

Research Article

Comparison of Clinical and Perioperative Outcomes in Patients Undergoing MIS-TLIF in Outpatient vs Inpatient Setting: Matched Cohort Analysis

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Background

The most common technique utilized for lumbar arthrodesis in an outpatient setting is minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF). While prior studies have assessed this technique's feasibility in an outpatient setting, there is a paucity of literature comparing long term clinical outcomes of MIS-TLIF in an outpatient versus inpatient setting. This study investigates the differences in clinical outcomes between these two settings through comparison of patient-reported outcome measures (PROMs) and minimum clinically important difference (MCID) achievement.

Methods

Primary, elective, single-level MIS-TLIF procedures performed between 2005 and 2021 for degenerative spinal pathology were identified in a surgical database. Patient

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[Conflicts of Interest Statement for Mr. Patel](#)

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demographics, perioperative characteristics, and PROM scores were collected. PROMs measuring physical function, back pain, leg pain, and disability were administered at preoperative and 6-week, 12-week, 6-month, 1-year, and 2-year postoperative time-points. Patients were grouped into two cohorts, depending on whether a patient underwent surgery in an inpatient setting or in an outpatient setting at an ambulatory surgery center (ASC) where the patient was discharged within 23 hours. Coarsened exact match was carried out to control for significant demographic differences between cohorts. Demographic and perioperative characteristics were compared among groups using chi-square and Student's t-test for categorical and continuous variables, respectively. Mean PROM scores were compared between cohorts at each time point utilizing a two-sample t-test. Postoperative PROM improvement from preoperative baseline within each cohort was calculated with use of paired t-test. Achievement of Minimum Clinical Important Difference [MCID] was determined by comparing Δ PROM scores to previously established threshold values. Rates of MCID achievement were compared among groups using simple logistic regression.

Results

After coarsened exact matching, 227 patients were excluded and final patient cohort consisted of 391 patients – 339 patients in the Inpatient MIS-TLIF cohort and 52 patients in the Outpatient MIS-TLIF cohort (**Table 2**). Mean estimated blood loss (EBL), postoperative length of stay (LOS), and postoperative narcotic consumption on days 0 and 1 were observed to be significantly lower in Outpatient MIS-TLIF cohort ($p < 0.041$, all) (**Table 3**). Preoperative and postoperative mean PROM scores were not significantly different for all PROMs collected (**Table 5**). Both cohorts demonstrated significant improvement for PROMIS-PF, SF-12 PCS, VAS back, and VAS leg at 2-year time-point from preoperative baseline (**Table 4**). Patients in the Inpatient MIS-TLIF cohort demonstrated greater proportion achieving MCID for overall SF-12 PCS and overall VAS back ($p < 0.022$, all) (**Table 6**). No significant differences for MCID achievement rates were noted between cohorts at specific postoperative time points (**Table 6**). Inpatient cohort demonstrated significantly higher rates of postoperative nausea and vomiting ($p = 0.001$) (**Table 4**).

Conclusion

After careful patient selection, patients undergoing MIS-TLIF in an outpatient setting demonstrated similar long term clinical outcomes for back pain, leg pain, physical function, and disability as defined by PROMs and MCID achievement. Additionally, patients in outpatient cohort demonstrated reduced postoperative narcotic consumption. Results from our study would suggest patient safety and outcome quality is not compromised from undertaking MIS-TLIF in an outpatient setting.

INTRODUCTION

Low back pain (LBP) is a prevalent condition worldwide and is known to be a leading cause of disability in adults (Hoy et al. 2014). It is reported that 50-80% of adults experience LBP at some point in their life (Rubin 2007). Although a variety of etiologies to LBP exist, most cases are mechanical in origin, arising from spinal structures such as intervertebral discs, facet joints, or paraspinal muscles (Chien and Bajwa 2008; Will, Bury, and Miller 2018; El Sayed and Callahan 2021). Conditions that involve these structures include degenerative disc disease, spinal stenosis, herniated discs, and facet joint syndrome (Chien and Bajwa 2008). Mechanical back pain often responds to conservative management, but if pain continues to persist, surgical intervention such as Lumbar Fusion, can be used to alleviate symptoms (Fritzell et al. 2002).

Of the different lumbar fusion techniques, Minimally Invasive Transforaminal Lumbar Interbody Fusion (MIS-TLIF)

is a widely used procedure in the setting of degenerative disc and facet joint disease. This posterior approach allows for direct access to the required intervertebral foraminal space while minimizing iatrogenic damage to nearby nerve roots and structural ligaments (Mobbs et al. 2015). Furthermore, the minimally invasive technique only requires a single unilateral incision for proper access of discs, which has been associated with a reduction of operative time and blood loss (Cole et al. 2009; Mura et al. 2011; de Kunder et al. 2017). Due to the effectiveness of MIS-TLIF, the volume of this procedure has increased yearly in the United States and internationally (Saifi et al. 2019; Kobayashi et al. 2018).

