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Original Investigation

A Modified Jaslow-Transforaminal Lumbar Interbody Fusion for the Treatment of Isthmic Spondylolisthesis

ChaoJiang YU¹, Xiao GAO¹, Kai HUANG¹, BuQing CHANG¹, Hu FENG¹, Jie ZHAO²

¹The Affiliated Hospital of Xuzhou Medical University, Department of Orthopedics, Xuzhou, China

²Ninth People's Hospital, Shanghai Jiaotong University, Department of Orthopedics, Shanghai, China

ABSTRACT

AIM: To describe a modified Jaslow-transforaminal lumbar interbody fusion (TLIF) technique for the treatment of single-level, isthmic spondylolisthesis (IS).

MATERIAL and METHODS: Between April 2011 and September 2012, 32 patients with IS undergoing a modified Jaslow-TLIF were retrospectively reviewed. The intervertebral space height (IH), vertebral slippage ratio, lordotic angles of the treated segments (SA) and lumbar lordotic angles (LA) were measured and the scores by Visual Analogue Scale (VAS), Oswestry Disability Index (ODI) and Japanese Orthopaedic Association (JOA) were recorded.

RESULTS: An average follow-up duration of over 2 years was available. The average slippage percentage was $17.8 \pm 4.3\%$ preoperatively, $5.3 \pm 2.4\%$ postoperatively, and $5.4 \pm 2.5\%$ at the last follow-up. The average IH was 7.7 ± 1.9 mm preoperatively, 10.3 ± 1.6 mm postoperatively, and 10.2 ± 1.5 mm at the final follow-up. The average SA and LA were, respectively, $11.7 \pm 5.8^\circ$ and $49.1 \pm 13.9^\circ$ preoperatively, $13.5 \pm 5.7^\circ$ and $48.3 \pm 9.4^\circ$ postoperatively, and $13.2 \pm 5.3^\circ$ and $47.7 \pm 8.8^\circ$ at the last follow-up. The mean VAS was ameliorated from 7.7 ± 0.6 to 2.4 ± 0.5 , ODI from $49.6 \pm 1.6\%$ to $10.5 \pm 1.3\%$, and JOA from 10.8 ± 1.3 to 26.6 ± 1.0 , at the last follow-up. All patients had clinical and radiographic evidence of solid fusion without any need for revision.

CONCLUSION: The modified Jaslow-TLIF technique for the treatment of IS was advantageous for greater safety and efficacy.

KEYWORDS: Insert-and-rotate technique, Isthmic spondylolisthesis, Modified Jaslow technique, Transforaminal lumbar interbody fusion

INTRODUCTION

Isthmic spondylolisthesis (IS) is a common cause of low back pain and leg pain, for which surgery is the optimum option in the case of conservative therapy failure or aggravated disease as well as progressive neurological deficits (9,12). Surgery for IS involves neurological decompression and sagittal spinal balance reconstruction, with reversal of the lumbosacral deformity achieved by reduction maneuvers. A number of surgical techniques can reportedly achieve reduction of lumbar IS (10,15,22,24,27,36,37). The insert-and-rotate posterior lumbar interbody fusion (PLIF) technique, which employed autogenous spinous process, was first

described by Jaslow in 1946 (16). Sears (36) first reported the application of this technique in the treatment of IS, with satisfactory clinical outcomes. Thereafter, a modified PLIF technique to transforaminal lumbar interbody fusion (TLIF) technique, which has been applied as an alternative technique for surgical treatment of lumbar degenerative diseases (13,44).

However, there is a paucity of reports on the outcomes of the insert and-rotate TLIF technique for the treatment of IS. In addition, no rigid criterion with respect to the distraction of interbody space is available, and most of the *de facto* operations could only be performed by the most experienced orthopedists, which greatly hampers the generalization of this



Corresponding author: Hu FENG

E-mail: xzfeng_hu@126.com

technique. Recently, we modified the Jaslow technique to reduce the slippage of vertebrae combined with TLIF in the surgery for IS. We aimed to investigate the efficacy and safety of this reduction technique in IS in adults.

