife, and the protruded nucleus pulposus was removed using nucleus pulposus forceps. The intervertebral space was thoroughly cleaned by a reamer and a nucleus clamp, and the upper or lower vertebra endplate cartilage was cleaned using the endplate curette. The previously reserved bone was implanted into the intervertebral space as a bone graft. Then, the cage was filled with autogenous bone particles inserted into the intervertebral space, and the compression of the nerve root was evaluated. Next, the other intervertebral space, including the contralateral spinal canal and the nerve root canal was decompressed using the same method, but the fusion device was not inserted into the contralateral side. We determined whether the intervertebral fusion device was located in a satisfactory position by X-ray based on the following criteria: pedicle screws were fully inserted, previous bending rods were placed accurately after being temporarily fixed, and rod length and screw position were confirmed. After rotation and attachment of the

**Table 2.** Patient surgical data

| Groups | One level | Two levels | Three levels | Total |
|---|---|---|---|---|
| OR time (min) | 106.76±9.38 | 157.62±11.98 | 191.23±10.78 | 146.21±34.20 |
| EBL (ml) | 382.11±59.02 | 521.98±60.59 | 644.23±58.13 | 496.85±114.74 |
| Transfusion | | | | |
| n | 0 | 4 | 7 | 11 |
| Average volume (ml) | 0 | 377.78 | 514.29 | 440.0 |

*OR time* operative time, *EBL* estimated blood loss, Values are given as *mean (range) or number*.

**Table 3.** Major complications

| Groups | One level | Two levels | Three levels | Total |
|---|---|---|---|---|
| Incision infection | 1 | 1 | 3 | 5 |
| Urinary tract infection | None | 1 | 1 | 2 |
| Pulmonary infection | None | 1 | None | 1 |
| Cerebrospinal fluid leaks | None | 1 | 1 | 2 |
| Neurologic deficit | None | None | None | None |
| Pedicle screw malposition | None | 1 | 2 | 3 |
| Deep venous thrombosis | 1 | None | 1 | 2 |
| Total | 2 | 5 | 8 | 15 |

Values are given as *number*.

screw cap, the operative area was flushed with saline, the indwelling drainage tubes were placed on the two sides, and the incision was closed using layer suturing.

After the operation, the patients were treated with swelling and pain relief therapy and nerve nutrition therapy for 3-5 days. The drainage tubes were removed when the single tube drainage was less than 50 ml. The arrangements were reexamined in the A-P view using lateral plain film of the lumbar to verify the position of the nail, stick, and cage, and if the position was good, the patients were encouraged to begin walking using a wearable lumbar brace.

*Outcome measures and follow-up*

A total of 124 patients were monitored by telephone or outpatient follow-up, and the average follow-up time was 36.2 months (18-48 months). We recorded the operation duration, amount of bleeding, amount of transfused blood, and surgical complications. We used the visual analog scale (VAS) scoring system, the Japanese Orthopedic Association (JOA) score, and Macnab criteria to evaluate the improvement of postoperative symptoms and functional recovery.

*Ethics*

This study was performed under the guidance of relevant laws and regulations. Patients who did not sign informed consent forms were excluded from the study. This study was approved by the Guangxi Zhuang Autonomous Region People's Hospital Medical Ethics Committee.

*Statistical analysis*

The data obtained from this study were analyzed using the statistical software package SPSS 17.0. The original data regarding the operative time, amount of bleeding, and VAS and JOA scores were transformed into means and standard deviations. Normally distributed data were analyzed using a t-test, and non-normally distributed data were analyzed by a single factor analysis of variance. Enumeration data were analyzed with a chi-square test. We set the significance level as $\alpha=0.05$, and *P*-values <0.05 were considered statistically significant.

## Results

All patients successfully underwent surgery. The average operative duration was 146.21± 34.20 min. The amount of bleeding was within 496.85±114.74 ml. 11 patients required the blood transfusion, with an average of 440 ml of blood loss and resulting in a blood transfusion rate of 8.87% (**Table 2**).

Four patients (3.23%) experienced spinal dural injury and received silk thread sutures and autologous fascia repair. Two patients (1.61%) had cerebrospinal fluid leakage after the operation. Five cases (4.03%) of superficial infection occurred after the operation, including in 3 diabetic patients (2.42%), and these patients healed well after active anti-infection therapy and dressing changes. Among the cases of


**Figure 2.** Imaging data of a female patient with L4-S1 stenosis before and after treatment. (A and B) hyperextension and hyperflexion before the operation, (C and D) lumbar magnetic resonance imaging before the operation, (E and F) X-ray views of the lumbar region at 3 days and 2 years postoperatively.