Lumbar spinal fusions have been traditionally completed in an inpatient setting, which allows for close monitoring of postoperative recovery. The supervision of the patient from medical staff can aid in the management of potential complications while in the hospital. However, there has been an increasing trend in numerous spine procedures being completed in outpatient centers, including TLIF (Mundell et al.

2018). One of the justifications for the migration of spine procedures to outpatient settings can be attributed to cost savings (Mikhail et al. 2021). In 2016, the treatment and management of spine pathology was the highest cause of healthcare spending in the US, which was approximately \$134.5 billion (Dieleman et al. 2020). This transition of orthopedic procedures to the outpatient setting has already been associated with a reduction in costs by up to 43% (Fabricant et al. 2016). Regardless of cost savings, the clinical outcomes of spinal procedures in the outpatient setting must also be assessed, as the safety and well-being of the patient are of utmost priority. Studies analyzing the outcomes of outpatient spine surgeries have reported similar perioperative outcomes to inpatient surgery, such as complication rates and readmission rates (Sivaganesan et al. 2018; Emami et al. 2016). In addition, a meta-analysis by Mundell et al. reported better short-term outcomes from outpatient spine procedures compared to in the inpatient setting (Mundell et al. 2018).

To best optimize outpatient MIS-TLIF outcomes, a combination of careful patient selection, implementation of multimodal analgesic (MMA) protocols, and improved surgical workflow efficiency has been integrated into the ambulatory setting (Nolte, Lynch, and Cha 2020). Selection of patients from certain demographics such as lower age groups, BMI, or ASA class, ensures minimization of risk from postoperative complications. MMA protocols indicate the administration of a combination of medications such as opioids, muscle relaxants, anticonvulsants, and anti-inflammatories during different stages of the surgical process (Parrish et al. 2020). The use of this protocol in spine surgery has been associated with proper pain management, decreased use of postoperative narcotics, and reduction in length of hospital stay (Singh et al. 2017; Devin and McGirt 2015). Finally, the standardization of instrumentation, staff training, and operating room arrangements can aid in streamlining the surgical process to improve efficiency (Nolte, Lynch, and Cha 2020).

Despite the economic advantages and feasibility of outpatient spine operations, the inherent complexities associated with the MIS-TLIF procedure warrants further assessment of surgical outcomes. In spine surgery, patient-reported outcome measures (PROMs) have been increasingly utilized to measure the effectiveness of interventions by comparing the well-being of the patients before and after surgery (Finkelstein and Schwartz 2019). The use of these questionnaires allows for relevant insight into the patient's perception of their own health status at different points of the surgical process. However, the shortcomings of solely using PROMs are that improvements in numerical values from the questionnaire are difficult to assess for direct clinical significance (Auffinger et al. 2013). Therefore, supplementing PROMs with Minimum Clinical Important Difference (MCID) achievement have aided in properly establishing a threshold to determine treatment effectiveness (Auffinger et al. 2013). Long-term outcome studies are indicated to longitudinally monitor the potential risks and functional status of patients following spinal procedures such as lumbar fusion. Our study aims to compare the long-

term clinical outcomes in the context of MIS-TLIF in an outpatient versus inpatient setting by using both PROMs and MCID achievement.

METHODS

PATIENT POPULATION

Prior to conducting the study, Institutional Review Board (IRB) approval (ORA #14051301) and patient informed consent were obtained. A prospectively maintained surgical database was retrospectively reviewed for lumbar procedures between November 2005 and March 2021. Inclusion criteria was set as primary, elective, single-level MIS TLIF procedures for degenerative spinal pathology. Patients undergoing a revision procedure, or surgery indicated for infectious, malignant, or traumatic etiologies were excluded. Additionally, patients with preoperative diagnosis of isthmic spondylolisthesis or degenerative scoliosis were excluded. The surgical approach was performed by a single fellowship-trained spine surgeon at a single institution. Patients were grouped into two cohorts, depending on whether a patient underwent surgery in an inpatient setting or in an outpatient setting at an ambulatory surgery center (ASC) where patient was discharged within 23 hours.