■ MATERIAL and METHODS

Patients

We retrospectively reviewed data from 32 selected patients, who had been surgically treated for IS in our hospital between April 2011 and September 2012. The inclusion criteria were as follows:

- (1) IS of grade I or II
- (2) Persistent or recurrent low back pain or leg pain lasting at least 6 months before operation with no benefits from conservative treatment over 3 months.

We excluded patients with osteoporosis, diabetes mellitus, symptomatic vascular diseases, active infection, tumor, IS of Grade II or greater, or clinical data deficiency. The protocol was approved by the Institutional Ethics Review Board and conducted in accordance with the provisions of the Declaration of Helsinki, with written informed consents provided by all the patients or their legal representatives.

Clinical and Radiological Evaluation

Clinical status of each patient was evaluated with the Visual Analogue Scale (VAS), Oswestry Disability Index (ODI) and Japanese Orthopedic Association (JOA) preoperatively and at the last follow-up. Functional improvement was expressed as the recovery rate by JOA (30). In addition, surgery duration, intra-operative blood loss and perioperative complications were also recorded. Subjective satisfaction outcomes were evaluated with a five-score scale (excellent, good, fair, unchanged, worse) (7). Radiologic assessments were performed with the assistance of lateral plain radiographs preoperatively, postoperatively and at the last follow-up. The intervertebral space height (IH), the ratio of vertebral slippage, lordotic angles of the treated segments (SA) and lumbar lordosis angles (LA) were assessed using plain lateral radiographs prior and subsequent to surgery, and at the last follow-up (Figure 1). Additionally, osseous fusion was confirmed by the following criteria (8):

- (1) The presence of continuous trabeculation and bone bridging between cage and vertebral endplates shown by lateral X-ray photography.
- (2) The absence of a radiolucent line between the graft and endplates.
- (3) The absence of angular motion of greater than 5° and anteroposterior motion of over 3 mm at dynamic lateral lumbar radiograms at the fused levels.

Surgical Technique

Under general anesthesia, the patient was placed in a prone position on the Wilson frame. With bilateral vertebral lamina and articular process exposed, pedicle screws were

placed. Subsequent to the floating total laminectomy and neuroradicular decompression, a preflexed short segmental rod was applied to stabilize the unilateral pedicle screw, with the upper screw nut semi-mobile and the hypogynous screw nut fastened to the fixed jaw (Figure 2A). A trial spacer of the smallest size was then advanced into intervertebral space and rotated by 90 degrees (Figure 2B,C), followed by the fixation of upper screw nut to achieve intervertebral distraction (Figure 2D). With the pedicle screw instrumentation locked in place, the nucleus pulposus and cartilaginous end plates were removed (Figure 2E). With the upper screw nut released (Figure 2F), the intervertebral space was expanded with another spacer of a larger size (Figure 2G).

The criteria of intervertebral distraction were as follows:

- (1) Normal tonus of the anterior wall of annulus fibrosus and anterior longitudinal ligament.
- (2) The height of segment concerned approximate to the mean height of superior and inferior intervertebral space by intraoperative radiography.

With the intervertebral space height restored, the annular ligamentotaxis gradually developed some tension, which could partially promote the reduction of the slipped vertebrae (Figure 2H). In addition, complete decompression of the intervertebral disc also contributed to vertebral reduction. Cancellous bone from lamina and facet joints was introduced into the disc space and a parallelogram-shaped cage implanted within. Preflexed connecting rods were bilaterally fixed at pedicle screw with nuts. Finally, with neuroradicular relaxation achieved, a lumbar transverse connector was placed.

Statistical Analysis

Data were expressed as mean±SD and all statistical analyses were conducted using SPSS 18.0 software, with $p < 0.05$ considered statistically significant. The results were statistically analyzed using a two-tailed paired Student *t* test.

