Clinical Study

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Optimizing lie-to-stand time to avoid orthostatic intolerance during early mobilization after enhanced recovery after surgery program for minimally invasive spine surgery: oblique lateral interbody fusion versus minimally invasive transforaminal lumbar interbody fusion: a prospective cohort study in Thailand

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Study Design: Prospective study.
Purpose: To evaluate the hemodynamic response to early mobilization following oblique lateral interbody fusion (OLIF) compared to minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) with an enhanced recovery after surgery (ERAS) program.
Overview of Literature: The ERAS program mitigates surgical stress and facilitates early recovery. Orthostatic intolerance (OI) may impede early mobilization after spine surgery. Data on OI after OLIF and MIS-TLIF with an ERAS are limited. This study compares OI incidence and outcomes of these two procedures.
Methods: The hemodynamic response to postural changes (supine to sitting and standing) was evaluated preoperatively and at 6, 12, 24, and 48 hours postoperatively in 30 patients who underwent single-level OLIF versus MIS-TLIF within an ERAS protocol. The protocols were evaluated sequentially, beginning with a change from supine to sitting, followed immediately by standing, with the patient remaining in the standing position for 3 minutes for evaluation.
Results: This study compared OLIF and MIS-TLIF in 60 patients and found no significant differences in baseline characteristics. The OLIF group demonstrated greater hemodynamic stability within 6 hours after surgery, exhibiting smaller decreases in systolic blood pressure and mean arterial pressure, along with reduced fluid responsiveness compared to the MIS-TLIF group. Both groups of patients exhibited comparable heart rates and cardiac output stabilization over time. Clinically, OLIF resulted in greater postoperative back pain relief, lower blood loss (45±7.31 mL vs. 99.33±14.13 mL), and higher postoperative hemoglobin levels compared to MIS-TILF. Operative time, hospital stay, and complication rates were comparable between the OLIF and MIS-TLIF groups.
Conclusions: OLIF was associated with improved hemodynamic parameters within 6 hours postoperatively, less blood loss, and improved pain relief compared to MIS-TLIF, while both procedures demonstrated similar operative times, hospital stays, and no complications.

Keywords: Enhanced recovery after surgery; Orthostatic intolerance; Minimally invasive surgical procedures; Spinal fusion

Introduction

The enhanced recovery after surgery (ERAS) protocol is a multidisciplinary and multimodal approach designed to mitigate the surgical stress response, length of hospitalization, and surgery-related complications while promoting postoperative rehabilitation and recovery [1]. Early postoperative mobilization after spinal surgery is important, which can decrease the rates of thromboembolic events and pulmonary complications. However, postoperative orthostatic intolerance (OI) may impede early recovery and increase the risk of fainting, falls, and subsequent fractures [1,2]. Yang et al. [3] reported a high early postoperative incidence of OI (69.86%) and signs of cerebral hypoperfusion during ambulation in patients undergoing open posterior spinal surgeries. Nonetheless, there are no reports on postoperative OI after the minimally invasive (MI) lumbar interbody fusion surgeries, including the oblique lateral interbody fusion (OLIF) and minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) performed within an ERAS protocol.

This study aimed to determine the incidence of postoperative OI at 6, 12, 24, and 48 hours after a single-level OLIF procedure compared to the MIS-TLIF procedure, with both procedures performed under the ERAS protocol. Furthermore, we assessed alterations in hemodynamic status, hemoglobin concentration, blood loss, pain scores, opioid consumption, length of hospital stay, and postoperative complications.

Materials and Methods

This study was designed as a single-center prospective cohort study. Eligible patients were treated between February 2022 and May 2024. Ethical approval was obtained from the Institutional Review Board of the Faculty of Medicine, Chulalongkorn University (IRB number: 095/64), and informed consent was obtained from all patients included in the study.

Populations

The study included patients with degenerative lumbar spondylolisthesis aged 40–90 years who underwent single-level OLIF or MIS-TLIF surgery at L4/5. Exclusion criteria included patients with preoperative OI, cardiac diseases, autonomic dysfunction, systolic blood pressure (SBP) <90 mm Hg or >180 mm Hg, diastolic blood pressure (DBP) <60 mm Hg or >110 mmHg, heart rate (HR) >120 beats per minute (bpm) or <40 bpm, oxygen saturation <95%, hematocrit <30%, the American Society of Anesthesiologists (ASA) classification >III, body mass index (BMI) <18 kg/m^2 or >40 kg/m^2 and those with communication difficulties.

Anesthetic protocol

All patients were managed using a standardized perioperative protocol for enhanced recovery. During the preoperative fasting period, patients were allowed clear fluids for up to 2 hours and solid foods for up to 6 hours before the induction of general anesthesia (GA). Premedication consisted of 325 mg of paracetamol, specifically two tablets administered orally 30 minutes before surgery. Both groups underwent standardized GA in accordance with the institutional protocol. In our institution, intraoperative neuromonitoring is not routinely used for these procedures and was not employed in either group. During the intraoperative phase, GA was administered to every patient using endotracheal intubation and mechanical ventilation. Anesthetic induction was performed using propofol at 1.5–2.5 mg/kg, followed by fentanyl at 1–2 μg/kg, and cisatracurium at 0.15–0.2 mg/kg. Anesthesia was maintained with cisatracurium bolus and desflurane in oxygen-enriched air (at or above a minimum alveolar concentration) to achieve targeted hemodynamic parameters and depth of anesthesia. Additional doses of fentanyl were administered intraoperatively at the discretion of the attending anesthesiologist. After patient positioning, a ketamine bolus (50 mg) and an infusion of nefopam (20 mg infusion in 100 mL of normal saline) were administered. During surgical wound closure, patients received either parecoxib 40 mg or ketorolac 30 mg and 1 g of paracetamol infusion. Prophylaxis for postoperative nausea and vomiting included dexamethasone 10 mg administered before the surgical incision and ondansetron 4 mg during skin closure. Intraoperative normothermia was maintained using a forced-air heating blanket and warmed intravenous (IV) fluid administration. The anesthetic depth was monitored with the bispectral index, with values maintained between 40 and 60. Hemodynamic monitoring followed the ASA Standards for Basic Anesthetic Monitoring, including blood pressure, HR, oxygen saturation, and temperature. Although the anesthesiologists were not blinded to the surgical procedure, they adhered to the same anesthetic protocol for both groups. The use of intraoperative anesthetic agents was consistent across both groups.

Intraoperative fluid management began with an initial bolus of isotonic saline at 12 mL/kg, followed by a

maintenance rate of 6 mL/kg until the end of the surgery. Intraoperative blood loss was replaced using a colloid solution or blood in a 1:1 ratio. A local anesthetic solution consisting of 20 mL of 0.5% bupivacaine, 0.3 mg of epinephrine, 30 mg of ketorolac, and normal saline to a total volume of 60 mL was infiltrated into the skin, subcutaneous tissue, and lumbar fascia prior to wound closure.

Postoperative analgesia was attained using a multimodal approach. All patients received patient-controlled analgesia with IV fentanyl (administered without basal infusion; at a 20 μg demand dose every 30 minutes). Postoperative medications included Arcoxia at 90 mg (one tablet) orally once daily, paracetamol 500 mg (two tablets) orally every 6 hours, Myonal (one tablet) orally every 8 hours, and Lyrica 75 mg (one capsule) orally once daily. To minimize potential confounding of hemodynamic measurements, muscle relaxants known to induce hypotension were not administered during the first 48 hours following surgery.

Diagnosis of orthostatic intolerance

OI was defined as the presence of signs indicative of cerebral hypoperfusion, including dizziness, nausea, blurred vision, or syncope. Furthermore, patients were categorized as having OI if they exhibited a decline in SBP greater than 20 mm Hg or a decrease in DBP greater than 10 mm Hg upon changing positions [4].

Orthostatic intolerance evaluation

We evaluated the hemodynamic status and OI related symptoms in patients who underwent single-level OLIF compared to those who underwent MIS-TLIF during the preoperative period and at 6, 12, 24, and 48 hours postoperatively. Initially, the patient's hemodynamic parameters were measured in the supine position using the EV1000 clinical platform (Edwards Lifesciences LLC, Irvine, CA, USA), a non-invasive hemodynamic monitoring system, along with the ClearSight finger cuff (Edwards Lifesciences LLC). The patient was assisted into a sitting position on the bed, and hemodynamic parameters were assessed again. Subsequently, the patient stood up, and a further hemodynamic evaluation was done. Finally, the patient remained in the standing position for 3 minutes, after which a final hemodynamic evaluation was performed (Fig. 1).

Surgical techniques

OLIF

The procedures were performed by two authors (W.S. and W.L.), both of whom had more than 10 years of experience in spine surgery. Their levels of experience and skill in MIS spine surgery were comparable. The patients were operated on in the right lateral decubitus position for the surgery. The surgical approach was made through the left anterolateral aspect of the abdomen to access the retroperitoneal corridor between the left psoas muscle and the great vessels. Self-retaining retractors were positioned at the operative disc level following the use of sequential dilators. Discectomy and endplate preparation were subsequently performed. An appropriately sized cage (CLYDESDALE; Medtronic, Minneapolis, MN, USA), packed with demineralized bone matrix (DBM) (GRAFTON; Medtronic) was inserted orthogonally into the disc space. Subsequently, the patient was repositioned to the prone position, and percutaneous posterior instrumentation was placed [5,6].

Fig. 1. The non-invasive hemodynamic monitoring system was used to measure the patient's hemodynamic parameters in supine position **(A)**, sitting position **(B)**, standing position **(C)**, and after standing for 3 minutes **(D)**. Written informed consent for the publication of this image was obtained from the patient.