**Table 4.** Outcome scores in the treatment groups

| Groups | One level | Two levels | Three levels | Total |
|---|---|---|---|---|
| VAS scores | | | | |
| Preoperative | 6.91±1.08 | 7.26±1.04 | 7.23±1.03 | 7.13±1.06 |
| Last follow-up | 0.93±0.76 | 1.11±0.78 | 1.31±0.93 | 1.07±0.82 |
| *P* value | <0.05 | <0.05 | <0.05 | <0.05 |
| JOA scores | | | | |
| Preoperative | 12.13±1.84 | 12.05±1.71 | 11.81±1.67 | 12.03±1.74 |
| Last follow-up | 24.29±1.75 | 23.83±1.89 | 23.92±1.60 | 24.02±1.78 |
| *P* value | <0.05 | <0.05 | <0.05 | <0.05 |
| Macnab scores | | | | |
| Excellent | 27 (60.00%) | 28 (52.83%) | 14 (53.85%) | 69 (55.65%) |
| Good | 16 (35.56%) | 21 (39.62%) | 10 (34.61%) | 47 (37.90%) |
| Acceptable | 2 (4.44%) | 4 (7.55%) | 2 (7.69%) | 8 (6.45%) |
| Worse | None | None | None | None |

Values are given as *mean (standard error of mean) or number*.

organ/space infection, 2 patients (1.61%) had urinary tract infections, and one patient (0.81%) had a pulmonary infection. Additionally, 2 patients (1.61%) had deep venous thrombosis that occurred in the one and three levels according to a B ultrasound examination of the lower extremity vasculature, but the patients were asymptomatic. All patients were treated based on guidance from a relevant specialist. In 3 cases (2.42%), the pedicle screw was not positioned well. However, no pedicle screw breakage, loosening, or rejection of the artificial implant were observed in the latest follow-up (**Table 3**; **Figure 2**).

Seven patients (5.65%) retained some root symptoms after the operation, but they could live and work normally. Compared to the previous condition of patients, anesthesia and pain were increased in one patient (0.81%), but they were noticeably decreased within 6 days after the swelling and pain were relieved.

The VAS scale and JOA scores in the latest follow-up were significantly different (P<0.05) from the preoperative VAS scale and JOA scores, respectively. According to the Macnab scoring criteria, the clinical outcome was excellent in 69 patients (55.65%), good in 47 patients (37.90%), acceptable in 8 patients (6.45%), and worse in none of the patients. The rate of excellent or good outcomes was 93.55% (**Table 4**).

## Discussion

Lumbar fusion is currently the most commonly used surgical method for the treatment of lumbar spinal stenosis, and its clinical use continues to increase every year [10]. However, concerns regarding the curative effect and safety of the operation have exposed the problematic aspects of lumbar fusion. A period of development and creativity has resulted from addressing these issues. TLc-LIF was named after its unique decompression position. To the best of our knowledge, this manuscript presents the application value of TLc-LIF for the treatment of lumbar spinal stenosis.

For patients, the remission of symptoms after surgery can improve their quality of life, which increases their trust in their doctor and consequently plays a significant role in their further treatment and recovery. The TLc-LIF procedure relieves pain due to the following reasons. (1) The operation's safe decompression position causes minimal injury to the nerve root and endorhachis, which is a unique advantage of relieving the stenosis of the nerve root and the central canal. Due to this advantage, patients have reduced nerve symptoms after the operation, and the favorable surgical outcome rate was high, although it was different from the 80% satisfaction rate of the PLIF operation [11]. (2) The regression of lumbar zygapophyses controlled by the posterior branch of the spinal nerve is one of the etiologies of chronic low back pain. In TLc-LIF, to decompress the nerve root, the inferior articular process is severed, which injures the posterior medial branch. It also reduces the probability of minor arthritis of the upper back. In addition, to maintain lumbar stability, TLc-LIF retains the integrity of more posterior structures such as the ligamentum supraspinale and the spinous process, and it causes less damage to the normal anatomical structure, which can ensure early activity and the functional recovery of the lumbar dorsal muscle after the operation. It causes minimal disruption to the canalis spinalis, which avoids the occurrence of intradural adhesion observed after PLIF [12]. These advantages reduce the lumbar pain to some extent and help maintain the curative effect of the operation.

