




Original Article

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Higher American Society of Anesthesiologists Classification Does Not Limit Safety or Improvement Following Minimally Invasive Transforaminal Lumbar Interbody Fusion

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Objective: The American Society of Anesthesiologists (ASA) physical status classification has been used to risk stratify surgical candidates. Our study compares outcomes of minimally invasive transforaminal lumbar interbody fusion (MIS TLIF) procedures based on preoperative ASA physical status classification.

Methods: A surgical registry was reviewed for primary, single-level MIS TLIF patients. Patients were categorized by preoperative ASA physical status classification: ASA I, ASA II, ASA III+. Perioperative complications were compared among groups. Patient-reported outcome measures (PROMs) for back pain, leg pain, physical function, and disability were recorded preoperatively and at 6-week, 12-week, 6-month, 1-year, and 2-year postoperative timepoints. PROM improvement from baseline (Δ PROM) and minimum clinically important difference (MCID) achievement was calculated for each timepoint and compared among groups. MCID achievement was determined as Δ PROMs that surpassed previously established MCID values.

Results: Of the 487 patients, 64 had an ASA classification of I, whereas 336 had an ASA of II, and 87 had an ASA of III or greater. Rates of complications were not associated with ASA classification (all $p > 0.050$). Neither mean PROM scores nor Δ PROM scores were significantly associated with ASA classification at any timepoint (all $p > 0.050$). MCID achievement was significantly associated with ASA classification for back pain at 1 year only ($p = 0.041$). Overall MCID achievement was not significantly associated with ASA classification for any PROM ($p > 0.050$).

Conclusion: While ASA classification has been commonly used to risk stratify surgical candidates for spinal procedures, patients with an ASA of III or greater may be able to achieve similar long-term outcomes following MIS TLIF given proper selection criteria.

Keywords: Anesthesiologist, Patient-reported outcomes, Minimally invasive surgery, Transforaminal lumbar interbody fusion



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INTRODUCTION

Minimally invasive transforaminal lumbar interbody fusion (MIS TLIF) has proven to be an efficacious treatment option

for those experiencing degenerative spine pathologies such as central stenosis and spondylolisthesis while minimizing soft tissue trauma and disruption of posterior musculature.¹ As with many surgical procedures, evidence-based patient selection cri-

teria are essential to performing MIS TLIF procedures safely and effectively. While a number of factors contribute to surgical decision making, the American Society of Anesthesiologists (ASA) physical status classification is widely used to assess the preoperative physical health of a patient.² Ranging from I–VI, the classification is determined through subjective assessment by an anesthesiologist, with a classification of I representing completely healthy patients and III representing a patient with severe systemic disease.³ While the classification itself only accounts for the physical health of the patient, several past studies have demonstrated a correlation between ASA classification and operative outcomes such as postoperative complications, intraoperative blood loss, and overall morbidity and mortality.² Within the spine population, studies have reported a high ASA classification to be a significant risk factor for outcomes such as reoperation and readmission rates, postoperative complications, and greater direct costs.^{4–6} However, some evidence suggests that these risks may be lower for minimally invasive spinal procedures.⁷ In light of these conflicting findings, it is necessary to comprehensively address ASA classification in the context of various perioperative characteristics to better understand outcomes following MIS TLIF procedures specifically.

In addition to the more traditional objective assessment of operative outcomes, patient-reported outcome measures (PROMs) are self-reported questionnaires that allow clinicians to understand postoperative pain, disability and physical function from the patient's perspective.⁸ By quantifying PROM scores in terms of the minimum clinically important difference (MCID), a value that represents the minimum change in score a patient perceives as beneficial, clinicians can identify changes that are clinically significant to the patient.⁹ While a significant number of studies have investigated ASA classification and perioperative outcomes in the spine population, there is limited literature focusing on ASA in the context of PROMs. The few studies that have addressed this topic have generally been overly broad to draw direct conclusions about ASA classification for specific populations, or were limited in their reporting of long-term outcome improvement.^{10,11} This relative dearth of patient-centered data highlights the need to investigate the relationship between ASA classification and PROMs in the context of specific spine procedures.

ASA has been previously used as selection criteria to assess whether a patient is fit for surgery, but beyond this safety profile, there is limited literature to indicate whether the score can successfully predict a patient's course of recovery. We aim to clarify this relationship and determine the value of ASA classi-

fication as a patient selection criterion for minimally invasive spine surgery, which may have important implications for clinical practice. Investigating ASA classification and PROMs, in addition to other perioperative characteristics, will improve the understanding of this scoring system's effect on longitudinal, clinically significant outcomes.