MIS-TLIF

This procedure was also performed by two authors (W.S. or W.L.) using a similar surgical technique. The patient was placed in the prone position. The operative steps included hemilaminectomy, medial facetectomy, and ligamentum flavum removal on the approach side, followed by discectomy and endplate preparation. An interbody cage (CAPSTONE; Medtronic), filled with local autogenous bone graft, was then inserted into the prepared disc space. Finally, the supplemental posterior percutaneous screw fixation was done in standard fashion [5,6].

Data collection

The patient's demographic data, including age, gender, underlying medical conditions, BMI, and ASA classification, were recorded. In addition, the patient's hemodynamic parameters—consisting of blood pressure, HR, stroke volume, stroke volume variation (SVV), cardiac output, mean arterial pressure (MAP), oxygen saturation—along with estimated blood loss (EBL), fluid management, and total opioid use, were also collected.

Sample size calculation

The sample size was calculated using the formula: n/group=$2(Z_{\alpha/2}+Z_{\beta})2\sigma2/(\mu_1-\mu_2)$. We applied a Type I error of 0.05, a Type II error of 0.1, and a statistical power of 80% in this formula. The remaining variables were adopted from the study by Jans et al. [7]. The mean difference and standard deviation (SD) of SBP between the supine and standing positions at 6 hours postoperatively were 15±24 mm Hg. Including an additional 10% to account for potential dropouts, the calculated sample size indicated that a minimum of 30 patients per group was required.

Data analyses

Statistical analysis was performed using the Stata 17 software (StataCorp LP, College Station, TX, USA). Continuous variables are presented as mean±SD, while categorical variables are expressed as numbers (percentages). Intergroup comparisons of baseline characteristics were performed employing independent *t*-tests for continuous variables and chi-square or Fisher's exact tests for categorical variables. The primary outcome was the incidence of OI and associated hemodynamic changes at 6 hours postoperatively. Secondary outcomes included hemodynamic parameters at additional time points (12, 24, and 48 hours), clinical outcomes, and complications. Hemodynamic changes over time were analyzed using generalized estimating equations (GEE) with an exchangeable correlation structure to account for within-subject correlation of repeated measurements. The GEE models included surgical technique (OLIF vs. MIS-TLIF) as the primary independent variable, along with time point, and the interaction between surgical technique and time. To address potential confounding, multivariable GEE models were constructed with adjustments for age, BMI, baseline blood pressure, intraoperative blood loss, and operative time. The clinical outcomes were analyzed using the repeated analysis of variance test. A *p*-value of less than 0.05 was considered statistically significant.

Results

Patient characteristics

This study included 60 patients, with 30 undergoing OLIF and the remaining undergoing MIS-TLIF. The demographic data were collected and adjusted for age and sex. There were no significant differences between the groups in age, sex, or underlying diseases. The mean age of the patients was 65.67±10.3 years in the OLIF group and 64.53±9.69 years in the MIS-TLIF group (p=0.662). The mean BMI was 25.85±3.83 kg/m^2 in the OLIF group and 25.85±4.00 kg/m^2 in the MIS-TLIF group (p=0.978). There were no statistically significant differences between the groups regarding underlying medical conditions. All the patients were diagnosed with spondylolisthesis at L4–5 (Table 1).

Hemodynamic responses

Systolic blood pressure

Preoperative SBP values in the supine position were comparable between the OLIF and MIS-TLIF groups (131.97±4.99 mm Hg vs. 132.00±4.67 mm Hg, p=0.979). Six hours postoperatively, in the supine position, the OLIF group patients exhibited a significantly higher SBP than the MIS-TLIF group patients (123.9±12.32 mm Hg vs. 110.73±11.79 mm Hg; mean difference, 13.17 mm Hg; p<0.001). The MIS-TLIF group experienced a significantly greater reduction in SBP from the preoperative period to 6 hours postoperatively compared to the OLIF group (mean change, −21.27 mm Hg vs. −8.07 mm Hg; mean difference, 13.2 mm Hg; p<0.001). At 12 hours postoperatively, the reduction in SBP was signifi-

Table 1. Demographic data

Characteristic	OLIF (n=30)	MIS-TLIF (n=30)	*p*-value
Age (yr)	65.67±10.3	64.53±9.69	0.662
Gender			0.781
Female	20 (66.7)	21 (70)	
Male	10 (33.3)	9 (30)	
Body mass index (kg/m²)	25.82±3.83	25.85±4	0.978
Underlying disease			
Diabetes mellitus	2 (6.7)	1 (3.3)	0.554
Hypertension	14 (46.7)	15 (50)	0.796
Dyslipidemia	7 (23.3)	6 (20)	0.754
No	12 (40)	12 (40)	1
Operative time (hr)	2.09±0.31	2.11±0.29	0.766
Blood loss (mL)	45±7.31	99.33±14.13	<0.001*
Drain (mL)	-	63±18.03	NA
Hb preoperative (g/dL)	13.06±0.98	12.9±0.97	0.545
Hb day1 (g/dL)	12.29±1.13	11.71±0.73	0.022*
Length of hospital stays (day)	3.17±0.38	3.23±0.43	0.527
Intraoperative-fentanyl (mcg)	76.67±48.87	84.5±45.53	0.523
Actual (counts)	8.27±5.74	14.97±13.55	0.016*
Demand (counts)	14.4±14.39	20.4±15	0.119
Actual (mcg)	167.96±120.21	167.96±120.21	1
Total (mcg)	219.96±125.16	249.96±122.02	0.351

Values are presented as mean±standard deviation or number (%).
OLIF, oblique lumbar interbody fusion; MIS-TLIF, minimally invasive transforaminal lumbar interbody fusion; NA, not applicable; Hb, hemoglobin; Intraoperative-fentanyl, fentanyl administered during surgery; Actual, actual number of doses delivered; Demand, number of times the patient pressed the PCA button; Actual (mcg), actual amount of fentanyl delivered in micrograms; Total, cumulative amount of fentanyl administered.
*p<0.05 (Statistical significance).

cantly smaller in the OLIF group compared to the MIS-TLIF group (−1.93 mm Hg vs. −6.67 mm Hg, p=0.023). However, at 24 and 48 hours, there were no significant differences in the changes between the OLIF and MIS-TLIF groups (Table 2).

In the sitting position, significant SBP differences between the OLIF and MIS-TLIF groups were noted at 6 hours (p<0.001) and 12 hours (p=0.022). At 6 hours, patients who underwent MIS-TLIF demonstrated a significantly greater SBP reduction (mean difference, 27.77; p<0.001). However, at 24 and 48 hours postoperatively, there was no significant difference in SBP alterations between the OLIF and MIS-TLIF groups (Table 3).

At 6 hours postoperatively, SBP in the standing position was significantly higher in the OLIF group (119.17±14.34 mm Hg) than in the MIS-TLIF group (106.73±20.07 mm Hg). The decrease in SBP at 6 hours postoperatively was significantly smaller in the OLIF group (−12.7 mm Hg) compared to the MIS-TLIF group (−25.37 mm Hg, p=0.01). At 12, 24, and 48 hours postoperatively, there was no significant difference in SBP or the change in SBP between the OLIF and MIS-TLIF groups (Table 4).

At 6 hours, after standing for 3 minutes, SBP was lower in the MIS-TLIF group compared to the OLIF group, with a near-significant difference (mean difference, 8.77; p=0.055). No significant differences in SBP between the OLIF and MIS-TLIF groups were observed at 12, 24, or 48 hours postoperatively (Table 5).

Diastolic blood pressure

The preoperative DBP in the supine position was 79.13±10.06 mm Hg in the OLIF group and 76.23±6.17 mm Hg in the MIS-TLIF group, with no significant difference (p=0.184). At 6 hours postoperatively in the supine position, DBP was significantly higher in the OLIF group compared to the MIS-TLIF group (74.77±8.54 mm Hg vs. 64.47±7.51 mm Hg; mean difference, 10.3 mm Hg; p<0.001). This difference in DBP in the supine position was not significant at subsequent postoperative time points (Table 2). At 6 hours postoperatively in the sitting position, MIS-TLIF patients demonstrated a lower DBP (60.27±8.92 mm Hg) than the OLIF group patients (73±9.52 mm Hg), with a significantly smaller decrease in DBP in the OLIF group (−6.67 mm Hg) compared to the MIS-TLIF group (−17.63 mm Hg, p<0.001) (Table 3). At 6 hours postoperatively in the standing position, DBP was marginally higher in the OLIF group than in the MIS-TLIF group patients (69.73±9.35 mm Hg vs. 67.97±11.78 mm Hg, p=0.523). At 12, 24, and 48 hours postoperatively, there was no significant difference in DBP alterations between the OLIF and MIS-TLIF group patients (Table 4). No significant DBP changes were observed between the OLIF and MIS-TLIF group patients after standing for 3 minutes (Table 5).

Oxygen saturation

Preoperative and postoperative oxygen saturation values were comparable between the groups at every studied time point, with no statistically significant differences (Tables 2–5).

Heart rate

There were no statistically significant differences in HR between the OLIF and MIS-TLIF groups at any time point (Tables 2–5).

