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Original Article

Bilateral transformational thoracolumbar interbody fusion for the treatment of giant central thoracolumbar junction disc herniation: A prospective clinical and radiological study

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ABSTRACT

Study design: Clinical and radiological assessment of prospective single-center data.

Background: The optimal treatment strategy for giant central thoracolumbar junction disc herniation (TLDH) remains controversial.

Objective: This study aimed to report the clinical and radiological results of bilateral transformational thoracolumbar interbody fusion (bilateral TTIF) to treat giant central TLDH. **Methods:** Seventeen consecutive patients with giant central TLDH underwent bilateral TTIF from January 2014 to June 2014 and were followed for 9–15 months. Clinical and radiological data were prospectively examined, including operative time, blood loss, pre- and postoperative American Spinal Injury Association (ASIA) score for sensory and motor function, visual analog scale (VAS) and Oswestry Disability Index (ODI) scores, fusion rate, extent of decompression, rate of instrumentation failure, and complications.

Results: The average time of surgery was 160 ± 37 min, and blood loss was 884 ± 197 ml. The ASIA sensory and motor scores improved from 72.76 ± 3.36 to 90.71 ± 2.54 and from 68.47 ± 4.7 to 88.0 ± 3.2 , respectively. VAS for back pain and ODI decreased from 6.65 ± 1.93 to 2.23 ± 0.56 and from 42.82 ± 5.08 to 11.3 ± 2.3 , respectively. Canal encroachment improved from $50.3 \pm 6.6\%$ to $2 \pm 0.3\%$ at the last follow-up. Surgery complications were seen in 5 patients (29%), who experienced intraoperative dural tear and cerebrospinal fluid leak. There were no other major complications at the last follow-up.

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Conclusions: Bilateral TTIF produced satisfactory outcomes and may be one of the surgical treatments of choice for myelopathy due to giant central TLDH.

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1. Introduction

Disc herniations at the thoracolumbar junction (T11–12, T12–L1, L1–L2 levels) constitute no more than 5% of all lumbar disc herniations.^{1,2} The main symptoms of this disorder are neurological deficits and high rates of disability.³ Several approaches have been developed to treat thoracic disc herniations, including posterolateral variants; lateral extra-cavitary, transthoracic, and thoroscopic approaches; and a posterior midline incision.^{4,5} The optimal treatment strategy for giant central thoracolumbar junction disc herniation (TLDH) remains controversial.

Transformational thoracolumbar interbody fusion (TTIF),⁶ which has become widely used as a minimally invasive surgery in recent years, allows circumspinal decompression and safe interbody fusion using a single, posterior approach to reconstruct thoracic and thoracolumbar junction spine lesions associated with neurological deficits. To our knowledge, no study on the treatment of thoracolumbar junction disc herniation using bilateral TTIF has been published previously. At our institution, we have treated 17 patients with giant central TLDH using bilateral TTIF. Here, we report their preliminary clinical and radiological outcomes. The purpose of this study was to assess the efficacy and safety of the procedure. Particular attention was paid to surgical complications, improvement in neurological function, and postoperative back pain.

2. Materials and methods

2.1. Study design

This investigation was designed as a prospective clinical and radiological study and conducted at a single center. The study protocol was approved by the Ethics Committee of the Honghui Hospital Affiliated to Xi'an Jiaotong University; its ChiCTR number is ChiCTR-ONC-14004348. Written informed consent was obtained from each participant before the start of the trial.

2.2. Study population

Consecutive patients who were brought to our center with giant central TLDH from January 2014 to June 2014 were considered for enrollment. Seventeen patients met the inclusion criteria and consented to participate in this study. The inclusion criteria were as follows: symptomatic thoracolumbar disc herniation from T11–12 to L1–2 due to medullary or caudal equina syndrome. Patients were excluded from the study if they had a history of previous surgery on the same spinal level, significant spondylosis or ossification of the

ligamentum flavum, thoracic instability without neural compression, spinal fracture, scoliotic deformity, tumor, or infection.