■ RESULTS

Patient Demographics

There were 32 patients (28 females and 4 males) with a mean age of 52.6±9.6 yrs (range, 34 to 80 yrs) at the time of the surgery. The location of slippage was L4–L5 in 20 patients (62.5%) and L5–S1 in 12 patients (37.5%). The median duration of follow-up was 33.0±2.8 months (range, 27 to 38 months). The mean duration of operation was 152±10 minutes (range: 140 to 170 minutes), and the average volume of estimated intraoperative blood loss was 534±106 ml (range, 410 to 780 ml). One patient had the complication of cerebrospinal fluid leakage and was cured in 7 days. There were no postoperative neurologic complications, wound infections or fracture of rod and nail and subsidence of the cages.

Radiological Outcomes

The average ratio of vertebral slippage was significantly lower postoperatively than was preoperatively (17.8±4.3% vs. 5.3±2.4%, $p < 0.001$). The IH was significantly increased



Figure 1: The ratio of vertebral slippage= $(B/A) \times 100\%$; **A**=The anteroposterior dimension of the slipped vertebral body, **B**=The distance between the posterior line of the vertebral body below the slipped vertebrae and the parallel line extending through a posterior rim of the slipped vertebrae; **IH**= $(C+D+E)/3$; **C**=Height of anterior intervertebral space, **D**=Height of median intervertebral space, **E**=Height of posterior intervertebral space, **SA**=Between the superior end plate of the slipped vertebral body and the superior end plate of the vertebrae below the slipped vertebrae using the Cobb method, **LA**=Between the superior end plate of L1 to the inferior end plate of L5 using the Cobb method.

postoperatively than preoperatively (10.3 ± 1.6 mm vs. 7.7 ± 1.9 mm, $p < 0.001$) at the operated segment. There was no statistical difference in the ratio of vertebral slippage and IH postoperatively and at last follow-up ($p > 0.01$). The SA slight increased postoperatively than did preoperatively (13.5 ± 5.7 vs. 11.7 ± 5.8), with insignificant statistical difference, and the LA exhibited modest decline, but with insignificant statistical difference (Table I). All patients were confirmed to achieve bony fusion. Results in a patient with a one-level IS at L4–L5 was shown in Figure 3A–H.

Clinical Outcomes

The VAS score at the last follow-up was significantly decreased as compared to that preoperatively (2.4 ± 0.5 vs. 7.7 ± 0.6 , $p < 0.001$), as was also true of ODI score (49.6 ± 1.6 vs. 10.5 ± 1.3 , $p < 0.001$, Table II), whereas the corresponding JOA scores at the last follow-up were significantly increased versus those preoperatively (10.8 ± 1.3 vs. 26.6 ± 1.0 , $p < 0.001$, Table II). The subjective evaluation outcomes at the last follow-up were encouraging, with “excellent” in 30 patients (93.75 %) and “good” in 2 patients (6.25%).

DISCUSSION

IS is common in adolescents and adults, with L5–S1 and L4–L5 levels being the most frequently involved segments (18,43). IS is defined as the forward slippage of a vertebra resulting from a defect in the pars interarticularis, with an incidence ranging from 6 to 8.2% and higher in males than in females (18). For the initial onset of IS in adolescents, conservative therapy is recommended, whereas surgery is considered in the case of conservative therapy failure, aggravation or progression of the condition (9,12,26,40). Surgical options include a primary decompression without fusion, or combination with interbody fusion. In prior years, a decompression procedure alone was the most frequent surgical regimen in a selected patient group (3), but due to

