Comparison of perioperative outcomes following open versus minimally invasive transforaminal lumbar interbody fusion in obese patients

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Object. Minimally invasive (MI) transforaminal lumbar interbody fusion (TLIF) has proven to be effective in the treatment of spondylolisthesis and degenerative disc disease (DDD). Compared with the traditional open TLIF, the MI procedure has been associated with less blood loss, less postoperative pain, and a shorter hospital stay. However, it is uncertain whether the advantages of an MI TLIF also apply specifically to obese patients. This study was dedicated to evaluating whether obese patients reap the perioperative benefits similar to those seen in patients with normal body mass index (BMI) when undergoing MI TLIF.

Methods. Obese patients—that is, those with a BMI of at least 30 kg/m²—who had undergone single-level TLIF were retrospectively identified and categorized according to BMI: Class I obesity, BMI 30.0–34.9 kg/m²; Class II obesity, BMI 35.0–39.9 kg/m²; or Class III obesity, BMI ≥ 40.0 kg/m². In each obesity class, patients were stratified by TLIF approach, that is, open versus MI. Perioperative outcomes, including intraoperative estimated blood loss (EBL), complications (overall, intraoperative, and 30-day postoperative), and hospital length of stay (LOS), were compared. The chi-square test, Fisher exact test, or 2-tailed Student t-test were used when appropriate.

Results. One hundred twenty-seven patients were included in the final analysis; 49 underwent open TLIF and 78 underwent MI TLIF. Sixty-one patients had Class I obesity (23 open and 38 MI TLIF); 45 patients, Class II (19 open and 26 MI); and 21 patients, Class III (7 open and 14 MI). Overall, mean EBL was 397.2 ml and mean hospital LOS was 3.7 days. Minimally invasive TLIF was associated with significantly less EBL and a shorter hospital stay than open TLIF when all patients were evaluated as a single cohort and within individual obesity classes. Overall, the complication rate was 18.1%. Minimally invasive TLIF was associated with a significantly lower total complication rate (11.5% MI vs 28.6% open) and intraoperative complication rate (3.8% MI vs 16.3% open) as compared with open TLIF. When stratified by obesity class, MI TLIF was still associated with lower rates of total and intraoperative complications. This effect was most profound and statistically significant in patients with Class III obesity (42.9% open vs 7.1% MI).

Conclusions. Minimally invasive TLIF offers obese patients perioperative benefits similar to those seen in patients with normal BMI who undergo the same procedure. These benefits include less EBL, a shorter hospital stay, and potentially fewer complications compared with open TLIF. Additional large retrospective studies and randomized prospective studies are needed to verify these findings.
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KEY WORDS • blood loss • complication • length of stay •
minimally invasive procedure • obesity • transforaminal lumbar interbody fusion

THE prevalence of severe obesity is steadily rising, and the proper surgical management of a population with this condition will continue to be an increasingly important issue.⁹ Obesity is a well-known risk factor for a multitude of diseases, such as diabetes mellitus,¹⁰ hypertension,²¹ osteoarthritis,⁸ and even certain types of cancers.² In addition to the increased risk for medical comorbidities there is, according to a growing body of literature, a higher risk for perioperative complications.^{1,6,16,18,22,28}

Abbreviations used in this paper: BMI = body mass index; DDD = degenerative disc disease; EBL = estimated blood loss; LOS = length of stay; MI = minimally invasive; TLIF = transforaminal lumbar interbody fusion.

Specifically, obese patients have a greater risk for wound infections,^{6,18} complications associated with their obesity-related comorbidities,²⁸ deep vein thrombosis,¹ and pulmonary embolus.¹ Moreover, there are higher readmission rates due to postoperative complications in obese patients.¹ Therefore, not surprisingly, obese patients who undergo traditional open lumbar spine surgery also have an increased risk for a variety of perioperative complications, including reoperation, as compared with patients with a BMI within the normal range.^{11,13,26,30,33,34}