On admission, disc herniation was diagnosed in all patients by means of magnetic resonance imaging (MRI), computerized tomography (CT), or both to determine the levels that required decompression and measure the extent of canal encroachment. The herniation was classified as central type when the bulk of the herniation was against the midline of the thecal sac. Giant herniated thoracic disc was defined as occupying more than 40% of the spinal canal of the spinal cord based on CT and/or MRI.⁷ Preoperative CT scans were assessed to evaluate calcification, which was also confirmed as an intraoperative finding during the operation. Upright flexion–extension radiographs were used to assess dynamic instability. Motor evoked potentials (MEP) and somatosensory evoked potentials (SSEP) were monitored intraoperatively to determine the degree of medullary dysfunction.

2.3. Surgical technique

The patients were induced under general anesthesia and placed on the surgical table in the prone position with the abdomen suspended in midair. The posterior elements were exposed through a standard midline posterior approach; the tips of transverse processes of the fused levels were carefully performed up; bilateral pedicle screws were inserted at the segments of decompression, the rod was contoured and set into the screw head, and the locking plugs were tightened on one side to achieve interim stability. The laminectomy was performed using an electric grinder, and the entire inferior articular process and superior portion of the superior articular process were resected from lateral to medial aspects of the intervertebral foramina using an osteotome and Kerrison rongeurs on one side in order to gain sufficient exposure of the discs and avoid retraction of the dural sac. To prevent the lamina edge from pinching the spinal cord, epidural venous plexus and vessels accompanying the exiting nerve root were coagulated carefully, and the exiting nerve root was identified and protected with a small piece of cotton. A discectomy was performed using instrumentation including curettes, small-angled Kerrison rongeurs, pituitary rongeurs, rasps, and Kerrison rongeurs without retraction of the dural sac. In creating space between the lateral side of the dural sac and pedicles, care was taken to prevent compression or injury to the cranial wad of soft tissue containing the exiting nerve root. When this decompression step had been performed, a rod was set into the screw heads on the side for interim stability. The rod on the other side was taken down, and the same surgical procedure was repeated. Interbody distractors were introduced in the disc space. Autologous bone graft obtained from the removed facet and lamina was packed in the anterior disc

Fig. 1 – Illustrative patient. (A) Preoperative coronal MRI of a 57-year-old woman showing herniated disc at the T12-L1 level (arrow). (B) Sagittal MRI T2-weighted showing spinal canal narrowing of 51%. (C) Postoperative coronal CT reconstruction at 13-month follow-up showing bony union across the disc space and the removal of the entire inferior articular process and superior portion of the superior articular process. (D) Sagittal MRI scan showing spinal canal narrowing of only 2%.

space, or a single PEEK cage was inserted obliquely across the disc space. Then bilateral rods were set into the screw heads, and the locking plugs were tightened. Compression force was applied to correct the local kyphosis (Fig. 1A, B).

If the disc was calcified or longitudinal ligament ossification was observed, which was continuous with the adjacent vertebrae and resembled a “hard shell”, a neural dissector was inserted into the gap between the “hard shell” and the dural sac. In order to resect the calcified herniated discs safely, we carefully separated the adhesion, used an osteostome and disc rongeurs gently, and through interactive manipulation knocked the “hard shell” off of the vertebra from an angle parallel to the horizon and pulled it down into the interbody space before its final removal. Decompression was performed until no residual compression was noted. If adhesions to the dura mater were difficult to separate, the “hard shell” was cut very thin and allowed to float away from the dural sac without removal (Fig. 2E, F).

2.4. Clinical and radiological evaluation

Operative time and intraoperative blood loss were recorded. In addition to radiographic analysis, there was postoperative

follow-up evaluation by telephone interview with the first author of this study and a visit to the outpatient clinic. Back and leg pain was quantified by visual analog scale (VAS) and Oswestry Disability Index (ODI) scores were collected from the patients preoperatively and at last follow-up. The percentage of neurological recovery was determined by evaluation of American Spinal Injury Association (ASIA) score for sensory and motor function. Postoperative radiological evaluation included anteroposterior and lateral plain radiographs, CT scans, and MRI. Fusion rates were assessed by an independent radiologist using reconstruction CT scans at last follow-up. Fusion was confirmed by the observation of trabecular bone bridging on the fusion surfaces on both the sagittal and coronary positions when no instrumentation breakage was present.

