EFFECTIVENESS IN INDIRECT DECOMPRESSION USING MIS TLIF IN SINGLE LEVEL LUMBO-SACRAL SPONDYLOLISTHESIS

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Minimally invasive surgery - transforaminal lumbar interbody fusion (MIS TLIF) was considered as a promising treatment in lumbo-sacral spondylolisthesis, especially using intraoperative neuromonitoring will provide safer and faster recovery with less complications. The objective of this study was to confirmed the safety of the innovative MIS TLIF in releasing nerves without exposure. From 2022 to March 2024, 20 single-level lumbo-sacral spondylolisthesis was performed for indirect decompression using MIS TLIF with intraoperation neuromonitoring. During perioperative and follow-up, demographic data, operation time, blood loss, VAS, ODI, modified MacNab criteria, radiographic evaluation and complications were collected and analyzed. 20 patients were followed up for more than 12 months. Mean age: 52.1 and mean follow-up 15.2 months. VAS back pain: 7.4 preoperatively and 0.8 at the final. VAS of leg pain was 7.1 preoperatively and 0.9 at the final. ODI was 52.4% preoperatively and 15.6% at the final. MIS-TLIF was associated with reduction of spondylolisthesis, increase in disc height (+6 mm), foraminal height (+3,1 mm), and segmental lordosis (+4.8°). Patients with hypolordosis (<40°) significant increases +6.1° and overall lordosis +7.6°. Pelvic parameters were not significantly changed. According to the modified MacNab criteria: 75% excellent, 20% good and 51% fair. There was no complication perioperatively. Indirect decompression using MIS TLIF seems to be a safe, effective, and feasible technique in managing single level lumbo-sacral spondylolisthesis.

Keywords: MIS TLIF, indirect decompression, spondylolisthesis, intraoperation neuromonitoring, Visual Analogue Scale (VAS), Oswestry Disability Index (ODI).

I. INTRODUCTION

Minimally invasive surgery (MIS) has progressed significantly in the past 2 decades.[1] Advances in image guidance and instrumentation technology have evolved to maximize patient-reported outcomes (PROs) and radiographic evaluation.[2-3] In the management of spondylolisthesis, MIS TLIF was considered as a promising treatment with decreased blood loss, shorter lengths of hospital stay, improve rapid mobilization, lower opioid use, and earlier return to work, while maintaining comparable long-term clinical outcomes.

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Received: 15/05/2024
Accepted: 08/07/2024

The indirect decompression used in MIS TLIF is a proposed modification to the standard MIS TLIF.[4] This approach points to the Kambin's triangle after partier removing the superior articular process, without exposure of the neural strucures; the intervertebral space was prepared followed by a lordotic cage interbody fusion with less risk to both exiting and traversing nerve roots.[5] Indirect decompression was achieved via discectomy, facetectomy, restoration of disc height and segmental realignment. During every single surgical steps, the intraoperation neuromonitoring was followed to ensure that there was no damage to neural structures .

The objective of this study is to evaluate the clinical outcomes and radiographic results of indirect decompression in MIS-TLIF with placement of a lordotic interbody device. We report (1) PRO measures; (2) radiographic outcomes of sagittal segmental, regional lumbar, and pelvic parameters, and the safety and complications.

II. PATIENTS AND METHODS

1. Patients selection

PRO measures

A prospectively maintained surgical database was retrospectively reviewed and followed for the treatment of lumbo-sacral spondylolishesis (grade I and II) with MIS TLIF from 2022 to March 2024 at Hanoi Medical University Hospital. We collected informationon demographics, clinical characteristics, and operative details. PRO measures were assessed preoperatively and during routine postoperative clinic visits at 6 months, 12 months follow-up. We used the VAS (VAS/10) for back pain and legs pain and ODI (ODI/50) for physical disability.