DATA COLLECTION

Comprehensive demographic information including age, gender, ethnicity, body mass index (BMI), smoking status, diabetic status, hypertension status, American Society for Anesthesiologists (ASA) Classification, Charlson Comorbidity Index (CCI) Score, and insurance type were retrieved. Past medical and surgical history were also recorded. Perioperative information, such as operative level, spinal pathology, operative time, and estimated blood loss (EBL) were recorded. Postoperative information such as length of stay, postoperative narcotic consumption, postoperative complications, and 1-year arthrodesis rates were also recorded. Patient-reported outcome measures (PROM) scores were collected. PROMs were administered at preoperative and 6-week, 12-week, 6-month, 1-year, and 2-year postoperative time-points and included Patient-Reported Outcomes Measurement Information System- Physical Function (PROMIS-PF), Visual Analogue Scale (VAS) for back and leg pain, Oswestry Disability Index (ODI), 12-Item Short Form Physical Composite Score (SF-12 PCS).

STATISTICAL ANALYSIS

Descriptive statistics were performed for demographic and operative characteristics. Coarsened exact match was carried out to control for significant demographic difference between cohorts. Demographic and perioperative characteristics were compared among groups using chi-square and Student's t-test for categorical and continuous variables, respectively. Mean PROM scores were compared between cohorts at each time point utilizing a two-sample t-test. Postoperative PROM improvement from preoperative baseline within each cohort was calculated with use of

Table 1. Patient Demographics - Unmatched

Characteristic	Total (n=618)	Inpatient MIS-TLIF (n=563)	Outpatient MIS-TLIF (n=55)	*p-value
Age (mean $\pm$ SD, years)	51.8 $\pm$ 11.5	51.8 $\pm$ 11.7	51.0 $\pm$ 9.0	0.611
BMI (mean $\pm$ SD, kg/m ²)	30.8 $\pm$ 6.2	30.8 $\pm$ 6.2	28.4 $\pm$ 4.5	0.005
Gender				0.127
Female	36.7% (227)	37.7% (212)	27.3% (15)	
Male	63.3% (391)	62.3% (351)	72.7% (40)	
Ethnicity				0.466
Caucasian	69.2% (426)	69.6% (392)	64.2% (34)	
African-American	12.8% (79)	13.1% (74)	9.4% (5)	
Hispanic	12.9% (80)	12.3% (69)	20.8% (11)	
Asian	1.3% (8)	1.2% (7)	1.9% (1)	
Other	3.7% (23)	3.7% (21)	3.8% (2)	
Diabetic Status				0.094
Non-Diabetic	87.4% (540)	86.7% (488)	94.6% (52)	
Diabetic	12.6% (78)	13.3% (75)	5.5% (3)	
Smoking Status				0.034
Non-Smoker	80.0% (492)	78.9% (442)	90.9% (50)	
Smoker	20.0% (123)	21.1% (118)	9.1% (5)	
Hypertension Status				0.010
Normotensive	61.4% (377)	59.8% (335)	77.8% (42)	
Hypertensive	38.6% (237)	40.2% (225)	22.2% (12)	
ASA Classification				0.076
<2	80.9% (494)	80.0% (448)	90.2% (46)	
>2	19.2% (117)	20.0% (112)	9.8% (5)	
CCI Score (mean $\pm$ SD)	2.1 $\pm$ 1.9	2.2 $\pm$ 1.9	1.1 $\pm$ 1.2	<0.001
Insurance				0.025
Workers' Compensation	43.4% (268)	42.9% (242)	47.3% (26)	
Private	47.7% (295)	47.3% (266)	52.7% (29)	
Medicare/Medicaid	8.9% (55)	9.8% (55)	0.0% (0)	

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; SD= standard deviation

paired t-test. Achievement of Minimum Clinical Important Difference (MCID) was determined by comparing Δ PROM scores to previously established threshold values. Rates of MCID achievement were compared among groups using simple logistic regression.

RESULTS

DESCRIPTIVE ANALYSIS

Prior to coarsened exact match, a total of 618 patients were eligible in the study. A total of 563 patients in the Inpatient MIS-TLIF cohort and 55 in the Outpatient MIS-TLIF cohort. Significant demographic differences between cohorts were demonstrated for BMI, smoking, Hypertension, Charlson Comorbidity Index (CCI) score, and insurance status ($p \leq 0.034$, all) ([Table 1](#)).

After coarsened exact matching, a total of 227 patients were excluded. The final patient cohort consisted of 391 patients, with 339 patients in the Inpatient MIS-TLIF cohort

and 52 patients in the Outpatient MIS-TLIF cohort ([Table 2](#)).

Significant differences between cohorts were noted for CCI after matching ($p < 0.025$) ([Table 2](#)). A significantly greater proportion of patients in the Outpatient MIS-TLIF cohort had a preoperative diagnosis of foraminal stenosis ($p \leq 0.001$) ([Table 3](#)). Both mean estimated blood loss (EBL) and postoperative length of stay (LOS) were observed to be significantly lower in the Outpatient MIS-TLIF cohort ($p < 0.041$, all) ([Table 3](#)). Postoperative narcotic consumption on days 0 and 1 were significantly greater for patients in the Inpatient cohort ($p < 0.001$, all) ([Table 3](#)).

