

Research Article

Predictors of Early Clinically Significant Improvement Among Lumbar Fusion Patients: A Multivariate Analysis

Madhav R. Patel, BS^{1a}, Kevin C. Jacob, BS^{1b}, Hanna Pawlowski, BS^{1c}, Elliot D.K. Cha, MS^{1d}, Conor P. Lynch, MS^{1e}, Michael C. Prabhu, BS^{1f}, Nisheka N. Vanjani, BS^{1g}, Kern Singh, MD^{1h}

¹ Rush University Medical Center

Keywords: lumbar fusion, minimum clinically important difference, patient-reported outcome measures, MCID, PROMs

<https://doi.org/10.60118/001c.34668>

Journal of Orthopaedic Experience & Innovation

Vol. 3, Issue 1, 2022

Background

Minimum clinically important difference (MCID) achievement is a more patient-centric metric that evaluates the perception of a significant improvement in symptoms. However, few studies have investigated the factors associated with achieving this threshold earlier rather than later in a patient's postoperative course of recovery.

Objective

To determine the baseline factors associated with achievement of an early MCID among patients who underwent a transforaminal, anterior, or lateral lumbar interbody fusion (TLIF, ALIF, LLIF).

Methods

A single-surgeon database was retrospectively reviewed for patients undergoing primary or revision, 1- or 2-level MIS TLIF, ALIF, or LLIF. Patient reported outcome measurements (PROMs) were recorded using Visual Analogue Scale (VAS) back/leg, Oswestry Disability Index (ODI), and 12-Item Short Form (SF-12) Physical Composite Score (PCS). Early achievement of MCID was defined as having a difference in pre- and

a Mr. Patel is a medical student at Georgetown University School of Medicine. He is currently taking a gap year between M3 and M4 to contribute to spinal surgery research under the guidance of Dr. Kern Singh at Midwest Orthopaedics at Rush.

[Conflicts of Interest Statement for Madhav Patel](#)

b Mr. Jacob is currently taking a year between his 3rd and 4th year of medical school to work as a research coordinator for Dr. Kern Singh at Midwest Orthopaedics at Rush. He is interested in pursuing a career as an Orthopaedic Surgeon with the eventual goal to sub-specialize in Spine Surgery.

[Conflicts of Interest Statement for Kevin Jacob](#)

c Ms. Pawlowski is a Research Assistant for Dr. Kern Singh.

[Conflicts of Interest Statement for Hanna Pawlowski](#)

d Mr. Cha is a medical student and former research coordinator for Dr. Kern Singh.

[Conflicts of Interest Statement for Dr. Cha](#)

e Mr. Lynch is a fourth-year medical student at the Geisinger Commonwealth School of Medicine.

[Conflicts of Interest Statement for Conor Lynch](#)

f Mr. Prabhu is a Research Assistant for Dr. Kern Singh.

[Conflicts of Interest Statement for Michael Prabhu](#)

g Ms. Vanjani is a Research Assistant for Dr. Kern Singh.

[Conflicts of Interest Statement for Nisheka Vanjani](#)

h Dr. Singh is a Professor of Orthopaedic Surgery at Rush University Medical Center in Chicago, IL. His practices focuses primarily on minimally invasive spinal surgery techniques.

[Conflicts of Interest Statement for Dr. Singh](#)

postoperative PROM scores that were equal to or greater than the established values at the 6-week or 12-week timepoint. Using simple logistic regression, a cutoff of $p \leq 0.025$ was used to determine covariates correlating with early MCID achievement. Using multiple logistic regression, we then completed a post-regression analysis to assess the influence of covariates on timing of MCID achievement across VAS, ODI, and SF-12 PROMs.

Results

405 patients were included, with a mean age of 53.8 years and the majority being male (64.2%) and non-obese (50.5%). Mean preoperative VAS back, VAS leg, and ODI scores were 6.4 ± 2.4 , 5.6 ± 2.8 , and 41.5 ± 16.8 , respectively (Table 1). Majority of patients presented with degenerative spondylolisthesis (56.5%), followed by isthmic spondylolisthesis (30.5%), recurrent herniated nucleus pulposus (24.6%), and degenerative scoliosis (9.6%). Majority of procedures were primary (89.0%) in nature, with 42 cases (11.0%) being revision surgeries. Most patients received MIS TLIF (75.1%), while 16.5% received LLIF, and 8.4% received ALIF. 374 1-level procedures (92.3%) and 31 2-level procedures (7.7%) were performed. Mean operative time, blood loss, and postoperative stay was 135.1 minutes, 53.0 milliliters, and 32.7 hours, respectively (Table 2). Most patients demonstrated MCID achievement from 12-weeks to 1-year for back pain. For leg pain, disability, and physical function, majority of patients demonstrated MCID achievement at 6-months and 1-year. By 1-year following fusion and for overall, a majority of subjects (>50%) attained MCID across VAS/ODI/SF-12 PROMs (Table 3). At 6-weeks, patients with higher preoperative VAS and ODI scores demonstrated greater odds of MCID achievement ($p < 0.001$, all). Patients with higher preoperative SF-12 PCS experienced lower odds of SF-12 PCS achievement at 6-weeks ($p < 0.001$). Workers' Compensation (WC) status was associated with decreased odds of MCID achievement at this timepoint across pain and disability PROMs studied ($p \leq 0.003$, all). For VAS back, degenerative spondylolisthesis increased odds for achievement ($p = 0.023$), while for ODI, revision procedures were associated with a decreased odds for 6-week MCID achievement ($p = 0.034$). Arthritis decreased odds of 6-week MCID achievement for SF-12 PCS ($p = 0.007$), while history of myocardial infarction (MI) increased odds of achievement for VAS leg ($p = 0.034$) (Table 4). For 12-weeks, MCID achievement for all PROMs was again more likely among patients with higher preoperative scores ($p < 0.001$, all), with WC associated with decreased odds of achievement ($p < 0.001$, all). In addition, ALIF surgery was associated with decreased odds of 12-week MCID achievement for VAS leg and ODI ($p \leq 0.037$, both), while diabetic status was associated with increased odds of attainment for SF-12 PCS ($p = 0.037$) (Table 5).

Conclusion

Early MCID achievement for back pain, leg pain, disability, and physical function were more likely among patients with worse preoperative PROM values. This suggests that patients who benefit the earliest from lumbar fusion may be limited to individuals who report more severe preoperative symptoms. Furthermore, WC claimants, patients presenting for revision surgery, and those receiving ALIF (vs MIS TLIF/LLIF) are likely to experience delays in clinically meaningful recovery of pain and/or disability following lumbar fusion.