2. Methods

Surgical technique

The operation was performed under general anesthesia, with the patient on prone position. A neurological monitoring system was used to monitor somatosensory evoked potentials and free-running electromyography during the whole procedure. The tubular retractor position on the entry point on the skin was ~ 4 – 5 cm from the midline, heading to the lateral border of the superior articular process. The Kambin's triangle was exposed by removing the superior articular process and partial inferior articular process. A serie intervertebral space dilators was inserted into the disc space to create sufficient space for the implant. Curettes, reamers and pituitary rongeurs were used to prepare the space for the endplate through the tubuluar retractor. Local bone and synthetic bone graft were used with cage for interbody fusion, then percutaneous pedicle screws through the same skin incision were placed following by intraoperative neuromonitoring under the fluroscopic guidance. Rods placement, compression and finally skin closure completed the the operation.

Radiographic measures

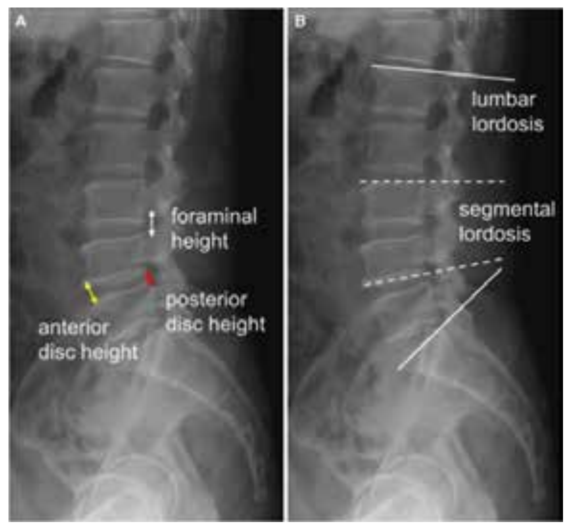

Figure 1. Lumbo-sacral parameters on lateral xray

Sagittal segmental parameters were taken on upright lateral radiographs of the lumbo-sacral spine. Serial radiographs were obtained preoperatively, postoperatively and during routine postoperative follow-up at 6 and 12 months. Sagittal segmental parameters were disc height (DH), foraminal height (FH), segmental lordosis (SL), and spondylolisthesis grade.

- DH was measured anteriorly, from inferior endplate of the upper vertebra to the superior endplate of the lower vertebra.

- FH was measured as the interpedicular space.

- SL was measured as the lateral Cobb angle at the superior and inferior endplates of the spinal unit.

- The grade of listhesis was measured as the percentage offset (slip) of the vertebral body posterior wall relative to the adjacent lower body.