PATIENT-REPORTED OUTCOME MEASURES (PROMS)

Preoperative mean PROM scores were not significantly different for all PROMs collected ([Table 5](#)). No significant differences in mean PROMs at postoperative timepoints were demonstrated between cohorts across all PROMs collected. Both cohorts demonstrated significant improvement

Table 2. Patient Demographics – Matched -227 observations deleted

Characteristic	Total (n=391)	Inpatient MIS-TLIF (n=339)	Outpatient MIS-TLIF (n=52)	*p-value
Age (mean ± SD, years)	50.2 ± 10.4	50.1 ± 10.5	50.9 ± 9.2	0.601
BMI (mean ± SD, kg/m ²)	28.8 ± 4.6	28.8 ± 4.7	28.4 ± 4.5	0.511
Gender				0.263
Female	33.8% (132)	34.8% (118)	26.9% (14)	
Male	66.2% (259)	65.2% (221)	73.1% (38)	
Ethnicity				0.424
Caucasian	69.7% (271)	70.5% (239)	64.0% (32)	
African-American	11.8% (46)	12.4% (42)	8.0% (4)	
Hispanic	14.1% (55)	12.9% (44)	22.0% (11)	
Asian	1.3% (5)	1.2% (4)	2.0% (1)	
Other	3.1% (12)	2.9% (10)	4.0% (2)	
Diabetic Status				0.536
Non-Diabetic	92.1% (360)	91.7% (311)	94.2% (49)	
Diabetic	7.9% (31)	8.3% (28)	5.8% (3)	
Smoking Status				0.383
Non-Smoker	88.8% (347)	88.2% (299)	92.3% (48)	
Smoker	11.3% (44)	11.8% (40)	7.7% (4)	
Hypertension Status				0.187
Normotensive	68.5% (267)	67.3% (228)	76.5% (39)	
Hypertensive	31.5% (123)	32.7% (111)	23.5% (12)	
ASA Classification				0.369
<2	93.0% (360)	93.5% (315)	90.0% (45)	
>2	7.0% (27)	6.5% (22)	10.0% (5)	
CCI Score (mean ± SD)	1.6 ± 1.6	1.6 ± 1.6	1.0 ± 1.1	0.025
Insurance				0.633
Workers' Compensation	45.0% (176)	44.5% (151)	48.1% (25)	
Private	54.9% (215)	55.5% (188)	51.9% (27)	

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; SD= standard deviation

for PROMIS-PF, SF-12 PCS, VAS back, and VAS leg at 2-year time-point from preoperative baseline ([Table 5](#)). Patients in the Inpatient MIS-TLIF cohort demonstrated greater proportion achieving MCID for overall SF-12 PCS and overall VAS back ($p < 0.022$, all) ([Table 6](#)). No significant differences for MCID achievement rates were noted between cohorts at specific postoperative time points ([Table 6](#)). Inpatient cohort demonstrated significantly higher rates of postoperative nausea and vomiting ($p=0.001$) ([Table 4](#)).

DISCUSSION

Transforaminal Lumbar Interbody Fusion utilizes a posterior approach for stabilization and treatment degenerative disc disease that has failed appropriate improvement with conservative measures. The requirements of neural retraction in the posterior approach places the patient at risk for potential nerve root injury, epidural fibrosis, and dural tears. However, the TLIF technique directly accesses the unilateral intervertebral foraminal space, reducing direct dissection and surgical trauma to the spinal muscles. This

unilateral approach to the neural foramen reduces associated trauma to the nerve roots, dura, and ligamentum flavum that posterior approaches may compromise. Marked advantages of the TLIF include the relative ease of posterior structure access to the facet joints, ligamentum flavum, and lamina, while preserving the ligamentous and adjacent structures (Mobbs et al. 2015; Hsieh et al. 2007; Phan et al. 2015; Audat et al. 2012). Like PLIF, the main disadvantages of the approach originate from significant paraspinal iatrogenic injury associated with prolonged muscle retraction, difficulty restoring lordosis, correction of coronal imbalance, and with endplate preparation (Craig Humphreys et al. 2001; Sakeb and Ahsan 2013; McAfee et al. 2005). The TLIF procedure has been increasingly utilized as a minimally invasive surgery (MIS-TLIF) and is the most common technique used for lumbar arthrodesis in the outpatient setting (Chin et al. 2016; Basques et al. 2019; Ahn et al. 2016). Benefits of MIS surgery include reduced intraoperative blood loss, less paraspinal muscle and nerve traction, and rapid return to activities of daily life (Vaishnav, Othman, et al. 2019; Starkweather et al. 2008; Park et al. 2020).