Table 2. Hemodynamic in supine position

Hemodynamic in supine position	Time	OLIF (n=30)	MIS–TLIF (n=30)	MD (95% CI) between groups	*p*-value
SBP (mm Hg)	Preop	131.97±4.99	132±4.67	–0.03 (–2.53 to 2.46)	0.979
	6 hr	123.9±12.32	110.73±11.79	13.17 (6.94 to 19.4)	<0.001*
	12 hr	130.03±6.19	125.33±7	4.7 (1.29 to 8.11)	0.008*
	24 hr	132.33±5.67	131.87±8.96	0.47 (–3.42 to 4.36)	0.811
	48 hr	134.23±6.46	130.93±9.14	3.3 (–0.79 to 7.39)	0.112
	Change at 6 hr	–8.07 (–12.91 to –3.23)	–21.27 (–25.9 to –16.63)	13.2 (6.64 to 19.76)	<0.001*
	Change at 12 hr	–1.93 (–5.16 to 1.29)	–6.67 (–9.28 to –4.05)	4.73 (0.67 to 8.8)	0.023*
	Change at 24 hr	0.37 (–2.11 to 2.84)	–0.13 (–3.8 to 3.53)	0.5 (–3.83 to 4.83)	0.818
	Change at 48 hr	2.27 (–0.5 to 5.03)	–1.07 (–4.3 to 2.17)	3.33 (–0.83 to 7.5)	0.115
DBP (mm Hg)	Preop	79.13±10.06	76.23±6.17	2.9 (–1.41 to 7.21)	0.184
	6 hr	74.77±8.54	64.47±7.51	10.3 (6.14 to 14.46)	<0.001*
	12 hr	76.07±9.18	73.53±7.21	2.53 (–1.73 to 6.8)	0.239
	24 hr	76.43±9.83	77.17±9.29	–0.73 (–5.67 to 4.21)	0.767
	48 hr	79±4.23	79.53±4.39	–0.53 (–2.76 to 1.7)	0.634
	Change at 6 hr	–4.37 (–8.69 to –0.05)	–11.77 (–15.5 to –8.03)	7.4 (1.81 to 12.99)	0.01*
	Change at 12 hr	–3.07 (–6.42 to 0.29)	–2.7 (–6.31 to 0.91)	–0.37 (–5.19 to 4.46)	0.88
	Change at 24 hr	–2.7 (–5.71 to 0.31)	0.93 (–3.61 to 5.47)	–3.63 (–8.96 to 1.7)	0.178
	Change at 48 hr	–0.13 (–3.41 to 3.14)	3.3 (0.59 to 6.01)	–3.43 (–7.59 to 0.72)	0.104
O_2 sats (%)	Preop	98.47±1.11	98.73±1.05	–0.27 (–0.82 to 0.29)	0.342
	6 hr	98.2±1.56	97.97±1.73	0.23 (–0.62 to 1.09)	0.586
	12 hr	98.63±1	98.4±1.33	0.23 (–0.37 to 0.84)	0.445
	24 hr	98.47±1.31	98.8±1.1	–0.33 (–0.96 to 0.29)	0.289
	48 hr	98.47±1.04	98.73±1.26	–0.27 (–0.86 to 0.33)	0.375
	Change at 6 hr	–0.27 (–0.95 to 0.42)	–0.77 (–1.51 to –0.02)	0.5 (–0.49 to 1.49)	0.317
	Change at 12 hr	0.17 (–0.26 to 0.6)	–0.33 (–0.93 to 0.27)	0.5 (–0.22 to 1.22)	0.17
	Change at 24 hr	0 (–0.54 to 0.54)	0.07 (–0.38 to 0.52)	–0.07 (–0.75 to 0.62)	0.846
	Change at 48 hr	0 (–0.46 to 0.46)	0 (–0.44 to 0.44)	0 (–0.62 to 0.62)	1
HR (bpm)	Preop	72.43±7.46	73.3±8.93	–0.87 (–5.12 to 3.39)	0.685
	6 hr	83.63±12.09	80.47±10.38	3.17 (–2.66 to 8.99)	0.281
	12 hr	77.97±8.86	76.9±10.83	1.07 (–4.05 to 6.18)	0.678
	24 hr	72.77±6.76	74.6±6.62	–1.83 (–5.29 to 1.62)	0.293
	48 hr	71.43±7.47	74.33±6.04	–2.9 (–6.41 to 0.61)	0.104
	Change at 6 hr	11.2 (6.89 to 15.51)	7.17 (3.57 to 10.77)	4.03 (–1.47 to 9.53)	0.147
	Change at 12 hr	5.53 (2.22 to 8.85)	3.6 (–0.66 to 7.86)	1.93 (–3.35 to 7.22)	0.467
	Change at 24 hr	0.33 (–3.42 to 4.09)	1.3 (–2.67 to 5.27)	–0.97 (–6.31 to 4.38)	0.719
	Change at 48 hr	–1 (–4.59 to 2.59)	1.03 (–2.57 to 4.63)	–2.03 (–7.01 to 2.95)	0.417
CO (L/min)	Preop	4.71±1.03	4.77±1.21	–0.06 (–0.64 to 0.52)	0.845
	6 hr	5.33±1.44	5.01±1.1	0.32 (–0.34 to 0.98)	0.337
	12 hr	5.24±1.12	5.1±1.01	0.14 (–0.41 to 0.69)	0.614
	24 hr	4.94±0.92	5.34±1.1	–0.4 (–0.93 to 0.13)	0.133
	48 hr	4.76±0.96	5.33 ± 1.41	–0.57 (–1.2 to 0.05)	0.071
	Change at 6 hr	0.62 (–0.01 to 1.25)	0.24 (–0.18 to 0.66)	0.38 (–0.36 to 1.12)	0.313

(Continued on the next page)

Table 2. Continued

Hemodynamic in supine position	Time	OLIF (n=30)	MIS–TLIF (n=30)	MD (95% CI) between groups	*p*-value
	Change at 12 hr	0.53 (–0.08 to 1.13)	0.33 (–0.3 to 0.96)	0.2 (–0.66 to 1.05)	0.648
	Change at 24 hr	0.23 (–0.21 to 0.67)	0.57 (0.04 to 1.11)	–0.34 (–1.02 to 0.33)	0.313
	Change at 48 hr	0.05 (–0.31 to 0.4)	0.56 (0.18 to 0.95)	–0.52 (–1.03 to 0)	0.049*
SV (mL/beat)	Preop	63.63±14.48	66.73±16.58	–3.1 (–11.14 to 4.94)	0.444
	6 hr	61.3±13.52	60.83±13.12	0.47 (–6.42 to 7.35)	0.893
	12 hr	62.07±10.83	67.9±13.33	–5.83 (–12.11 to 0.44)	0.068
	24 hr	63.73±15.41	71.17±14.48	–7.43 (–15.16 to 0.3)	0.059
	48 hr	62.97±12.58	68.13±13.15	–5.17 (–11.82 to 1.48)	0.125
	Change at 6 hr	–2.33 (–8.02 to 3.35)	–5.9 (–10.96 to –0.84)	3.57 (–3.88 to 11.02)	0.342
	Change at 12 hr	–1.57 (–7.41 to 4.28)	1.17 (–6.16 to 8.49)	–2.73 (–11.91 to 6.44)	0.553
	Change at 24 hr	0.1 (–2.29 to 2.49)	4.43 (–2.16 to 11.03)	–4.33 (–11.29 to 2.62)	0.215
	Change at 48 hr	–0.67 (–4.74 to 3.41)	1.4 (–3.32 to 6.12)	–2.07 (–8.16 to 4.03)	0.5
SVV (%)	Preop	9.63±3.23	11.6±4.87	–1.97 (–4.1 to 0.17)	0.071
	6 hr	9.53±3.31	10.2±4.41	–0.67 (–2.68 to 1.35)	0.51
	12 hr	9.57±3.8	10.1±4.07	–0.53 (–2.57 to 1.5)	0.602
	24 hr	9.87±3.8	9.8±4.57	0.07 (–2.11 to 2.24)	0.951
	48 hr	9.73±3.3	10.9±3.96	–1.17 (–3.05 to 0.72)	0.22
	Change at 6 hr	–0.1 (–1.39 to 1.19)	–1.4 (–3.39 to 0.59)	1.3 (–1.03 to 3.63)	0.268
	Change at 12 hr	–0.07 (–1.34 to 1.2)	–1.5 (–3.71 to 0.71)	1.43 (–1.07 to 3.94)	0.256
	Change at 24 hr	0.23 (–1.17 to 1.64)	–1.8 (–4.17 to 0.57)	2.03 (–0.67 to 4.74)	0.137
	Change at 48 hr	0.1 (–1.49 to 1.69)	–0.7 (–2.64 to 1.24)	0.8 (–1.66 to 3.26)	0.517
MAP (mm Hg)	Preop	96.6±9	95.4±9.65	1.2 (–3.62 to 6.02)	0.62
	6 hr	93±9.64	82.63±10.4	10.37 (5.18 to 15.55)	<0.001*
	12 hr	94.2±8.28	90.87±7.89	3.33 (–0.85 to 7.51)	0.116
	24 hr	94.8±7.19	95.83±8.65	–1.03 (–5.14 to 3.08)	0.617
	48 hr	100.7±8.49	96.83±7.09	3.87 (–0.17 to 7.91)	0.06
	Change at 6 hr	–3.6 (–7.74 to 0.54)	–12.77 (–17.73 to –7.8)	9.17 (2.84 to 15.49)	0.005*
	Change at 12 hr	–2.4 (–5.4 to 0.6)	–4.53 (–8.63 to –0.44)	2.13 (–2.83 to 7.1)	0.394
	Change at 24 hr	–1.8 (–4.33 to 0.73)	0.43 (–3.87 to 4.73)	–2.23 (–7.11 to 2.65)	0.364
	Change at 48 hr	4.1 (1.01 to 7.19)	1.43 (–2.02 to 4.88)	2.67 (–1.87 to 7.2)	0.244

Values are presented as mean±standard deviation or MD (95% CI) unless otherwise stated.
OLIF, oblique lumbar interbody fusion; MIS-TLIF, minimally invasive transforaminal lumbar interbody fusion; MD, mean difference; CI, confidence interval; SBP, systolic blood pressure; Preop, preoperative; DBP, diastolic blood pressure; O_2 sats, oxygen saturation; HR, heart rate; bpm, beats per minute; CO, cardiac output; SV, stroke volume; SVV, stroke volume variation; MAP, mean arterial pressure.
*p<0.05 (Statistical significance).