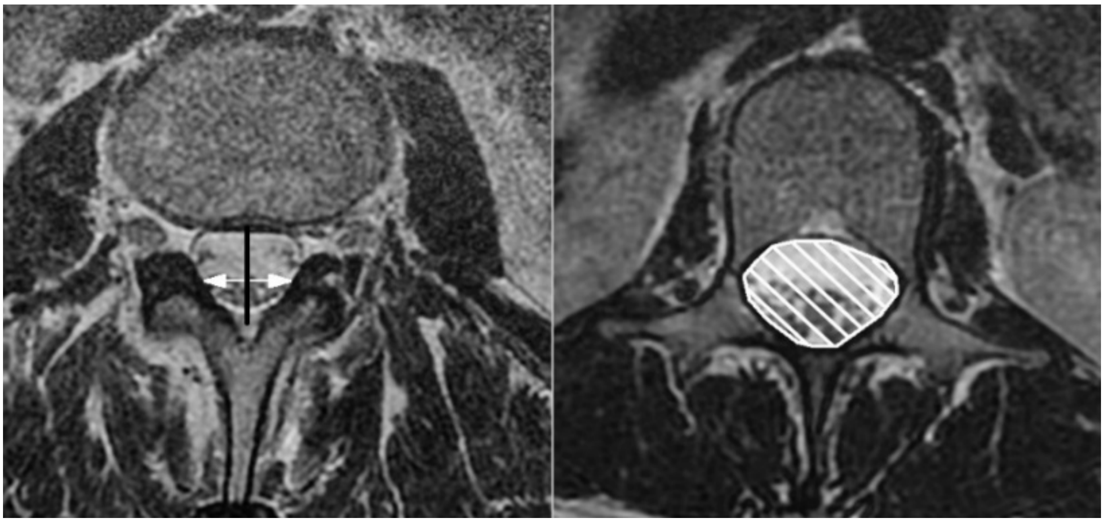

Figure 2. Lumbar central spinal canal dimensions on MRI scans

Lumbar central spinal canal dimensions were made on preoperative and postoperative T2-weighted MRI scans. The anteroposterior and transverse dimensions of each the dural sac were measured manually at a single axial slice through the center of the disc at the affected level(s). The anteroposterior length of the spinal canal was measured from the posterior edge of the intervertebral disk space to the most posterior point of the bony canal in the axial plane. The transverse length was measured as the distance between the inner surfaces of flaval ligaments on a line connecting the joint space of facet joints.

Cross sectional area of the spinal canal was measured on preoperative and postoperative T2-weighted MRI scans at a single axial slice through the center of the disc at the affected levels.

3. Statistical analysis

All statistical analyses were performed using SPSS 20.0 software (SPSS Inc., Chicago, IL, USA). Qualitative and continuous variables were described as percentages and medians (with interquartile ranges [IQRs]). Quantitative variables were compared using the T - test. *P*-values < 0.05 were considered significant.

Our Institutional Review Board approved this study (Ref: 627/GCN-HDDDNCYSH-DHYHN, dated April 20, 2023).

III. RESULTS

1. Baseline Characteristics: Demographics and Operative Details

A total of 20 patients (65% male) underwent indirect decompression using MIS-TLIF at 20 levels. The mean age at surgery was 52.1 ± 9.2 year old (range 35-65). 12/20 (60%) procedures were performed at L5S1. All (100%) patients received lordotic interbody devices. The mean postoperative follow-up duration was 15.2 months.

Table 1. Demographic and Operative Characteristics of MIS-TLIF Patients

Patient characteristics		N = 20
Level		20 levels
Age		52.1 ± 9.2
Sex (Male/Female)		13/7
Grade of spondylolisthesis	I	6 (30 %)
	II	14 (70 %)
Level	L45	8
	L5S1	12
Mean follow-up		15.2months
Operation time		90.7 ± 15 mins
Blood loss		67.3 ± 22.5 ml
Time walking		1.2 ± 0.5 days
Discharged		5.7 ± 0.7 days

2. Patient-Reported Outcomes

Patients experienced significant improvements on self-reported measures of low back pain, legs pain and disability. Mean VAS back pain decreased from 7.4/10 ± 0.8 to 3.3 ± 1 postoperatively, and 0.8 ± 0.6 at 12 months. Mean VAS legs pain decreased from 7.1/10 ± 0.9 to 1.1 ± 0.7 postoperatively, and 0.9 ± 0.7 at 12 months.

Similarly, the mean cumulative ODI score improved from 52,4 ± 4.3 % at baseline to 29 ± 1.8 % postoperatively and 15.6 ± 1.4 at 12 months.

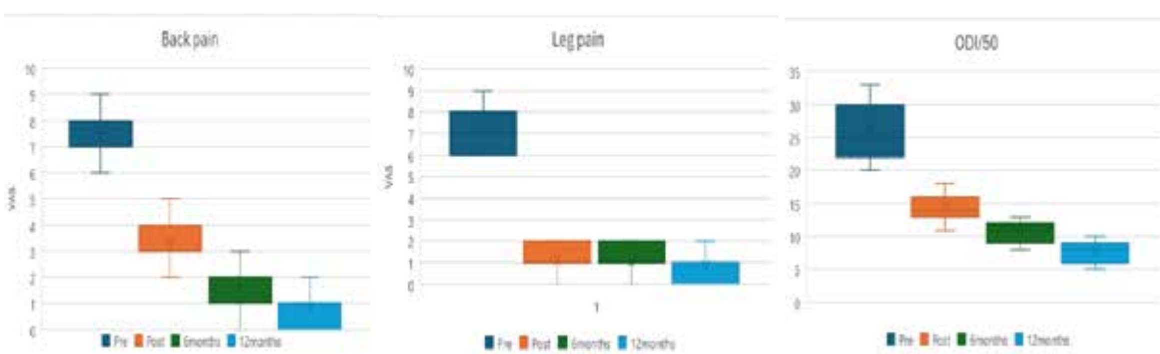

Figure 3. Patient-Reported Outcomes

The Macnab Criteria

According to the criteria: 75% excellent, 20% good and 5% fair.