MATERIALS AND METHODS

1. Patient Population

This study was approved by the Institutional Review Board of Rush University Medical Center (ORA #14051301) and written informed consent were obtained from patient prior to subject enrollment and data collection. Prospectively collected data was retrospectively reviewed via a private surgical database for minimally invasive lumbar fusion patients from January 2014 to February 2020. Inclusion criteria were patients undergoing primary, elective, single-level MIS TLIF procedures for degenerative spinal pathology. Exclusion criteria were patients missing a preoperative ASA classification or whose procedures were indicated for traumatic, infectious, or malignant etiologies. Additionally, to mitigate the confounding effects on outcomes following MIS TLIF, multilevel procedures were also excluded from the study. All procedures were performed by a single attending spine surgeon.

2. Data Collection

Patient demographic data was collected, including age, gender, body mass index (BMI), smoking status, and workers' compensation status. Prevalence of various preoperative medical diagnoses were recorded for diabetes mellitus, acute immune deficiency syndrome (AIDS), history of myocardial infarction, neurological disease, arthritis, congestive heart failure, peripheral vascular disease, metastasis, liver disease, renal failure, chronic lung disease, and gastrointestinal bleeding. Prevalence of pre-existing spinal pathology was assessed for recurrent herniated nucleus pulposus, degenerative spondylolisthesis, and isthmic spondylolisthesis. Perioperative characteristics including operative duration (from skin incision to skin closure), estimated blood loss (EBL), and postoperative length of stay were recorded. Incidences of postoperative complications such as aspiration requiring reintubation, urinary retention, urinary tract infection, epidural hematoma, acute renal failure, postoperative anemia, altered mental status, venous thromboembolism, pulmonary embolism, pneumothorax, arrhythmia, ileus, pneumonia, atelectasis, pleural effusion, fever, or pancreatitis were re-

corded and confirmed via direct review of the electronic medical record. Specific circumstances and outcomes regarding confirmed complications were then reviewed and described.

PROMs were administered preoperatively and at 6-week, 12-week, 6-month, 1-year, and 2-year postoperative timepoints via a secure online portal and completed by patients either in the clinic using a provided electronic tablet prior to the appointment or at home using personal devices. Administered PROMs included the visual analogue scale (VAS) back, VAS leg, Oswestry Disability Index (ODI), 12-Item Short Form health survey

physical composite score (SF-12 PCS), and Patient-Reported Outcomes Measurement Information System physical function (PROMIS PF).

3. Surgical Technique

Following localization of the appropriate spinal level via lateral fluoroscopy, an incision was made lateral to the midline and sequential dilators were used to gain exposure. A central laminectomy and bilateral partial facetectomy were performed. Following preparation of the endplates, an interbody cage along

Table 1. Patient demographics and baseline characteristics

Characteristic	Total (n = 487)	ASA PS classification			p-value [†]
		I (n = 64)	II (n = 336)	III+ (n = 87)	
Age (yr)	52.1 ± 11.7	42.1 ± 10.2	52.4 ± 11.1	58.1 ± 10.1	<0.001*
Sex					0.083
Female	209 (42.9)	21 (32.8)	155 (46.1)	33 (37.9)	
Male	278 (57.1)	43 (67.2)	181 (53.9)	54 (62.1)	
Body mass index (kg/m ²)					<0.001*
< 30	260 (53.4)	45 (70.3)	189 (56.3)	26 (29.9)	
≥ 30	227 (46.6)	19 (29.7)	147 (43.8)	61 (70.1)	
Smoking status					0.776
Nonsmoker	404 (83)	54 (84.4)	280 (83.3)	70 (80.5)	
Smoker	83 (17)	10 (15.6)	56 (16.7)	17 (19.5)	
Insurance					0.003*
Non-WC	311 (63.9)	29 (45.3)	227 (67.6)	55 (63.2)	
WC	176 (36.1)	35 (54.7)	109 (32.4)	32 (36.8)	
Medical diagnosis					
Diabetes mellitus	58 (11.9)	0 (0)	30 (8.9)	28 (32.2)	<0.001*
AIDS	0 (0)	0 (0)	0 (0)	0 (0)	-
Myocardial infarction	5 (1)	0 (0)	1 (0.3)	4 (4.6)	0.001*
Hypertension	177 (36.4)	4 (6.3)	113 (33.7)	60 (69)	<0.001*
Neurological disease	9 (1.9)	0 (0)	2 (0.6)	1 (8.1)	<0.001*
Arthritis	87 (17.9)	1 (1.6)	63 (18.8)	23 (26.4)	<0.001*
Congestive heart failure	5 (1)	1 (1.6)	1 (0.3)	3 (3.5)	0.031*
PVD	9 (1.9)	0 (0)	4 (1.2)	5 (5.7)	0.010*
Metastasis	0 (0)	0 (0)	0 (0)	0 (0)	-
Liver disease	5 (1)	0 (0)	5 (1.5)	0 (0)	0.320
Renal failure	4 (0.8)	0 (0)	2 (0.6)	2 (2.3)	0.216
Chronic lung disease	32 (6.6)	0 (0)	24 (7.2)	8 (9.2)	0.059
GI bleed	1 (0.21)	0 (0)	0 (0)	1 (1.1)	0.100

Values are presented as mean ± standard deviation or number (%).