Stroke volume variation

At 6 hours postoperatively, after standing for 3 minutes, the OLIF group exhibited a lower SVV compared to the MIS-TLIF group, with values of 9.8±4.5 vs. 12.43±5.06 (p=0.037). No significant differences in SVV were observed between the OLIF and MIS-TLIF group patients at 12, 24, or 48 hours postoperatively (Tables 2–5).

Mean arterial pressure

There was no significant difference in preoperative MAP between the OLIF and MIS-TLIF group patients. Significant differences in MAP were noted at 6 hours postoperatively in the supine position, with higher MAP in the OLIF group than the MIS-TLIF group patients (93±9.64 mm Hg vs. 82.63±10.4 mm Hg; mean difference, 10.37 mm Hg; p<0.001). At 6 hours postoperatively, the MAP reduction was greater in the MIS-

Table 3. Hemodynamics in the sitting position

Hemodynamic in sit position	Time	OLIF (n=30)	MIS–TLIF (n=30)	MD (95% CI) between groups	*p*-value
SBP (mm Hg)	Preop	132.9±6.08	133.7±5.92	–0.8 (–3.9 to 2.3)	0.607
	6 hr	121.8±14.25	94.83±16.94	26.97 (18.88 to 35.06)	<0.001*
	12 hr	130.8±7.98	123.7±14.44	7.1 (1.07 to 13.13)	0.022*
	24 hr	133.63±5.58	130.87±6.78	2.77 (–0.44 to 5.97)	0.09
	48 hr	132.67±6.65	130±7.42	2.67 (–0.97 to 6.31)	0.148
	Change at 6 hr	–11.1 (–16.5 to –5.7)	–38.87 (–45.88 to –31.85)	27.77 (19.1 to 36.43)	<0.001*
	Change at 12 hr	–2.1 (–4.87 to 0.67)	–10 (–15.21 to –4.79)	7.9 (2.13 to 13.67)	0.008*
	Change at 24 hr	0.73 (–1.25 to 2.72)	–2.83 (–5.96 to 0.29)	3.57 (–0.06 to 7.19)	0.054
	Change at 48 hr	–0.23 (–3.04 to 2.57)	–3.7 (–6.53 to –0.87)	3.47 (–0.43 to 7.36)	0.08
DBP (mm Hg)	Preop	79.67±6.36	77.9±7.47	1.77 (–1.82 to 5.35)	0.328
	6 hr	73±9.52	60.27±8.92	12.73 (7.96 to 17.5)	<0.001*
	12 hr	76.53±7.23	72.9±10.33	3.63 (–0.98 to 8.24)	0.12
	24 hr	77.7±5.54	77.93±7.69	–0.23 (–3.7 to 3.23)	0.893
	48 hr	78.23±8.27	79.43±7.55	–1.2 (–5.29 to 2.89)	0.56
	Change at 6 hr	–6.67 (–11.2 to –2.13)	–17.63 (–21.48 to –13.79)	10.97 (5.15 to 16.79)	<0.001*
	Change at 12 hr	–3.13 (–5.76 to –0.5)	–5 (–8.95 to –1.05)	1.87 (–2.78 to 6.51)	0.424
	Change at 24 hr	–1.97 (–4.12 to 0.19)	0.03 (–3.48 to 3.54)	–2 (–6.05 to 2.05)	0.325
	Change at 48 hr	–1.43 (–4.62 to 1.75)	1.53 (–1.44 to 4.51)	–2.97 (–7.23 to 1.3)	0.169
O_2 sats (%)	Preop	98.17±1.49	98.37±1.4	–0.2 (–0.95 to 0.55)	0.594
	6 hr	98.67±1.47	98.1±2.06	0.57 (–0.36 to 1.49)	0.225
	12 hr	98.53±1.36	98.23±1.41	0.3 (–0.41 to 1.01)	0.404
	24 hr	98.33 ±1.47	98.63±1.35	–0.3 (–1.03 to 0.43)	0.414
	48 hr	98.1±1.49	98.67±1.4	–0.57 (–1.31 to 0.18)	0.135
	Change at 6 hr	0.5 (–0.21 to 1.21)	–0.27 (–1.19 to 0.66)	0.77 (–0.38 to 1.91)	0.184
	Change at 12 hr	0.37 (–0.09 to 0.82)	–0.13 (–0.64 to 0.37)	0.5 (–0.17 to 1.17)	0.139
	Change at 24 hr	0.17 (–0.33 to 0.67)	0.27 (–0.31 to 0.85)	–0.1 (–0.85 to 0.65)	0.79
	Change at 48 hr	–0.07 (–0.56 to 0.42)	0.3 (–0.16 to 0.76)	–0.37 (–1.03 to 0.29)	0.27
HR (bpm)	Preop	73.27±6.06	75.2±7.16	–1.93 (–5.36 to 1.49)	0.263
	6 hr	85.67±10.59	85.97±9.95	–0.3 (–5.61 to 5.01)	0.91
	12 hr	80.9±10.47	78.97±10.86	1.93 (–3.58 to 7.45)	0.486
	24 hr	74.5±7.48	75.9±6.48	–1.4 (–5.02 to 2.22)	0.442
	48 hr	72.7±6.46	74.27±6.9	–1.57 (–5.02 to 1.89)	0.368
	Change at 6 hr	12.4 (8 to 16.8)	10.77 (6.08 to 15.45)	1.63 (–4.66 to 7.93)	0.605
	Change at 12 hr	7.63 (3.99 to 11.28)	3.77 (–0.52 to 8.05)	3.87 (–1.64 to 9.37)	0.165
	Change at 24 hr	1.23 (–1.49 to 3.96)	0.7 (–2.47 to 3.87)	0.53 (–3.56 to 4.63)	0.795
	Change at 48 hr	–0.57 (–3.03 to 1.9)	–0.93 (–3.66 to 1.79)	0.37 (–3.23 to 3.96)	0.839
CO (L/min)	Preop	4.45±0.9	4.77±1.58	–0.32 (–0.99 to 0.35)	0.345
	6 hr	5.19±1.49	4.82±1.46	0.38 (–0.39 to 1.14)	0.328
	12 hr	5.31±1.6	5.2±1.51	0.11 (–0.69 to 0.91)	0.785
	24 hr	4.54±0.91	4.94±1.34	–0.41 (–1 to 0.18)	0.173
	48 hr	4.76±0.84	4.55±1	0.21 (–0.27 to 0.69)	0.384
	Change at 6 hr	0.74 (0.18 to 1.3)	0.05 (–0.58 to 0.67)	0.69 (–0.13 to 1.52)	0.097

(Continued on the next page)

Table 3. Continued

Hemodynamic in sit position	Time	OLIF (n=30)	MIS–TLIF (n=30)	MD (95% CI) between groups	*p*-value
	Change at 12 hr	0.85 (0.23 to 1.47)	0.43 (–0.2 to 1.05)	0.43 (–0.44 to 1.29)	0.327
	Change at 24 hr	0.08 (–0.22 to 0.39)	0.17 (–0.48 to 0.83)	–0.09 (–0.8 to 0.62)	0.8
	Change at 48 hr	0.31 (–0.03 to 0.64)	–0.22 (–0.65 to 0.21)	0.53 (–0.01 to 1.06)	0.054
SV (mL/beat)	Preop	60.17±13.67	58.97±16.9	1.2 (–6.74 to 9.14)	0.763
	6 hr	56.27±11.54	55.8±16.02	0.47 (–6.75 to 7.68)	0.897
	12 hr	58.9±10.55	64.63±16.13	–5.73 (–12.78 to 1.31)	0.109
	24 hr	60.2±14.16	60 ±12.98	0.2 (–6.82 to 7.22)	0.955
	48 hr	64.6±12.35	60.7±14.75	3.9 (–3.13 to 10.93)	0.271
	Change at 6 hr	–3.9 (–7.73 to –0.07)	–3.17 (–8.5 to 2.17)	–0.73 (–7.17 to 5.71)	0.82
	Change at 12 hr	–1.27 (–8.05 to 5.52)	5.67 (–1.95 to 13.29)	–6.93 (–16.92 to 3.05)	0.17
	Change at 24 hr	0.03 (–3.54 to 3.61)	1.03 (–6.47 to 8.54)	–1 (–9.21 to 7.21)	0.807
	Change at 48 hr	4.43 (0.81 to 8.06)	1.73 (–3.09 to 6.55)	2.7 (–3.2 to 8.6)	0.364
SVV (%)	Preop	10.13±2.6	10.7±3.72	–0.57 (–2.22 to 1.09)	0.496
	6 hr	11.03±2.83	11.37±3.03	–0.33 (–1.85 to 1.18)	0.662
	12 hr	9.23±2.36	9.93±3.13	–0.7 (–2.13 to 0.73)	0.332
	24 hr	9.4±1.77	9.87±2.45	–0.47 (–1.57 to 0.64)	0.401
	48 hr	9.47±1.59	11.1±2.83	–1.63 (–2.83 to –0.44)	0.008*
	Change at 6 hr	0.9 (–0.44 to 2.24)	0.67 (–1.02 to 2.35)	0.23 (–1.87 to 2.34)	0.825
	Change at 12 hr	–0.9 (–2.3 to 0.5)	–0.77 (–2.67 to 1.14)	–0.13 (–2.45 to 2.18)	0.909
	Change at 24 hr	–0.73 (–2 to 0.53)	–0.83 (–2.4 to 0.73)	0.1 (–1.87 to 2.07)	0.919
	Change at 48 hr	–0.67 (–1.79 to 0.46)	0.4 (–1.07 to 1.87)	–1.07 (–2.88 to 0.75)	0.244
MAP (mm Hg)	Preop	101.53±10.6	101.77±9.38	–0.23 (–5.41 to 4.94)	0.928
	6 hr	92.2±11.53	79.13±11.8	13.07 (7.04 to 19.09)	<0.001*
	12 hr	96.43±8.49	92.93±13.34	3.5 (–2.28 to 9.28)	0.23
	24 hr	97.3±6.24	98.33±7.02	–1.03 (–4.47 to 2.4)	0.549
	48 hr	98±10.44	103.07±8.18	–5.07 (–9.92 to –0.22)	0.041
	Change at 6 hr	–9.33 (–14.22 to –4.45)	–22.63 (–28.11 to –17.16)	13.3 (6.12 to 20.48)	<0.001*
	Change at 12 hr	–5.1 (–8.93 to –1.27)	–8.83 (–14.37 to –3.29)	3.73 (–2.86 to 10.32)	0.261
	Change at 24 hr	–4.23 (–8.31 to –0.15)	–3.43 (–7.13 to 0.26)	–0.8 (–6.19 to 4.59)	0.767
	Change at 48 hr	–3.53 (–7.11 to 0.04)	1.3 (–1.5 to 4.1)	–4.83 (–9.27 to –0.39)	0.033