No complications was reported.

3. Radiographic Outcomes

Indirect decompression in MIS-TLIF with a lordotic interbody device was associated with immediate and sustained increases in index level FH, DH, and SL. Mean FH increased significantly from 9 ± 1.6 mm preoperatively to 12.3 ± 1.5 mm immediately postoperatively and was 12.1 ± 1.5mm on the last follow-up, totally FH increased by 3.1 ± 1.1mm. Similarly, DH increased from 10.5 ± 2.2 mm to 17.1 ± 2.2 mm immediately following surgery and was sustained at 16.6 ± 2.1mm late postoperatively, totally DH increased by 6.1 ± 1.1mm.

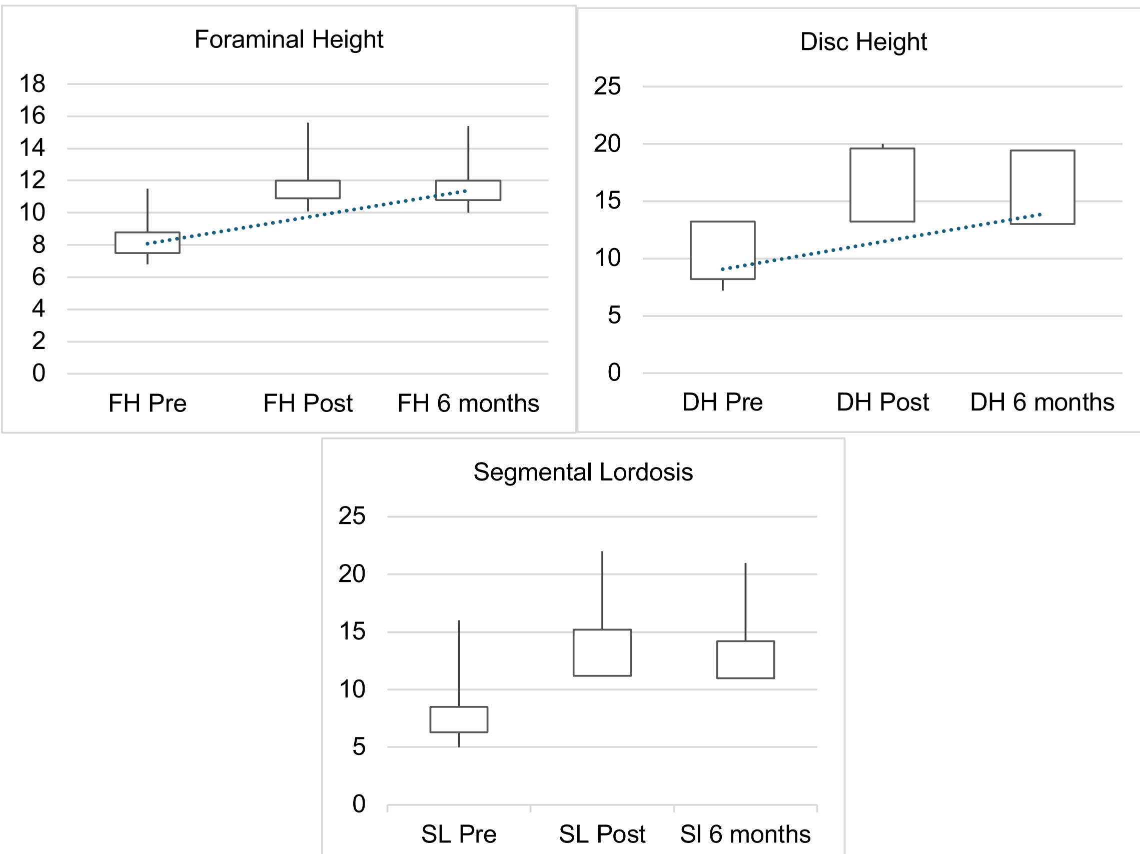

Figure 4. Sagittal Radiographic Measures

There was an immediate and large increase in SL from 8.9 ± 3.9^{o} preoperatively to 14.9 ± 3.3^{o} postoperatively (mean paired change 4.9^{o}, $p = 0.05$). SL increases were maintained during late follow-up.