ASA PS, American Society of Anesthesiologists physical status; WC, workers' compensation; AIDS, acute immune deficiency syndrome; PVD, peripheral vascular disease; GI, gastrointestinal.

*p < 0.05, statistically significant differences. †p-values calculated using 1-way analysis of variance (continuous) or chi-square analysis (categorical).

with bone graft was subsequently positioned in the interbody space. Bilateral pedicle screws were then placed above and below the level of interest and rods were attached to achieve compression.

4. Statistical Analysis

Patients were grouped according to their preoperative ASA classification based on a score of I, II, or III+. Demographic characteristics, preoperative medical and spinal pathology, and perioperative characteristics were compared between groups using chi-square or 1-way analysis of variance (ANOVA) for

categorical and continuous variables, respectively. Rates of individual and total postoperative complications were compared between groups using Fisher exact test.

Δ PROM scores were calculated as the difference between preoperative values and each postoperative timepoint. Mean PROM scores and Δ PROM scores were compared among groups for each measure at each timepoint using 1-way ANOVA. Achievement of an MCID was determined by comparing Δ PROM score to previously established threshold values: 2.2 (VAS back),¹² 5.0 (VAS leg),¹² 8.2 (ODI),¹² 2.5 (SF-12 PCS),¹² and 4.5 (PROM-IS PF).¹³ Rates of MCID achievement for each measure were

Table 2. Perioperative characteristics

Characteristic	Total (n = 487)	ASA PS classification			p-value [†]
		I (n = 64)	II (n = 336)	III+ (n = 87)	
Spinal pathology					
Recurrent HNP	31 (6.4)	5 (7.8)	20 (6.0)	6 (6.9)	0.834
Degenerative spondylolisthesis	263 (65.8)	27 (58.7)	188 (67.6)	48 (63.2)	0.432
Isthmic spondylolisthesis	127 (31.8)	19 (40.4)	843 (0.3)	24 (31.6)	0.388
Operative time (min)	127.9 ± 35.8	122.9 ± 32.2	126.3 ± 35.3	137.9 ± 38.6	0.013*
Estimated blood loss (mL)	68.6 ± 69.5	62.8 ± 44.4	69.3 ± 74.9	69.7 ± 62.2	0.792
Length of stay (hr)	50.5 ± 38.1	46.2 ± 30.0	49.3 ± 37.8	58.4 ± 43.3	0.089

Values are presented as number (%) or mean ± standard deviation.

ASA PS, American Society of Anesthesiologists physical status; HNP, herniated nucleus pulposus.

*p < 0.05, statistically significant differences. †p-values calculated using 1-way analysis of variance (continuous) or chi-square analysis (categorical).

Table 3. Postoperative complications

Complication [‡]	Total (n = 487)	ASA PS classification			p-value [†]
		I (n = 64)	II (n = 336)	III+ (n = 87)	
Aspiration/reintubation	0 (0)	0 (0)	0 (0)	0 (0)	-
Urinary retention	5 (1)	0 (0)	4 (1.2)	1 (1.2)	0.999
UTI	3 (0.6)	0 (0)	3 (0.9)	0 (0)	0.999
Epidural hematoma	2 (0.4)	0 (0)	2 (0.6)	0 (0)	0.999
Acute renal failure	1 (0.2)	0 (0)	1 (0.3)	0 (0)	0.999
Postoperative anemia	3 (0.6)	0 (0)	2 (0.6)	0 (0)	0.672
Altered mental status	1 (0.2)	0 (0)	0 (0)	1 (1.2)	0.310
Arrhythmia	1 (0.2)	0 (0)	0 (0)	1 (1.2)	0.310
Ileus	1 (0.2)	0 (0)	1 (0.3)	0 (0)	0.999
Atelectasis	1 (0.2)	1 (1.6)	0 (0)	0 (0)	0.131
Pancreatitis	1 (0.2)	0 (0)	1 (0.3)	0 (0)	0.999
Total	19 (3.9)	1 (1.6)	14 (4.2)	3 (3.4)	0.593

Values are presented as number (%).