2.5. Statistical analysis

Continuous variables are reported as mean and standard deviation. Student's *t*-test was used for the comparison of continuous variables, and *p* values below 0.01 were accepted as significant.

Fig. 2 – Illustrative patient. (A) Preoperative coronal CT of a 24-year-old man showing herniated disc at the T12-L1/L1-L2 level with longitudinal ligament ossification. (B) Sagittal CT showing spinal canal narrowing of 59%. (C) Postoperative coronal CT reconstruction at 12-month follow-up showing bony union across the disc space and removal of the entire inferior articular process and superior portion of the superior articular process. (D) Sagittal CT scan showing spinal canal narrowing of 1.7%.

3. Results

The study included 17 patients (seven men and ten women) with 18 giant central TLDH. Their mean age was 44 ± 9.3 years (range, 24–62 years). All patients presented with back pain ($n = 17$ [100%]) and varying degrees of radiating pain ($n = 13$ [76%]), leg numbness ($n = 5$ [30%]), motor or sensory deficit ($n = 13$ [76.5%]), knee reflex change ($n = 9$ [53%]), or positive femoral stretch test ($n = 14$ [82%]). No sphincter dysfunction occurred in this series. Fusion levels included T11-T12 in four (24%) patients, T12-L1 in seven (41%) patients, L1-L2 in five patients (29%), and T12-L1/L1-L2 in one patient (6%). The patients' demographic characteristics and the procedures performed are listed in Table 1

The study included seven patients with calcification or longitudinal ligament ossification and ten patients without calcification. The average operative time was 160 ± 37 min (range 120–220 min), and the estimated blood loss was 884 ± 197 ml (range 610–1300 ml). In the patient who had two calcified disc herniations (T12-L1/L1-L2), operation time and blood loss were 1300 min and 220 min, respectively.

All patients underwent follow-up, and the mean follow-up time was 13.4 months (range, 9–15 months). At the time of last follow-up, the ASIA sensory and motor scores improved from 72.76 ± 13.36 to 90.71 ± 12.54 and from 68.47 ± 14.7 to 88.0 ± 13.2 , respectively. Two patients developed postoperative transient deterioration of leg numbness. There were no cases of neurological worsening. The VAS for back pain and ODI decreased from 6.65 ± 1.93 to 2.23 ± 0.56 and from 42.82 ± 5.08 to 11.3 ± 2.3 , respectively. The differences in these preoperative and postoperative outcome variables were

Table 1 – Demographic data and clinical presentation of 17 patients who underwent bilateral TTIF.

Patients (n)	17 patients with 18 giant central TLDH
Mean age $\pm$ standard deviation (years)	44 ± 9.3
Male:female (% male)	7:10 (41%)
Symptoms and signs [n (%)]	
Back pain	17 (100%)
Radicular pain	13 (76%)
Leg numbness	5 (30%)
Motor or sensory deficit	13 (76.5%)
Knee reflex change	9 (53%)
Positive femoral stretch test	14 (82%)
Level of fusion [n (%)]	18 (100%)
T11-T12	4 (24%)
T12-L1	7 (41%)
L1-L2	5 (29%)
T12-L1/L1-L2	1 (6%)
Calcified:uncalcified	7:10
Blood loss (ml)	884 ± 197
Operation time (min)	160 ± 37
Surgery complications	
Dural tear and CSFL	5 (29%)
Transient deterioration of leg numbness	2 (12%)

Table 2 – Preoperative and postoperative canal encroachment, VAS, ODI, and ASIA sensory and motor scores.