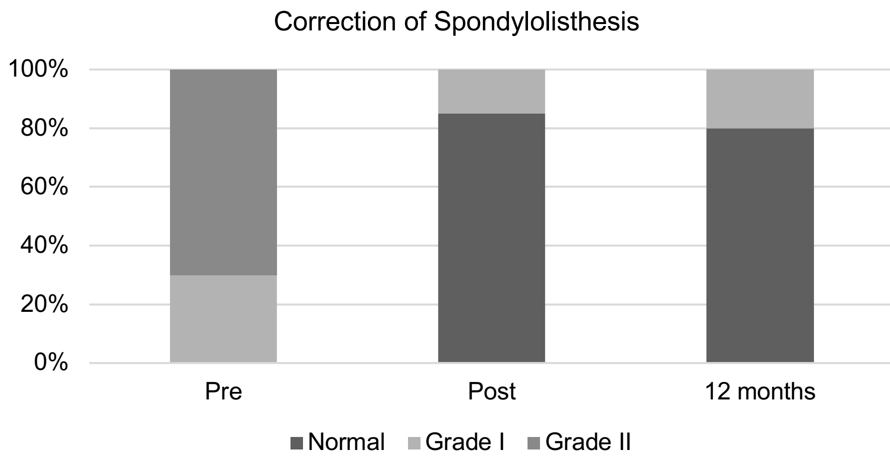

Figure 5. Sagittal correction Postoperation

There was a sustained postoperative reduction in spondylolisthesis. Prior to surgery, 6/20 (30%) operative levels had grade I spondylolisthesis, and the remaining 14/20 (70%) were grade II (>25% slip). Postoperation, the total correction to normal balance was 85% but after 12 months, it slightly decrease to 80%.

IV. DISCUSSION

Summary of the Findings

In summary, patients with lumbo-sacral spondylolisthesis who underwent MIS-TLIF with indirect decompression and placement of expandable interbody devices experienced immediate and sustained improvements in clinical outcomes and radiographic sagittal segmental parameters. PRO measures for VAS and ODI were improved during short- and long-term follow-up. We observed immediate increases in surgical unit: anterior DH (~ 6.1 mm), FH (~ 3.1 mm), and SL (~ 4.8^{o}). To be sure for the correction, we need to maximized disc and facet release by release both appophysial ring between vertebraes.

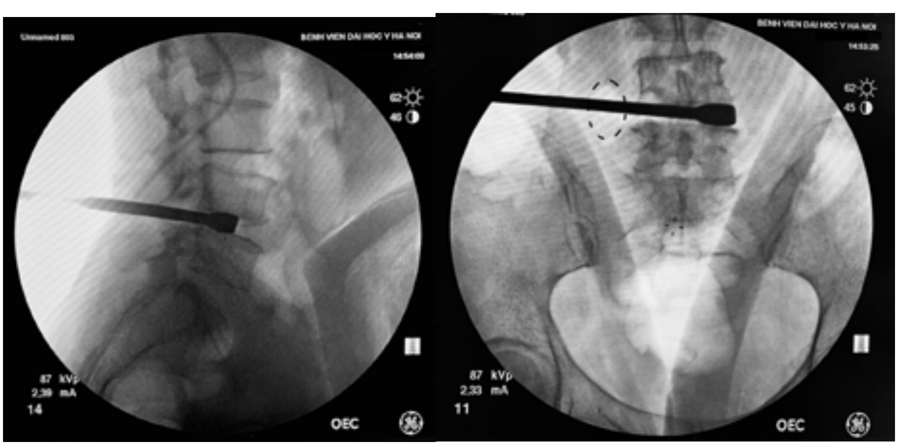

Figure 6. Intraoperative fluroscope shows approach from unilateral to contraraleral appophyseal ring for maxium release

However, our stratified analysis showed significant differences between strata by preoperative overall lumbar lordosis, suggesting that the variance in segmental and regional lordotic changes is explained by baseline radiographic factors. Specifically, preoperative hypolordosis was associated with large positive corrections in SL and overall lumbar lordosis.