Table 3. Perioperative Characteristics

Characteristic	Total (n=391)	Inpatient MIS TLIF (n=339)	Outpatient MIS TLIF (n=52)	*p-value
Spinal Pathology				
Recurrent HNP	19.4% (76)	17.8% (60)	30.8% (16)	0.072
Degenerative Spond	60.9% (238)	59.0% (200)	73.1% (38)	0.063
Foraminal Stenosis	28.6% (112)	21.5% (72)	75.0% (39)	<0.001
Central Stenosis	82.6% (323)	81.1% (275)	92.3% (48)	0.084
Operative Levels				0.328
L2-L3	0.51% (2)	0.51% (2)	0.0% (0)	
L3-L4	4.1% (16)	4.1% (16)	0.0% (0)	
L4-L5	52.4% (205)	51.3% (174)	59.6% (31)	
L5-S1	42.9% (168)	41.4% (147)	40.4% (21)	
Operative Time (Mean $\pm$ SD; min)	117.9 $\pm$ 33.5	117.8 $\pm$ 34.6	118.2 $\pm$ 25.2	0.934
Estimated Blood Loss (Mean $\pm$ SD; mL)	58.2 $\pm$ 51.8	60.1 $\pm$ 53.9	43.3 $\pm$ 28.9	0.041
Length of Stay (Mean $\pm$ SD; hours)	45.1 $\pm$ 30.6	49.7 $\pm$ 29.2	7.4 $\pm$ 7.2	<0.001
Postoperative Narcotic Consumption				
POD 0	88.6 $\pm$ 69.3	97.5 $\pm$ 69.6	29.0 $\pm$ 22.5	<0.001
POD 1	69.2 $\pm$ 79.1	79.1 $\pm$ 80.3	4.8 $\pm$ 13.8	<0.001
Postoperative Vas Pain				
POD 0	5.2 $\pm$ 1.7	5.2 $\pm$ 1.7	5.2 $\pm$ 2.4	0.953
1-year Arthrodesis (%)	94.0%	94.0%	93.8%	0.964

Table 4. Postoperative Complications

Complication	Inpatient MIS TLIF (n=339)	Outpatient MIS TLIF (n=52)	P value
Reintubation	0.3% (1)	0.0% (0)	0.698
Urinary Retention	7.8% (27)	1.9% (1)	0.122
Urinary Tract Infection	0.3% (1)	0.0% (0)	0.698
Acute Renal Failure	0.3% (1)	0.0% (0)	0.698
Postoperative Anemia	0.6% (2)	0.0% (0)	0.582
Altered Mental Status	0.9% (3)	0.0% (0)	0.500
Atelectasis	1.2% (4)	0.0% (0)	0.436
Arrhythmia	0.3% (1)	0.0% (0)	0.698
Dysphagia	0.3% (1)	0.0% (0)	0.698
Ileus	0.0% (0)	0.0% (0)	-
Incontinence	0.0% (0)	0.0% (0)	-
Nausea/Vomiting	17.1% (58)	0.0% (0)	0.001

P-values calculated using unpaired sample t-test

A meta-analysis including 54 studies assessing complications of MIS-TLIF reported a 19.2% total complication rate, most often related to temporary neurological deficit from muscle retraction (Joseph et al. 2015). However, this alarming rate is not an accurate assessment of long-term, worrisome complications related to spine surgery, as near complete resolution of symptoms occurred in most patients. Compared to MIS lateral lumbar interbody fusion, rates of

medical complications and reoperation were similar in the meta-analysis (Joseph et al. 2015).

Outpatient MIS of the spine has become increasingly utilized as patients may benefit from shorter recovery time and healthcare systems can more effectively utilize their limited resources compared to inpatient surgery (Basil and Wang 2019; Beschloss et al. 2021; Allen and Garfin 2010). Compared to inpatient surgery, outpatient MIS-TLIF has demonstrated no significant differences in postoperative

