Impact of Body Mass Index on Postsurgical Outcomes for Workers' Compensation Patients Undergoing Minimally Invasive Transforaminal Lumbar Interbody Fusion

Madhav R. Patel, Kevin C. Jacob, Frank A. Chavez, Justin T. DesLaurier, Hanna Pawlowski, Michael C. Prabhu, Nisheka N. Vanjani and Kern Singh

Int J Spine Surg 2022, 16 (4) 595-604
doi: https://doi.org/10.14444/8309
https://www.ijssurgery.com/content/16/4/595

The International Journal of Spine Surgery
2397 Waterbury Circle, Suite 1,
Aurora, IL 60504, Phone: +1-630-375-1432

International Journal of Spine Surgery, Vol. 16, No. 4, 2022, pp. 595–604
https://doi.org/10.14444/8309

Impact of Body Mass Index on Postsurgical Outcomes for Workers' Compensation Patients Undergoing Minimally Invasive Transforaminal Lumbar Interbody Fusion

MADHAV R. PATEL, BS[1]; KEVIN C. JACOB, BS[1]; FRANK A. CHAVEZ, BS[1]; JUSTIN T. DESLAURIER, BS[1]; HANNA PAWLOWSKI, BS[1]; MICHAEL C. PRABHU, BS[1]; NISHEKA N. VANJANI, BS[1]; AND KERN SINGH, MD[1]
[1]*Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, IL, USA*

ABSTRACT

Background: Increased morbidity associated with obesity imposes a greater financial burden on companies that provide insurance to their employees. Few studies have investigated the relationship between body mass index (BMI) and patient-reported outcome measures (PROMs) for minimally invasive transforaminal lumbar interbody fusion (MIS TLIF) in the workers' compensation (WC) population.

Methods: WC patients who underwent a primary, single-level MIS TLIF were included/grouped according to BMI: nonobese (<30 kg/m^2); obese I (≥30, <35 kg/m^2); severe + morbid (≥35). PROMs were collected pre- and postoperatively: visual analog scale (VAS), Oswestry Disability Index (ODI), 12-Item Short Form (SF-12) physical composite score (PCS), and Patient-Reported Outcome Measurement Information System physical function (PROMIS-PF). BMI predictive power grouping on PROMs was evaluated using simple linear regression. Established minimum clinically important difference values were used to compute achievement rates across PROMs using logistic regression.

Results: A total of 116 nonobese, 70 obese I, and 61 severe + morbid patients were included. Demographics among BMI grouping significantly differed in gender, hypertensive status, and American Society of Anesthesiologists score ($P \leq 0.037$, all). Operative time was significantly different in perioperative values among BMI grouping ($P \leq 0.001$). Increased BMI was significantly associated with greater VAS back at 12 weeks and 2 years ($P \leq 0.026$, all), greater ODI preoperatively at 12 weeks and 6 months ($P \leq 0.015$, all), and decreased PROMIS-PF at 12 weeks ($P \leq 0.011$, all). Mean PROMs between obese I and severe + morbid cohorts differed in SF-12 PCS at 12 weeks, only ($P = 0.050$). ODI overall was the only parameter for which minimum clinically important difference was achieved among BMI cohorts ($P \leq 0.023$).

Conclusion: WC patients with increased BMI were more likely to develop significant back pain and disability at numerous postoperative timepoints compared with nonobese individuals. Our findings highlight the weight management importance within WC population to minimize back pain and disability following MIS TLIF, but provide a sense of reassurance with comparable clinical improvement regardless of BMI.

Clinical Relevance: When considering the effect of weight, surgeons may incorporate these findings in managing patient expectations in the WC population undergoing lumbar spine surgery.

Level of Evidence: 3.

Minimally Invasive Surgery

Keywords: workers' compensation, MIS TLIF, BMI, obesity, PROM, MCID

INTRODUCTION

Orthopedic surgeons are some of the most commonly consulted physicians for patients receiving workers' compensation (WC) insurance, likely due to the traumatic or otherwise musculoskeletal etiologies contributing to nearly one-third of claims.[1] The Bureau of Labor Statistics reported 2.8 million nonfatal workplace injuries in 2019. Of the 900,000 injuries resulting in days away from work in the private industry, approximately 136,000 cases (15%) involved the back.[2] The majority of literature has routinely reported poorer outcomes in WC patients when compared with non-WC patients for a wide range of orthopedic pathologies.[3,4] In lumbar spine surgery specifically, a meta-analysis by Russo et al found that WC patients had higher postoperative pain, decreased postoperative satisfaction, and delays in return to work (RTW) when compared with their non-WC counterparts.[5] To compound this, separate data have shown an increase in all-cause mortality associated with disability among WC patients with lower back injuries.[6]

Although obesity has not been shown to cause considerable change in short-term outcomes following lumbar fusion, longer-term results demonstrate inferior complication rates and back pain recovery with increased need for pain relief among morbidly obese patients.[7] While Goerz et al similarly reported inferior physical functioning in obese subjects, comparable short- and longer-term postoperative back pain, leg pain, mental health, and disability scores were found among obese patients undergoing minimally invasive transforaminal lumbar interbody fusion (MIS TLIF).[8] Perioperative complications including instrument malfunction, dural tears, and revision rates also did not differ by obesity status in this study.[8] Nevertheless, results of previously published findings on body mass index (BMI) are consistent within the WC population: greater BMI is associated with increased indemnity expenses, missed workdays, disability, and overall costs among claimants.[9–12]

MIS TLIF has grown in popularity over the last few decades, as imaging and surgical technology have improved significantly since its introduction. Benefits of MIS over open techniques have included decreased blood loss, decreased postoperative pain, decreased hospitalization and recovery times, and improved functional outcome compared with open TLIF. [13,14] In the setting of an at-risk population like WC patients requiring TLIF, the MIS approach may be especially indicated. Due to the nature of shared patient-physician goals surrounding pain, function, and quality of life in the setting of spine surgery, patient-reported outcome measures (PROMs) are an area of increasing focus in medical disciplines.[15,16] PROMs often utilized in the assessment of outcomes lumbar fusion studies will also be evaluated in the present study, include visual analog scale (VAS) for back and leg pain, Oswestry Disability Index (ODI), 12-Item Short Form Survey (SF-12) physical composite score (PCS), and Patient-Reported Outcome Measurement Information System physical function (PROMIS-PF).[17–19] The measurement of a minimum clinically important difference (MCID) in patient outcomes was developed to further enhance the type of patient data gathered by PROMs, as PROMs in isolation provide incomplete clinical information from the patient perspective.[20–22] MCID is defined as the minimum change in a PROM required to produce a clinically significant change for the patient, an improved benchmark for introducing modifications to clinical practice.[23]

The complicated nature of WC cases and the added financial burden of obesity among claimants may complicate postoperative success; however, no prior study to our knowledge has evaluated the interplay of both variables on outcomes.[12] Studying the influence of BMI on postoperative recovery may allow physicians to better predict and therefore counsel WC patients on the safety and effectiveness of MIS TLIF by BMI status.[24] This study uniquely aims to isolate BMI as a modifier of postoperative PROMs in WC patients undergoing MIS TLIF.