Despite their higher risk for complications, obese patients still exhibit good long-term outcomes (comparable to those in patients with normal BMI) in terms of symptomatic relief and disease treatment when they undergo ei-

ther open or MI surgery for the treatment of degenerative diseases of the lumbar spine.^{5,17} One of the most common surgical techniques using an MI approach is TLIF for the treatment of spondylolisthesis and DDD.⁷ The advantages of MI TLIF are less postoperative pain, less intraoperative blood loss, and shorter hospital stays while providing long-term outcomes similar to those for open TLIF.^{4,15,27} However, there remains a paucity of studies assessing whether these perioperative benefits also apply to obese patients; most studies evaluating the use of MI TLIF have incorporated patients with normal BMI. In the present study, we determined whether obese patients undergoing MI or open TLIF reap similar perioperative benefits. We directly compared intraoperative EBL, complication rate, and duration of hospital stay for open and MI TLIF in separate cohorts of patients with Class I, Class II, and Class III obesity.

Methods

Approval from the University of Michigan Institutional Review Board was obtained prior to performing this study and reviewing the electronic medical records.

Patient Population

Patients who had undergone open or MI TLIF performed by one of two neurosurgeons (P.P. or F.L.M.) between 2006 and 2012 were retrospectively identified through the use of electronic medical records. From those initially identified were excluded those patients with the following characteristics: age < 18 years, BMI < 30.0 kg/m², and TLIF of more than 1 level. Patients who had undergone additional spinal instrumentation and posterior fusion beyond 1 vertebra above and below the site of TLIF were then excluded from our analysis to allow a more homogeneous cohort. This resulted in a cohort of obese (BMI ≥ 30.0 kg/m²) adults who had undergone single-level TLIF. Indications for surgery were pain unresponsive to nonoperative management, neurological deficit, and/or spinal instability (Fig. 1). The MI TLIF technique used in these patients has been described in the literature.²³

Data Collection

Data regarding patient demographics, including age at the time of surgery (in years), sex, and BMI (in kg/m²), were recorded. Body mass index was calculated utilizing the following standard formula: weight in kg/height in square meters. The presence of comorbidities and the patient's smoking status were also noted. Comorbidities included hypertension, coronary artery disease (or history of myocardial infarct), diabetes mellitus, kidney disease, and anemia. Kidney disease was considered to be present if patients had a preoperative creatinine value > 1.3 mg/dl in men and > 1.1 mg/dl in women. Anemia was defined as a preoperative hemoglobin value < 13.5 g/dl in men and < 12.0 g/dl in women. Smoking status was categorized into 3 groups: never (patients who never smoked), past smokers (patients who quit at least 1 year prior to surgery), and current smokers. Diagnoses indicated for surgery included spondylolisthesis, DDD alone (without other associated

Fig. 1. **Left:** Lateral radiograph obtained in an obese woman with symptomatic L4–5 spondylolisthesis. **Right:** Postoperative lateral radiograph obtained after MI TLIF in the same patient, showing instrumentation and interbody cage at L4–5.

pathology), DDD with stenosis, DDD with deformity, and DDD with disc herniation. The lumbar level in which a TLIF was performed was also noted.

Primary outcomes of interest were intraoperative EBL (recorded in ml), complication (total, intraoperative, and 30-day postoperative), and length of hospital stay. Total, or overall, complication rate was computed by totaling the number of patients who experienced at least 1 intraoperative and/or postoperative complication. Intraoperative and postoperative complications were recorded separately as well. A postoperative complication was defined as any unforeseen event related to surgery that required additional medical and/or surgical intervention up to 30 days following the surgery. Length of hospital stay was determined by totaling the number of days the patient was hospitalized, beginning on the date of surgery and ending on the date of hospital discharge.

Statistical Analysis

Patients who met the study inclusion criteria were first categorized into 3 groups based on the WHO BMI classification system: Class I obesity, BMI 30.0–34.9 kg/m²; Class II obesity, BMI 35.0–39.9 kg/m²; and Class III obesity, BMI ≥ 40 kg/m². Among each obesity class, patients were subsequently categorized based on whether they had undergone an open or MI TLIF. For each of the 3 obesity classes, descriptive and statistical comparisons of demographics, comorbidities, and diagnoses for the open and MI groups were performed. Comparisons of EBL, total complication rate, intraoperative complications, 30-day postoperative complications, and length of hospital stay were then performed. For categorical outcomes (complications) with a cumulative sample size of at least 50 patients (Class I obesity), the chi-square test was used, and for sample sizes less than 50 patients (Class II and III obesity), the Fisher exact test was applied. For continuous variables (EBL and LOS), a 2-tailed Student t-test was used. A $p < 0.05$ was considered significant in this study. All statistical analyses were performed using SAS software, version 9.2 (SAS Institute, Inc.).