Table 5. Mean PROMs and Postoperative Improvement

PROM	Inpatient MIS-TLIF Mean $\pm$ SD	Inpatient MIS-TLIF Postoperative Improvement	Outpatient MIS-TLIF Mean $\pm$ SD	Outpatient MIS-TLIF Postoperative Improvement	*p-value
PROMIS-PF					
Preoperative	35.6 $\pm$ 6.4 (85)	-	36.2 $\pm$ 6.2 (28)	-	0.633
6-weeks	37.7 $\pm$ 7.1 (70)	0.009	39.9 $\pm$ 6.7 (23)	0.016	0.178
12-weeks	41.8 $\pm$ 7.1 (66)	<0.001	42.1 $\pm$ 6.4 (23)	<0.001	0.855
6-months	45.8 $\pm$ 8.3 (62)	<0.001	43.0 $\pm$ 6.8 (22)	<0.001	0.168
1-year	45.5 $\pm$ 8.7 (55)	<0.001	43.5 $\pm$ 6.2 (13)	0.007	0.447
2-year	44.9 $\pm$ 9.8 (48)	<0.001	42.8 $\pm$ 8.3 (16)	0.004	0.601
SF-12 PCS					
Preoperative	30.8 $\pm$ 8.4 (132)	-	30.2 $\pm$ 7.4 (42)	-	0.687
6-weeks	31.0 $\pm$ 8.1 (108)	0.096	34.0 $\pm$ 8.7 (31)	0.008	0.075
12-weeks	35.5 $\pm$ 9.7 (113)	<0.001	36.3 $\pm$ 8.5 (27)	0.021	0.681
6-months	40.5 $\pm$ 11.6 (102)	<0.001	38.4 $\pm$ 11.1 (26)	<0.001	0.404
1-year	40.9 $\pm$ 11.9 (96)	<0.001	38.7 $\pm$ 11.6 (12)	0.061	0.558
2-year	41.9 $\pm$ 10.9 (53)	<0.001	36.2 $\pm$ 6.9 (6)	0.009	0.216
VAS back					
Preoperative	6.7 $\pm$ 2.1 (303)	-	6.2 $\pm$ 2.8 (46)	-	0.138
6-weeks	4.0 $\pm$ 2.4 (307)	<0.001	4.0 $\pm$ 2.5 (37)	<0.001	0.971
12-weeks	3.8 $\pm$ 2.5 (294)	<0.001	3.9 $\pm$ 2.3 (31)	<0.001	0.714
6-months	3.7 $\pm$ 2.7 (276)	<0.001	3.8 $\pm$ 2.9 (32)	<0.001	0.974
1-year	3.1 $\pm$ 2.8 (80)	<0.001	4.1 $\pm$ 2.7 (15)	<0.001	0.212
2-year	3.0 $\pm$ 2.3 (45)	<0.001	2.5 $\pm$ 2.3 (13)	<0.001	0.691
VAS leg					
Preoperative	5.9 $\pm$ 2.9 (147)	-	5.6 $\pm$ 3.2 (46)	-	0.593
6-weeks	3.1 $\pm$ 2.9 (148)	<0.001	2.5 $\pm$ 2.6 (37)	<0.001	0.219
12-weeks	2.9 $\pm$ 2.8 (144)	<0.001	2.1 $\pm$ 2.5 (31)	<0.001	0.150
6-months	2.8 $\pm$ 2.8 (138)	<0.001	2.4 $\pm$ 2.4 (32)	<0.001	0.450
1-year	2.9 $\pm$ 2.9 (80)	<0.001	2.5 $\pm$ 2.5 (15)	<0.001	0.667
2-year	2.4 $\pm$ 2.6 (46)	<0.001	1.6 $\pm$ 1.5 (3)	<0.001	0.622
ODI					
Preoperative	41.5 $\pm$ 7.7 (150)	-	41.4 $\pm$ 18.4 (46)	-	0.991
6-weeks	36.6 $\pm$ 19.9 (153)	0.206	33.4 $\pm$ 17.5 (36)	0.062	0.377
12-weeks	31.8 $\pm$ 19.5 (153)	<0.001	28.4 $\pm$ 16.5 (31)	<0.001	0.365
6-months	24.8 $\pm$ 18.9 (147)	<0.001	26.1 $\pm$ 18.1 (35)	<0.001	0.729
1-year	24.1 $\pm$ 21.4 (95)	<0.001	26.8 $\pm$ 21.7 (15)	0.016	0.651
2-year	21.8 $\pm$ 18.4 (44)	<0.001	12.7 $\pm$ 5.0 (3)	0.109	0.403

Boldface indicates statistical significance

SD = Standard Deviation

*p-values calculated using unpaired Student's t-test to determine postoperative improvement