METHODS

Patient Population

Institutional Review Board approval (ORA #14051301) and patient informed consent were acquired in advance of the start of this project. A single-surgeon retrospective database that is prospectively maintained was searched to collect patients who underwent MIS TLIF. The following inclusion criteria were implemented: WC patients undergoing primary, single-level MIS TLIF. The following exclusion criteria were implemented: patients requiring lumbar fusion surgery for trauma, infection, or tumor-related diagnoses.

Data Collection

The following patient demographics were acquired for analysis: gender, age, BMI, ethnicity, American Society of Anesthesiologists (ASA) score, ageless Charlson Comorbidity Index, and history of diabetes, smoking, and hypertension. The following perioperative characteristics were collected: spinal pathology, operative time (minutes), mean estimated blood loss (milliliters), postoperative length of stay (hours), and day of discharge. Patient pathologies represented include degenerative and isthmic spondylolisthesis, recurrent herniated nucleus pulposus, and degenerative scoliosis. PROMs, including VAS back and leg, ODI, SF-12 PCS, and PROMIS-PF, were administered and recorded for preoperative and postoperative timepoints (6 weeks, 12 weeks, 6 months, 1 year, 2 years).

Statistical Analysis

Stata 16.0 (StataCorp LP, College Station, TX) was used to perform all data analysis for this study. Patients were grouped by BMI into 3 cohorts: nonobese (<30 kg/m^2); obese I (≥30 and <35 kg/m^2); severe + morbid (≥35). Using χ^2 analysis for categorical variables and Student's t test for independent samples for continuous variables, BMI cohorts were compared for differences in demographic and perioperative characteristics. A linear regression analysis was performed to evaluate the predictive capability of BMI on each PROM. For subanalysis between obese I and severe + morbid groups, post hoc pairwise comparisons of adjusted means were performed. To evaluate the relationship between BMI and

Table 1. Patient demographics.

Characteristic	Nonobese (n = 116)	Obese I (n = 70)	Severe + Morbid (n = 61)	P Value[a]
Age, y, mean ± SD	45.7 ± 18.7	45.7 ± 9.3	47.8 ± 10.2	0.315
Gender, % (n)				**0.037**
Female	20.16% (25)	14.9% (11)	31.9% (23)	
Male	79.8% (99)	85.1% (63)	68.9% (49)	
Ethnicity, % (n)				0.163
African American	12.2% (15)	24.7% (18)	19.4% (14)	
Asian	2.4% (3)	0.0% (0)	0.0% (0)	
Hispanic	30.9% (38)	27.4% (20)	27.8% (20)	
White	49.6% (61)	48.0% (35)	50.0% (36)	
Other	4.9% (6)	0.0% (0)	2.8% (2)	
Diabetic status, % (n)				0.113
Nondiabetic	94.9% (114)	84.8% (65)	81.9% (59)	
Diabetic	0.0% (0)	12.2% (9)	18.1% (13)	
Smoking status, % (n)				0.584
Nonsmoker	72.6% (90)	74.0% (54)	79.2% (57)	
Smoker	27.4% (34)	26.0% (19)	20.8% (15)	
Blood pressure, % (n)				**<0.001**
Normotensive	79.7% (98)	60.3% (44)	47.2% (34)	
Hypertensive	20.3% (25)	39.7% (29)	52.8% (38)	
ASA score, % (n)				**<0.001**
≤2	92.7% (114)	77.8% (56)	69.0% (49)	
>2	7.3% (9)	22.2% (16)	31.0% (22)	
Charlson Comorbidity Index score, % (n)				0.063
<1	37.9% (44)	33.8% (23)	21.4% (15)	
≥1	62.1% (72)	66.2% (45)	78.6% (55)	
Insurance type, % (n)				
Medicare/Medicaid	0.0% (0)	0.0% (0)	0.0% (0)	
Workers' compensation	100% (124)	100% (74)	100% (72)	
Private	0.0% (0)	0.0% (0)	0.0% (0)	

Abbreviation: ASA, American Society of Anesthesiologists.
Note: **Boldface** indicates statistical significance.
[a]P value calculated using χ^2 analysis or Student's t test.

follow-up completion (defined by completing preoperative and at least 6-month, 1-year, or 2-year surveys), simple linear regression analysis was performed. Logistic regression was utilized to obtain MCID attainment rates by BMI grouping based on previously established thresholds for PROMs: VAS back = 2.1,[20] VAS leg = 2.8,[20] ODI = 14.9,[20] SF-12 = 2.5,[21] and PROMIS-PF = 4.5.[25] To compare MCID achievement among cohorts, χ^2 analysis was performed.

RESULTS

Descriptive Analysis

A total of 247 patients were included in this study. The nonobese, obese, and severe + morbid groups contained 116, 70, and 61 patients with mean ages of 45.7, 45.7, and 47.8 years, respectively. Demographics that differed significantly among the groups include gender, hypertensive status, and ASA score (all $P \leq 0.037$) (Table 1). The total cohort lost an estimated 56.2 mL of blood on average, with the operation lasting for a mean of 120 minutes (Table 2). The only difference in perioperative values among cohorts was for operative duration (P = 0.001), with greater BMI being associated with higher values (Table 2).

Primary Outcome Measures

Poorer PROMs were significantly predicted by higher BMI status for VAS back at 12 weeks and 2 years ($P \leq 0.026$, both), ODI preoperatively at 12 weeks and 6 months ($P \leq 0.015$, all), and PROMIS-PF at 12 weeks ($P \leq 0.011$) (Table 3). Obese I vs severe + morbid groups significantly differed by mean PROMs only for PROMIS-PF at 12 weeks (P = 0.050) (Table 3). BMI had no significant impact for completing follow-up at 6 months or onward for any PROMs studied (Table 3). ODI overall was the only MCID achievement variable found to differ between groups, with obese I and severe + morbid cohorts demonstrating significantly lower and higher attainment rates, respectively, compared with nonobese patients ($P \leq 0.023$, both) (Table 4).