INTRODUCTION

Lumbar interbody fusion (LIF) is a surgical procedure for the treatment of degenerative spine conditions, which include but are not limited to, degenerative disc disease, isthmic/degenerative spondylolisthesis or spondylosis, and spinal and/or foraminal stenosis (Xu et al. 2018; Lener et al. 2020; de Kunder et al. 2018; Kim et al. 2020; Rosenberg 1975; Mobbs et al. 2015). In general, LIF procedures involve the placement of a cage within the intervertebral space after discectomy and endplate preparation, with a goal of restoring proper disc height and lordosis (Kim et al. 2020).

Some of the most common LIF procedures include anterior LIF (ALIF), transforaminal LIF (TLIF), and lateral LIF (LLIF), all which differ in approach. An ALIF approach exposes the direct midline of the lumbar disc thus allowing a wide discectomy so as to place a large interbody cage (Xu et al. 2018). On the other hand, the LLIF approach involves going through the psoas muscle to displace the lumbar plexus nerves in order to expose the lateral surface of the disc space (Xu et al. 2018). Finally, a TLIF approach involves opening the neural foramen on one side through direct unilateral access (Mobbs et al. 2015).

In transitioning from traditional open LIF to minimally invasive LIF (MIS LIF) procedures, surgeons and clinicians are looking for evidence regarding the efficacy of MIS LIF treatments (Højmark et al. 2016). Traditionally, post-surgical outcomes were assessed from the surgeon's perspective of the patients' health without regard for patient perception (Finkelstein and Schwartz 2019). In recent years, however, the perceived outcomes of surgery have shifted to include the patient perspective (Finkelstein and Schwartz 2019; Schwartz, Ayandeh, and Finkelstein 2015). With the increased emphasis on patient perception in clinical care, patient reported outcome measures (PROMs) are increasingly being administered to and collected from patients undergoing spinal surgery (Højmark et al. 2016). In spinal surgery, PROMs include the Visual Analog Scale (VAS) for back and leg pain, the Oswestry Disability Index (ODI) for back disability, and the 12-item Short Form Physical Composite Score (SF-12 PCS) for physical function, all of which are collected pre- and post-operatively (Deshpande et al. 2011; Field, Holmes, and Newell 2019). While PROMs are widely used and accepted, they are limited in their ability to offer statistical value as they do not represent meaningful clinical change (Malhotra et al. 2015; Leopold and Porcher 2017; Ogura et al. 2019; Katz, Paillard, and Ekman 2015).

In response to this, the concept of a minimum clinically important difference (MCID) was created. An MCID value is defined as the smallest change in PROM scores that is considered meaningful. Achievement of an MCID is viewed as a more patient-centric metric that evaluates the perception of a significant improvement in symptoms. However, few studies have investigated the factors associated with achieving this threshold earlier rather than later in a patient's postoperative course of recovery. In this study, we aim to determine the baseline factors associated with achievement of an early MCID among patients who underwent a TLIF, ALIF, or LLIF procedure.

METHODS

Prior to the commencement of this research, our institution's Institutional Review Board (IRB) approved the study (ORA #14051301) and patients consented to inclusion. A single-surgeon database at an academic institution was retrospectively reviewed for patients undergoing a primary or revision 1- or 2-level MIS TLIF, ALIF, or LLIF. Procedures for trauma, infection, or malignancy were excluded.

DATA COLLECTION

Patient demographic data were collected, which included age, self-reported gender, body mass index (BMI), diabetic status, smoking status, American Society for Anesthesiologist (ASA) score, Charlson Comorbidity Index (CCI), insurance type, and other present medical comorbidities. Perioperative information was also recorded, which included spinal pathology, procedure type (primary or revision), lumbar fusion approach (transforaminal, anterior, or lateral), number of operative levels, operative time, estimated blood loss (EBL), and postoperative length of stay (LOS).

Patient-reported outcome measurements (PROMs) were collected preoperatively and postoperatively at 6 weeks, 12 weeks, 6 months, and 1 year. PROMs recorded included Visual Analogue Scale (VAS) back, VAS leg, Oswestry Disability Index (ODI), and 12-Item Short Form (SF-12) Physical Composite Score (PCS). MCID achievement was calculated for each PROM and compared among cohorts to determine the clinically significant improvement in clinical outcomes.

STATISTICAL ANALYSIS

Stata 16.0 (StataCorp LP, College Station, TX) was used for all data analysis. The following established thresholds of change from preoperative to postoperative mean scores were utilized to determine MCID achievement: VAS back = 2.1 (Parker et al. 2011); VAS leg = 2.8 (Parker et al. 2011); ODI = 14.9 (Parker et al. 2011); SF-12 PCS = 4.9 (Copey et al. 2008). Early achievement of MCID was defined as having a difference in pre- and postoperative PROM scores that were equal to or greater than the established values at the 6-week or 12-week timepoint. Using simple logistic regression, a cutoff of $p \leq 0.025$ was established to determine covariates correlating with early MCID achievement. Using multiple logistic regression, we then completed a post-regression analysis to assess the influence of covariates on the timing of MCID achievement across VAS, ODI, and SF-12 PROMs at 6 weeks and 12 weeks.

RESULTS

DEMOGRAPHIC DATA AND PERIOPERATIVE CHARACTERISTICS

A total of 405 patients were included (mean age of 53.8 years) with the majority being male (64.2%) and non-obese (50.5%). The majority of patients were non-diabetic (89.9%), non-smokers (88.6%), and presented an ASA score of ≥ 2 (89.0%). The mean CCI was 0.7 and most patients had private insurance (66.9%) followed by WC (27.6%) and Medicare/Medicaid (5.4%). Some patients presented with other medical comorbidities, the most common being hypertension (31.1%), followed by arthritis (16.8%), myocardial infarction (MI) (4.2%), chronic obstructive pulmonary disease (COPD) (2.2%), peripheral vascular disease (0.7%), neurological disease (0.5%), chronic kidney disease (0.5%), cancer metastasis (0.5%), and liver disease (0.3%) ([Table 1](#)).