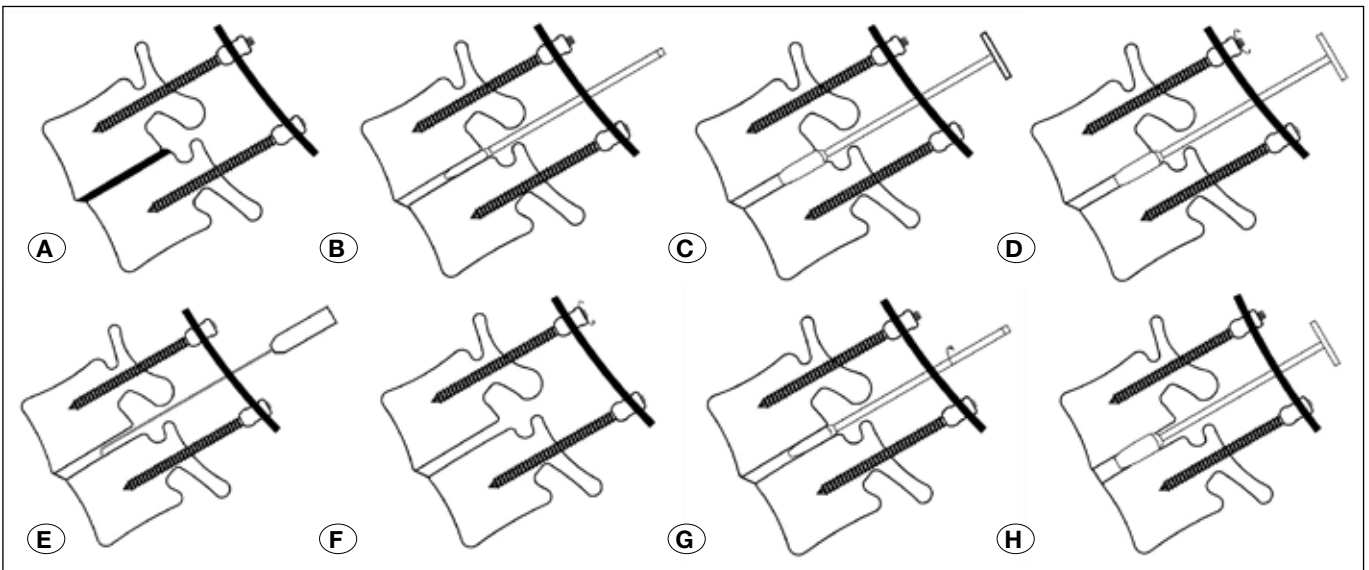


Figure 2: Reduction technique of the isthmic spondylolisthesis.

Table I: Radiological Results in all the Patients

	Preoperative	Postoperative	Last follow-up
Slippage ratio (%)	17.8±4.3	5.3±2.4*	5.4±2.5*
IH (mm)	7.7±1.9	10.3±1.6*	10.2±1.5*
SA (°)	11.7±5.8	13.5±5.7	13.2±5.3
LA (°)	49.1±13.9	48.3±9.4	47.7±8.8

p* < 0.05 compared with preoperative values. **IH: Intervertebral space height, **SA:** Lordotic angle of the treated segment, **LA:** Lumbar lordotic angle.

Table II: Clinical Results in Patients

	VAS scores	ODI scores	JOA scores
Preoperative	7.7±0.6	49.6±1.6	10.8±1.3
Last follow-up	2.4±0.5*	10.5±1.3*	26.6±1.0*

p* < 0.05 compared with preoperative values. **VAS: Visual analogue scale, **ODI:** Oswestry disability index, **JOA:** Japanese Orthopaedic Association.