DISCUSSION

Obesity, which the World Health Organization defines with a BMI ≥30 kg/m^2, has manifested into

Table 2. Perioperative characteristics.

Characteristic	Nonobese ($n = 116$)	Obese I ($n = 70$)	Severe + Morbid ($n = 61$)	P Value[a]
Spinal pathology, % (n)				
Degenerative spondylolisthesis	37.9% (47)	36.5% (27)	41.7% (30)	0.798
Isthmic spondylolisthesis	19.4% (24)	16.2% (12)	20.8% (15)	0.763
Recurrent herniated nucleus pulposus	29.0% (36)	23.0% (17)	22.2% (16)	0.480
Scoliosis	0.8% (1)	2.7% (2)	0.0% (0)	0.270
Operative time, min, mean ± SD	120.0 ± 34.3	125.3 ± 27.6	140.1 ± 48.4	**<0.001**
Estimated blood loss, mL, mean ± SD	56.2 ± 27.8	51.7 ± 22.2	60.3 ± 30.3	0.160
Length of stay, h, mean ± SD	46.1 ± 27.2	49.4 ± 29.6	53.0 ± 30.9	0.282
Day of discharge, % (n)				0.097
POD 0	13.3% (16)	10.0% (7)	5.6% (4)	
POD 1	30.8% (37)	27.1% (19)	35.2% (25)	
POD 2	30.0% (36)	35.7% (25)	22.5% (16)	
POD 3	18.3% (22)	18.6% (13)	29.6% (21)	
POD 4	2.5% (3)	0.0% (0)	4.2% (3)	
POD 5	0.0% (0)	0.0% (0)	1.4% (1)	
POD 6	0.0% (0)	2.9% (2)	0.0% (0)	
POD 7	0.0% (0)	0.0% (0)	1.4% (1)	

Abbreviation: POD, postoperative day of discharge.
Note: **Boldface** indicates statistical significance.
[a]P value calculated using χ^2 analysis or Student's t test.

a major public health concern in the United States in recent years.[9,26] With a prevalence that was 42.8% in 2017–2018 and that continues to climb annually, a rise in obesity-related illnesses including diabetes, heart disease, hypertensive-related disorders, and other comorbidities may follow, thereby compromising quality of life and increasing economic burden.[27–29] By inflicting an average of $1901 in health care costs to each patient for a total of $149.4 billion in US medical expenditures overall, obesity instills an increasing financial burden on both individual and systemic level.[10,30] One setting where obesity can especially impose economic consequences is within the workplace. Studies show obesity increases medical costs for employers by 21%, adding to the expenses of WC insurance claims frequently provided by companies.[31,32] Increasing BMI in workers has also been demonstrated to have a direct, linear impact on the rate of WC claims, consequently leading to higher health care expenditures.[10]

A major proportion of WC claims are back-related, with 25.7% of US workers reporting low back pain (LBP) and back injuries accounting for 37% of all WC claims.[33,34] Those with obesity are also more likely to suffer from spondylosis, spinal stenosis, spondylolisthesis, and spinal arthritis, which can further aggravate their LBP.[29,35–38]

MIS TLIF is a well-established method for treatment of LBP, gaining popularity among spine surgeons due to reduced injury to adjacent tissue and favorable postoperative outcomes in many PROMs including VAS back and leg, ODI, SF-12 PCS, and PROMIS-PF.[39–4444] Although obesity is not a contraindication for MIS TLIF, obese patients have previously demonstrated greater complication rates, longer operative times, and prolonged postoperative stay, despite mixed patient-perceived outcomes.[7,8,45,46] Several studies have examined the individual contributions of BMI and WC to operative results following MIS TLIF, but no study has assessed patient-reported outcomes related to the interplay between these 2 variables.[47,48] This study aimed to determine the influence of BMI within the WC population on PROMs and MCID following MIS TLIF.

Pain

While our results found no significant differences in PROMs or MCID for leg pain among cohorts, higher BMI was significantly associated with worse back pain at 12 weeks and 2 years in WC patients undergoing MIS TLIF. Pain has been shown to significantly predict quality of life, with several studies demonstrating delayed RTW in employees with severe pain.[49–53] Prior literature has demonstrated mixed results on BMI's impact on PROMs following MIS TLIF when studying combined WC and non-WC cohorts.[39,50,54–56,7,8,45,46] Our findings convey that claimant employees with higher BMI demonstrate significantly poorer initial and longer-term postoperative back pain. Nevertheless, lack of significant differences in back pain–related MCID achievement between BMI groupings suggests obesity may not play a clinically significant role among claimants. This coincides with multiple studies suggesting no meaningful influence of BMI on MCID attainment following MIS TLIF.[56,57] The use of preoperative weight reduction management in WC patients with higher baseline BMI may be beneficial for optimizing recovery in patient-perceived postoperative pain and avoiding delays

Table 3. Impact of BMI on PROMs and follow-up completion.