ASA PS, American Society of Anesthesiologists physical status; UTI, urinary tract infection.

†p-value calculated using Fisher exact test. ‡Patients did not have complications associated with a venous thromboembolism, pulmonary embolism, pneumothorax, pneumonia, pleural effusion, or fever of unknown origin.

compared among groups at each postoperative timepoint and overall using simple logistic regression.

RESULTS

A total of 487 MIS TLIF patients were included with an average age of 52.1 years. Of these, 64 patients had an ASA classification of I, whereas 336 had an ASA classification of II, and 87 had an ASA classification \geq III. A majority of patients were male (57.1%), nonobese (BMI $<$ 30 kg/m²), and nonsmokers (83.0%) (Table 1). ASA groups significantly differed on the basis of age ($p < 0.001$), BMI ($p < 0.001$), and workers' compensation status ($p = 0.003$). Prevalence of diabetes ($p < 0.001$), AIDS ($p = 0.001$), myocardial infarction ($p < 0.001$), hypertension ($p < 0.001$), neurological disease ($p < 0.001$), arthritis ($p < 0.001$), congestive heart failure ($p = 0.031$), and peripheral vascular disease ($p = 0.010$) were significantly associated with ASA groups. Preoperative spinal pathology did not significantly vary between ASA groups (all $p > 0.05$). Operative duration was significantly associated with ASA groups ($p = 0.013$), while EBL ($p = 0.792$) and postoperative length of stay ($p = 0.089$) were not (Table 2). A total of 5 patients experienced urinary retention, 3 urinary tract infection, 2 epidural hematoma, 1 acute renal failure, 3 postoperative anemia, 1 altered mental status, 1 arrhythmia, 1 ileus, 1 atelectasis, and 1 pancreatitis. No individual complication type nor

total complication rates were significantly associated with ASA groups (all $p > 0.05$) (Table 3). Circumstances and outcomes of individual complications are detailed in Table 4.

Neither mean PROM scores nor Δ PROM scores significantly differed based on ASA group at any timepoint for any measure (all $p > 0.05$) (Tables 5, 6). MCID achievement significantly varied among ASA groups for VAS back at 1 year only ($p = 0.041$), but did not vary for any other individual timepoints nor overall (all $p > 0.05$) (Table 7).

DISCUSSION

ASA classification has been viewed as a concise way of conveying a patients' general physical health status and thereby, their risk of undergoing general anesthesia. While higher ASA scores have been used by many spine surgeons as a key part of their patient selection criteria, literature supporting the utility of this measure is somewhat limited in the field of spine surgery. Furthermore, beyond the immediate perioperative period, the impact of ASA classification on more long-term patient-reported outcomes is relatively unreported. While ASA classification was clearly associated with increased medical comorbidity in our cohort, differences in perioperative outcomes were relatively minor and impact on long-term clinical improvement was negligible.

Table 4. Individual incidences of complications and associated outcomes

Urinary retention	5 Patients with significantly elevated PVR required a foley catheter upon discharge but discontinued use by first follow-up appointment.
UTI	3 Patients developed a urinary tract infection and were discharged on antibiotics
Epidural hematoma	2 Patients developed epidural hematomas, underwent evacuation, and were discharged in stable condition
Acute renal failure	1 Patient had acute tubular necrosis on POD1 with a Cr increased 2-fold from baseline on POD4. Monitored in medical ICU until Cr dropped to 2.2 and was discharged safely to a rehab facility.
Postoperative anemia	2 Patients required transfusion with 1 unit of PRBC, 1 patient with 2 units. All patients were discharged in stable condition.
Altered mental status	1 Patient experienced recurrent staring episodes on POD1. CT scan was concerning for subarachnoid hemorrhage and was transferred to neuro ICU with a negative workup. Mental status returned to baseline on POD6 and was transferred to a rehab facility for concerns of alcohol withdrawal
Arrhythmia	1 Patient had atrial fibrillation with RVR on POD1, underwent TTE and cardioversion. Discharged in stable condition and followed up with PCP and cardiology.
Ileus	1 Patient experienced abdominal distention on POD3. Gastroenterology consulted. Rectal tube was placed to decompress the large bowel. Patient was tolerating a regular diet by discharge.
Atelectasis	Linear opacities were identified on chest x-ray with low lung volumes consistent with atelectasis; patient was discharged in stable condition to follow up with sleep study.
Pancreatitis	1 Patient had elevated lipase and was thought to be suffering from mild pancreatitis. Lipase significantly decreased by discharge and instructed to follow up with gastroenterology.