Values are presented as mean±standard deviation or MD (95% CI) unless otherwise stated.
OLIF, oblique lumbar interbody fusion; MIS-TLIF, minimally invasive transforaminal lumbar interbody fusion; MD, mean difference; CI, confidence interval; SBP, systolic blood pressure; Preop, preoperative; DBP, diastolic blood pressure; O_2 sats, oxygen saturation; HR, heart rate; bpm, beats per minute; CO, cardiac output; SV, stroke volume; SVV, stroke volume variation; MAP, mean arterial pressure.
*p<0.05 (Statistical significance).

TLIF group (–22.63 mm Hg) than in the OLIF group (–9.33 mm Hg, p<0.001) (Tables 2–3). However, no difference was observed between the OLIF and MIS-TLIF groups at 6, 12, 24, and 48 hours in the standing position or following standing for 3 minutes (Tables 4–5).

Clinical outcomes

There was no significant difference in baseline preoperative clinical parameters, including VAS scores for back and leg pain, between the OLIF and MIS-TLIF groups. The VAS scores for back pain in all techniques indicated significant improvement at any postoperative time point (1, 2, and 3 days) when compared to the preoperative score for each procedure. The OLIF group demonstrated significantly greater improvement in VAS back pain scores on postoperative days 1, 2, and 3 compared to the MIS-TLIF group (p<0.001). The VAS leg scores for all procedures significantly decreased from

Table 4. Hemodynamics in the standing position

Hemodynamic in stand position	Time	OLIF (n=30)	MIS–TLIF (n=30)	MD (95% CI) between groups	*p*-value
SBP (mm Hg)	Preop	131.87±6.51	132.1±6.14	–0.23 (–3.5 to 3.04)	0.887
	6 hr	119.17±14.34	106.73±20.07	12.43 (3.42 to 21.45)	0.008*
	12 hr	130.77±5.23	126.3±10.99	4.47 (–0.02 to 8.95)	0.051
	24 hr	133.4±4.51	130±7.25	3.4 (0.27 to 6.53)	0.034*
	48 hr	133.4±5.18	129.83±8.27	3.57 (–0.01 to 7.15)	0.051
	Change at 6 hr	–12.7 (–18.36 to –7.04)	–25.37 (–33.34 to –17.39)	12.67 (3.09 to 22.24)	0.01*
	Change at 12 hr	–1.1 (–3.06 to 0.86)	–5.8 (–10.8 to –0.8)	4.7 (–0.61 to 10.01)	0.081
	Change at 24 hr	1.53 (–1.36 to 4.43)	–2.1 (–5.43 to 1.23)	3.63 (–0.69 to 7.96)	0.098
	Change at 48 hr	1.53 (–0.53 to 3.59)	–2.27 (–5.36 to 0.82)	3.8 (0.15 to 7.45)	0.042*
DBP (mm Hg)	Preop	78.97±8.18	79.13±7.63	–0.17 (–4.25 to 3.92)	0.935
	6 hr	69.73±9.35	67.97±11.78	1.77 (–3.73 to 7.27)	0.523
	12 hr	73.03±8.21	72.17±8.2	0.87 (–3.37 to 5.11)	0.684
	24 hr	78.27±5.57	78.5±5.99	–0.23 (–3.22 to 2.76)	0.876
	48 hr	79.47±6.37	79.5±8.03	–0.03 (–3.78 to 3.71)	0.986
	Change at 6 hr	–9.23 (–14.24 to –4.22)	–11.17 (–16.57 to –5.76)	1.93 (–5.28 to 9.15)	0.594
	Change at 12 hr	–5.93 (–9.89 to –1.98)	–6.97 (–11.37 to –2.56)	1.03 (–4.76 to 6.82)	0.722
	Change at 24 hr	–0.7 (–3.28 to 1.88)	–0.63 (–4.35 to 3.08)	–0.07 (–4.5 to 4.36)	0.976
	Change at 48 hr	0.5 (–2.14 to 3.14)	0.37 (–2.71 to 3.44)	0.13 (–3.83 to 4.1)	0.947
O_2 sats (%)	Preop	98.13±1.2	97.97±1.19	0.17 (–0.45 to 0.78)	0.59
	6 hr	98.63±1.22	98.4±1.25	0.23 (–0.4 to 0.87)	0.467
	12 hr	98.43±1.17	98.13±1.14	0.3 (–0.29 to 0.89)	0.317
	24 hr	98.63±1.1	98.53±1.22	0.1 (–0.5 to 0.7)	0.74
	48 hr	98.43±1.07	98±1.34	0.43 (–0.19 to 1.06)	0.172
	Change at 6 hr	0.5 (–0.06 to 1.06)	0.43 (–0.28 to 1.15)	0.07 (–0.82 to 0.95)	0.881
	Change at 12 hr	0.3 (–0.18 to 0.78)	0.17 (–0.4 to 0.73)	0.13 (–0.59 to 0.86)	0.715
	Change at 24 hr	0.5 (–0.03 to 1.03)	0.57 (–0.03 to 1.16)	–0.07 (–0.84 to 0.71)	0.864
	Change at 48 hr	0.3 (–0.16 to 0.76)	0.03 (–0.44 to 0.51)	0.27 (–0.38 to 0.92)	0.414
HR (bpm)	Preop	78.73±4.83	80.13±6.44	–1.4 (–4.34 to 1.54)	0.345
	6 hr	86.37±13.3	86.1±10.93	0.27 (–6.03 to 6.56)	0.933
	12 hr	79.43±8.56	82.37±9.54	–2.93 (–7.62 to 1.75)	0.215
	24 hr	78±5.32	77.5±7.07	0.5 (–2.73 to 3.73)	0.758
	48 hr	78.03±4.54	77.57±5.97	0.47 (–2.28 to 3.21)	0.735
	Change at 6 hr	7.63 (2.56 to 12.71)	5.97 (2.2 to 9.73)	1.67 (–4.52 to 7.85)	0.592
	Change at 12 hr	0.7 (–2.3 to 3.7)	2.23 (–0.63 to 5.1)	–1.53 (–5.6 to 2.53)	0.453
	Change at 24 hr	–0.73 (–2.63 to 1.17)	–2.63 (–5.28 to 0.02)	1.9 (–1.29 to 5.09)	0.238
	Change at 48 hr	–0.7 (–2.16 to 0.76)	–2.57 (–4.92 to –0.21)	1.87 (–0.85 to 4.59)	0.174
CO (L/min)	Preop	4.43±0.98	4.62±1.08	–0.19 (–0.72 to 0.35)	0.488
	6 hr	4.92±1.16	4.5±1.38	0.42 (–0.24 to 1.08)	0.207
	12 hr	5.12±1.19	5.38±1.55	–0.26 (–0.97 to 0.46)	0.476
	24 hr	4.98±0.9	4.69±0.96	0.29 (–0.19 to 0.77)	0.238
	48 hr	4.92±0.86	4.67±0.89	0.25 (–0.2 to 0.7)	0.266
	Change at 6 hr	0.49 (–0.07 to 1.05)	–0.12 (–0.76 to 0.52)	0.61 (–0.22 to 1.44)	0.149