PROM	Nonobese (mean ± SD)	Obese I (mean ± SD)	Severe + Morbid (mean ± SD)	*P* Value[a]	*P* Value[b]	*P* Value[c]
VAS back						0.339
Preoperative	6.7 ± 2.0	7.3 ± 1.9	7.1 ± 1.7	0.114	0.897	
6 wk	4.8 ± 2.2	5.3 ± 2.2	5.5 ± 2.2	0.068	0.536	
12 wk	4.6 ± 2.4	5.6 ± 2.2	5.5 ± 2.1	**0.007**	0.944	
6 mo	4.7 ± 2.6	5.3 ± 2.1	5.1 ± 2.6	0.388	0.992	
1 y	5.2 ± 2.8	4.5 ± 2.7	5.1 ± 2.8	0.812	0.893	
2 y	3.3 ± 2.6	6.3 ± 2.2	6.7 ± 2.9	**0.026**	0.990	
VAS leg						0.186
Preoperative	5.3 ± 2.9	6.4 ± 2.9	6.6 ± 2.1	0.051	0.993	
6 wk	4.4 ± 3.3	4.1 ± 3.3	5.5 ± 2.6	0.168	0.168	
12 wk	3.9 ± 3.0	4.5 ± 2.5	4.8 ± 2.5	0.388	0.825	
6 mo	3.5 ± 2.7	4.3 ± 2.6	4.9 ± 2.8	0.099	0.521	
1 y	3.7 ± 3.0	3.7 ± 3.5	4.6 ± 2.8	0.629	0.870	
2 y	2.5 ± 2.6	5.3 ± 3.4	5.1 ± 2.7	0.100	0.968	
Oswestry Disability Index						0.056
Preoperative	44.2 ± 15.1	53.9 ± 13.9	55.6 ± 15.0	**0.008**	0.928	
6 wk	47.5 ± 17.4	51.8 ± 16.1	52.2 ± 17.2	0.372	0.827	
12 wk	39.5 ± 15.6	51.5 ± 10.8	46.8 ± 16.5	**0.003**	0.790	
6 mo	35.0 ± 19.8	43.7 ± 13.7	45.6 ± 18.2	**0.015**	0.727	
1 y	38.7 ± 24.3	39.6 ± 22.1	46.6 ± 20.8	0.409	0.539	
2 y	27.1 ± 21.1	49.0 ± 13.6	47.6 ± 21.1	0.076	1.000	
12-Item Short Form physical composite score						0.081
Preoperative	28.3 ± 6.3	30.6 ± 13.2	25.8 ± 4.8	0.090	0.103	
6 wk	29.7 ± 7.1	25.5 ± 7.5	25.5 ± 5.1	0.057	0.959	
12 wk	29.6 ± 6.6	29.8 ± 8.9	27.3 ± 6.8	0.513	0.483	
6 mo	31.9 ± 8.5	31.0 ± 8.2	30.4 ± 6.3	0.817	0.933	
1 y	31.2 ± 11.8	32.6 ± 11.7	33.3 ± 9.2	0.819	0.944	
2 y	38.0 ± 14.2	29.3 ± 5.8	29.5 ± 12.0	0.227	0.916	
PROMIS-PF						0.303
Preoperative	35.2 ± 6.4	32.7 ± 4.1	30.1 ± 4.7	0.021	0.910	
6 wk	33.4 ± 6.7	31.2 ± 3.9	31.4 ± 3.8	0.616	0.992	
12 wk	39.2 ± 6.7	38.1 ± 7.7	31.8 ± 2.6	**0.011**	**0.050**	
6 mo	40.4 ± 7.1	39.3 ± 8.6	36.6 ± 6.7	0.542	0.662	
1 y	39.6 ± 9.7	41.3 ± 8.1	37.9 ± 6.4	0.640	0.613	
2 y	38.6 ± 11.6	33.7 ± 6.5	36.5 ± 8.2	0.683	0.875	

Abbreviations: BMI, body mass index; PROM, patient-reported outcome measures; PROMIS-PF, Patient-Reported Outcome Measurement Information System physical function; VAS, visual analog scale.
Note: **Boldface** indicates statistical significance.
[a]*P* values calculated using linear regression of PROMs by BMI.
[b]*P* values calculated using post hoc pairwise comparisons of adjusted means to compare PROMs between obese I and severe + morbid cohorts.
[c]*P* values calculated using linear regression of follow-up completion by BMI.

in RTW. Nevertheless, obese WC patients should be positively encouraged to anticipate similar postoperative clinical benefit regardless of baseline BMI.

Disability

Obese I and severe + morbid status were significantly associated with higher preoperative self-reported disability scores compared with the nonobese cohort, a trend that continued until 6 months following surgery. This signifies that WC patients who are obese perceived themselves as having a poorer quality of life due to disability compared with the nonobese group.[49] WC patients often suffer from increased depressive thoughts, which as stated by existing literature may significantly interfere with RTW.[58,59] Obese patients are also more prone to develop depression; therefore, a worsened perceived disability among employees who are obese and claim WC may further exacerbate existing mental health symptoms, which could further delay RTW.[60–62] MCID achievement rates for overall ODI varied significantly between cohorts, with obese I patients demonstrating significantly decreased MCID attainment and severe + morbid patients demonstrating significantly increased MCID attainment. Previous studies have found no significant relationship between BMI and ODI; however, these studies included non-WC patients in their cohorts.[56,57] MCID thresholds are defined around a single-point value, which along with individualized factors such as patient health, makes its calculation prone to variance.[63,64] Given that MCID achievement for ODI at other timepoints did not differ significantly by BMI, it appears more likely that MIS TLIF is well tolerated and advantageous for disability-related clinical recovery in WC patients regardless of

Table 4. Impact of body mass index on MCID achievement.

PROM	6 wk	12 wk	6 mo	1 y	2 y	Overall
VAS back	*n* = 89	*n* = 85	*n* = 82	*n* = 16	*n* = 8	*n* = 146
Nonobese	43.4% (56)	44.7% (38)	45.1% (37)	12.5% (2)	37.5% (3)	45.9% (67)
Obese I	31.5% (28)	31.7% (27)	29.3% (24)	43.8% (7)	37.5% (3)	27.4% (40)
Severe + morbid	23.6% (21)	23.5% (20)	25.6% (21)	43.8% (7)	25.0% (2)	26.7% (39)
P valuea	0.425	0.279	0.783	0.106	0.184	1.000
VAS leg	*n* = 31	*n* = 30	*n* = 38	*n* = 13	*n* = 9	*n* = 59
Nonobese	38.7% (12)	40.0% (12)	44.7% (17)	30.8% (4)	33.3% (3)	39.0% (23)
Obese I	38.7% (12)	30.0% (9)	29.0% (11)	38.5% (5)	22.2% (2)	28.8% (17)
Severe + morbid	22.6% (7)	30.0% (9)	26.3% (10)	30.8% (4)	44.4% (4)	32.2% (19)
P valuea	0.323	0.830	0.701	0.646	0.866	0.424
Owestry Disability Index	*n* = 19	*n* = 24	*n* = 39	*n* = 15	*n* = 5	***n* = 50**
Nonobese	31.6% (6)	29.2% (7)	38.5% (15)	6.7% (1)	20.0% (1)	**34.0% (17)**
Obese I	26.3% (5)	25.0% (6)	25.6% (10)	40.0% (6)	0.0% (0)	**24.0% (12)**
Severe + morbid	42.1% (8)	45.8% (11)	35.9% (14)	53.3% (8)	80.0% (4)	**42.0% (21)**
P valuea	0.640	0.339	0.823	0.053	0.230	**0.023**
12-Item Short Form physical composite score	*n* = 16	*n* = 20	*n* = 17	*n* = 19	*n* = 11	*n* = 48
Nonobese	50.0% (8)	40.0% (8)	52.9% (9)	31.6% (6)	45.5% (5)	37.5% (18)
Obese I	25.0% (4)	30.0% (6)	29.4% (5)	26.3% (5)	36.4% (4)	33.3% (16)
Severe + morbid	25.0% (4)	30.0% (6)	17.7% (3)	42.1% (8)	18.2% (2)	29.2% (14)
P valuea	0.445	0.891	0.484	0.587	0.631	0.409
PROMIS-PF	*n* = 8	*n* = 9	*n* = 14	*n* = 13	*n* = 7	*n* = 26
Nonobese	75.0% (6)	66.7% (6)	50.0% (7)	23.1% (3)	42.9% (3)	38.5% (10)
Obese I	25.0% (2)	33.3% (3)	28.6% (4)	30.8% (4)	28.6% (2)	30.8% (8)
Severe + morbid	0.0% (0)	0.0% (0)	21.4% (3)	46.2% (6)	28.6% (2)	30.8% (8)
P valuea	0.096	0.076	0.376	0.571	0.927	0.723