	Preoperative index	Postoperative index
Patients (n)	17	17
Canal encroachment (%), mean $\pm$ SD	50.3 ± 6.6	$2 \pm 0.3^*$
VAS, mean $\pm$ SD	6.65 ± 1.93	$2.23 \pm 0.56^*$
ODI, mean $\pm$ SD	42.82 ± 5.08	$11.3 \pm 2.3^*$
ASIA sensory, mean $\pm$ SD	72.76 ± 13.36	$90.71 \pm 12.54^*$
ASIA motor, mean $\pm$ SD	68.47 ± 14.7	$88.0 \pm 13.2^*$

ODI, Oswestry Disability Index; VAS, visual analog scale; ASIA, American Spinal Injury Association; SD, standard deviation.

* $p < 0.01$.

statistically significant (all $p < 0.01$). The preoperative and postoperative clinical outcomes are shown in Table 2.

Canal encroachment of the spinal canal at the level of the herniation was measured in all 17 patients using the axial CT or MRI scans and expressed as a percentage of the area of the adjacent intact vertebra. These values improved from $50.3 \pm 6.6\%$ (range: 42–64%) to $2 \pm 0.3\%$ (range: 0–3%) at the last follow-up. At the final follow-up, there were no cases of instrumentation failure, kyphosis, or collapse at the discectomy site, clinically or radiologically. All 17 patients showed bridging fusion, and the postoperative fusion rate was 100% (Figs. 1C, D and 2G, H).

Surgery complications were observed in 5 patients (29%) who experienced intraoperative dural tear and cerebrospinal fluid (CSF) leaks, which were treated with dura mater repair and a lumbar drain for 72 h. No wound infection or deep venous thromboembolism of the leg occurred. All complications resolved uneventfully.

4. Discussion

The optimal treatment of giant central TLDH remains controversial, and it continues to present a surgical challenge due to its lower incidence than herniations in the cervical or lumbar spine. The incidence of giant central TLDH, defined as only T11-T12, T12-L1, and L1-L2, comprises approximately 1–2% of all herniated lumbar discs.¹ Several approaches have been reported in the literature to treat giant central TLDH. There is no gold standard, and each technique has unique advantages and disadvantages.^{8–10} Our objective was to describe our surgical approach and management strategy in dealing with patients with a giant central TLDH.

Operations at this level are especially problematic because they might injure the spinal cord or conus medullaris, causing upper motor neuron signs, bowel and bladder dysfunction, and an array of lower motor neuron signs.¹¹ Thus, selecting an appropriate surgical approach for the removal of giant central TLDH is important. The anterior surgical approach is effective in decompressing the central and calcified TDH with the presence of osteophytes, and transthoracic approaches have particularly been favored in central, giant, and calcified TDH due to their greater safety in achieving ventral spinal cord decompression.

However, the procedures have a variety of limitations, especially in cases of chest disease and decreased respiratory function.^{12,7,13} Although various posterior approaches have been developed, including partial hemilaminectomy with medial facetectomy or minimally invasive transforaminal interbody fusion, decompressing the central herniation, with or without osteophytes, remains a challenge.²

A new transforaminal thoracic reconstruction technique has been reported by Machino et al.⁶ in which a unilateral facetectomy and laminectomy combined with an anterior decompression and interbody fusion is performed. Machino et al. reported that TTIF enables posterior decompression, unilateral anterior decompression (total 270° decompression), interbody fusion reconstruction of the anterior middle column from the transforaminal zone, and posterior fixation with a pedicle screw system, which is highly effective for decompression. However, application of TTIF for patients with central-type disc herniation is difficult and unsafe for achieving decompression because the spinal canals are narrower and giant central disc herniation involves anterior midline compression. Therefore, we applied a bilateral TTIF.

Through bilateral resection of the entire inferior articular process and superior portion of the superior articular process, this procedure provides an adequate and wide working space with safe, 360° circumspinal decompression under direct view of the surgeon throughout the discectomy process. The disc was reached through a bilateral far-lateral approach and resected by interactive, collaborative manipulation on both sides. Even in the case of central lesions with or without calcification, the thecal sac, traversing root, exiting root, and disc space can be easily visualized. This method ensures effective decompression and safe placement of the bone graft and cage without excessive retraction of the neural structures. In our study, all patients obtained satisfactory functional restoration and recovery through circumspinal decompression, with spinal canal narrowing, as measured on CT or MRI, improved from $50.3 \pm 6.6\%$ to $2 \pm 0.3\%$, and ASIA sensory and motor scores improved from 72.76 ± 3.36 to 90.71 ± 2.54 and from 68.47 ± 4.7 to 88.0 ± 3.2 , respectively (all $p < 0.01$). There were no cases of neurological worsening, and no postoperative neurological deficits were evident in the present series.