PVR, postvoid residual volume; UTI, urinary tract infection; POD, postoperative day; Cr, creatinine; ICU, intensive care unit; PRBC, packed red blood cells; CT, computed tomography; RVR, rapid ventricular response; TTE, transthoracic echocardiogram; PCP, primary care physician.

Table 5. Patient-reported outcomes

PROM	ASA PS classification			p-value [†]
	I	II	III+	
VAS back				
Preoperative	6.7±1.5	6.7±2.2	6.6±2.6	0.939
6 Weeks	3.9±2.1	3.9±2.4	3.9±2.6	0.981
12 Weeks	3.6±2.8	3.6±2.5	4.0±2.6	0.479
6 Months	3.8±2.9	3.5±2.6	3.9±2.9	0.439
1 Year	2.2±2.3	3.0±2.5	4.1±2.8	0.126
2 Years	3.8±3.1	3.4±2.9	4.7±3.3	0.367
VAS leg				
Preoperative	4.5±3.2	5.6±2.9	5.6±2.8	0.230
6 Weeks	2.3±3.1	3.2±2.8	3.2±3.2	0.356
12 Weeks	2.7±3.0	2.8±2.7	3.1±2.8	0.798
6 Months	2.1±3.2	2.6±2.7	2.9±2.9	0.553
1 Year	1.3±1.7	2.7±2.9	2.1±2.8	0.274
2 Years	1.9±2.7	2.6±2.8	4.0±3.6	0.264
ODI				
Preoperative	38.5±17.4	40.9±16.3	44.2±14.5	0.553
6 Weeks	33.9±23.0	35.4±18.7	40.4±17.7	0.274
12 Weeks	27.6±20.4	29.5±18.4	36.0±18.6	0.130
6 Months	21.9±21.8	24.3±18.8	31.5±19.5	0.097
1 Year	20.4±15.4	24.3±22.3	27.3±21.8	0.658
2 Years	21.7±17.6	23.4±20.2	33.9±30.0	0.302
SF-12 PCS				
Preoperative	33.3±7.5	31.5±9.0	29.0±10.1	0.149
6 Weeks	33.4±9.2	31.8±8.5	28.1±8.5	0.074
12 Weeks	38.5±9.8	35.0±9.8	32.6±10.8	0.183
6 Months	44.7±9.1	39.2±11.3	34.7±11.8	0.032
1 Year	42.0±10.3	40.7±12.3	37.2±10.1	0.436
2 Years	46.0±7.8	41.1±11.5	33.4±11.5	0.087
PROMIS PF				
Preoperative	37.1±6.4	35.7±6.2	34.5±5.3	0.387
6 Weeks	40.2±7.0	38.0±7.1	34.9±6.6	0.103
12 Weeks	43.9±7.6	40.8±7.3	41.0±7.5	0.397
6 Months	47.0±5.7	44.3±7.1	40.5±7.5	0.066
1 Year	47.4±11.3	46.1±9.3	40.8±10.0	0.126
2 Years	48.6±4.1	44.7±9.5	36.7±8.2	0.088

Values are presented as mean ± standard deviation.

PROM, patient-reported outcome measure; ASA PS, American Society of Anesthesiologists physical status; VAS, visual analogue scale; ODI, Oswestry Disability Index; SF-12 PCS, 12-item Short Form health survey physical composite score; PROMIS PF, Patient-Reported Outcomes Measurement Information System physical function.

[†]p-values calculated using 1-way analysis of variance.

Table 6. Postoperative improvement (Δ PROM scores)