The majority of patients presented with degenerative spondylolisthesis (56.5%), followed by isthmic spondylolisthesis (30.5%), recurrent herniated nucleus pulposus (24.6%), and degenerative scoliosis (9.6%). The majority of surgeries were primary procedures (89.0%), with 42 cases (11.0%) being revision surgeries. Most patients received MIS TLIF (75.1%), while 16.5% received LLIF, and 8.4% received ALIF. Three hundred seventy-four 1-level procedures (92.3%) and 31 2-level procedures (7.7%) were performed. Mean operative time, blood loss, and postoperative stay were 135.1 minutes, 53.0 milliliters, and 32.7 hours, respectively ([Table 2](#)).

Table 1. Patient Demographics

Characteristic	Total (n=405)
Age (mean $\pm$ SD)	53.8 $\pm$ 11.4
Gender	
Female	35.8% (145)
Male	64.2% (260)
Body Mass Index	
<30 kg/m ²	50.5% (203)
$\geq$ 30 kg/m ²	49.5% (199)
Diabetic Status	
Non-Diabetic	89.9% (364)
Diabetic	10.1% (41)
Smoking Status	
Non-Smoker	88.6% (359)
Smoker	11.4% (46)
ASA Classification	
<2	11.0% (44)
$\geq$ 2	89.0% (356)
CCI Score (mean $\pm$ SD)	0.7 $\pm$ 0.4
Insurance	
Medicare/Medicaid	5.4% (22)
Workers' Compensation	27.6% (112)
Private	66.9% (271)
Preoperative VAS Back	6.4 $\pm$ 2.4
Preoperative VAS Leg	5.6 $\pm$ 2.8
Preoperative ODI	41.5 $\pm$ 16.8
Preoperative SF-12 PCS	30.2 $\pm$ 8.6
Medical Comorbidities	
Myocardial infarction	4.2% (17)
Hypertension	31.1% (126)
Neurological Disease	0.5% (2)
Arthritis	16.8% (68)
Peripheral Vascular Disease	0.7% (3)
Cancer Metastasis	0.5% (2)
Liver Disease	0.3% (1)
COPD	2.2% (9)
Chronic Kidney Disease	0.5% (2)

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; SD = standard deviation; VAS = Visual Analogue Scale; ODI = Oswestry Disability Index; SF-12 PCS = 12-Item Short Form Physical Composite Score; COPD = Chronic Obstructive Pulmonary Disease

PRIMARY OUTCOME MEASURES

Mean preoperative VAS back, VAS leg, and ODI scores were 6.4 $\pm$ 2.4, 5.6 $\pm$ 2.8, and 41.5 $\pm$ 16.8, respectively ([Table 1](#)). Most patients demonstrated MCID achievement from 12 weeks to 1 year for back pain (>50% of patients) ([Table 3](#)). For leg pain, disability, and physical function, the majority of patients demonstrated MCID achievement at 6 months and 1 year (>50% of patients, all) ([Table 3](#)). By 1 year following fusion and overall, the majority of subjects

Table 2. Perioperative Characteristics

Characteristic	Total (n=405)
Spinal Pathology	
Recurrent Herniated Nucleus Pulposus	26.4% (66)
Degenerative Scoliosis	9.6% (39)
Degenerative Spondylolisthesis	56.5% (199)
Isthmic Spondylolisthesis	30.5% (106)
Procedure Type	
Primary	89.0% (357)
Revision	11.0% (42)
Lumbar Fusion Approach	
Transforaminal (TLIF)	75.1% (304)
Anterior (ALIF)	8.4% (34)
Lateral (LLIF)	16.5% (67)
Number of Operative Levels	
1-Level	92.3% (374)
2-Levels	7.7% (31)
Operative Time (Mean $\pm$ SD; min)	135.1 $\pm$ 37.2
Estimated Blood Loss (Mean $\pm$ SD; mL)	53.0 $\pm$ 29.5
Length of Stay (Mean $\pm$ SD; hours)	32.7 $\pm$ 18.8

TLIF=transforaminal lumbar interbody fusion; ALIF=anterior lumbar interbody fusion; lateral lumbar interbody fusion; SD=standard deviation

(>50%) attained MCID across VAS, ODI and SF-12 PROMs ([Table 3](#)). At 6 weeks, patients with higher preoperative VAS and ODI scores demonstrated greater odds of MCID achievement ($p<0.001$, all). Patients with higher preoperative SF-12 PCS experienced lower odds of SF-12 PCS achievement at 6 weeks ($p<0.001$). WC status was associated with decreased odds of MCID achievement at this timepoint across pain and disability PROMs studied ($p\leq 0.003$, all). For VAS back, degenerative spondylolisthesis increased the odds for MCID achievement ($p=0.023$), while for ODI, revision procedures were associated with decreased odds of 6-week MCID achievement ($p=0.034$). Arthritis decreased the odds of 6-week MCID achievement for SF-12 PCS ($p=0.007$), while a history of MI increased the odds of MCID achievement for VAS leg ($p=0.034$) ([Table 4](#)). For 12 weeks, MCID achievement for all PROMs was again more likely among patients with higher preoperative scores ($p<0.001$, all); WC was associated with decreased odds of MCID achievement ($p<0.001$, all). In addition, ALIF surgery was associated with decreased odds of 12-week MCID achievement for VAS leg and ODI ($p\leq 0.037$, both), while diabetic status was associated with increased odds of MCID attainment for SF-12 PCS ($p=0.037$) ([Table 5](#)).

DISCUSSION

In 1989, Jaeschke et al. introduced the MCID as 'the smallest difference in score in the domain of interest which patients perceive as beneficial and which would mandate, in the ab-

Table 3. MCID Achievement

PROM	MCID Achievement (%)
VAS Back	
6 weeks	49.1% (172)
12 weeks	53.5% (174)
6 months	56.7% (170)
1 year	59.4% (95)
Overall	71.6% (277)
VAS Leg	
6 weeks	47.1% (164)
12 weeks	48.1% (156)
6 months	50.5% (152)
1 year	51.5% (83)
Overall	64.4% (242)
ODI	
6 weeks	29.1% (102)
12 weeks	39.4% (128)
6 months	55.6% (168)
1 year	53.7% (86)
Overall	59.4% (228)
SF-12 PCS	
6 weeks	32.0% (91)
12 weeks	48.7% (131)
6 months	57.7% (131)
1 year	67.4% (124)
Overall	67.6% (236)

VAS, Visual analogue scale; ODI, Oswestry disability index; SF-12 PCS, 12-Item Short Form Physical Composite Score