Zhao et al.¹⁴ performed transforaminal lumbar intervertebral fusion to treat thoracolumbar disc herniation and found it to be anatomically simple, visually distinct, relatively safe, reliable, and efficacious, but they did not provide a detailed description of the procedure for giant central thoracolumbar junction disc herniation. Ryoji et al.¹⁵ performed posterior thoracic interbody fusion by bilateral total facetectomies with pedicle screw fixation for thoracic disc herniation and observed satisfactory outcomes. This procedure is similar to the BTTIF described here, in that bilateral total facetectomies were used. However, these authors did not describe the removal of calcified herniation and osteophytes.

Using bilateral TTIF with the anatomically simple surgical approach, the rate of complications, blood loss, and operation time were low. The average operation time was 160 ± 37 min (range 120–220 min), and the estimated blood loss was 884 ± 197 ml (range 610–1300 ml). In the patient who had two calcified disc herniations (T12-L1/L1-L2), operation time and blood loss were 1300 ml and 220 min, respectively.

Additionally, only 5 patients (29%) experienced intraoperative dural tear and CSF leaks. Interbody fusion and internal fixation with the pedicle screw system allow early rehabilitation training of the patients, and thus reducing the risk of the complications of long-term bed rest; in our study, there were no postoperative complications, such as wound infection or deep venous thromboembolism in the leg. Furthermore, in cases of calcification or longitudinal ligament ossification, the central portion of the disc was first cut off at its base rather than at its peak, which directly compressed the cord.

By contrast, the circumspinal approach involves extensive excision of posterior structures, including bilateral facet joints and the posterolateral annular fibrosus of the disc, resulting in the circumspinal destruction of segmental structures and increased risk of postoperative spinal instability. Therefore, interbody fusion and posterior instrumentation are necessary to prevent kyphosis aggravation, correct kyphosis, and provide pain relief due to spinal instability. In our series, the autologous bone graft obtained from the removed facet, and lamina or PEEK cage was inserted obliquely across the disc space, combined with posterior instrumentation implanted to obtain firm interfusion and kyphosis correction. Postoperative imaging revealed the spinal cord to be unobstructed posteriorly; no instability of the spine or loosening or breakage of the internal fixation was noted. The VAS for back pain and ODI significantly decreased from 6.65 ± 1.93 to 2.23 ± 0.56 and from 42.82 ± 5.08 to 11.3 ± 2.3 , respectively (both $p < 0.01$).

Patients with thoracic disc herniations have a reported calcification or longitudinal ligament ossification rate of 30–70%. Choi et al.¹⁶ reported on the technical aspects of the transdural approach to calcified central disc herniations of the upper lumbar spine and identified some risks of neural injury and persistent CSF leakage. To our knowledge, if the patient is tilted more obliquely, even the central calcified portion of the disc or longitudinal ligament ossification can be easily viewed, and the herniated central mass can be removed without excessive neural retraction. Among the patients with calcification, 3 (43%) experienced intraoperative dural tear and CSF leaks, which were treated with dura mater repair and a lumbar drain for 72 h and resolved uneventfully.¹⁷

The present study has some limitations. First, it is prospective clinical outcomes achieved during a short follow-up period without consideration of psychosocial factors. A prospective trial comparing this method and other types of procedures in which patients are randomized to study groups with long-term follow-up periods would provide more definitive answers.

This preliminary clinical study demonstrated that the bilateral TTIF enabled circumspinal decompression; the procedure is effective and safe that may be particularly well-suited for the treatment of giant central TLDH. However, it must be recognized that circumspinal decompression necessitates a major destructive procedure. Long-term follow-up studies are needed to further justify its use.

Conflicts of interest

The authors have none to declare.

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