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Table 4. Continued

Hemodynamic in stand position	Time	OLIF (n=30)	MIS–TLIF (n=30)	MD (95% CI) between groups	*p*-value
	Change at 12 hr	0.69 (0.16 to 1.22)	0.76 (0.05 to 1.47)	–0.07 (–0.94 to 0.8)	0.872
	Change at 24 hr	0.54 (0.13 to 0.96)	0.07 (–0.36 to 0.5)	0.47 (–0.11 to 1.06)	0.112
	Change at 48 hr	0.49 (0.15 to 0.83)	0.05 (–0.33 to 0.43)	0.44 (–0.06 to 0.94)	0.083
SV (mL/beat)	Preop	62.03±13.62	60.6±17.03	1.43 (–6.53 to 9.4)	0.72
	6 hr	55.93±15.21	53.37±16.4	2.57 (–5.61 to 10.74)	0.532
	12 hr	58.8±13.87	63.73±17.22	–4.93 (–13.02 to 3.15)	0.227
	24 hr	64.77±13.62	60.43±15.72	4.33 (–3.27 to 11.93)	0.259
	48 hr	63.7±12.95	59.57±14.09	4.13 (–2.86 to 11.13)	0.242
	Change at 6 hr	–6.1 (–10.85 to –1.35)	–7.23 (–13.13 to –1.34)	1.13 (–6.28 to 8.55)	0.761
	Change at 12 hr	–3.23 (–8.98 to 2.52)	3.13 (–4.37 to 10.63)	–6.37 (–15.62 to 2.88)	0.174
	Change at 24 hr	2.73 (–1.45 to 6.92)	–0.17 (–5.14 to 4.81)	2.9 (–3.46 to 9.26)	0.365
	Change at 48 hr	1.67 (–2.52 to 5.86)	–1.03 (–7.73 to 5.66)	2.7 (–5.03 to 10.43)	0.487
SVV (%)	Preop	10.83±3.71	10.17±3.93	0.67 (–1.31 to 2.64)	0.502
	6 hr	11.07±3.14	10.27±3.77	0.8 (–0.99 to 2.59)	0.375
	12 hr	9.9±3.49	9.8±2.94	0.1 (–1.57 to 1.77)	0.905
	24 hr	9.97±2.08	10.9±4.05	–0.93 (–2.61 to 0.74)	0.267
	48 hr	10.97±4.06	10.97±4.13	0 (–2.12 to 2.12)	1
	Change at 6 hr	0.23 (–1.69 to 2.15)	0.1 (–1.86 to 2.06)	0.13 (–2.55 to 2.82)	0.921
	Change at 12 hr	–0.93 (–2.82 to 0.96)	–0.37 (–1.96 to 1.23)	–0.57 (–2.99 to 1.86)	0.641
	Change at 24 hr	–0.87 (–2.3 to 0.57)	0.73 (–0.81 to 2.28)	–1.6 (–3.66 to 0.46)	0.126
	Change at 48 hr	0.13 (–1.75 to 2.02)	0.8 (–0.68 to 2.28)	–0.67 (–3.01 to 1.68)	0.572
MAP (mm Hg)	Preop	98.47±8.33	102.53±9.23	–4.07 (–8.61 to 0.48)	0.078
	6 hr	88.57±13.3	85.7±12.36	2.87 (–3.77 to 9.5)	0.391
	12 hr	92.7±7.35	92.1±8.92	0.6 (–3.62 to 4.82)	0.777
	24 hr	94.97±5.82	96.5±6.39	–1.53 (–4.69 to 1.63)	0.335
	48 hr	99.4±8.53	102.07±8.18	–2.67 (–6.99 to 1.65)	0.222
	Change at 6 hr	–9.9 (–15.9 to –3.9)	–16.83 (–23.1 to –10.56)	6.93 (–1.56 to 15.42)	0.108
	Change at 12 hr	–5.77 (–9.19 to –2.34)	–10.43 (–14.51 to –6.35)	4.67 (–0.55 to 9.88)	0.078
	Change at 24 hr	–3.5 (–6.4 to –0.6)	–6.03 (–9.41 to –2.66)	2.53 (–1.82 to 6.89)	0.249
	Change at 48 hr	0.93 (–2.34 to 4.21)	–0.47 (–3.76 to 2.82)	1.4 (–3.15 to 5.95)	0.54

Values are presented as mean±standard deviation or MD (95% CI) unless otherwise stated.
OLIF, oblique lumbar interbody fusion; MIS-TLIF, minimally invasive transforaminal lumbar interbody fusion; MD, mean difference; CI, confidence interval; SBP, systolic blood pressure; Preop, preoperative; DBP, diastolic blood pressure; O_2 sats, oxygen saturation; HR, heart rate; bpm, beats per minute; CO, cardiac output; SV, stroke volume; SVV, stroke volume variation; MAP, mean arterial pressure.
*p<0.05 (Statistical significance).

the preoperative period to each postoperative time point (days 1, 2, and 3) in both the OLIF and MIS-TLIF groups. There was no statistically significant difference between the groups (Table 6).

The OLIF group exhibited significantly less EBL (45±7.31 mL) compared to the MIS-TLIF group (99.33±14.13 mL) (p<0.001). There was no significant difference in the mean preoperative hemoglobin concentration between the OLIF group (13.06±0.98 g/dL) and the MIS-TLIF group (12.9±0.97 g/dL). On the first postoperative day, however, the hemoglobin concentration in the MIS-TLIF group (11.71±0.73 g/dL) decreased significantly more than that of the OLIF group (12.29±1.13 g/dL). None of the patients required a blood transfusion during the perioperative period. Additionally, there was no significant difference in the mean operative duration between the OLIF group (2.09±0.31 hours) and the MIS-TLIF group (2.11±0.29

Table 5. Hemodynamics in the standing position to 3 minutes

Hemodynamic in stand to 3 min	Time	OLIF (n=30)	MIS–TLIF (n=30)	MD (95%CI) between groups	*p*-value
SBP (mm Hg)	Preop	137.27±6.26	135.9±7.29	1.37 (–2.15 to 4.88)	0.439
	6 hr	125.63±13.22	116.87±20.51	8.77 (–0.18 to 17.72)	0.055
	12 hr	130.1±9.76	129.7±11.87	0.4 (–5.22 to 6.02)	0.887
	24 hr	135.13±4.67	132.9±6.13	2.23 (–0.58 to 5.05)	0.118
	48 hr	137.63±6.61	134.67±8.38	2.97 (–0.93 to 6.87)	0.133
	Change at 6 hr	–11.63 (–16.5 to –6.77)	–19.03 (–26.25 to –11.82)	7.4 (–1.14 to 15.94)	0.088
	Change at 12 hr	–7.17 (–10.86 to –3.47)	–6.2 (–10.41 to –1.99)	–0.97 (–6.45 to 4.52)	0.726
	Change at 24 hr	–2.13 (–4.42 to 0.15)	–3 (–6.57 to 0.57)	0.87 (–3.28 to 5.02)	0.677
	Change at 48 hr	0.37 (–2.18 to 2.91)	–1.23 (–4.15 to 1.68)	1.6 (–2.19 to 5.39)	0.401
DBP (mm Hg)	Preop	83.87±7.61	82.7±8.08	1.17 (–2.89 to 5.22)	0.567
	6 hr	76.2±8.98	72.5±10.76	3.7 (–1.42 to 8.82)	0.153
	12 hr	80.8±7.23	76.9±8.07	3.9 (–0.06 to 7.86)	0.053
	24 hr	80.47±7.69	79.93±7.52	0.53 (–3.4 to 4.46)	0.787
	48 hr	82.57±7.65	80.93±8.44	1.63 (–2.53 to 5.8)	0.435
	Change at 6 hr	–7.67 (–12.44 to –2.89)	–10.2 (–15.39 to –5.01)	2.53 (–4.36 to 9.43)	0.465
	Change at 12 hr	–3.07 (–6.44 to 0.3)	–5.8 (–9.38 to –2.22)	2.73 (–2.08 to 7.54)	0.26
	Change at 24 hr	–3.4 (–5.12 to –1.68)	–2.77 (–6.85 to 1.32)	–0.63 (–5.02 to 3.75)	0.772
	Change at 48 hr	–1.3 (–3.25 to 0.65)	–1.77 (–4.67 to 1.14)	0.47 (–2.95 to 3.89)	0.786
O_2 sats (%)	Preop	97.9±1.45	97.8±1.16	0.1 (–0.58 to 0.78)	0.769
	6 hr	98.13±1.04	98.2±1.16	–0.07 (–0.64 to 0.5)	0.815
	12 hr	98.3±1.12	98.2±1.19	0.1 (–0.5 to 0.7)	0.738
	24 hr	98.43±1.41	98.4±1.22	0.03 (–0.65 to 0.71)	0.922
	48 hr	98.3±1.49	98.03±1.27	0.27 (–0.45 to 0.98)	0.459
	Change at 6 hr	0.23 (–0.35 to 0.82)	0.4 (–0.08 to 0.88)	–0.17 (–0.91 to 0.57)	0.653
	Change at 12 hr	0.4 (–0.2 to 1)	0.4 (–0.17 to 0.97)	0 (–0.81 to 0.81)	1
	Change at 24 hr	0.53 (–0.04 to 1.11)	0.6 (0.1 to 1.1)	–0.07 (–0.81 to 0.68)	0.859
	Change at 48 hr	0.4 (–0.16 to 0.96)	0.23 (–0.2 to 0.67)	0.17 (–0.53 to 0.86)	0.633
HR (bpm)	Preop	79.27±8.08	79.9±8.33	–0.63 (–4.87 to 3.61)	0.766
	6 hr	91.03±15.13	89±16.11	2.03 (–6.04 to 10.11)	0.616
	12 hr	81.9±9.41	85.27±9.63	–3.37 (–8.29 to 1.55)	0.176
	24 hr	78.5±8.16	78.53±8.83	–0.03 (–4.43 to 4.36)	0.988
	48 hr	78.17±7.34	76.9±9.4	1.27 (–3.09 to 5.63)	0.563
	Change at 6 hr	11.77 (5.53 to 18)	9.1 (3.69 to 14.51)	2.67 (–5.41 to 10.75)	0.512
	Change at 12 hr	2.63 (–0.49 to 5.76)	5.37 (2.08 to 8.65)	–2.73 (–7.17 to 1.7)	0.223
	Change at 24 hr	–0.77 (–3.43 to 1.9)	–1.37 (–4.72 to 1.99)	0.6 (–3.59 to 4.79)	0.776
	Change at 48 hr	–1.1 (–3.34 to 1.14)	–3 (–6.41 to 0.41)	1.9 (–2.1 to 5.9)	0.345
CO (L/min)	Preop	4.53±0.85	4.51±0.97	0.02 (–0.46 to 0.49)	0.944
	6 hr	4.82±0.95	4.74±1.34	0.09 (–0.51 to 0.69)	0.774
	12 hr	5.05±1.16	5.11±1.14	–0.06 (–0.65 to 0.54)	0.849
	24 hr	4.83±0.74	4.56±1.08	0.27 (–0.21 to 0.75)	0.259
	48 hr	4.84±0.79	4.59±0.87	0.26 (–0.17 to 0.68)	0.235
	Change at 6 hr	0.29 (–0.12 to 0.71)	0.22 (–0.38 to 0.82)	0.07 (–0.64 to 0.78)	0.845