Table 4. Factors Associated with Achievement of MCID at 6 weeks

Factor	Odds Ratio	95% C.I.	*p-value
VAS Back			
Workers' Compensation	0.303	0.154 - 0.594	0.001
Degenerative Spond.	2.46	1.13 - 5.37	0.023
Preoperative value	1.70	1.47 - 1.97	<0.001
VAS Leg			
Workers' Compensation	0.305	0.138 - 0.672	0.003
Myocardial Infarction	8.97	1.17 - 67.3	0.034
Preoperative value	1.62	1.42 - 1.86	<0.001
ODI			
Revision Procedure	0.264	0.077 - 0.906	0.034
Workers' Compensation	0.202	0.097 - 0.420	<0.001
Preoperative value	1.06	1.05 - 1.09	<0.001
SF-12 PCS			
Arthritis	0.316	0.137 - 0.725	0.007
Preoperative value	0.896	0.859 - 0.934	<0.001

Spond=spondylolisthesis

*p-values calculated using multiple logistic regression

sence of troublesome side effects and excessive cost, a change in the patient's management' (Jaeschke, Singer, and Guyatt 1989). Based on this description and its current use in the spinal literature, physicians compute the MCID achievement to determine if clinically meaningful improvements, from the perspective of the patient, have occurred following surgery (Copay et al. 2007). By assessing MCID achievement rates, surgeons are able to determine the effectiveness of treatments and make more informed surgical decisions. A widely utilized method to evaluate patient-perceived HRQOL outcomes is by administration of PROM questionnaires preoperatively and at postoperative follow-up visits. For LIF procedures, including ALIF, MIS TLIF, and LLIF, commonly reported PROMs in the literature include VAS for pain, the ODI for back pain-related disability, and the SF-12 Physical Composite Score for physical health.

As patient satisfaction gains importance in the evaluation of surgical success and holds economic implications for reimbursement schemes, evaluating characteristics that may increase patient satisfaction is important (Menendez et al. 2019). In a recent systematic review, Menendez et al. highlighted "efficacy/clinical outcomes" as one of seven dimensions of patient satisfaction, along with pain, function, and patient preferences (Menendez et al. 2019). Because earlier achievement of MCID affords the opportunity

to address several of the mentioned dimensions of satisfaction, careful analysis of factors associated with early MCID attainment across PROMs allows surgeons to better understand baseline characteristics that may lead to improved postoperative satisfaction (Menendez et al. 2019). Therefore, the current study aims to evaluate baseline characteristics associated with earlier achievement of clinically meaningful improvements (as measured by MCID) pertaining to pain, disability, and physical function PROMs following lumbar fusion surgery (ALIF, LLIF, MIS TLIF).

Our final cohort included a total of 405 patients, with the majority undergoing 1-level MIS TLIF, followed by ALIF and LLIF. MCID was achieved amongst the majority of patients (>50%) by 6 months following fusion for back pain, leg pain, disability, and physical function. Meanwhile, at 6 weeks, a minority of patients (<50%) achieved MCID across all PROMs studied, a trend which also held true at 12 weeks, with the exception of the VAS back. Our results therefore indicate that while most patients obtain clinically meaningful improvements by 6 months and onwards, MCID is less frequently attained in the early postoperative period. In the following paragraphs, we will assess factors associated with MCID achievement at 6 and 12 weeks.

For VAS back, MCID achievement at 6 weeks and 12 weeks, WC status was associated with decreased odds of

Table 5. Factors Associated with Achievement of MCID at 12 weeks

Factor	Odds Ratio	95% C.I.	*p-value
VAS Back			
Workers' compensation	0.144	0.067 - 0.304	<0.001
Preoperative value	1.57	1.37 - 1.81	<0.001
VAS Leg			
Workers' compensation	0.225	0.104 - 0.484	<0.001
ALIF	0.248	0.067 - 0.916	0.037
Preoperative value	1.65	1.45 - 1.91	<0.001
ODI			
Workers' compensation	0.151	0.073 - 0.313	<0.001
ALIF	0.242	0.066 - 0.873	0.030
Preoperative value	1.06	1.04 - 1.08	<0.001
SF-12 PCS			
Workers' compensation	0.282	0.138 - 0.579	0.001
Diabetes	0.369	0.144 - 0.943	0.037
Number of operative levels	0.236	0.081 - 0.686	0.008
Preoperative value	0.897	0.862 - 0.933	<0.001

*p-values calculated using multiple logistic regression

early attainment and greater preoperative VAS back score was associated with increased odds of attainment. In a recent study evaluating risk factors for failure to reach MCID following MIS TLIF, Hijji et al. similarly discovered that WC claimants had lower probability of achieving MCID for back pain relief ($p < 0.001$) (Hijji et al. 2018). The authors concluded that WC status may therefore deter achievement of clinically meaningful pain relief. Our results also conveyed that a higher preoperative value for VAS back was associated with greater MCID achievement for VAS back both at 6 weeks and 12 weeks. Jacob et al. similarly discovered that patients presenting with greater back pain prior to MIS TLIF experienced greater MCID achievement for VAS back in the overall postoperative period, which was in alignment with our findings (Jacob et al. 2021). Therefore, patients presenting with worse baseline pain scores appear to be more likely to exhibit clinically meaningful improvements. Meanwhile, MCID achievement for back pain at 6 weeks was additionally positively influenced by degenerative spondylolisthesis pathology. This is unsurprising, as MIS TLIF is a well-established operative treatment for degenerative spondylolisthesis, but is less established in the literature for operative management of isthmic spondylolisthesis (Massel et al. 2020). Therefore, our patients pre-

senting with this degenerative disc slippage may preferentially benefit from earlier clinically meaningful back pain-related improvements.