†p-values calculated using two-sample t-test to compare mean PROM scores

Table 6. MCID Achievement

PROM	Inpatient MIS-TLIF (%)	Outpatient MIS-TLIF (%)	*p-value
ODI			
6-weeks	35.3%	27.3%	0.380
12-weeks	41.9%	42.8%	0.932
6-months	54.1%	53.1%	0.922
1-year	53.6%	53.9%	0.988
2-year	51.3%	66.7%	0.609
Overall	63.7%	54.6%	0.274
PROMIS-PF			
6-weeks	17.5%	16.7%	0.937
12-weeks	37.9%	33.3%	0.724
6-months	53.5%	40.0%	0.350
1-year	50.0%	37.5%	0.512
2-year	47.6%	66.7%	0.383
Overall	63.3%	45.8%	0.127
SF-12 PCS			
6-weeks	30.3%	40.7%	0.313
12-weeks	55.1%	46.2%	0.424
6-months	61.3%	59.1%	0.854
1-year	71.8%	50.0%	0.162
2-year	72.7%	83.3%	0.578
Overall	74.1%	54.1%	0.022
VAS back			
6-weeks	57.2%	55.9%	0.880
12-weeks	59.2%	53.6%	0.565
6-months	56.9%	51.7%	0.597
1-year	62.3%	61.5%	0.958
2-year	69.2%	66.7%	0.926
Overall	75.8%	59.1%	0.019
VAS Leg			
6-weeks	49.6%	58.8%	0.339
12-weeks	53.1%	64.3%	0.282
6-months	48.4%	58.6%	0.321
1-year	47.8%	61.5%	0.364
2-year	54.1%	33.3%	0.489
Overall	65.7%	61.4%	0.596

Boldface indicates statistical significance

*p-values calculated using logistic regression

complication rates, readmission rates, ODI, or VAS pain scores, while demonstrating similar clinical outcomes (Emami et al. 2016).

While promising, the clinical data assessing outpatient versus inpatient outcomes of MIS TLIF has been limited. In a retrospective cohort study assessing 1- and 2-level MIS TLIF patient outcomes for inpatient (n=64) versus outpatient (n=32) surgery, Emami et al. reported no significant differences in postoperative complications, ODI, VAS pain scores, or readmission rates (Emami et al. 2016). Villavicencio et al., described similar findings in a retrospective

study (inpatient n=25, outpatient n=27), reporting no significant difference in complications and significantly decreased postoperative back pain in both cohorts compared to the patients' preoperative VAS scores (Villavicencio et al. 2013). A non-cohort matched retrospective study (inpatient n=50, outpatient n=50) by Schlesinger et al. reported no differences in operative time, need for transfusions, or incidence of iatrogenic complications. Their study did note significantly shorter total LOS in the outpatient surgery cohort (Schlesinger et al. 2020).

This study aimed to directly compare patient reported outcomes and complications following MIS TLIF in outpatient and inpatient cohorts. Results from our analysis yield a more robust comparison of clinical and perioperative outcomes following inpatient and outpatient MIS TLIF to supplement the current literature. Reducing potential confounding, the matched cohort populations demonstrated significantly similar age, BMI, gender, ethnicity, comorbid diseases (diabetes status, smoking, hypertension, and ASA classification), and insurance status. Significant differences were only noted in CCI. Previous literature has described that regardless of CCI score, MIS TLIF may significantly benefit patients by achieving minimum clinically important difference in their outcomes (Jenkins et al. 2021). Past studies assessing inpatient and outpatient TLIF outcomes failed to appropriately match cohorts for age, ASA classification, and CCI (Emami et al. 2016), or match cohorts at all (Villavicencio et al. 2013; Schlesinger et al. 2020), posing a limitation in the current literature. In our study, perioperative comparison of cohorts noted significant differences in spinal pathology, with a greater prevalence of foraminal stenosis in outpatient procedures, and less estimated blood loss in the outpatient surgery cohort. While reduced EBL is commonly reported in MIS TLIF versus open surgery, studies have noted agreement with our findings, demonstrating decreased EBL in outpatient spine surgery compared to inpatient procedures (Gornet et al. 2018; Adamson et al. 2016).

In our study, compared to preoperative PROMs, patients in both cohorts reported similar improvements in PROMIS-PF, SF-12 PCS, VAS back and leg, and ODI at nearly all follow-up intervals. No significant differences were noted between cohorts for these outcomes, indicating similar inpatient and outpatient postoperative satisfaction following MIS-TLIF. Reports comparing PROMs following outpatient spine surgery have noted similar findings to our study, including operations of both the cervical and lumbar spine (Vaishnav, Hill, et al. 2019; Patel et al. 2019). MCID achievement in both cohorts was similar, noting a significant difference only at overall SF-12 PCS and VAS back pain, both favoring the inpatient cohort. However, at individual follow-up assessments, both cohorts reported similar MCID rates for these outcomes. Our findings demonstrate similar long term outcomes up to 2-years postoperatively for inpatient and outpatient cohorts following MIS TLIF. Previous studies have noted similar findings in MCID achievement comparing inpatient and outpatient cohorts, or reported other promising long term improvements following surgery in each operative setting (Vaishnav, Hill, et al. 2019; Liu, Briner, and Friedman 2009). These results highlight the continuing encouragement for outpatient surgery in appropriately selected patients to benefit other aspects of care and resource utility while maintaining longitudinal patient outcomes. For our study, MCID was assessed with PROMs to develop an accurate appraisal of postoperative outcomes, reducing limitations of MCID, such as poor consensus and misclassification of achievement (Wright et al. 2012; Cook 2008).