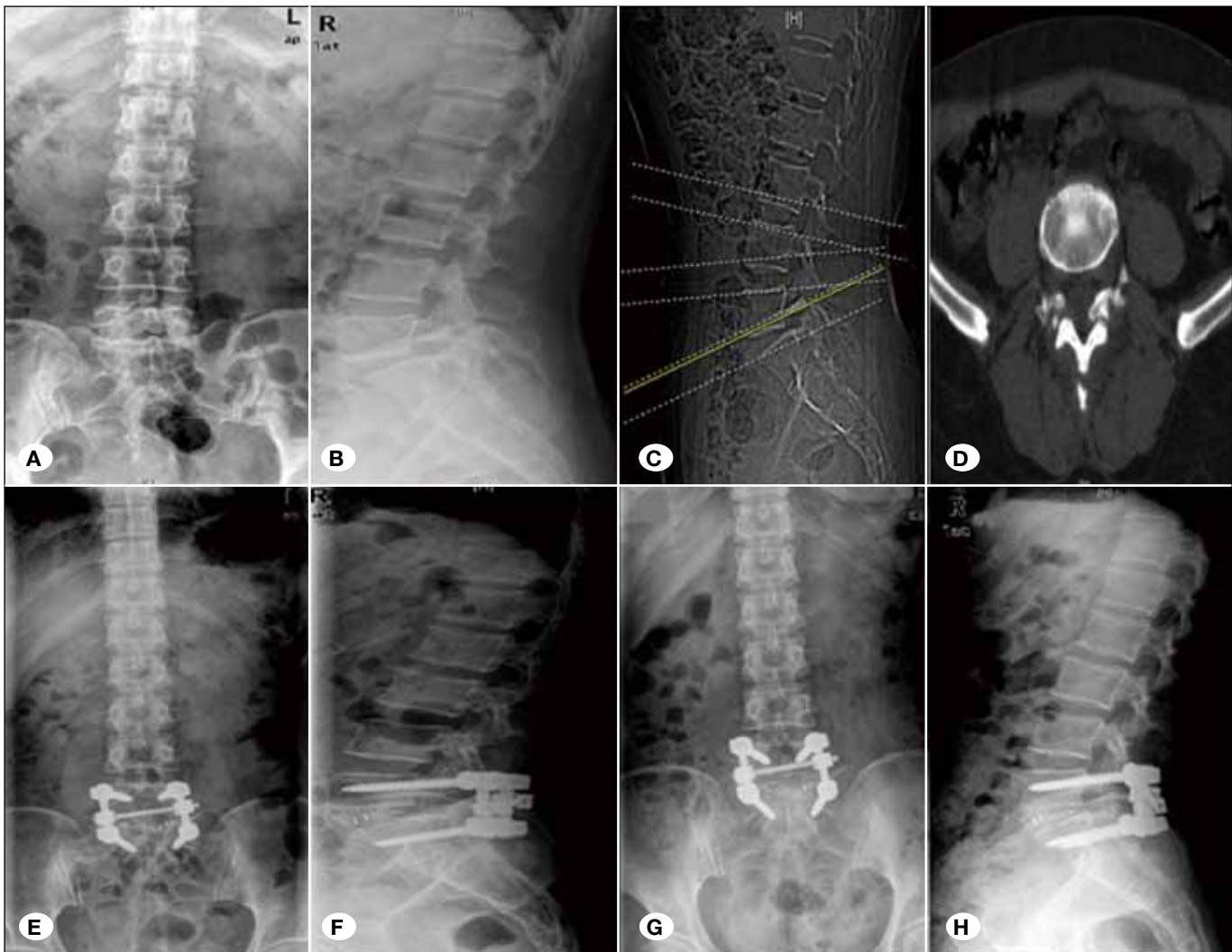


Figure 3: **A,B)** Preoperative anteroposterior and lateral view of a 44-year old female patient with L5 grade 1 spondylolisthesis. **C,D)** Preoperative lateral CT scanogram and axial CT scan, **E,F)** Anteroposterior and lateral films at first postoperative day, **G,H)** Anteroposterior and lateral films at the last follow-up.

the inherent instability of IS *per se*, decompression alone is no longer recommended (5). Currently, the most popular procedure is lumbar fusion combined with decompression, which yields better results than decompression alone (38). Types of lumbar fusion included posterolateral lumbar fusion (PLF), anterior lumbar interbody fusion (ALIF), PLIF, and TLIF. However, no consensus has been reached as to what kind of surgery is the optimal and the decision of a decompression alone or combination with a lumbar fusion in any given patient.

Disputes also exist with respect to the feasibility and the extent of reduction of vertebral slippage. Fusion *in situ* used to be the prevailing surgical procedure in the treatment of mild spondylolisthesis, with good and safe long-term results (21,33,42), and was identified superior to reduction for severe spondylolisthesis (17,32). However, reconstruction of spinal balance has been widely accepted in the treatment of spinal disorders (37), since realignment of the spine and achievement of sagittal spine balance may prevent premature degeneration of adjacent level disc in the long run (1,4,6,19,20,39) and reduce the incidence of peri-operative complications (34). Despite the lack of a consensus as to the criteria of optimal surgical approach and the potential risks of neurologic injury from instrumented slippage reduction, this approach is still practiced among many surgeons (22,25). All the patients in our study underwent reduction, in which disc space was appropriately distracted and spontaneous slippage partially reduced without screw traction, with the screw tension and failure risks for osteosynthesis and reduction remarkably decreased.