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Results

Five hundred ninety-nine patients who had undergone TLIF were identified. Among this initial cohort, 127 patients met the study's a priori criteria of adults with a BMI of at least 30.0 and who had undergone a single-level TLIF. Sixty-one patients had Class I obesity (mean BMI 32.0 kg/m²); 45 patients, Class II obesity (mean BMI 37.0 kg/m²); and 21 patients, Class III obesity (mean BMI 44.4 kg/m², range 40.0–53.6 kg/m²). Of the 127 patients, 49 (38.6%) underwent an open TLIF; and 78 (61.4%), an MI TLIF. Most patients underwent TLIF for spondylolisthesis (59.1%). The rest underwent TLIF for DDD alone (18.9%), DDD with stenosis (15.7%), DDD with deformity (0.1%), and DDD with disc herniation (5.5%). The two most common levels in which TLIF was performed were L4–5 (44.9%) and L5–S1 (40.2%). In the overall cohort, mean EBL was 397.2 ml, complication rate was 18.1%, and mean hospital LOS was 3.7 days.

Comparisons of Demographics, Comorbidities, and Diagnoses

Table 1 features demographics, medical comorbidities,

and diagnoses of patients with Class I obesity for the open and MI TLIF groups. Among the 61 patients, 23 (37.7%) underwent open TLIF and 38 (62.3%) underwent MI TLIF. The two groups were well matched. There were no significant differences in any of the covariates between the two groups. Table 2 features demographics, medical comorbidities, and diagnoses of patients with Class II obesity for the open and MI TLIF groups. Among the 45 patients, 19 (42.2%) underwent open TLIF and 26 (57.8%) underwent MI TLIF. The cohorts were well matched, as there were no significant differences among the covariates. Similarly, Table 3 features demographics, medical comorbidities, and diagnoses of 21 patients with Class III obesity for the open and MI TLIF groups. Seven patients (33.3%) underwent open TLIF, and 14 (66.7%) underwent MI TLIF. There were no significant differences in covariates between these two groups; both cohorts were well matched.

Intraoperative Blood Loss

Table 4 features intraoperative EBL among patients who underwent open or MI TLIF. Overall mean EBL was

TABLE 1: Baseline characteristics of patients with Class I obesity who underwent open or MI TLIF procedures*

Parameter	No. (%)			p Value
	Total	Open TLIF	MI TLIF	
no. of patients	61	23	38	
mean BMI in kg/m ²	32.0 ± 1.4	32.3 ± 1.4	31.8 ± 1.4	0.860
mean age in yrs	53.1 ± 13.2	54.1 ± 14.1	52.5 ± 12.8	0.593
male sex	31 (50.8)	12 (52.2)	19 (50.0)	0.869
hypertension	29 (47.5)	11 (47.8)	18 (47.4)	0.972
coronary artery disease	5 (8.2)	3 (13.0)	2 (5.3)	0.283
diabetes mellitus	14 (23.0)	7 (30.4)	7 (18.4)	0.280
kidney disease†	4 (6.6)	3 (13.0)	1 (2.6)	0.283
anemia‡	4 (6.6)	3 (13.0)	1 (2.6)	0.111
smoking status				0.406
never	34 (55.7)	15 (65.2)	19 (50.0)	
past	14 (23.0)	5 (21.7)	9 (23.7)	
current	13 (21.3)	3 (13.0)	10 (26.3)	
diagnosis				0.222
spondylolisthesis	35 (57.4)	11 (47.8)	24 (63.2)	
DDD alone	13 (21.3)	8 (34.8)	5 (13.2)	
DDD w/ stenosis	8 (13.1)	3 (13.0)	5 (13.2)	
DDD w/ deformity	0 (0.0)	0 (0.0)	0 (0.0)	
DDD w/ disc herniation	5 (8.2)	1 (4.3)	4 (10.5)	
level of surgery				0.152
L1–2	1 (1.6)	1 (4.3)	0 (0.0)	
L2–3	2 (3.3)	0 (0.0)	2 (5.3)	
L3–4	7 (11.5)	5 (21.7)	2 (5.3)	
L4–5	26 (42.6)	9 (39.1)	17 (44.7)	
L5–S1	25 (41.0)	8 (34.8)	17 (44.7)	

* Values expressed as means ± standard deviations, unless indicated otherwise.