Abbreviations: MCID, minimum clinically important difference; PROM, patient-reported outcome measure; PROMIS-PF, Patient-Reported Outcome Measurement Information System physical function.
Note: **Boldface** indicates statistical significance.
[a]*P* values calculated using χ^2 analysis.

preoperative BMI. Moreover, although reporting increased disability shortly after MIS TLIF, patients with higher BMI experienced similar longer-term disability status compared with lower BMI claimants. As patient-perceived outcomes between BMI groupings equalized after 6 months, and MCID achievement rates were mostly comparable, it appears that BMI does not play a significant role on patient-perceived or clinically meaningful recovery following MIS TLIF.

Physical Functioning

Obesity-based grouping was not significantly predictive for trends in either physical health survey (SF-12 or PROMIS) at any timepoint, except for worse PROMIS-PF scores among higher BMI patients at 12 weeks postoperatively, indicating that BMI does not largely appear to significantly influence physical health in WC patients undergoing MIS TLIF. Although subgroup analysis comparing mean PROMs among obese I and severe + morbid cohorts mostly did not demonstrate differences in either questionnaires, physical ability at 12 weeks was significantly lower in the latter cohort at this timepoint as well. In contrast to our results demonstrating little influence of BMI on physical ability, prior literature has demonstrated worse SF-12 PCS and PROMIS-PF at numerous timepoints among spinal surgery patients with higher BMI.[56,65,66] It must be noted, however, that these studies included non-WC patients in their total cohort. Since patient-perceived outcomes were comparable for both physical health questionnaires following the 12-week timepoint and MCID attainment did not differ at any point for SF-12 PCS and PROMIS-PF, the present study's results indicate that BMI largely does not influence patient-perceived or clinical-based health progress following MIS TLIF.

Follow-Up Completion

A linear regression was utilized in this study to decipher whether loss to follow-up was a confounding factor that may have led to noticed differences among BMI groups. Results, however, showed no significant differences were present, indicating that higher or lower BMI did not predict whether patients completed PROM questionnaires at least up to 6 months.

Clinical Implications

Our study's results provide assurance of substantial clinical recovery (as measured by MCID) in WC patients regardless of BMI. Our findings also support that MIS TLIF is a safe and effective treatment for back injuries regardless of BMI for WC populations, in accordance with previous studies in non-WC populations.[7,8,46] Providing guidance for weight management through diet, exercise, and professional support preoperatively could minimize the potential worsened perceived postoperative back pain and disability found among obese WC patients, plausibly improving delays in RTW and financial hardships among claimants and employers. Nevertheless, with similar MCID attainment rates between BMI groups across all PROMs at all timepoints (other than overall ODI), it appears that BMI does not significantly impact clinical recovery among WC patients undergoing MIS TLIF. Additionally, as higher BMI workers have demonstrated similar and even decreased rates of back reinjury, this further indicates lack of significant imposed burden from obesity.[67,68]

Limitations

There are several limitations of this study worth mentioning. While several demographic and perioperative characteristics differed among cohorts, most differences are well supported by existing literature. Higher BMI groups had significantly greater blood pressure, ASA classification score, and operative time, in line with previous literature.[69,70,45] Although men are more likely to claim WC insurance (resulting in a greater number of men in our study), gender significantly differed by BMI grouping potentially adding confounder bias to our study.[71,72] Furthermore, this study was performed by a surgeon at an academic institution, limiting the external validity and generalizability of our findings. PROMs are also based on subjective metrics, which may contribute recall bias to our findings.

CONCLUSION

The prevalence of back pain and disability among WC patients with a greater BMI was significantly higher at numerous postoperative timepoints when compared with nonobese patients. In subgroup analysis, however, there was little discernible difference between mean PROMs of obese I vs severe + morbid cohorts. For any PROM, there were no significant differences in follow-up rates across BMI groups. MCID attainment rates indicated similar clinically improvements among patients regardless of BMI. While WC patients should be provided preoperative weight reduction counseling to optimize recovery for back pain and disability, obese patients should be reminded that MIS TLIF is an efficacious operation for this population that offers similar clinical benefit across majority of health measures irrespective of BMI status.