MIS-TLIF With a lordotic Interbody Device

The use of expandable interbody devices provides additional sagittal segmental correction when compared with historical data on MIS lumbar fusions using static devices. Several studies examine the effects of device type on sagittal segmental parameters after traditional or MIS-TLIF. Yee et al [6] showed that patients undergoing TLIF experienced marginal increases in SL, regardless of whether expandable (1 – 2^0) or static devices were used. However, in a radiographic analysis by Hawasli et al,[5] patients who underwent MIS-TLIF with expandable versus static devices showed a larger increases in DH (8,2mm vs 2,6mm cm), FH (1,3mm vs 5 mm), and SL (5.2^0 vs 2.3^0). We did not perform a direct comparison by device type. However, we speculate that expandable devices may add greater DH and SL to widen the interpedicular distance, as compared to static devices, with no meaningful difference in endplate subsidence or fusion.

Our results compare favorably with published radiographic and clinical outcomes after MIS-TLIF using a lordotic interbody devices, but to create more lordosis, we put the disc shaver more anterior but not too far in case of anterior longitudinal ligament rupture. In a retrospective cohort of 44 patients who underwent MIS-TLIF at 49 levels and 1.5 yr median follow-up, Massie et al [2] observed significant changes in sagittal segmental parameters, specifically increases of 4.94^0 in SL and 3,1mm in posterior DH, and a reduction of 4,3mm in spondylolisthesis. They did not observe significant increases in spinopelvic parameters of sagittal vertical axis or PT.

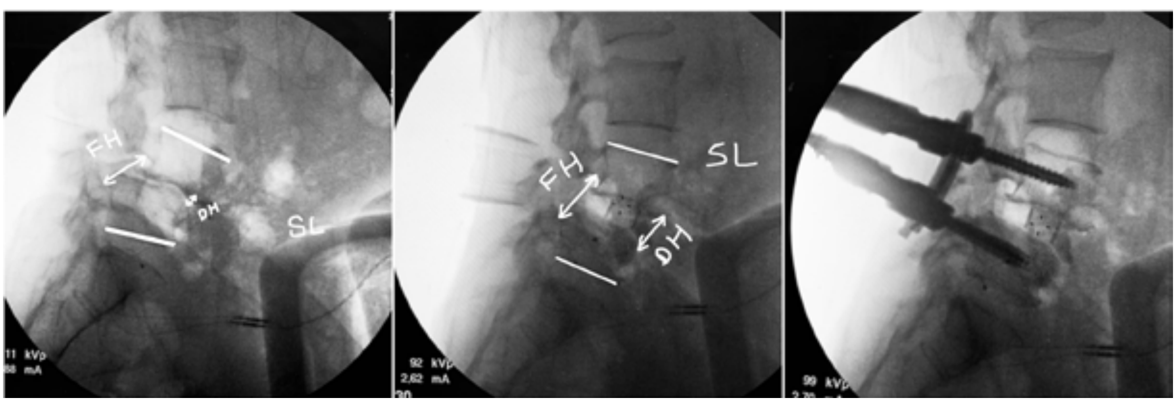

Figure 7. Radiographic improvements

Preop: DH 3,1mm, FH 5,2mm, SL +13,2^0, after interbody fusion: DH 11mm, FH 6,1, SL -7,2^0 and final correction with percutaneous screws

Local and Regional Sagittal Balance After MIS

The restoration of local and regional sagittal balance is an important consideration after MIS. In a literature review comprising 1182 patients from 24 anterior, lateral, and posterior/transforaminal MISS lumbar interbody fusion study cohorts (6 studies examining MIS-TLIF), Uribe et al[3] reported a 3.9^0 increase in SL, from an average 8.1^0 preoperatively to 12.0^0 postoperatively. In a subsequent systematic review, Carlson et al[7] identified 9 studies that reported SL and regional lordotic changes after MIS-TLIF. The mean preoperative SL was 12.7^0 and postoperative SL was 15^0, an increase of 2.1^0. Change in SL ranged between $0,1^0$ and 8.4^0, with most reports between 0^0 and 3^0. This is slightly lower than observed in our series. Notably, the majority (111/171, 65%) of included cases in the systematic review used static interbody devices, which may provide less lordotic restoration than lordotic interbody devices.[2,5] The authors were cautious in their publication because of marked variability within the literature in the measurement and reporting of radiographic parameters.