(Continued on the next page)

Table 5. Continued

Hemodynamic in stand to 3 min	Time	OLIF (n=30)	MIS–TLIF (n=30)	MD (95%CI) between groups	*p*-value
	Change at 12 hr	0.52 (0.06 to 0.98)	0.59 (0.06 to 1.13)	–0.07 (–0.76 to 0.62)	0.832
	Change at 24 hr	0.3 (–0.05 to 0.65)	0.05 (–0.33 to 0.43)	0.26 (–0.25 to 0.76)	0.315
	Change at 48 hr	0.31 (0.03 to 0.6)	0.07 (–0.28 to 0.43)	0.24 (–0.2 to 0.68)	0.284
SV (mL/beat)	Preop	55.8±12.28	56.93±15.22	–1.13 (–8.28 to 6.01)	0.752
	6 hr	53.7±13.21	54.17±13.05	–0.47 (–7.25 to 6.32)	0.891
	12 hr	56.67±13.61	61.3±17.36	–4.63 (–12.69 to 3.43)	0.255
	24 hr	56.13±12.66	58.6±15.23	–2.47 (–9.71 to 4.77)	0.498
	48 hr	58.4±10.32	57.93±13.13	0.47 (–5.64 to 6.57)	0.879
	Change at 6 hr	–2.1 (–7.49 to 3.29)	–2.77 (–8.89 to 3.36)	0.67 (–7.32 to 8.65)	0.868
	Change at 12 hr	0.87 (–4.01 to 5.74)	4.37 (–3.71 to 12.44)	–3.5 (–12.77 to 5.77)	0.452
	Change at 24 hr	0.33 (–3.48 to 4.14)	1.67 (–3 to 6.33)	–1.33 (–7.23 to 4.56)	0.652
	Change at 48 hr	2.6 (–0.16 to 5.36)	1 (–3.73 to 5.73)	1.6 (–3.76 to 6.96)	0.553
SVV (%)	Preop	11.3±4.94	9.9±3.87	1.4 (–0.89 to 3.69)	0.226
	6 hr	9.8±4.5	12.43±5.06	–2.63 (–5.11 to –0.16)	0.037*
	12 hr	10.4±3.4	9.63±3.21	0.77 (–0.94 to 2.48)	0.373
	24 hr	10.8±3.24	10.17±2.28	0.63 (–0.81 to 2.08)	0.385
	48 hr	11.03±3.97	10.03±2.13	1 (–0.66 to 2.66)	0.23
	Change at 6 hr	–1.5 (–3.83 to 0.83)	2.53 (0.63 to 4.44)	–4.03 (–6.98 to –1.09)	0.008*
	Change at 12 hr	–0.9 (–3.24 to 1.44)	–0.27 (–1.84 to 1.3)	–0.63 (–3.39 to 2.12)	0.647
	Change at 24 hr	–0.5 (–2.51 to 1.51)	0.27 (–0.95 to 1.48)	–0.77 (–3.08 to 1.54)	0.508
	Change at 48 hr	–0.27 (–2.87 to 2.34)	0.13 (–1.16 to 1.43)	–0.4 (–3.27 to 2.47)	0.78
MAP (mm Hg)	Preop	103.67±7.25	105.93±11.99	–2.27 (–7.39 to 2.85)	0.379
	6 hr	94±11.83	91.1±13.34	2.9 (–3.62 to 9.42)	0.377
	12 hr	95.33±10.29	96.83±10.62	–1.5 (–6.9 to 3.9)	0.581
	24 hr	99±6.09	98.83±7.1	0.17 (–3.25 to 3.58)	0.923
	48 hr	104.73±9.26	103.27±8.49	1.47 (–3.13 to 6.06)	0.525
	Change at 6 hr	–9.67 (–14.65 to –4.68)	–14.83 (–22.22 to –7.44)	5.17 (–3.56 to 13.89)	0.241
	Change at 12 hr	–8.33 (–11.97 to –4.69)	–9.1 (–14.84 to –3.36)	0.77 (–5.89 to 7.42)	0.818
	Change at 24 hr	–4.67 (–6.95 to –2.38)	–7.1 (–11.51 to –2.69)	2.43 (–2.46 to 7.33)	0.322
	Change at 48 hr	1.07 (–2.36 to 4.49)	–2.67 (–7.13 to 1.8)	3.73 (–1.77 to 9.24)	0.18

Values are presented as mean±standard deviation or MD (95% CI) unless otherwise stated.
OLIF, oblique lumbar interbody fusion; MIS-TLIF, minimally invasive transforaminal lumbar interbody fusion; MD, mean difference; CI, confidence interval; SBP, systolic blood pressure; Preop, preoperative; DBP, diastolic blood pressure; O_2 sats, oxygen saturation; HR, heart rate; bpm, beats per minute; CO, cardiac output; SV, stroke volume; SVV, stroke volume variation; MAP, mean arterial pressure.
*$p<0.05$ (Statistical significance).

hours). The length of hospital stay was also comparable between the two groups, with the OLIF group averaging 3.17±0.38 days and the MIS-TLIF group 3.23±0.43 days ($p=0.527$). No perioperative complications were documented in any patient (Table 1).

Discussion

Early mobilization is essential for a successful recovery after spinal surgery, as it minimizes complications associated with prolonged bed rest, mitigates the risk of pulmonary embolism, supports muscular and respiratory system recovery, and helps lower overall medical costs [8,9]. However, postoperative OI can lead to symptoms such as dizziness, blurred vision, headache, and syncope, presenting a significant barrier to early postoperative mobilization [3,10]. These symptoms occur due to lowered cardiac preload and decreased arterial pres-

Table 6. Clinical outcomes

Clinical outcomes	Time	OLIF (n=30)	MIS-TLIF (n=30)	MD (95% CI) between groups	*p*-value
VAS back	Preoperative	7.4±1	6.93±0.94	0.47 (–0.04 to 0.97)	0.069
	Day 1	2.17±0.65	3.8±0.76	–1.63 (–2 to –1.27)	<0.001*
	Day 2	0.8±0.66	2.03±0.72	–1.23 (–1.59 to –0.88)	<0.001*
	Day 3	0.33±0.48	1.6±0.56	–1.27 (–1.54 to –1)	<0.001*
VAS leg	Preoperative	8.6±0.5	8.57±0.63	0.03 (–0.26 to 0.33)	0.82
	Day 1	0.1±0.31	0.13±0.43	–0.03 (–0.23 to 0.16)	0.732
	Day 2	0±0	0±0	NA	-
	Day 3	0±0	0±0	NA	-

Values are presented as mean±standard deviation or MD (95% CI) unless otherwise stated.
OLIF, oblique lumbar interbody fusion; MIS-TLIF, minimally invasive transforaminal lumbar interbody fusion; MD, mean difference; CI, confidence interval; VAS back, Visual Analog Scale of back pain; VAS leg, Visual Analog Scale of leg pain; NA, not applicable.
*$p<0.05$ (Statistical significance).

sure, which, in turn, impair orthostatic cardiovascular regulation. Consequently, cerebral deoxygenation may occur, potentially delaying ambulation in the patients.

The hemodynamic response of the patients in this study reveals a lower OI incidence in patients who underwent OLIF compared to those who received MIS-TLIF. The reductions in SBP and DBP were less pronounced in the OLIF group compared to the MIS-TLIF group, particularly during the first 6 to 12 hours postoperatively. This study indicates that minimally invasive approaches, especially OLIF, may more effectively preserve hemodynamic stability during the early postoperative period. The observed association between OLIF and reduced OI incidence suggests that surgical technique may contribute to this outcome by minimizing disruption to the paraspinal musculature and neurovascular structures [11,12]. Preservation of these soft tissues has been linked to reduced intraoperative blood loss, postoperative pain, and attenuated inflammatory and neurohumoral response induced by muscle injury [12-14]. Collateral tissue damage may trigger increased sympathetic activity and catecholamine release, contributing to hemodynamic instability and a higher risk of postoperative OI [12,15-17].

This study revealed significant variations in SBP, DBP, and MAP between the OLIF and MIS-TLIF group patients, particularly within the first 6 hours postoperatively. The OLIF group patients consistently exhibited higher SBP and MAP compared to the MIS-TLIF group patients, suggesting augmented hemodynamic resilience. The smaller reduction in hemoglobin concentration observed in the OLIF group further supports these findings, as better-preserved oxygen-carrying capacity may enhance overall hemodynamic stability. Interestingly, SVV was significantly lower in the OLIF group after maintaining the standing position for 3 minutes postoperatively. This demonstrates improved cardiovascular adaptability in OLIF patients, potentially mitigating the risk of developing symptomatic OI during early mobilization. The significantly lower EBL in the OLIF group also contributed to the reduced hemoglobin loss, thereby minimizing the need for fluid replacement or blood transfusion. Additionally, it supported better maintenance of circulatory volume, thereby reducing the risk of postoperative OI.

Other potential intraoperative factors impacting the hemodynamic response include variations in the duration of prone positioning. Patients in the MIS-TLIF group remained in the prone position for approximately 2 hours, which may have contributed to increased fluid shifts and venous pooling. Conversely, OLIF patients remained in the prone position for only about 30 minutes during posterior instrumentation. This variation in positioning duration may explain the more pronounced hemodynamic changes observed in the MIS-TLIF group; however, further investigation is warranted to confirm this association.