† High creatinine was defined as a preoperative creatinine value > 1.3 mg/dl in men and > 1.1 mg/dl in women.

‡ Anemia was defined as a preoperative hemoglobin value < 13.5 g/dl in men and < 12.0 g/dl in women.

TABLE 2: Baseline characteristics of patients with Class II obesity who underwent open or MI TLIF procedures

Parameter	No. (%)			p Value
	Total	Open TLIF	MI TLIF	
no. of patients	45	19	26	
mean BMI in kg/m ²	37.0 ± 1.4	37.2 ± 1.5	36.9 ± 1.4	0.750
mean age in yrs	53.4 ± 13.4	57.4 ± 12.6	50.5 ± 13.4	0.792
male sex	20 (44.4)	8 (42.1)	12 (46.2)	0.787
hypertension	29 (64.4)	12 (63.2)	17 (65.4)	0.878
coronary artery disease	3 (6.7)	1 (5.3)	2 (7.7)	0.747
diabetes mellitus	9 (20.0)	4 (21.1)	5 (19.2)	0.880
kidney disease	4 (8.9)	2 (10.5)	2 (7.7)	0.741
anemia	7 (15.6)	5 (26.3)	2 (7.7)	0.089
smoking status				0.674
none	25 (55.6)	12 (63.2)	13 (50.0)	
past	9 (20.0)	3 (15.8)	6 (23.1)	
current	11 (24.4)	4 (21.1)	7 (26.9)	
diagnosis				0.214
spondylolisthesis	23 (51.1)	8 (42.1)	15 (57.7)	
DDD alone	9 (20.0)	3 (15.8)	6 (23.1)	
DDD w/ stenosis	12 (26.7)	8 (42.1)	4 (15.4)	
DDD w/ deformity	0 (0.0)	0 (0.0)	0 (0.0)	
DDD w/ disc herniation	1 (2.2)	0 (0.0)	1 (3.8)	
level of surgery				0.073
L1–2	0 (0.0)	0 (0.0)	0 (0.0)	
L2–3	2 (4.4)	2 (10.5)	0 (0.0)	
L3–4	5 (11.1)	4 (21.1)	1 (3.8)	
L4–5	18 (40.0)	7 (36.8)	11 (42.3)	
L5–S1	20 (44.4)	6 (31.6)	14 (53.8)	

397.2 ml. Among the 127 patients, MI TLIF was associated with significantly lower EBL than open TLIF (168.6 vs 661.0 ml, respectively; $p < 0.001$). Among all 3 obesity classes, MI TLIF was also associated with significantly lower EBL than open TLIF: Class I obesity, $p < 0.001$; Class II obesity, $p < 0.001$; and Class III obesity, $p = 0.040$. In the Class I obesity group, the open TLIF group had a mean EBL of 741.3 ml compared with 141.7 ml in the MI TLIF group. In the Class II obesity group, the open TLIF group had a mean EBL of 596.8 ml and the MI TLIF group had a mean EBL of 153.5 ml. In patients with Class III obesity, open and MI TLIF were associated with a mean EBL of 614.3 and 269.6 ml, respectively.

Complication Rates for Open and MI TLIF

Complication rates among patients who underwent open or MI TLIF are shown in Table 5. The total complication rate was 18.1%. Patients who underwent open TLIF had significantly higher rates of complication than those who underwent MI TLIF (28.6% vs 11.5%, respectively; $p = 0.017$). In addition, open TLIF was associated with significantly higher rates of intraoperative complication than MI TLIF (16.3% vs 3.8%, respectively; $p = 0.015$). Postoperative complication rates were similar between the two groups (12.2% open vs 10.3% MI; $p = 0.729$).