For VAS leg MCID at 6 weeks and 12 weeks, WC claimants again had lower odds of achievement. Gum et al. similarly discovered that among lumbar fusion recipients, those with WC experienced less improvement from preoperative to postoperative on numeric rating scale (NRS) leg pain scores (Gum, Glassman, and Carreon 2013). While MCID achievement was not directly evaluated, it appeared that WC status was a deterrent to postoperative improvements and thus may reasonably lead to delays in the achievement of MCID. Our analysis also revealed that those with greater preoperative leg pain had increased odds of early achievement at both 6 weeks and 12 weeks. This also aligns with the existing literature, such as the conclusions of Khan et al., in which patients with leg pain predominance (LPP) demonstrated higher VAS leg MCID following lumbar fusion vs. those with back pain predominance (BPP) (Khan et al. 2020). Interestingly, patients with MI also demonstrated higher odds of early achievement at 6 weeks. Patients receiving MIS TLIF may present with cardiovascular (CV) comorbidities such as a history of MI, with one study reporting an incidence of 22% for CV disorders within their study population (Perez-Cruet et al. 2014; Lee, Kim, and Ryu 2016). In the current analysis, those presenting with a history of MI may be more likely to perceive clinically meaningful leg pain improvements earlier in the postoperative course due to poorer baseline status and thus potential for larger increments of improvement. However, as only 4.2% (17) of 405 patients presented with a history of MI, the statistical power of this finding remains limited. Meanwhile, patients undergoing ALIF demonstrated lower odds of early MCID achievement for VAS leg at 12 weeks. Moses et al. demonstrated the increased usage by spinal surgeons of MIS TLIF for patients with greater baseline leg pain, illustrating that MIS TLIF may be better suited for leg pain improvements (Moses et al. 2021). This trend was also supported by Jacob et al., illustrating higher MCID achievement for VAS leg at 6 weeks and during the overall postoperative period for MIS TLIF vs. ALIF recipients (Jacob, Patel, Ribot, et al. 2022). While ALIF thus may be less likely to offer early clinically meaningful improvements for leg pain, the surgeon should consider patient-specific characteristics, patient preference, and must comprehensively evaluate advantages and disadvantages of each procedure when arriving at an operative decision. Nevertheless, patients selecting to receive ALIF can be reassured that significant leg pain improvements are still likely to occur, as suggested by several authors (Viel et al. 2019; Jägersberg et al. 2014; Duggal et al. 2004).

For disability-related MCID achievement at 6 weeks and 12 weeks, higher preoperative disability was associated with greater odds of achievement. Jacob et al. stratified patients by preoperative ODI score and similarly found that those presenting with higher disability (ODI >41) experienced greater MCID attainment for disability throughout the entire postoperative period (including at 6 weeks) (Jacob, Patel, Collins, et al. 2022). Meanwhile, WC status was

associated with lower odds of disability achievement at 6 weeks and 12 weeks. In a systematic review and meta-analysis by Russo et al., the authors concluded that WC patients suffered from greater disability following lumbar surgery (Russo et al. 2021). In a separate study by Carreon et al., the authors found that <20% of patients with WC insurance achieved MCID for ODI, while the proportion of non-WC achieving MCID was almost double (Carreon et al. 2010). Therefore, our findings of lower rates in clinically meaningful disability recovery amongst WC claimants closely align with the existing literature. Furthermore, receiving a revision procedure was also associated with poorer odds of ODI achievement at 6 weeks. This aligns with published literature which has associated revision lumbar fusion with poorer disability-related recovery. For instance, Ibrahim et al. reported a 13-point decrease in disability improvement between primary and revision surgery (Ibrahim et al. 2020). Montenegro et al. also showed poorer ODI scores and MCID achievement for ODI among patients undergoing revision procedures in comparison to primary procedures (Montenegro et al. 2021). Finally, receiving ALIF was also associated with decreased odds of MCID achievement for ODI, specifically at 12 weeks. However, this seems to be unsupported by the current literature, as one study demonstrated no significant difference in MCID for ODI between ALIF and TLIF, concluding that the fusion approach performed had little effect on ODI improvements (Owens et al. 2016). Park et al. similarly discovered no change in ODI outcomes among ALIF vs. TLIF, while Jacob et al. reported greater MCID achievement for ODI among ALIF vs. TLIF recipients (Jacob, Patel, Ribot, et al. 2022; Park et al. 2021). However, as this study had a separate study population due to the inclusion of double-level procedures and LLIF patients, our findings may not directly contradict existing literature. Ultimately, by recognizing risk factors that deter early improvements in disability to a clinically meaningful extent, surgeons and patients may better formulate expectations regarding recovery.

Finally, for SF-12 PCS, a greater preoperative score was associated with lower odds of early MCID achievement both at 6 weeks and 12 weeks. In other words, patients with worse physical functioning at baseline were at higher odds of improving in a clinically meaningful manner. This theme is supported by the results of Parrish et al., who evaluated the influence of preoperative Patient-Reported Outcome Measurement Information System physical function (PROMIS-PF) scores on magnitude of improvement, discovering that those with poorer baseline physical function improved to a significantly greater extent (Parrish et al. 2020). Moreover, WC status was again associated with lower odds of MCID achievement at 12 weeks. This is well supported by existing literature such as Cha et al., who reported poorer overall MCID achievement for SF-12 PCS when comparing WC vs. non-WC claimants receiving TLIF (Cha et al. 2022). As the SF-12 PCS has been used frequently in the spinal literature to evaluate physical functioning outcomes, it may partially contribute to the delayed return to work status observed among WC claimants following lumbar spinal surgery (Russo et al. 2021). A greater number of operative

levels was also linked to decreased odds of SF-12 PCS MCID achievement (at 12 weeks). This finding suggests that when both single-level and double-level procedures are well-suited for a patient, performance of single-level fusion may preferentially allow for more clinically meaningful physical health improvements. Interestingly, comorbidities of arthritis and diabetes were associated with decreased odds of MCID achievement following lumbar fusion. Weiner et al. described that patients with lower back pain (LBP) often had coexisting pain in the hip or knee joints, suggesting that osteoarthritis or biomechanical instability may be the underlying cause (Weiner et al. 2003). The authors suggested that the addition of musculoskeletal pathologies to LBP may impair treatment outcomes. While diabetes was also shown to deter early physical function improvements, the existing literature suggests little influence of diabetic status on SF-36 outcomes among patients undergoing cervical decompression surgery (Epstein 2017). Lynch et al. similarly compared diabetics vs. non-diabetics undergoing cervical fusion (Lynch et al. 2021). The authors reported no difference in MCID achievement for SF-12 PCS throughout the majority of the postoperative period (including the early postoperative window of 6 weeks/12 weeks), and no difference in PROMIS-PF achievement throughout the entire postoperative period. Nonetheless, our study included lumbar fusion patients, providing a potential explanation for the differences amongst reported literature and our findings. Surgeons should discuss expected clinical outcomes and provide comprehensive guidance for physical function rehabilitation following surgery, especially to patients with WC status and comorbidities (arthritis, diabetes), to maximize clinically meaningful improvements in the months following lumbar fusion.