The clinical outcomes further highlight the advantages of the OLIF approach, as postoperative pain scores—particularly for back pain—were significantly less in the OLIF group during the first three postoperative days. This could be attributed to reduced surgical trauma and less disruption of posterior spinal elements in the OLIF approach compared to MIS-TLIF [18,19].

These findings provide valuable insights for considering implementation of the ERAS protocol in spine surgery. The reduced incidence of postoperative OI and the associated improvements in hemodynamic parameters observed in OLIF patients support its use as a preferred approach for single-level lumbar fusion within the framework of ERAS guidelines. Nevertheless, the results should be approached with caution due to the

observational design and inherent methodological limitations of the study. Larger, multicenter randomized trials are required to corroborate these observations and establish causality. Future research should explore the specific mechanisms underlying these hemodynamic differences, including the impact of positioning duration and surgical approach on autonomic function. Early mobilization—a key component of ERAS—is facilitated by reduced complications and improved outcomes, potentially boosting recovery [1,20-24]. The multimodal analgesia regimen employed in this study, which included both preemptive and postoperative strategies, effectively minimized the need for opioid administration leading to a reduced incidence of postoperative opioid-related side effects, such as dizziness, nausea, blurred vision, and syncope, which could delay ambulation [17,25-27]. This ERAS protocol also emphasized the significance of maintaining adequate fluid balance to optimize patient outcomes. A previous study reported a high incidence of OI related to postoperative hypovolemia or impaired fluid balance. These complications can induce a reduction in central blood volume while transitioning from a supine to an upright position, potentially impairing ambulation [3].

This study reported no perioperative complications in any patients. Previous studies suggest that prolonged immobilization after spine surgery could lead to deep vein thrombosis, pressure ulcers, pneumonia, bowel ileus, and lung atelectasis [3,27-29]. The integration of ERAS protocol with single-level OLIF surgery may facilitate faster recovery and reduce the risk of postoperative complications.

This study has multiple limitations. First, the absence of intraoperative neuromonitoring in our study represents both a strength and a limitation. While it eliminated potential confounding from differential anesthetic requirements associated with neuromonitoring, it also limits the generalizability of our findings to centers where intraoperative neuromonitoring is routinely employed for these procedures. Second, this study was conducted at a single academic institution, the results may not be generalized to centers with differing patient populations or ERAS protocols. Multicenter trials are needed to verify our findings across diverse clinical settings. Third, although the sample size was adequate to detect differences in the primary outcome, it was too small to robustly support multivariable analysis. Therefore, the potential influence of residual confounding cannot be excluded, and the findings should be interpreted as hypothesis-generating rather than definitive. Additionally, although the study was adequately powered to detect differences in hemodynamic parameters, it may have lacked the statistical power to identify rare complications or less frequent outcomes. Finally, long-term outcomes, such as functional recovery and quality of life, were not assessed.

Conclusions

This study suggests that OLIF performed within the framework of an ERAS protocol may be associated with a lower incidence of postoperative OI, greater hemodynamic stability, and improved early postoperative pain scores compared to MIS-TLIF. These potential advantages, coupled with decreased blood loss and comparable operative efficiency, warrant further investigation through randomized controlled trials. Future studies should focus on validating these findings and evaluating long-term outcomes across diverse surgical settings.

Key Points

- Postoperative orthostatic intolerance (OI) is a common but under-recognized barrier to early mobilization following minimally invasive spine surgery.
- Patients who underwent oblique lateral interbody fusion (OLIF) experienced significantly lower rates of OI and more stable hemodynamic parameters during early mobilization compared to MIS-minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF).
- OLIF was also associated with reduced blood loss, less postoperative hemoglobin drop, and lower back pain scores compared to MIS-TLIF.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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References

1. Elsarrag M, Soldozy S, Patel P, et al. Enhanced recovery after spine surgery: a systematic review. Neurosurg Focus 2019;46:E3.
2. Wang MY, Chang PY, Grossman J. Development of an Enhanced Recovery After Surgery (ERAS) approach for lumbar spinal fusion. J Neurosurg Spine 2017;26:411-8.
3. Yang Y, Chen Y, Tong B, et al. Orthostatic hypotension following posterior spinal fusion surgeries for spinal deformity correction in adolescents: prevalence and risk factors. BMC Musculoskelet Disord 2021;22:1039.
4. Lanier JB, Mote MB, Clay EC. Evaluation and management of orthostatic hypotension. Am Fam Physician 2011;84:527-36.
5. Mobbs RJ, Phan K, Malham G, Seex K, Rao PJ. Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. J Spine Surg 2015;1:2-18.
6. Yingsakmongkol W, Jitpakdee K, Varakornpipat P, et al. Clinical and radiographic comparisons among minimally invasive lumbar interbody fusion: a comparison with three-way matching. Asian Spine J 2022;16:712-22.
7. Jans O, Bundgaard-Nielsen M, Solgaard S, Johansson PI, Kehlet H. Orthostatic intolerance during early mobilization after fast-track hip arthroplasty. Br J Anaesth 2012;108:436-43.
8. Bansal T, Sharan AD, Garg B. Enhanced recovery after surgery (ERAS) protocol in spine surgery. J Clin Orthop Trauma 2022;31:101944.
9. Nazareth A, D'Oro A, Liu JC, et al. Risk factors for postoperative venous thromboembolic events in patients undergoing lumbar spine surgery. Global Spine J 2019;9:409-16.
10. Bundgaard-Nielsen M, Jorgensen CC, Jorgensen TB, et al. Orthostatic intolerance and the cardiovascular response to early postoperative mobilization. Br J Anaesth 2009;102:756-62.
11. Liu L, Xue H, Han Z, et al. Comparison between OLIF and MISTLIF in degenerative lumbar stenosis: an age-, sex-, and segment-matched cohort study. Sci Rep 2023;13:13188.
12. Song Z, Zhang Z, Zheng J, et al. Short-term and mid-term evaluation of three types of minimally invasive lumbar fusion surgery for treatment of L4/L5 degenerative spondylolisthesis. Sci Rep 2024;14:4320.
13. Debono B, Wainwright TW, Wang MY, et al. Consensus statement for perioperative care in lumbar spinal fusion: Enhanced Recovery After Surgery (ERAS(R)) Society recommendations. Spine J 2021;21:729-52.
14. Kleppe KL, Greenberg JA. Enhanced recovery after surgery protocols: rationale and components. Surg Clin North Am 2018;98:499-509.
15. Baldini G, Bagry H, Aprikian A, Carli F. Postoperative urinary retention: anesthetic and perioperative considerations. Anesthesiology 2009;110:1139-57.
16. Ling LI, Rong HU, Yumei ZH. Value of enhanced recovery after surgery in patients undergoing minimally invasive transforaminal lumbar interbody fusion during perioperative period. J Clin Med Pract 2022;26:42-5.
17. Gobezie NZ, Endalew NS, Tawuye HY, Aytolign HA. Prevalence and associated factors of postoperative orthostatic intolerance at University of Gondar Comprehensive Specialized Hospital, Northwest Ethiopia, 2022: cross sectional study. BMC Surg 2023;23:108.
18. Zhu HF, Fang XQ, Zhao FD, et al. Comparison of oblique lateral interbody fusion (OLIF) and minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) for treatment of lumbar degeneration disease: a prospective cohort study. Spine (Phila Pa 1976) 2022;47:E233-42.
19. Sun WX, Liu HN, Chen MT, et al. Meta-analysis of the clinical efficacy and safety of oblique lateral interbody fusion and transforaminal interbody fusion in the treatment of degenerative lumbar spondylolisthesis. EFORT Open Rev 2022;7:663-70.
20. Shao X, Li R, Zhang L, Jiang W. Enhanced recovery after surgery protocol for oblique lumbar interbody fusion. Indian J Orthop 2022;56:1073-82.
21. Naftalovich R, Singal A, Iskander AJ. Enhanced recovery after surgery (ERAS) protocols for spine surgery: review of literature. Anaesthesiol Intensive Ther 2022;54:71-9.
22. Porche K, Samra R, Melnick K, et al. Enhanced recovery after surgery (ERAS) for open transforaminal lumbar interbody fusion: a retrospective propensity-matched cohort study. Spine J 2022;22:399-410.
23. Guo T, Ding F, Fu B, et al. Efficacy and safety of enhanced recovery after surgery (ERAS) protocols for patients undergoing minimally invasive transforaminal lumbar interbody fusion surgery: a systematic review and meta-analysis. World Neurosurg 2024;188:199-210.
24. Lu HR, Yang A, Li X, He MZ, Sun JY. A new nursing pattern based on ERAS concept for patients with lumbar degenerative diseases treated with OLIF surgery: a retrospective study. Front Surg 2023;10:1121807.
25. Zeng ZY, Xu ZW, He DW, et al. Complications and prevention strategies of oblique lateral interbody fusion technique. Orthop Surg 2018;10:98-106.
26. Wainwright TW, Immins T, Middleton RG. Enhanced recovery after surgery (ERAS) and its applicability for major spine surgery. Best Pract Res Clin Anaesthesiol 2016;30:91-102.
27. Sun TS, Shen JX, Liu ZJ, et al. Expert consensus in enhanced recovery after spinal surgery in China: perioperative management. Chin J Bone Joint Surg 2017;10:271-79.

28. Fleege C, Arabmotlagh M, Almajali A, Rauschmann M. Pre- and postoperative fast-track treatment concepts in spinal surgery : patient information and patient cooperation. Orthopade 2014;43:1062-9.

29. Kerolus MG, Yerneni K, Witiw CD, et al. Enhanced recovery after surgery pathway for single-level minimally invasive transforaminal lumbar interbody fusion decreases length of stay and opioid consumption. Neurosurgery 2021;88:648-57.