On stratification by obesity, open and MI groups showed an analogous trend of higher total and intraoperative complication rates, while postoperative complication rates were similar between the open and MI groups. In the group of patients with Class I obesity, open TLIF was associated with higher overall (30.4% open vs 13.2% MI) and intraoperative (21.7% open vs 5.3% MI) complication rates than the MI group; this was close to being statistically significant ($p = 0.100$ and $p = 0.050$, respectively). Similarly, in patients with Class II obesity, open TLIF had higher overall (21.1% open vs 11.5% MI) and intraoperative (5.3% open vs 0.0% MI) complication rates than MI TLIF ($p = 0.384$ and $p = 0.237$, respectively). In patients with Class III obesity, there was a significant difference in the overall complication rate ($p = 0.049$). Patients who underwent open TLIF had a complication rate of 42.9%—a much higher rate than that of the MI group (7.1%). While the associations were not statistically significant, patients who underwent open TLIF also had higher intraoperative (28.6% open vs 7.1% MI, $p = 0.186$) and postoperative (14.3% open vs 7.1% MI, $p = 0.599$) complication rates than the MI group.

The complications experienced among the study cohort are specified in Table 6 and stratified based on obesity class and approach to TLIF. Most notably, durotomy requiring repair was the most common intraoperative

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TABLE 3: Baseline characteristics of patients with Class III obesity who underwent open or MI TLIF procedures

Parameter	No. (%)			p Value
	Total	Open TLIF	MI TLIF	
no. of patients	21	7	14	
mean BMI in kg/m ²	44.4 ± 4.2	46.3 ± 4.9	43.4 ± 3.7	0.351
mean age in yrs	55.5 ± 12.6	59.4 ± 12.9	53.5 ± 3.3	0.848
male sex	10 (47.6)	3 (42.9)	7 (50.0)	0.757
hypertension	16 (76.2)	5 (71.4)	11 (78.6)	0.717
coronary artery disease	2 (9.5)	1 (14.3)	1 (7.1)	0.599
diabetes mellitus	5 (23.8)	3 (42.9)	2 (14.3)	0.147
kidney disease	3 (14.3)	1 (14.3)	2 (14.3)	0.999
anemia	1 (4.8)	1 (14.3)	0 (0.0)	0.147
smoking status				0.829
none	15 (71.4)	5 (71.4)	10 (71.4)	
past	4 (19.0)	1 (14.3)	3 (21.4)	
current	2 (9.5)	1 (14.3)	1 (7.1)	
diagnosis				0.734
spondylolisthesis	17 (81.0)	6 (85.7)	11 (78.6)	
DDD alone	2 (9.5)	1 (14.3)	1 (7.1)	
DDD w/ stenosis	0 (0.0)	0 (0.0)	0 (0.0)	
DDD w/ deformity	1 (4.8)	0 (0.0)	1 (7.1)	
DDD w/ disc herniation	1 (4.8)	0 (0.0)	1 (7.1)	
level of surgery				0.091
L1–2	0 (0.0)	0 (0.0)	0 (0.0)	
L2–3	0 (0.0)	0 (0.0)	0 (0.0)	
L3–4	2 (9.5)	2 (28.6)	0 (0.0)	
L4–5	13 (61.9)	4 (57.1)	9 (64.3)	
L5–S1	6 (28.6)	1 (14.3)	5 (35.7)	

complication, and infection was the most common postoperative complication. There was 1 case in which a K-wire was fractured in an L-5 vertebral body during an MI TLIF.

Length of Hospital Stay

Table 7 compares hospital LOS for patients who underwent open TLIF and those who underwent MI TLIF, stratified by obesity class. The overall mean LOS was 3.7 days, and patients who underwent open TLIF had a significantly longer LOS than patients who underwent MI TLIF (4.7 days vs 3.1 days, respectively; $p < 0.001$). In fact, this association was also the case when stratified by obesity class. Among patients with Class I and Class II obesity, the open group had a significantly longer LOS than the MI group (Class I: 4.2 days vs 3.0 days, $p = 0.004$; and Class II: 4.7 days vs 3.0 days, $p = 0.002$, respectively). A similar trend was also seen in patients with Class III obesity; the open group stayed in the hospital for 4.6 days and the MI group stayed for 3.6 days, although this association was not statistically significant ($p = 0.345$).