LIMITATIONS

There are several limitations to this study that should be addressed. First, as a singular surgeon at one institution performed the lumbar fusion procedures (ALIF, LLIF, MIS TLIF), the generalizability of our findings remains limited. Furthermore, PROMs are based on patient perception therefore these surveys may be influenced by response bias. While the SF-12 PCS was utilized, there are other physical function surveys (i.e., PROMIS-PF, the Veterans RAND 12 Physical Component Score) that have been validated for lumbar fusion, thus limiting the scope of our physical function conclusions. While 405 patients were included, a majority were male, (64.2% vs. 35.8%), which may have also skewed our results. As differing spinal pathologies and lumbar fusion approaches were included, our findings may be influenced by confounder bias. Confounder bias may have also been introduced due to inclusion of both primary and revision procedures, and both 1-level and 2-level operations.

CONCLUSION

Patients presenting with poorer PROM scores at the preoperative stage were more likely to achieve clinically mean-

ingful improvements for back pain, leg pain, disability, and physical function during the early postoperative period (6 weeks, 12 weeks). Meanwhile, those with WC status generally had lower odds of early MCID achievement. Patients undergoing revision lumbar fusion, and those who underwent ALIF were also at higher odds of delay in MCID achievement in the early postoperative period. By recognizing these trends, surgeons may be able to better anticipate

the trajectory of clinical improvements in the early postoperative period. An understanding of the presented information may ultimately allow for more informed decision making during the preoperative stage.

Submitted: February 25, 2022 EDT, Accepted: April 16, 2022 EDT



This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CCBY-NC-ND-4.0). View this license's legal deed at <https://creativecommons.org/licenses/by-nc-nd/4.0> and legal code at <https://creativecommons.org/licenses/by-nc-nd/4.0/legalcode> for more information.

REFERENCES

- Carreon, Leah Y., Steven D. Glassman, Neha R. Kantamneni, Mark O. Mugavin, and Mladen Djurasovic. 2010. "Clinical Outcomes After Posterolateral Lumbar Fusion in Workers' Compensation Patients." *Spine* 35 (19): 1812–17. <https://doi.org/10.1097/brs.0b013e3181c68b75>.
- Cha, Elliot D.K., Conor P. Lynch, Caroline N. Jadcak, Shruthi Mohan, Cara E. Geoghegan, and Kern Singh. 2022. "Differences in Clinically Important Physical Function Improvement in Workers' Compensation Population." *International Journal of Spine Surgery* 16 (1): 176–85. <https://doi.org/10.14444/8186>.
- Copay, Anne G., Steven D. Glassman, Brian R. Subach, Sigurd Berven, Thomas C. Schuler, and Leah Y. Carreon. 2008. "Minimum Clinically Important Difference in Lumbar Spine Surgery Patients: A Choice of Methods Using the Oswestry Disability Index, Medical Outcomes Study Questionnaire Short Form 36, and Pain Scales." *The Spine Journal* 8 (6): 968–74. <https://doi.org/10.1016/j.spinee.2007.11.006>.
- Copay, Anne G., Brian R. Subach, Steven D. Glassman, David W. Jr. Polly, and Thomas C. Schuler. 2007. "Understanding the Minimum Clinically Important Difference: A Review of Concepts and Methods." *The Spine Journal* 7 (5): 541–46. <https://doi.org/10.1016/j.spinee.2007.01.008>.
- de Kunder, Suzanne L., Kim Rijkers, Inge J.M.H. Caelers, Rob A. de Bie, Peter J. Koehler, and Henk van Santbrink. 2018. "Lumbar Interbody Fusion: A Historical Overview and a Future Perspective." *Spine* 43 (16): 1161–68. <https://doi.org/10.1097/brs.0000000000002534>.
- Deshpande, PrasannaR, BLakshmi Sudeepthi, Surulivel Rajan, and CP Abdul Nazir. 2011. "Patient-Reported Outcomes: A New Era in Clinical Research." *Perspectives in Clinical Research* 2 (4): 137. <https://doi.org/10.4103/2229-3485.86879>.
- Duggal, Neil, Ignacio Mendiondo, Heraldo R. Pares, Balraj S. Jhavar, Kaushik Das, Kathy J. Kenny, and Curtis A. Dickman. 2004. "Anterior Lumbar Interbody Fusion for Treatment of Failed Back Surgery Syndrome: An Outcome Analysis." *Neurosurgery* 54 (3): 636–44. <https://doi.org/10.1227/01.neu.0000108423.87889.9e>.
- Epstein, Nancy E. 2017. "Predominantly Negative Impact of Diabetes on Spinal Surgery: A Review and Recommendation for Better Preoperative Screening." *Surgical Neurology International* 8 (1): 107. https://doi.org/10.4103/sni.sni_101_17.
- Field, Jonathan, Michelle M Holmes, and Dave Newell. 2019. "PROMs Data: Can It Be Used to Make Decisions for Individual Patients? A Narrative Review." *Patient Related Outcome Measures* Volume 10 (July):233–41. <https://doi.org/10.2147/prom.s156291>.
- Finkelstein, Joel A., and Carolyn E. Schwartz. 2019. "Patient-Reported Outcomes in Spine Surgery: Past, Current, and Future Directions: JNSPG 75th Anniversary Invited Review Article." *Journal of Neurosurgery: Spine* 31 (2): 155–64. <https://doi.org/10.3171/2019.1.spine18770>.
- Gum, Jeffrey L., Steven D. Glassman, and Leah Y. Carreon. 2013. "Is Type of Compensation a Predictor of Outcome after Lumbar Fusion?" *Spine* 38 (5): 443–48. <https://doi.org/10.1097/brs.0b013e318278ebe8>.
- Hijji, Fady Y., Ankur S. Narain, Daniel D. Bohl, Kelly H. Yom, Krishna T. Kudravalli, Gregory D. Lopez, and Kern Singh. 2018. "Risk Factors Associated With Failure to Reach Minimal Clinically Important Difference in Patient-Reported Outcomes Following Minimally Invasive Transforaminal Lumbar Interbody Fusion for Spondylolisthesis." *Clinical Spine Surgery: A Spine Publication* 31 (1): E92–97. <https://doi.org/10.1097/bsd.0000000000000543>.
- Højmark, Karen, C. Støttrup, L. Carreon, and M. O. Andersen. 2016. "Patient-Reported Outcome Measures Unbiased by Loss of Follow-up. Single-Center Study Based on DaneSpine, the Danish Spine Surgery Registry." *European Spine Journal* 25 (1): 282–86. <https://doi.org/10.1007/s00586-015-4127-3>.
- Ibrahim, John M., Paramjit Singh, Daniel Beckerman, Serena S. Hu, Bobby Tay, Vedat Deviren, Shane Burch, and Sigurd H. Berven. 2020. "Outcomes and Quality of Life Improvement After Multilevel Spinal Fusion in Elderly Patients." *Global Spine Journal* 10 (2): 153–59. <https://doi.org/10.1177/2192568219849393>.
- Jacob, Kevin C., Madhav R. Patel, Andrew P. Collins, Max A. Ribot, Hanna Pawlowski, Michael C. Prabhu, Nisheka N. Vanjani, and Kern Singh. 2022. "The Effect of the Severity of Preoperative Disability on Patient-Reported Outcomes and Patient Satisfaction Following Minimally Invasive Transforaminal Lumbar Interbody Fusion." *World Neurosurgery* 159 (March):e334–46. <https://doi.org/10.1016/j.wneu.2021.12.051>.
- Jacob, Kevin C., Madhav R. Patel, Alexander W. Parsons, Nisheka N. Vanjani, Hanna Pawlowski, Michael C. Prabhu, and Kern Singh. 2021. "The Effect of the Severity of Preoperative Back Pain on Patient-Reported Outcomes, Recovery Ratios, and Patient Satisfaction Following Minimally Invasive Transforaminal Lumbar Interbody Fusion (MIS-TLIF)." *World Neurosurgery* 156 (December):e254–65. <https://doi.org/10.1016/j.wneu.2021.09.053>.
- Jacob, Kevin C., Madhav R. Patel, Max A. Ribot, Alexander W. Parsons, Nisheka N. Vanjani, Hanna Pawlowski, Michael C. Prabhu, and Kern Singh. 2022. "Single-Level Minimally Invasive Transforaminal Lumbar Interbody Fusion versus Anterior Lumbar Interbody Fusion with Posterior Instrumentation at L5/S1." *World Neurosurgery* 157 (January):e111–22. <https://doi.org/10.1016/j.wneu.2021.09.108>.