REFERENCES

1. Franklin GM, Wickizer TM, Coe NB, Fulton-Kehoe D. Workers' compensation: poor quality health care and the growing disability problem in the United States. *Am J Ind Med*. 2015;58(3):245–251. doi:10.1002/ajim.22399
2. Bureau of Labor Statistics. *Injuries, Illnesses, and Fatalities 2019*. U.S. Bureau of Labor Statistics; 2020.
3. de Moraes VY, Godin K, Tamaoki MJS, Faloppa F, Bhandari M, Belloti JC. Workers' compensation status: does it affect orthopaedic surgery outcomes? A meta-analysis. *PLoS One*. 2012;7(12):e50251. doi:10.1371/journal.pone.0050251
4. Lu Y, Agarwalla A, Patel BH, et al. Influence of workers' compensation status on postoperative outcomes in patients following biceps tenodesis: a matched-pair cohort analysis. *J Shoulder Elbow Surg*. 2020;29(12):2530–2537. doi:10.1016/j.jse.2020.03.048
5. Russo F, De Salvatore S, Ambrosio L, et al. Does workers' compensation status affect outcomes after lumbar spine surgery? A systematic review and meta-analysis. *Int J Environ Res Public Health*. 2021;18(11):6165. doi:10.3390/ijerph18116165
6. Martin CJ, Jin C, Bertke SJ, Yiin JH, Pinkerton LE. Increased overall and cause-specific mortality associated with disability among workers' compensation claimants with low back injuries. *Am J Ind Med*. 2020;63(3):209–217. doi:10.1002/ajim.23083
7. Krüger MT, Naseri Y, Hohenhaus M, Hubbe U, Scholz C, Klingler J-H. Impact of morbid obesity (BMI > 40 kg/m^2) on complication rate and outcome following minimally invasive transforaminal lumbar interbody fusion (MIS TLIF). *Clin Neurol Neurosurg*. 2019;178:82–85. doi:10.1016/j.clineuro.2019.02.004
8. Goertz L, Stavrinou P, Hamisch C, et al. Impact of obesity on complication rates, clinical outcomes, and quality of life after minimally invasive transforaminal lumbar interbody fusion. *J Neurol Surg A Cent Eur Neurosurg*. 2021;82(2):147–153. doi:10.1055/s-0040-1718758
9. Chenoweth DH, Rager RC, Haynes RG. Relationship between body mass index and workers' compensation claims and costs. *Journal of Occupational & Environmental Medicine*. 2015;57(9):931–937. doi:10.1097/JOM.0000000000000506
10. Ostbye T, Dement JM, Krause KM. Obesity and workers' compensation: results from the Duke health and safety surveillance system. *Arch Intern Med*. 2007;167(8):766–773. doi:10.1001/archinte.167.8.766
11. Van Nuys K, Globe D, Ng-Mak D, Cheung H, Sullivan J, Goldman D. The association between employee obesity and employer costs: evidence from a panel of U.S. employers. *Am J Health Promot*. 2014;28(5):277–285. doi:10.4278/ajhp.120905-QUAN-428
12. LaCaille RA, DeBerard MS, LaCaille LJ, Masters KS, Colledge AL. Obesity and litigation predict workers' compensation costs associated with interbody cage lumbar fusion. *Spine J*. 2007;7(3):266–272. doi:10.1016/j.spinee.2006.05.014
13. Xie L, Wu W-J, Liang Y. Comparison between minimally invasive transforaminal lumbar interbody fusion and conventional open transforaminal lumbar interbody fusion: an updated meta-analysis. *Chin Med J (Engl)*. 2016;129(16):1969–1986. doi:10.4103/0366-6999.187847

14. Seng C, Siddiqui MA, Wong KPL, et al. Five-year outcomes of minimally invasive versus open transforaminal lumbar interbody fusion: a matched-pair comparison study. *Spine (Phila Pa 1976)*. 2013;38(23):2049–2055. doi:10.1097/BRS.0b013e3182a8212d

15. Finkelstein JA, Schwartz CE. Patient-reported outcomes in spine surgery: past, current, and future directions. *J Neurosurg Spine*. 2019;31(2):155–164. doi:10.3171/2019.1.SPINE18770

16. Deshpande PR, Rajan S, Sudeepthi BL, Abdul Nazir CP. Patient-reported outcomes: a new era in clinical research. *Perspect Clin Res*. 2011;2(4):137–144. doi:10.4103/2229-3485.86879

17. Vaishnav AS, Gang CH, Iyer S, McAnany S, Albert T, Qureshi SA. Correlation between NDI, PROMIS and SF-12 in cervical spine surgery. *Spine J*. 2020;20(3):409–416. doi:10.1016/j.spinee.2019.10.017

18. Boody BS, Bhatt S, Mazmudar AS, Hsu WK, Rothrock NE, Patel AA. Validation of patient-reported outcomes measurement information system (PROMIS) computerized adaptive tests in cervical spine surgery. *J Neurosurg Spine*. 2018;28(3):268–279. doi:10.3171/2017.7.SPINE17661

19. Haws BE, Khechen B, Bawa MS, et al. The patient-reported outcomes measurement information system in spine surgery: a systematic review. *J Neurosurg Spine*. 2019;30(3):405–413. doi:10.3171/2018.8.SPINE18608

20. Parker SL, Adogwa O, Paul AR, et al. Utility of minimum clinically important difference in assessing pain, disability, and health state after transforaminal lumbar interbody fusion for degenerative lumbar spondylolisthesis. *J Neurosurg Spine*. 2011;14(5):598–604. doi:10.3171/2010.12.SPINE10472

21. Parker SL, Mendenhall SK, Shau DN, et al. Minimum clinically important difference in pain, disability, and quality of life after neural decompression and fusion for same-level recurrent lumbar stenosis: understanding clinical versus statistical significance. *J Neurosurg Spine*. 2012;16(5):471–478. doi:10.3171/2012.1.SPINE11842

22. Paul AR, Kumar V, Roth S, Gooch MR, Pilitsis JG. Establishing minimal clinically important difference of spinal cord stimulation therapy in post-laminectomy syndrome. *Neurosurgery*. 2017;81(6):1011–1015. doi:10.1093/neuros/nyx153

23. McGlothlin AE, Lewis RJ. Minimal clinically important difference: defining what really matters to patients. *JAMA*. 2014;312(13):1342–1343. doi:10.1001/jama.2014.13128

24. Tao XG, Su P-Y, Yuspeh L, Lavin RA, Kalia-Satwah N, Bernacki EJ. Is obesity associated with adverse workers compensation claims outcomes? *J Occup Environ Med*. 2016;58(9):880–884. doi:10.1097/JOM.0000000000000834

25. Steinhaus ME, Iyer S, Lovecchio F, et al. Minimal clinically important difference and substantial clinical benefit using PROMIS CAT in cervical spine surgery. *Clin Spine Surg*. 2019;32(9):392–397. doi:10.1097/BSD.0000000000000895

26. Jackson KL, Devine JG. The effects of obesity on spine surgery: a systematic review of the literature. *Global Spine J*. 2016;6(4):394–400. doi:10.1055/s-0035-1570750

27. Fryar CD, Carroll MD, Afful J. *Prevalence of Overweight, Obesity, and Severe Obesity among Adults Aged 20 and over: United States, 1960--1962 through 2017--2018. NCHS Health E-Stats*. 2020. http://www.publicnow.com/view/57BFCB292A6D12A9A3EE633921C052DED8F0D94B.