Discussion

Transforaminal lumbar interbody fusion is a surgical

technique that has proven to be successful in improving symptoms associated with spondylolisthesis and DDD of the lumbar spine.¹⁹ The procedure has evolved over the past 10 years, with MI approaches becoming increasingly popular.^{7,15,24,27,35} Numerous studies, including several prospective ones, indicate that MI TLIF has advantages over open TLIF with regard to perioperative outcomes.^{27,31} Specifically, these advantages consist of less intraoperative blood loss,^{15,27,31} fewer intraoperative transfusion requirements,¹⁵ less postoperative pain,^{27,31} shorter time to am-

TABLE 4: Intraoperative EBL in patients who underwent open or MI TLIF procedures*

Group	Overall	Open TLIF	MI TLIF	p Value
overall	397.2 ± 494.6	661.0 ± 561.3	168.6 ± 16.2.1	<0.001
Class I obesity	443.2 ± 408.8	741.3 ± 453.7	141.7 ± 125.1	<0.001
Class II obesity	340.7 ± 356.6	596.8 ± 415.7	153.5 ± 114.2	<0.001
Class III obesity	384.5 ± 368.1	614.3 ± 449.7	269.6 ± 269.2	0.040

* Values expressed in ml.

TABLE 5: Complications in patients who underwent open or MI TLIF procedures

Group & Complication	Total	Open TLIF	MI TLIF	p Value
total				
no. of patients	127	49	78	
overall*	23 (18.1)	14 (28.6)	9 (11.5)	0.017
intraop	11 (8.7)	8 (16.3)	3 (3.8)	0.015
postop	14 (11.0)	6 (12.2)	8 (10.3)	0.729
Class I obesity				
no. of patients	61	23	38	
overall*	12 (19.7)	7 (30.4)	5 (13.2)	0.100
intraop	7 (11.5)	5 (21.7)	2 (5.3)	0.050
postop	6 (9.8)	2 (8.7)	4 (10.5)	0.816
Class II obesity				
no. of patients	45	19	26	
overall*	7 (15.6)	4 (21.1)	3 (11.5)	0.384
intraop	1 (2.2)	1 (5.3)	0 (0.0)	0.237
postop	6 (13.3)	3 (15.8)	3 (11.5)	0.679
Class III obesity				
no. of patients	21	7	14	
overall*	4 (19.0)	3 (42.9)	1 (7.1)	0.049
intraop	3 (14.3)	2 (28.6)	1 (7.1)	0.186
postop	2 (9.5)	1 (14.3)	1 (7.1)	0.599

* Overall complication rate is based on tally of individual patients who had an intraoperative and/or postoperative complication.

bulation,¹⁵ and shorter length of hospital stay^{15,27,31} while providing similar long-term functional outcomes as open TLIF.^{15,23} The main disadvantages of MI TLIF include additional exposure time to intraoperative radiation,²⁷ potential excess cost,²⁵ and the surgeon's ability to overcome the learning curve as traditional surgical landmarks can be distorted with the use of a tubular retractor.^{15,32}

Minimally invasive TLIF has been applied to the

treatment of overweight and obese patients, and prior studies have shown that in such cases the patients obtain benefits equal to those in patients with normal BMI. In a prospective, single-center, nonrandomized control clinical study, Wang et al.³⁵ showed that MI TLIF in overweight and obese patients resulted in significantly less operating time, less blood loss, and less postoperative back pain compared with open TLIF; these findings are similar to

TABLE 6: Specific complications in patients who underwent open or MI TLIF, stratified by BMI class and surgical approach*