- Jaeschke, Roman, Joel Singer, and Gordon H. Guyatt. 1989. "Measurement of Health Status." *Controlled Clinical Trials* 10 (4): 407–15. [https://doi.org/10.1016/0197-2456\(89\)90005-6](https://doi.org/10.1016/0197-2456(89)90005-6).
- Jägersberg, Max, Kristian Schneider, Carlo Schaller, and Marcus Richter. 2014. "ALIF versus TLIF for Post-Discectomy Syndrome." *Journal of Neurological Surgery Part A: Central European Neurosurgery* 75 (05): 329–35. <https://doi.org/10.1055/s-0034-1372432>.
- Katz, Nathaniel P, Florence C Paillard, and Evan Ekman. 2015. "Determining the Clinical Importance of Treatment Benefits for Interventions for Painful Orthopedic Conditions." *Journal of Orthopaedic Surgery and Research* 10 (1): 24. <https://doi.org/10.1186/s13018-014-0144-x>.
- Khan, Jannat M., Garrett K. Harada, Bryce A. Basques, Michael T. Nolte, Philip K. Louie, Michael Iloanya, Konstantin Tchalukov, et al. 2020. "Patients with Predominantly Back Pain at the Time of Lumbar Fusion for Low-Grade Spondylolisthesis Experience Similar Clinical Improvement to Patients with Predominantly Leg Pain: Mid-Term Results." *The Spine Journal* 20 (2): 276–82. <https://doi.org/10.1016/j.spinee.2019.09.021>.
- Kim, Young-Hoon, Kee-Yong Ha, Kee-Won Rhyu, Hyung-Youl Park, Chang-Hee Cho, Hun-Chul Kim, Hyo-Jin Lee, and Sang-Il Kim. 2020. "Lumbar Interbody Fusion: Techniques, Pearls and Pitfalls." *Asian Spine Journal* 14 (5): 730–41. <https://doi.org/10.31616/asj.2020.0485>.
- Lee, Hyeon-Jin, Jin-Sung Kim, and Kyeong-Sik Ryu. 2016. "Minimally Invasive TLIF Using Unilateral Approach and Single Cage at Single Level in Patients over 65." *BioMed Research International* 2016 (4679865): 1–10. <https://doi.org/10.1155/2016/4679865>.
- Lener, Sara, Christoph Wipplinger, R. Nick Hernandez, Ibrahim Hussain, Sertac Kirnaz, Rodrigo Navarro-Ramirez, Franziska Anna Schmidt, Eliana Kim, and Roger Härtl. 2020. "Defining the MIS-TLIF: A Systematic Review of Techniques and Technologies Used by Surgeons Worldwide." *Global Spine Journal* 10 (2 suppl): 151S–167S. <https://doi.org/10.1177/2192568219882346>.
- Leopold, Seth S., and Raphaël Porcher. 2017. "Editorial: The Minimum Clinically Important Difference—The Least We Can Do." *Clinical Orthopaedics & Related Research* 475 (4): 929–32. <https://doi.org/10.1007/s11999-017-5253-5>.
- Lynch, Conor P., Elliot D.K. Cha, Madhav R. Patel, Kevin C. Jacob, Shruthi Mohan, Cara E. Geoghegan, Caroline N. Jadcak, and Kern Singh. 2021. "Diabetes Mellitus Does Not Impact Achievement of a Minimum Clinically Important Difference Following Anterior Cervical Discectomy and Fusion." *World Neurosurgery* 154 (October): e520–28. <https://doi.org/10.1016/j.wneu.2021.07.074>.
- Malhotra, Neil R, Nikhil R Nayak, John Mitchell Coats, Kalil G Abdullah, and Sherman C Stein. 2015. "Tracking Patient-Reported Outcomes in Spinal Disorders." *Surgical Neurology International* 6 (Suppl 19): S490–99. <https://doi.org/10.4103/2152-7806.166892>.
- Massel, Dustin H., Benjamin C. Mayo, Grant D. Shifflett, Daniel D. Bohl, Philip K. Louie, Bryce A. Basques, William W. Long, et al. 2020. "Minimally Invasive Transforaminal Lumbar Interbody Fusion: Comparison of Isthmic Versus Degenerative Spondylolisthesis." *International Journal of Spine Surgery* 14 (2): 115–24. <https://doi.org/10.14444/7015>.
- Menendez, Joshua York, Nidal Bassam Omar, Gustavo Chagoya, Bornha Ethan Tabibian, Galal Ashraf Elsayed, Beverly Claire Walters, Barton Lucius Guthrie, and Mark Norman Hadley. 2019. "Patient Satisfaction in Spine Surgery: A Systematic Review of the Literature." *Asian Spine Journal* 13 (6): 1047–57. <https://doi.org/10.31616/asj.2019.0032>.
- Mobbs, R.J., K. Phan, G. Malham, K. Seex, and P.J. Rao. 2015. "Lumbar Interbody Fusion: Techniques, Indications and Comparison of Interbody Fusion Options Including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF." *J Spine Surg* 1 (1): 2–18.
- Montenegro, Thiago S., Glenn A. Gonzalez, Fadi Al Saiegh, Lucas Philipp, Kevin Hines, Ellina Hattar, Daniel Franco, et al. 2021. "Clinical Outcomes in Revision Lumbar Spine Fusions: An Observational Cohort Study." *Journal of Neurosurgery: Spine* 35 (4): 437–45. <https://doi.org/10.3171/2020.12.spine201908>.
- Moses, Ziev B., Sharmeen Razvi, Seok Yoon Oh, Andrew Platt, Kevin C. Keegan, Fadi Hamati, Christopher Witiw, et al. 2021. "A Retrospective Comparison of Radiographic and Clinical Outcomes in Single-Level Degenerative Lumbar Disease Undergoing Anterior versus Transforaminal Lumbar Interbody Fusion." *Journal of Spine Surgery* 7 (2): 170–80. <https://doi.org/10.21037/jss-20-673>.
- Ogura, Yoji, Koichi Ogura, Yoshiomi Kobayashi, Takahiro Kitagawa, Yoshiro Yonezawa, Yoshiyuki Takahashi, Kodai Yoshida, Akimasa Yasuda, Yoshio Shinozaki, and Jun Ogawa. 2019. "Minimally Clinically Important Differences for the Japanese Orthopaedic Association Back Pain Evaluation Questionnaire (JOABPEQ) Following Decompression Surgery for Lumbar Spinal Stenosis." *Journal of Clinical Neuroscience* 69 (November): 93–96. <https://doi.org/10.1016/j.jocn.2019.08.025>.
- Owens, R. Kirk, II, Mladen Djurasovic, Charles H. Crawford III, Steven D. Glassman, John R. Dimar II, and Leah Y. Carreon. 2016. "Impact of Surgical Approach on Clinical Outcomes in the Treatment of Lumbar Pseudarthrosis." *Global Spine Journal* 6 (8): 786–91. <https://doi.org/10.1055/s-0036-1582390>.