PROM	ASA PS classification			p-value [†]
	I	II	III+	
Δ VAS back				
6 Weeks	2.9 \pm 2.1	2.8 \pm 2.8	2.7 \pm 2.9	0.918
12 Weeks	3.0 \pm 2.4	3.1 \pm 2.8	2.5 \pm 3.0	0.330
6 Months	2.9 \pm 2.6	3.1 \pm 3.0	2.6 \pm 3.0	0.435
1 Year	4.5 \pm 2.8	3.3 \pm 3.1	2.6 \pm 2.8	0.296
2 Years	3.2 \pm 3.3	3.3 \pm 3.2	1.9 \pm 3.0	0.426
Δ VAS leg				
6 Weeks	1.9 \pm 3.2	2.6 \pm 3.3	2.4 \pm 2.9	0.589
12 Weeks	2.3 \pm 3.0	3.0 \pm 3.1	2.6 \pm 2.9	0.533
6 Months	1.8 \pm 2.7	2.9 \pm 3.3	2.6 \pm 3.0	0.407
1 Year	2.5 \pm 2.4	3.2 \pm 3.1	2.8 \pm 3.0	0.748
2 Years	2.4 \pm 2.5	3.6 \pm 2.7	2.2 \pm 3.2	0.253
Δ ODI				
6 Weeks	6.6 \pm 20.8	7.2 \pm 18.6	4.4 \pm 16.1	0.708
12 Weeks	10.3 \pm 13.8	13.3 \pm 17.6	8.5 \pm 14.5	0.281
6 Months	12.6 \pm 19.0	17.1 \pm 18.3	14.4 \pm 12.9	0.498
1 Year	18.2 \pm 15.7	17.9 \pm 18.8	18.5 \pm 15.4	0.992
2 Years	17.6 \pm 19.8	17.6 \pm 17.3	12.7 \pm 28.7	0.763
Δ SF-12 PCS				
6 Weeks	2.0 \pm 11.6	1.3 \pm 8.3	-0.7 \pm 7.8	0.536
12 Weeks	7.0 \pm 10.9	4.9 \pm 9.5	3.5 \pm 11.7	0.611
6 Months	11.8 \pm 5.9	8.7 \pm 11.4	5.4 \pm 9.6	0.320
1 Year	13.5 \pm 9.6	10.8 \pm 10.4	9.8 \pm 9.6	0.748
2 Years	8.1 \pm 7.1	9.2 \pm 10.5	6.2 \pm 10.2	0.687
Δ PROMIS PF				
6 Weeks	2.3 \pm 5.8	2.3 \pm 6.6	0.4 \pm 4.9	0.501
12 Weeks	4.9 \pm 5.7	5.7 \pm 7.3	5.3 \pm 5.5	0.937
6 Months	8.2 \pm 5.5	8.5 \pm 8.1	6.1 \pm 4.0	0.537
1 Year	8.7 \pm 6.4	10.8 \pm 8.3	7.0 \pm 5.8	0.245
2 Years	8.7 \pm 6.3	9.0 \pm 9.2	6.0 \pm 5.5	0.775

Values are presented as mean \pm standard deviation.

PROM, patient-reported outcome measure; ASA PS, American Society of Anesthesiologists physical status; VAS, visual analogue scale; ODI, Oswestry Disability Index; SF-12 PCS, 12-item Short Form health survey physical composite score; PROMIS PF, Patient-Reported Outcomes Measurement Information System physical function.

[†]p-values calculated using 1-way analysis of variance.

Our cohort demonstrated clear associations between a number demographic factors, as well as several significant medical comorbidities. Age was significantly associated with ASA classification, with each progressive ASA group demonstrating older mean ages than the group below. While a majority of the over-

Table 7. MCID achievement

PROM	ASA PS classification			p-value [†]
	I	II	III+	
VAS back				
6 Weeks	31 (60.8)	155 (56.2)	41 (56.2)	0.651
12 Weeks	25 (55.6)	150 (57.9)	30 (46.9)	0.280
6 Months	24 (54.6)	151 (59.9)	30 (50.9)	0.594
1 Year	6 (66.7)	52 (63.4)	5 (31.3)	0.041*
2 Years	3 (42.9)	30 (58.8)	5 (41.7)	0.740
Overall	39 (72.2)	227 (76.4)	54 (70.1)	0.657
VAS leg				
6 Weeks	4 (19.1)	38 (27)	7 (19.4)	0.825
12 Weeks	3 (17.7)	41 (29.9)	10 (28.6)	0.562
6 Months	2 (12.5)	38 (27.3)	8 (26.7)	0.421
1 Year	2 (22.2)	26 (31.3)	3 (18.8)	0.653
2 Years	1 (20.0)	15 (31.3)	3 (27.3)	0.903
Overall	7 (29.2)	71 (44.1)	15 (37.5)	0.723
ODI				
6 Weeks	10 (45.5)	68 (46.6)	11 (29.7)	0.146
12 Weeks	7 (43.8)	82 (58.6)	15 (41.7)	0.422
6 Months	11 (68.8)	95 (67.4)	22 (71.0)	0.803
1 Year	6 (66.7)	58 (69.1)	11 (73.3)	0.710
2 Years	3 (60.0)	32 (65.3)	7 (63.6)	0.948
Overall	17 (70.8)	128 (77.6)	32 (78.1)	0.569
SF-12 PCS				
6 Weeks	10 (52.6)	42 (41.6)	8 (33.3)	0.209
12 Weeks	9 (75.0)	52 (53.1)	13 (56.5)	0.466
6 Months	9 (90.0)	61 (63.5)	11 (64.7)	0.289
1 Year	6 (100)	61 (74.4)	13 (76.5)	0.489
2 Years	3 (100)	48 (75.0)	6 (54.6)	0.084
Overall	20 (95.2)	101 (77.7)	25 (78.1)	0.196
PROMIS PF				
6 Weeks	7 (50.0)	26 (36.1)	4 (23.5)	0.131
12 Weeks	7 (63.6)	32 (52.5)	10 (66.7)	0.767
6 Months	8 (88.9)	37 (66.1)	8 (57.1)	0.140
1 Year	6 (66.7)	38 (80.9)	10 (71.4)	0.943
2 Years	3 (75.0)	34 (70.8)	3 (60.0)	0.610
Overall	16 (88.9)	65 (75.6)	15 (75.0)	0.324