Group & Time of Complication	Open TLIF (no. of cases)	MI TLIF (no. of cases)
Class I obesity		
intraop	durotomy w/ primary repair (5)	durotomy w/ primary repair (1) fractured K-wire in L-5 vertebral body (1)
postop	UTI (1) valium w/drawal (1)	wound dehiscence (1) atrial fibrillation w/ rapid ventricular response (1) UTI (2)
Class II obesity		
intraop	durotomy w/ primary repair (1)	
postop	development of seroma (1) reoperation for screw revision (1) wound infection (1)	tachycardia associated w/ respiratory failure (1) UTI (1) lower-extremity DVT (1)
Class III obesity		
intraop	durotomy withdrawal primary repair (2)	durotomy w/ primary repair (1)
postop	reoperation for medially displaced pedicle screw & DVT (1)	UTI & pneumonia (1)

* DVT = deep vein thrombosis; UTI = urinary tract infection.

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TABLE 7: Hospital LOS for patients who underwent open or MI TLIF procedures*

Group	Overall	Open TLIF	MI TLIF	p Value
overall	3.7 ± 2.0	4.7 ± 2.1	3.1 ± 1.7	<0.001
Class I obesity	3.6 ± 2.0	4.2 ± 2.1	3.0 ± 2.0	0.004
Class II obesity	3.8 ± 1.9	4.7 ± 2.1	3.0 ± 1.4	0.002
Class III obesity	3.9 ± 1.9	4.6 ± 2.2	3.6 ± 1.6	0.345

* Values expressed in days.

those among patients with normal BMI.¹² In addition, in 2 earlier studies (Park et al.²⁴ and Lau et al.¹⁷), we demonstrated that there was no significant difference in the complication rate,^{17,24} intraoperative blood loss,¹⁷ or length of hospital stay¹⁷ between obese patients and patients with normal BMI when undergoing MI TLIF. Senker et al.³² also found similar results when comparing normal weight, overweight, and obese patients who underwent MI TLIF. These findings suggest that MI TLIF can also provide perioperative benefits to obese patients. However, formulating conclusions on whether MI TLIF can benefit patients of all obesity classes and applying the findings from current studies is difficult because of the heterogeneity of the cohorts and the nonoptimal classification and analysis of obese BMI. In the prospective clinical study by Wang et al.,³⁵ the authors rightfully defined overweight as 25.0–29.9 kg/m² and obesity as 30.0 kg/m² and greater. Upon analysis, however, they combined both categories and ended up with a mean BMI of 29.5 kg/m² in the MI group and 28.3 kg/m² in the open group. Formally, these BMIs correlate with the overweight category rather than the obese category. In addition, only 37% of patients were obese. Similarly, in one of our own prior studies, overweight patients were combined with obese patients, resulting in a mean BMI of 30.4 kg/m².²⁴ The study by Lau et al.¹⁷ had a patient cohort with a mean BMI of 37.4 kg/m² that formally met the definition of Class II obesity, but it consisted of a small cohort of 9 patients who underwent MI TLIF.

Therefore, the purpose of the present study was to determine if all classes of obese patients obtained the same perioperative benefits following MI TLIF. In this study, cohort sizes in each obesity class were adequate, and all 3 classes of obesity were well-matched when stratified into open and MI TLIF groups. Our findings suggested that MI TLIF is associated with significantly less EBL and a shorter hospital stay. With regard to complication rates, there is a trend for lower complication rates when patients with Class I and Class II obesity undergo MI TLIF compared with those who undergo open TLIF. In fact, among patients with Class III obesity, MI TLIF was associated with a significantly lower total complication rate than open TLIF, and the difference was quite profound, as the open group experienced about 36% more complications. Thus, it seems that MI TLIF can offer patients of all obesity classes the same perioperative benefits seen in patients with normal BMI. In addition, MI TLIF may even be associated with a reduction in the complication rate as obesity increases beyond a BMI of 40 kg/m².