Conventional TLIF technique is limited due to the insufficient manipulation dimensions for complete resection of nucleus pulposus and cartilaginous end plates, and thus we adopted a modified technique by temporary fixation of the distracted disc space to provide more procedural convenience, facilitating complete decompression of the intervertebral contents to promote vertebral reduction and bone fusion. Notably, we elaborated the criteria on the distraction of interbody space, i.e. normal tonus of the anterior wall of annulus fibrosus and anterior longitudinal ligament, or the height of segment concerned approximate to the mean height of superior and inferior intervertebral space by intraoperative radiography, which may greatly facilitate implementation and generalization.

Reduction of spondylolisthetic deformity can reportedly be achieved with an modified insert-and-rotate technique by means of diameter-ascending distractors, with the slippage percentage significantly reduced from the preoperative 27.9% to the postoperative 17.5%, local lordosis significantly increased from 11.5° preoperatively to 15.7° postoperatively as well as the significant elevation of disc height from 14.3 mm preoperatively to 25.7 mm postoperatively (22). In the present study, the slippage percentage was significantly corrected from the preoperative 17.8% to the postoperative 5.3% and accordingly, the IH of the operated segment was significantly increased from 7.7 mm to 10.3 mm and the SA was modestly increased from 11.7° to 13.5° with insignificant difference, whereas the LA was decreased from 49.1° to 48.3°. Our result was supported by prior studies in which the IH and

SA postoperatively were improved in patients undergoing TLIF for IS. However, a slight decrease in postoperative LA was paradoxically observed in our study. We attributed this discrepancy to the distinction between conventional pedicle screw reduction and our insert-and-rotate technique, which involved the trial spacer without screw elevation. Consequently, the tension of pedicle screw system was diminished, with the risks of failures in osteosynthesis and reduction greatly obviated, which was supported by the report of Pan et al. (31).

From the subjective evaluation questionnaires of 32 patients in our study, 'excellent' was in 30 patients and 'good' in 2 patients, with no patients scoring fair or worse at the final follow-up. In parallel, the clinical outcomes including VAS, ODI and JOA scores postoperatively and at the last follow-up exhibited significant improvements, with superior results (29,36). Bone fusion was achieved in all patients, with signs and symptoms significantly ameliorated.

PLIF can be associated with nerve injury, dural tear and epidural scarring, resulting from excess medial retraction of the dura mater during cage implantation (2,14,41). As an alternative to PLIF, TLIF adopts a posterior approach to the spine via the distal lateral portion of the vertebral foramen, which reduces the PLIF-associated risks of neurological injuries (11,45). In our study, the incidence of post-operative iatrogenic neurovascular dysfunction was 0%, which was consistent with the results of previous reports (23,35) and authenticated the efficacy of TLIF with low risk of neural injury. Both the wound infection and the re-operative rate was 0%.

All the patients achieved spontaneous partial reduction of slippage by the trial spacer without any necessity of screw elevation, with signs and symptoms significantly ameliorated or even disappearing. For the follow-up of over 2-year duration, the patients exhibited significantly reduced slippage percentage and increased IH, and modestly modified SA and LA. Despite the insignificant alterations of SA and LA in our study, our results were non-inferior to those with significant changes on grounds of our similar clinical outcomes (24,28).

Our study was limited because of the relatively small sample size and short follow-up period. Large-scale multicenter prospective trials are required to recruit more patients to evaluate this approach.

■ CONCLUSION

The modified Jaslow technique combined with TLIF technique for the treatment of IS is advantageous for its greater safety, reliability, feasibility and popularity.

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