- Park, Se-Jun, Jin-Sung Park, Chong-Suh Lee, and Keun-Ho Lee. 2021. "Metal Failure and Nonunion at L5-S1 after Long Instrumented Fusion Distal to Pelvis for Adult Spinal Deformity: Anterior versus Transforaminal Interbody Fusion." *Journal of Orthopaedic Surgery* 29 (3). <https://doi.org/10.1177/23094990211054223>.
- Parker, Scott L., Owoicho Adogwa, Alexandra R. Paul, William N. Anderson, Oran Aaronson, Joseph S. Cheng, and Matthew J. McGirt. 2011. "Utility of Minimum Clinically Important Difference in Assessing Pain, Disability, and Health State after Transforaminal Lumbar Interbody Fusion for Degenerative Lumbar Spondylolisthesis: Clinical Article." *Journal of Neurosurgery: Spine* 14 (5): 598–604. <https://doi.org/10.3171/2010.12.spine10472>.
- Parrish, James M., Nathaniel W. Jenkins, Nadia M. Hrynewycz, Thomas S. Brundage, and Kern Singh. 2020. "The Relationship Between Preoperative PROMIS Scores With Postoperative Improvements in Physical Function After Anterior Cervical Discectomy and Fusion." *Neurospine* 17 (2): 398–406. <https://doi.org/10.14245/ns.1938352.176>.
- Perez-Cruet, Mick J., Namath S. Hussain, G. Zachary White, Evan M. Begun, Robert A. Collins, Daniel K. Fahim, Girish K. Hiremath, Fadumo M. Adbi, and Sammy A. Yacob. 2014. "Quality-of-Life Outcomes with Minimally Invasive Transforaminal Lumbar Interbody Fusion Based on Long-Term Analysis of 304 Consecutive Patients." *Spine* 39 (3): E191–98. <https://doi.org/10.1097/brs.0000000000000078>.
- Rosenberg, NJ. 1975. "Degenerative Spondylolisthesis. Predisposing Factors." *The Journal of Bone & Joint Surgery* 57 (4): 467–74. <https://doi.org/10.2106/00004623-197557040-00004>.
- Russo, Fabrizio, Sergio De Salvatore, Luca Ambrosio, Gianluca Vadalà, Luca Fontana, Rocco Papalia, Jorma Rantanen, Sergio Iavicoli, and Vincenzo Denaro. 2021. "Does Workers' Compensation Status Affect Outcomes after Lumbar Spine Surgery? A Systematic Review and Meta-Analysis." *International Journal of Environmental Research and Public Health* 18 (11). <https://doi.org/10.3390/ijerph18116165>.
- Schwartz, Carolyn E., Armon Ayandeh, and Joel A. Finkelstein. 2015. "When Patients and Surgeons Disagree about Surgical Outcome: Investigating Patient Factors and Chart Note Communication." *Health and Quality of Life Outcomes* 13 (1): 161. <https://doi.org/10.1186/s12955-015-0343-0>.
- Vieli, Moira, Victor E Staartjes, Hubert A.J. Eversdijk, Marlies P De Wispelaere, Jan Wolter A Oosterhuis, and Marc L Schröder. 2019. "Safety and Efficacy of Anterior Lumbar Interbody Fusion for Discogenic Chronic Low Back Pain in a Short-Stay Setting: Data From a Prospective Registry." *Cureus* 11 (8). <https://doi.org/10.7759/cureus.5332>.
- Weiner, Debra K., Catherine L. Haggerty, Stephen B. Kritchewsky, Tamara Harris, Eleanor M. Simonsick, Michael Nevitt, and Anne Newman. 2003. "How Does Low Back Pain Impact Physical Function in Independent, Well-Functioning Older Adults? Evidence from the Health ABC Cohort and Implications for the Future." *Pain Medicine* 4 (4): 311–20. <https://doi.org/10.1111/j.1526-4637.2003.03042.x>.
- Xu, David S., Corey T. Walker, Jakub Godzik, Jay D. Turner, William Smith, and Juan S. Uribe. 2018. "Minimally Invasive Anterior, Lateral, and Oblique Lumbar Interbody Fusion: A Literature Review." *Annals of Translational Medicine* 6 (6): 104–104. <https://doi.org/10.21037/atm.2018.03.24>.