In obese patients, lower EBL and shorter LOS are most likely attributable to the same proposed mechanisms previously described in patients with normal BMI who undergo MI TLIF: smaller incisions, lower degree of tissue manipulation, and less muscle damage than traditional open approaches. However, it is less intuitive how one can achieve lower intraoperative complication rates with MI than with open TLIF among all 3 obesity classes. All intraoperative complications in the open group were durotomies requiring primary repair. The most likely reason for this finding is random chance or the inherent difficulties experienced when operating on obese patients. In such patients, especially the morbidly obese, it can be physically difficult to achieve adequate exposure given the presence of excess adiposity, muscle, and tissue around the surgical site, and at times, incisions and muscle dissections must be extended. In such circumstances, performing the discectomy and placing the interbody cage during a TLIF can also be more difficult, thus increasing the risk of durotomy. While it is true that with the MI TLIF, more tissue must be traversed with the tubular retractor, obtaining adequate exposure is less challenging as the retractor is inserted through the paraspinal musculature directly over the targeted segment. In this way, MI TLIF may decrease durotomy rates in obese patients.

Patients with Class III obesity who underwent open TLIF had higher intraoperative and postoperative complication rates than those who underwent MI TLIF. In patients with Class III obesity, the combination of both intraoperative and postoperative complications contributed to the finding that the total complication rate was significantly higher in the open TLIF group than in the MI TLIF group. Moreover, the combination of intraoperative and postoperative complications led to an overall complication rate of more than 40% in the open group. The reasons for the higher rates of postoperative complications that are not seen in Class I and Class II obesity may relate to the inherent medical attributes of patients with Class III obesity. As noted previously, adequate exposure through an open approach can be difficult to achieve in severely obese patients and can lead to increased difficulty in adequately performing the procedure. In particular, in open TLIF cases, obtaining the correct trajectory for pedicle screw placement in the severely obese can be challenging. This was actually well demonstrated in one of the Class III obesity patients who underwent open TLIF; the patient experienced a postoperative complication in the form of reoperation for replacement of a medially placed pedicle screw. This complication might have been avoided with MI percutaneous pedicle screw placement, as trajectory is not as strictly limited by exposure.

Postoperative medical management of patients with Class III obesity is probably different for patients in lower obesity classes. It is reported that approximately 75% of adults with Class III obesity have at least one comorbid condition, such as high blood pressure or diabetes mellitus.²⁰ This statistic conforms to our cohort of Class III obesity patients, which had a very high prevalence of hypertension, coronary artery disease, diabetes, and kidney disease. In addition, the rates of these comorbidities in the Class III obese were higher than those in the Class I and

II obese. Patients with Class III obesity also have additional risk factors that are not seen among Class I and II obese, such as a higher risk for deep vein thrombosis¹⁴ and a baseline 2-fold increased risk for all-cause mortality as compared with risks in the Class II obese.³ Therefore, additional care may be warranted during the postoperative course among these particular patients.

This study has important implications for clinical practice and future research. Obesity should not be considered a contraindication to MI lumbar spine surgery.²⁹ Moreover, the results of this study suggest that MI TLIF may result in a decreased complication risk in obese patients, especially those with Class III obesity.

Study Limitations

To our knowledge, this is the first study in which open and MI TLIF has been compared among the 3 obesity classes. However, there are limitations to the study. The major concern is the intrinsic drawback to a retrospective design, which allows susceptibility to certain biases. In this study, the major bias would be selection bias when deciding which patients should undergo an open or MI approach to TLIF. However, this bias (potential confounder) is probably not as significant, as the open and MI groups were all well matched with regard to demographics, comorbidities, and diagnoses.

Conclusions

In patients with Class I, II, and III obesity, MI TLIF offers perioperative benefits similar to those experienced by patients with normal BMI. Compared with open TLIF, MI TLIF is associated with significantly less intraoperative EBL and a shorter hospital LOS. Our results also suggest that an MI approach to TLIF in obese patients can lead to lower complication rates, especially for patients with Class III obesity (BMI ≥ 40.0 kg/m²).

Disclosure

Dr. Park is a consultant for Globus Medical and Medtronic. Dr. La Marca is a consultant for Globus Medical, Lanx, and Biomet, and has received royalties from Stryker and Globus Medical.

Author contributions to the study and manuscript preparation include the following. Conception and design: Park, La Marca. Acquisition of data: all authors. Analysis and interpretation of data: Park, Lau, Khan, Terman, Yee. Drafting the article: Lau, Khan, Terman, Yee. Critically revising the article: Park. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Park. Statistical analysis: Park, Lau. Study supervision: Park, La Marca.

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