Regional (OLL) lordotic changes after MISS lumbar interbody fusions are influenced by multiple factors, including operative levels, number of levels treated, interbody device position, device type, internal fixation, and use of compressive techniques. In a systematic review of 19 MISS lumbar interbody fusion cohorts and 720 patients, Uribe et al[3] reported a significant increase of 3.7^0 in regional lordosis, from an average 43.5^0 preoperatively to 47.2^0 postoperatively.

Segmental and regional lordotic changes may be explained by variation in preoperative lordosis. In the previously mentioned report, Uribe et al[3] found a significant inverse relationship between preoperative OLL and postoperative change in OLL ($r2 = 0.41$), whereas SL did not have a similar association ($r2 = 0.001$).

For these reasons, Uribe et al[3] make the distinction between alignment "preservation" and "restoration/correction." Alignment changes, particularly lordosis increases, are possible after MIS lumbar interbody fusion, even MIS-TLIF. However, the extent of correction gained largely depends on preoperative spinal lordosis.

Interbody Fusion and Device Subsidence

In a meta-analysis by Parajon et al [8] of 40 reports and 1533 patients, fusion rates for MIS-TLIF were high, ranging from 91.8% to 99.1%, regardless of graft material. At a minimum follow-up of 12 months, fusion rates for patients recombinant bone morphogenic protein were 98.8% and 93.1%, respectively. In the report by Massie et al,[2] in which titanium expandable interbody devices were used, fusion rate was 96% at 12 months and subsidence rate was 6.1%, and none of the cases were clinically significant nor required revision surgery. Although these results are reassuring, well-powered, prospective studies with extended follow-up are needed to estimate the risks of long-term complications with expandable devices, including adjacent segment disease, subsidence, and pseudarthrosis.

Intraoperative NeuroMonitoring (IONM) During Surgery

Intraoperative Neuromonitoring assessments during surgery were introduced and have developed into a useful tool, especially in deformities and spinal cord surgery. Sharan et al[9] could not find any evidence in the literature that IONM can help in preventing nerve root injuries during pedicle screw fixation.

Little is known so far about the possible positive effect of surgical decompression procedures to the electrophysiological response and functional outcome. Piasecki et al[10] found that immediate neurophysiological response in IONM after decompressive surgery for lumbar stenosis is correlated with positive effects on clinical outcomes after 8 months follow-up, but is not applicable to late follow-up (more than 28 months) possibly due to the observed erosion of functional improvement with time. Piasecki et al[10] suggest that the intraoperative neurophysiological improvement during decompressive surgery may predict clinical outcome at 6 months after surgery.

In our studywe recorded every single steps: facetectomy, disc preparation, interbody fusion and percutaneous screws. The signal raised during surgery were strongly associated with the improvement of clinical symptoms postoperative. All procedure were facilities done and also record no complication.

Limitations of the Study

This is a single observational study with a relatively small sample size, short time follow-up, with some missing variables. Radiographic results are subject to measurement error because of variable radiograph quality and because of observer errors. Moreover, as it is not possible to blind reviewers to a patient's operative state, measurements made on postoperative radiographs may be systematically biased to favorable changes in sagittal parameters.

V. CONCLUSIONS

Patients undergoing indirect decompression using MIS-TLIF with lordotic interbody devices experienced clinically meaningful improvements in PROs. Radiographic sagittal segmental parameters of SL, anterior DH, FH, and spondylolisthesis were improved early. This MIS-TLIF was associated with significant regional lordotic, feasible to perform safely, mostly with excellent and good results without any complication.

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