Values are presented as number (%).

ASA PS, American Society of Anesthesiologists physical status; MCID, minimum clinically important difference; PROM, patient-reported outcome measure; ASA PS, American Society of Anesthesiologists physical status; VAS, visual analogue scale; ODI, Oswestry Disability Index; SF-12 PCS, 12-item Short Form health survey physical composite score; PROMIS PF, Patient-Reported Outcomes Measurement Information System physical function.

*p<0.05, statistically significant differences. [†]p-values calculated using simple logistic regression.

all cohort had a BMI $< 30 \text{ kg/m}^2$, over 70% of the ASA III+ group was obese. Interestingly, workers' compensation patients made up the majority of the ASA I group only. To some degree, this is an expected distribution as those individuals who are able to claim workers' compensation are typically of age or physical ability to participate in the workforce. Past comparative studies have also noted this significant difference, whereby patients categorized as workers' compensation were significantly younger and had a lower comorbidity burden,¹⁴ both potential signs of reduced systemic disease burden. It would be more surprising to see a larger proportion of patients with an ASA of II or III+ who, by definition of the scoring system, would be dealing with mild to severe systemic disease, but nonetheless remain in the workforce. Unsurprisingly, both relatively severe cardiovascular pathology and more common diagnoses such as arthritis and hypertension were associated with increasing ASA classification. These strong statistical relationships between ASA classification and medical comorbidity are consistent with the measures' intended purpose and can be seen as confirmation that the appropriate classification was assigned.^{15,16}

ASA physical status classification has been suggested as a tool for preoperative risk stratification in spine surgery by a number of previous studies,^{4,5,17-19} although it should be noted that this was not the measure's originally intended purpose. Rather, the ASA classification was designed to be used as a concise way of conveying a patient's health status, primarily for statistical analysis and interprovider communication. Nonetheless, a host of researchers have reported greater rates of complications, extended postoperative stay, and readmissions among spine patients with an ASA classification $> \text{II}$.^{5,17-19} Specific to the posterior approach, prior studies looking at 30-day readmissions and complication rates noted that patients with an ASA $> \text{III}$ who underwent either a posterior lumbar interbody fusion or TLIF were at increased risk (odds ratio, 1.411; $p < 0.001$; 95% confidence interval, 1.177–1.692).²⁰ Additionally, Ondeck et al.²¹ analyzed approximately 16,500 posterior lumbar fusion patients and was able to demonstrate that ASA was particularly meaningful as a predictor of severe postoperative adverse events and extended length of stay, which was further supported by a multivariate analysis of posterior lumbar fusion patients.²² However, this may be a reflection of inherent differences between the 2 types of posterior fusion procedures, whereby MIS TLIF is associated with lower complication rate (8.7% vs. 17.0%) and odds ratio (OR, 0.47; 95% CI, 0.28–0.81; $p = 0.006$).²³

Our analysis among MIS TLIF patients failed to replicate this predictive value of ASA for perioperative morbidity. Interest-

ingly, operative duration was significantly greater for patients with the highest ASA classifications; however, EBL and length of stay, which might be more expected to correlate with increasing ASA, did not demonstrate significant associations with this measure. Overall, complications were quite rare amongst our cohort, which may be attributable to a combination of careful patient selection, minimally invasive surgical techniques, and the expertise of an experienced surgeon that regularly performs a high volume of MIS TLIF procedures. Nonetheless, the few complications that were observed were distributed relatively evenly among the 3 groups and demonstrated no significant associations with ASA classification. Given previous reports of increased surgical morbidity among patients with an ASA classification $> \text{II}$, some surgeons may view this threshold as an attractive criterion for patient selection, particularly for outpatient/ambulatory orthopaedic surgery.^{19,24,25} However, our results demonstrate that this practice may be too conservative and exclude patients who would otherwise safely benefit from minimally invasive spinal procedures. The current study is not alone in these findings; in fact, Narain et al.⁷ similarly reported that an ASA classification $> \text{II}$ was not significantly associated with greater rates of medical or surgical complications following minimally invasive lumbar fusion procedures.