28. Seravalle G, Grassi G. Obesity and hypertension. *Pharmacol Res*. 2017;122:1–7. doi:10.1016/j.phrs.2017.05.013

29. Liuke M, Solovieva S, Lamminen A, et al. Disc degeneration of the lumbar spine in relation to overweight. *Int J Obes (Lond)*. 2005;29(8):903–908. doi:10.1038/sj.ijo.0802974

30. Kim DD, Basu A. Estimating the medical care costs of obesity in the United States: systematic review, meta-analysis, and empirical analysis. *Value Health*. 2016;19(5):602–613. doi:10.1016/j.jval.2016.02.008

31. Finkelstein E, Fiebelkorn lan C, Wang G. The costs of obesity among full-time employees. *Am J Health Promot*. 2005;20(1):45–51. doi:10.4278/0890-1171-20.1.45

32. Anderson DR, Whitmer RW, Goetzel RZ, et al. The relationship between modifiable health risks and group-level health care expenditures. *Am J Health Promot*. 2016;15(1):45–52. doi:10.4278/0890-1171-15.1.45

33. Yang H, Haldeman S, Lu M-L, Baker D. Low back pain prevalence and related workplace psychosocial risk Factors: a study using data from the 2010 national health Interview survey. *J Manipulative Physiol Ther*. 2016;39(7):459–472. doi:10.1016/j.jmpt.2016.07.004

34. Murphy PL, Volinn E. Is occupational low back pain on the rise? *Spine (Phila Pa 1976)*. 1999;24(7):691–697. doi:10.1097/00007632-199904010-00015

35. Taylor VM, Deyo RA, Ciol M, Kreuter W. Surgical treatment of patients with back problems covered by workers compensation versus those with other sources of payment. *Spine (Phila Pa 1976)*. 1996;21(19):2255–2259. doi:10.1097/00007632-199610010-00014

36. Shiri R, Karppinen J, Leino-Arjas P, Solovieva S, Viikari-Juntura E. The association between obesity and low back pain: a meta-analysis. *Am J Epidemiol*. 2010;171(2):135–154. doi:10.1093/aje/kwp356

37. Romero-Vargas S, Zárate-Kalfópulos B, Otero-Cámara E, et al. The impact of body mass index and central obesity on the spino-pelvic parameters: a correlation study. *Eur Spine J*. 2013;22(4):878–882. doi:10.1007/s00586-012-2560-0

38. Othman YA, Alhammoud A, Aldahamsheh O, Vaishnav AS, Gang CH, Qureshi SA. Minimally invasive spine lumbar surgery in obese patients: a systematic review and meta-analysis. *HSS J*. 2020;16(2):168–176. doi:10.1007/s11420-019-09735-6

39. Terman SW, Yee TJ, Lau D, Khan AA, La Marca F, Park P. Minimally invasive versus open transforaminal lumbar interbody fusion: comparison of clinical outcomes among obese patients. *J Neurosurg Spine*. 2014;20(6):644–652. doi:10.3171/2014.2.SPINE13794

40. Park Y, Ha JW, Lee YT, Sung NY. Minimally invasive transforaminal lumbar interbody fusion for spondylolisthesis and degenerative spondylosis: 5-year results. *Clin Orthop Relat Res*. 2014;472(6):1813–1823. doi:10.1007/s11999-013-3241-y

41. Rouben D, Casnellie M, Ferguson M. Long-term durability of minimal invasive posterior transforaminal lumbar interbody fusion: a clinical and radiographic follow-up. *J Spinal Disord Tech*. 2011;24(5):288–296. doi:10.1097/BSD.0b013e3181f9a60a

42. Peng CWB, Yue WM, Poh SY, Yeo W, Tan SB. Clinical and radiological outcomes of minimally invasive versus open transforaminal lumbar interbody fusion. *Spine (Phila Pa 1976)*. 2009;34(13):1385–1389. doi:10.1097/BRS.0b013e3181a4e3be

43. Esses SI, Huler RJ. Indications for lumbar spine fusion in the adult. *Clin Orthop Relat Res*. 1992;(279):87–100.

44. Fritzell P, Hägg O, Wessberg P, Nordwall A, Swedish Lumbar Spine Study Group. Chronic low back pain and fusion: a comparison of three surgical techniques: a prospective multicenter

randomized study from the Swedish lumbar spine study group. *Spine (Phila Pa 1976)*. 2002;27(11):1131–1141. doi:10.1097/00007632-200206010-00002

45. Lingutla KK, Pollock R, Benomran E, et al. Outcome of lumbar spinal fusion surgery in obese patients: a systematic review and meta-analysis. *Bone Joint J*. 2015;97-B(10):1395–1404. doi:10.1302/0301-620X.97B10.35724

46. Onyekwelu I, Glassman SD, Asher AL, Shaffrey CI, Mummaneni PV, Carreon LY. Impact of obesity on complications and outcomes: a comparison of fusion and nonfusion lumbar spine surgery. *J Neurosurg Spine*. 2017;26(2):158–162. doi:10.3171/2016.7.SPINE16448

47. Pelton MA, Phillips FM, Singh K. A comparison of perioperative costs and outcomes in patients with and without workers' compensation claims treated with minimally invasive or open transforaminal lumbar interbody fusion. *Spine (Phila Pa 1976)*. 2012;37(22):1914–1919. doi:10.1097/BRS.0b013e318257d490

48. Djurasovic M, Bratcher KR, Glassman SD, Dimar JR, Carreon LY. The effect of obesity on clinical outcomes after lumbar fusion. *Spine (Phila Pa 1976*). 2008;33(16):1789–1792. doi:10.1097/BRS.0b013e31817b8f6f

49. McCormick JD, Werner BC, Shimer AL. Patient-reported outcome measures in spine surgery. *J Am Acad Orthop Surg*. 2013;21(2):99–107. doi:10.5435/JAAOS-21-02-99

50. DeVine J, Norvell DC, Ecker E, et al. Evaluating the correlation and responsiveness of patient-reported pain with function and quality-of-life outcomes after spine surgery. *Spine (Phila Pa 1976*). 2011;36(21 Suppl):S69-74. doi:10.1097/BRS.0b013e31822ef6de

51. Gauthier N, Sullivan MJL, Adams H, Stanish WD, Thibault P. Investigating risk factors for chronicity: the importance of distinguishing between return-to-work status and self-report measures of disability. *J Occup Environ Med*. 2006;48(3):312–318. doi:10.1097/01.jom.0000184870.81120.49

52. van der Giezen AM, Bouter LM, Nijhuis FJN. Prediction of return-to-work of low back pain patients sicklisted for 3-4 months. *Pain*. 2000;87(3):285–294. doi:10.1016/S0304-3959(00)00292-X