There is currently no recommended duration for patients to remain in the ASC following surgery. In our study, patients remained in the ASC for an average of 7.4 hours, significantly less compared to the inpatient average LOS of 49.7 hours. Previous studies have reported hospital LOS as a driver of increased costs, resulting in an associated \$11,033 in insurance charges, \$5,198 in hospital costs, and a 28% increased risk of readmission per additional day of hospital stay following spine surgery (Boylan et al. 2019; Missios and Bekelis 2015). Since patients in this study and others support the long term efficacy of outpatient spine surgery, costs may be markedly decreased while delivering equivalent patient safety and outcomes compared to inpatient TLIF. Further, to ensure safe discharge, patients should be monitored for adequate pain control, oral intake, spontaneous voiding, control of postoperative nausea and vomiting (PONV), stable vital signs, and a reassuring neurological examination (Pendharkar et al. 2018). With appropriate patient selection and preoperative planning, these discharge goals may be accomplished within hours of surgery.

In our study, relatively few patients experienced postoperative complications, however some reported urinary retention and PONV (7.8% and 17.1% of inpatient cohort, respectively). Postoperative urinary retention may delay discharge from the ASC and is defined as bladder visualization indicating greater than 300 mL of urine, requiring catheterization (Baldini et al. 2009; Altschul et al. 2017). While intraoperative phenylephrine and neostigmine may increase the risk of postoperative urinary retention, this complication often resolves without major or lasting consequence. The incidence of PONV was significantly greater in the inpatient MIS TLIF cohort, which may have led to the delay of discharge in some patients (Buvanendran and Thillainathan 2010; Swann et al. 2016). By utilizing a multimodal analgesia protocol, minimized dosing of analgesic agents and perioperative use of opioids may reduce this complication (Kurd et al. 2017; Yoo et al. 2019). Of note, significantly less postoperative narcotic consumption was noted in the outpatient cohort, potentially reducing the associated PONV. This finding is consistent in the literature as outpatient surgery has been associated with decreased postoperative opioid consumption regardless of other variables (Howard et al. 2019). Adequate perioperative intravenous hydration with administration of antiemetic agents have been reported to reduce the incidence and burden of PONV (Maharaj et al. 2005).

To safely conduct outpatient MIS TLIF, surgical expertise is imperative to minimize complications. MIS TLIF has demonstrated a steep learning curve among surgeons (Nandyala et al. 2014; Lee, Jang, and Shin 2012), however approximately 90% of the learning milestone reportedly may be reached by case 39 (Silva et al. 2013). Additionally, appropriate patient selection is necessary as fewer emergency services and care providers are available at ASCs compared to the inpatient setting. Ideally, patients for ASC spinal fusion will be younger without significant spinal deformity, few comorbidities ($ASA \leq 3$), BMI $< 42 \text{ kg/m}^2$, living within 30 minutes of a hospital, and favorable anatomy for

gaining posterior MIS access (Chin et al. 2016; Bovonratwet et al. 2018; Chin, Coombs, and Seale 2015; Chin et al. 2017; Hofer et al. 2008). While in this study, age was not identified as criteria for outpatient TLIF, the average inpatient and outpatient ages were 50.1 and 50.9 years, respectively. Prior studies have noted age >65 as a substantial risk factor for postoperative complications following outpatient lumbar surgery (Emami et al. 2016; Fleisher et al. 2004). The patients included in our analysis demonstrated a mean BMI of 30.8 kg/m² and 80.9% classified as ASA <2, indicating optimal patient selection among cohorts for outpatient lumbar fusion.

LIMITATIONS

This study complements the literature by adding a novel comparison of clinical and perioperative outcomes following inpatient versus outpatient MIS TLIF. With our large cohort size assessing a variety of PROMs and complications at longitudinal follow-up intervals, this study offers a distinctive analysis of the potential benefits of outpatient spine surgery. The authors do report limitations in this study as well. The retrospective design of this study may have resulted in a selection bias of participants. Secondly,

all surgeries were performed at the same academic institution by a single surgeon, potentially resulting in confounding and reducing the external validity of our findings. This study may benefit from a multicenter comparison of surgical outcomes including a variety of surgeons to establish comprehensive sampling. Lastly, assessment of radiographic findings may have strengthened this study by correlating clinical and radiographic outcomes.

CONCLUSION

After careful patient selection, patients undergoing MIS-TLIF in an outpatient setting demonstrated similar long term clinical outcomes for back pain, leg pain, physical function, and disability as defined by PROMs and MCID achievement. Additionally, patients in outpatient cohort demonstrated reduced postoperative narcotic consumption. Results from our study would suggest patient safety and outcome quality is not compromised from undertaking MIS-TLIF in an outpatient setting.

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