While a relatively substantial body of literature exists regarding the relationship between ASA classification and propensity for perioperative complications and adverse outcomes, research regarding the impact of ASA classification on patient-reported outcomes is much more limited. McGirt et al.¹⁰ conducted one of the few studies to assess the relationship of ASA classification with PROM scores. These authors used a large national database to create predictive models for outcomes among all elective lumbar procedures and determined that, among a variety of other factors, higher ASA classification was associated with worse 12-month outcomes in disability, pain, and quality of life following elective lumbar spinal surgery. While McGirt et al.¹⁰ did include improvement in PROM scores and achievement of MCID as outcomes in their relatively complex predictive model - detailed via 2 "hypothetical patients," they only reported direct analysis of the effects of ASA on mean PROM scores at preoperative and 12-month postoperative timepoints. This methodological/reporting choice, along with the significant heterogeneity of their population (single and multilevel, primary and revision, as well as a variety of procedure types) precludes meaningful conclusions about the direct relationship of ASA classification with postoperative improvement in patient-reported outcomes. Yoo et al.¹¹ performed a more focused analysis of the

impact of ASA classification on PROMS for TLIF procedures in particular, and determined that ASA classification was associated with improvement in VAS back, but not VAS leg, ODI, or SF-12 PCS. However, this analysis was also limited to 6-month outcomes and did not include quantification of MCID achievement.

Given the conflicting results and methodological limitations of these previous studies, it is important to directly and longitudinally assess the impact of ASA classification on patients' ability to achieve meaningful clinical improvement following minimally invasive lumbar fusion. Despite our use of a relatively large cohort to facilitate well-powered statistical analysis, we were unable to demonstrate any significant differences between ASA groups either in mean PROM scores or Δ PROM improvement at any of the assessed timepoints. Furthermore, analysis of MCID achievement showed no significant impacts of ASA for any of the assessed PROMs either overall or at individual timepoints through 2-years postoperatively, with the exception of VAS back at 1 year. These results allow for a more pertinent assessment of the relevance (or lack thereof) of ASA classification for this specific population because of our focused selection of only patients undergoing primary, single-level MIS TLIF procedures and our collection longitudinal PROM data throughout the full 2-year postoperative period.

One major potential shortcoming of the ASA classification is its relatively subjective assignment criteria. Several previous studies have demonstrated questionable interrater reliability in ASA classification assignment. Among 97 anesthesiologists in Hong Kong asked to classify 10 hypothetical patients, overall agreement on classification was below 60% for all but 1 patient (for whom agreement was 67%), and was as low as 36% for one patient.²⁶ An overall Cohen's Kappa of 0.34 was reported, indicating only fair reliability of rating between observers. These findings were consistent with those previously reported by an older, United States-based study by Owens et al.²⁷ This potential for inconsistency, coupled with the lack of significant effects either in terms of safety profiles or patient-reported outcomes may be cause to question the utility of ASA classification for some populations. Specifically, limiting selection criteria for MIS TLIF procedures to patients with an ASA classification \leq II may exclude some patients that could otherwise stand to safely and significantly benefit from outpatient MIS TLIF. Physicians that are sufficiently experienced in minimally invasive surgical techniques may consider removing ASA classification as part of their patient selection criteria for outpatient surgical procedures.

The present study represents one of the most comprehensive

assessments of the association of ASA classification with surgical outcomes specifically for MIS TLIF patients. However, our findings should be considered in the context of several limitations. First, while a moderately large sample was included, the single-surgeon, single-institution nature of this analysis may limit generalizability to other providers and populations. Additionally, previous studies have demonstrated variability in the assignment of ASA classification between different institutions and different regions.²⁶ Furthermore, while this study included patients with a range of ASA classifications from minimal to severe disease, patients were carefully vetted and selected by an experienced minimally invasive spine surgeon, which may play an important role in the favorable outcomes demonstrated in patients with higher ASA classification.

CONCLUSION

Increasing ASA classification was significantly associated with greater prevalence of a variety of medical comorbidities. However, while operative duration was significantly longer for patients with higher ASA classification, other perioperative outcomes were similar for all patients and rates of complications were favorable regardless of ASA classification. Similarly, patient-reported outcomes in pain, disability, and physical function including mean scores, absolute improvement, and achievement of MCID did not significantly vary based on preoperative ASA. Therefore, we recommend that ASA classification $>$ II should not necessarily preclude otherwise appropriate patients from undergoing MIS TLIF procedures, even in the outpatient setting.

NOTES

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