The amount of bleeding is one of the effective indices of the clinical safety of an operation. Some studies have shown that for non-cardiac surgery patients, the incidence of complications and mortality will increase if the amount of bleeding surpasses 500 ml [13]. Because lumbar spinal stenosis patients are mostly comprised of middle-aged and older individuals whose physical functions are naturally declining, a high amount of bleeding is more harmful for than in younger individuals [14]. The lack of blood products has created a crisis for clinical blood use. These factors have influenced the decisions of spinal surgeons to adopt measures to reduce the use of blood during operations. It has been shown that certain risk factors influence the amount of bleeding, including the operative method and number of fusion segments [15, 16]. Among the operative methods, TLIF has been reported to not cause a large amount of bleeding [17]. In our study, as the number of fusion segments increased, the amount of bleeding and the blood transfusion rate also increased. However, in most cases, TLc-LIF requires unilateral vertebral canal decompression, and it results in less severe trauma. Decompression, fusion, and the placement of screws on the symptomatic side can reduce the duration of exposure to muscle stripping. Based on these factors, it has been determined that the amount of bleeding and the blood transfusion rate are lower than those in the same segments during PLIF and TLIF.

TLc-LIF uses a posterior midline approach, and the incision length is similar to that of PLIF and TLIF. When only considering the influence of the length of the incision on the healing of the incision, the operations have a similar risk of abnormal incision healing. Currently, differences exist among the reports of abnormal incision healing rates after lumbar spinal fusion. Okuyama et al [18] conducted a clinical research study of 148 patients who underwent PLIF, and they showed that the rate of abnormal incision healing was 3.4%. Goz et al [19] reported that the rate of abnormal incision healing was 0.43% in the PLIF/TLIF operation. In the current study, abnormal incision healing occurred in 5 patients due to superficial infection, and organ/space infection occurred in 3 patients. An analysis of the factors that influence infection indicated that the age of the patients, underlying diseases, and multiple segmental fusion were the main factors. For older patients with low resistance, prolonging the treatment courses of prophylactic antibiotics and strengthening

the management of the surgical incision and body resistance was required to reduce the risk of infection after the operation.

Endorhachis and nerve root injury are serious complications in posterior lumbar surgery. Both occur in TLIF and PLIF, and they result in a certain degree of injury. According to the fatality and pathogenicity rate database of the Scoliosis Research Society, the rate of dural tear is 2.0% [20]. Some studies have shown that the rate of cerebrospinal fluid leakage in lumbar operations is 1-17.4% [21], while the rate of nerve root injury after the operation is 1.5-4.0%, which occurs mostly after PLIF [22]. Nerve root injury occasionally occurs after TLIF [23]. In the present study, 2 cases of endorhachis and no cases of nerve root injury occurred. We hypothesize that these findings are closely related to the decompression position of TLc-LIF. The working area of TLc-LIF is between the area manipulated during TLIF and PLIF, and this position can be accessed by removing the vertebral lamina and bony structure of the inferior articular process without destroying the ligamentum supraspinale, spinous process, and other posterior midline structures. The process of precise decompression of the symptomatic nerve root not only removes oppression of the nerve root, but it also moves the responsible structure in an outward direction, which reduces the pull on the nerve root and endorhachis. Moreover, maintenance of the integrity of the rear structure can avoid disturbing the asymptomatic lateral nerve root.

Although TLc-LIF has its own unique advantages, the procedure still requires improvement. (1) The results of this study are only applicable to lumbar spinal stenosis patients, and not patients with other lumbar degenerative diseases, although TLc-LIF could also have beneficial effects for these patients. However, we still suggest that less experienced surgeons can perform surgery on lumbar spinal stenosis patients. (2) Each operative method has a distinct learning curve. Although TLc-LIF is an improvement over the PLIF and TLIF procedures, less experienced surgeons could have difficulty in locating the decompression position and require constant advice or guidance from more experienced surgeons.

This study has certain limitations. First, it is a retrospective study of current cases obtained from databases. The limited sample size is based on the number of cases. Due to the short duration of the implementation of this method and the poor compliance of some patients, we did not obtain mid- and long-term follow-up data to analyze the mid- and long-term effectiveness and complications of this method. Based on these factors, we concluded that the data shown above indicate that the advantages of TLc-LIF include its safety and minimal short-term harmful effects when treating lumbar spinal stenosis patients, but it requires further quality improvement and studies conducted using large sample sizes and long-term patient follow-up.

In the TLc-LIF process, the decompression position is safe, and the posterior structures are only minimally disrupted. TLc-LIF can not only relieve the repression of the upper and inferior nerve roots and the central canal but can also relieve the discomfort of patients and effectively reduce the nerve root and endorhachis damage. It also has a particular advantage in reducing the amount of bleeding and the blood transfusion rate.

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## Disclosure of conflict of interest

None.

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