53. Reme SE, Hagen EM, Eriksen HR. Expectations, perceptions, and physiotherapy predict prolonged sick leave in subacute low back pain. *BMC Musculoskelet Disord*. 2009;10:139. doi:10.1186/1471-2474-10-139

54. Lau D, Khan A, Terman SW, Yee T, La Marca F, Park P. Comparison of perioperative outcomes following open versus minimally invasive transforaminal lumbar interbody fusion in obese patients. *Neurosurg Focus*. 2013;35(2):E10. doi:10.3171/2013.5.FOCUS13154

55. Adogwa O, Carr K, Thompson P, et al. A prospective, multi-institutional comparative effectiveness study of lumbar spine surgery in morbidly obese patients: does minimally invasive transforaminal lumbar interbody fusion result in superior outcomes? *World Neurosurg*. 2015;83(5):860–866. doi:10.1016/j.wneu.2014.12.034

56. Cha EDK, Lynch CP, Mohan S, Geoghegan CE, Jadczak CN, Singh K. Impact of obesity severity on achieving a minimum clinically important difference following minimally invasive transforaminal lumbar interbody fusion. *Clin Spine Surg*. 2022;35(1):E267–E273. doi:10.1097/BSD.0000000000001205

57. Goh GS-H, Liow MHL, Yeo W, et al. The influence of body mass index on functional outcomes, satisfaction, and return to work after single-level minimally-invasive transforaminal lumbar interbody fusion: a five-year follow-up study. *Spine (Phila Pa 1976)*. 2019;44(11):809–817. doi:10.1097/BRS.0000000000002943

58. Anderson JT, Haas AR, Percy R, Woods ST, Ahn UM, Ahn NU. Workers' compensation, return to work, and lumbar fusion for spondylolisthesis. *Orthopedics*. 2016;39(1):e1-8. doi:10.3928/01477447-20151218-01

59. Linge AD, Jensen C, Laake P, Bjørkly SK. Changes to body mass index, work self-efficacy, health-related quality of life, and work participation in people with obesity after vocational rehabilitation: a prospective observational study. *BMC Public Health*. 2021;21(1):936. doi:10.1186/s12889-021-10954-y

60. Novosel LM, Grant CA, Dormin LM, Coleman TM. Obesity and disability in older adults. *Nurse Pract*. 2017;42(4):40–47. doi:10.1097/01.NPR.0000513339.69567.75

61. Luppino FS, de Wit LM, Bouvy PF, et al. Overweight, obesity, and depression: a systematic review and meta-analysis of longitudinal studies. *Arch Gen Psychiatry*. 2010;67(3):220–229. doi:10.1001/archgenpsychiatry.2010.2

62. Sturm R, Ringel JS, Andreyeva T. Increasing obesity rates and disability trends. *Health Aff (Millwood)*. 2004;23(2):199–205. doi:10.1377/hlthaff.23.2.199

63. Cook CE. Clinimetrics corner: the minimal clinically important change score (MCID): a necessary pretense. *J Man Manip Ther*. 2008;16(4):E82-3. doi:10.1179/jmt.2008.16.4.82E

64. Wright A, Hannon J, Hegedus EJ, Kavchak AE. Clinimetrics corner: a closer look at the minimal clinically important difference (MCID). *J Man Manip Ther*. 2012;20(3):160–166. doi:10.1179/2042618612Y.0000000001

65. Yoo JS, Hrynewycz NM, Brundage TS, Singh K. The use of patient-reported outcome measurement information system physical function to predict outcomes based on body mass index following minimally invasive transforaminal lumbar interbody fusion. *Spine (Phila Pa 1976)*. 2019;44(23):E1388–E1395. doi:10.1097/BRS.0000000000003137

66. Patel DV, Bawa MS, Haws BE, et al. PROMIS Physical function for prediction of postoperative pain, narcotics consumption, and patient-reported outcomes following minimally invasive transforaminal lumbar interbody fusion. *J Neurosurg Spine*. 2019:1–7. doi:10.3171/2018.9.SPINE18863

67. Keeney BJ, Turner JA, Fulton-Kehoe D, Wickizer TM, Chan KCG, Franklin GM. Early predictors of occupational back reinjury: results from a prospective study of workers in Washington State. *Spine (Phila Pa 1976)*. 2013;38(2):178–187. doi:10.1097/BRS.0b013e318266187d

68. Elders LAM, Burdorf A. Prevalence, incidence, and recurrence of low back pain in scaffolders during a 3-year follow-up study. *Spine (Phila Pa 1976*). 2004;29(6):E101-6. doi:10.1097/01.brs.0000115125.60331.72

69. Planchard RF, Higgins DM, Mallory GW, et al. The impact of obesity on perioperative resource utilization after elective spine surgery for degenerative disease. *Global Spine J*. 2015;5(4):287–293. doi:10.1055/s-0035-1546819

70. Shariq OA, McKenzie TJ. Obesity-related hypertension: a review of pathophysiology, management, and the role of metabolic surgery. *Gland Surg*. 2020;9(1):80–93. doi:10.21037/gs.2019.12.03

71. Atlas SJ, Tosteson TD, Hanscom B, et al. What is different about workers' compensation patients? Socioeconomic predictors of baseline disability status among patients with lumbar radiculopathy. *Spine (Phila Pa 1976*). 2007;32(18):2019–2026. doi:10.1097/BRS.0b013e318133d69b

72. Kim K-B, Shin Y-A. Males with obesity and overweight. *J Obes Metab Syndr*. 2020;29(1):18–25. doi:10.7570/jomes20008

Funding: The author(s) received no financial support for the research, authorship, and/or publication of this article.

Declaration of Conflicting Interests: The authors report no conflicts of interest in this work.

Disclosures: Kern Singh discloses that he has received grants or contracts from the Cervical Spine Research Society; royalties or licenses from RTI Surgical, Zimmer Biomet, Stryker, Lippincott Williams & Wilkins, Theime, Jaypee Publishing, and Slack Publishing; consulting fees from K2M and Zimmer Biomet; patents planned, issued, or pending with TDi LLC; and leadership or fiduciary role on Vitals 5 LLC, TDi LLC, Minimally Invasive Spine Study Group, Contemporary Spine Surgery, Orthopedics Today, and Vertebral Columns. The remaining authors report no disclosures.

IRB Approval: ORA #14051301.

Corresponding Author: Kern Singh, Department of Orthopaedic Surgery, Rush University Medical Center, 1611 W. Harrison St, Suite #300, Chicago, IL 60612, USA; kern.singh@rushortho.com

Published 07 June 2022