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Research Article

Risk Factors for MCID Drop-Off in Patients Undergoing Anterior Cervical Discectomy and Fusion

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Background

Some patients may achieve a minimum clinically important difference (MCID) at an early postoperative time point, but these are not always retained long-term. We aim to characterize risk factors for regressing below a level of meaningful improvement in patients who had previously achieved an MCID following anterior cervical discectomy and fusion (ACDF).

Methods

A prospectively maintained surgical database was retrospectively reviewed for ACDF procedures. PROMs including visual analogue scale (VAS), Neck Disability Index (NDI), 12-Item Short Form Physical Component Summary (SF-12 PCS), Patient-Reported Outcomes Measurement Information System physical function (PROMIS PF), and Patient Health Questionnaire-9 (PHQ-9) were administered at preoperative and postoperative time points. MCID achievement was assessed by comparing postoperative improvements in PROM scores from preoperative baseline to the previously established threshold values.

Results

A total of 351 ACDF patients were included: 204 patients underwent single level procedures and 147 underwent multi-level ACDF. The greatest proportions of patients achieved MCID for VAS neck at 6-months (56.3%), VAS arm at 6-months (38.5%), NDI at 6-months (68.1%), SF-12 PCS at 6-months (45.1%), and PROMIS-PF at 1-year (69.0%) Significant predictors for MCID drop-off were: Preoperative PHQ-9 (RR 1.1, p=0.011) , smoker status (RR 2.2, p=0.038) and preoperative VAS arm (RR 1.2, p=0.001) for VAS arm , none for NDI, and BMI (RR 1.1, p=0.006) for PROMIS PF.

a Conflicts of Interest Statement for Madhav Patel

b Conflicts of Interest Statement for Kevin Jacob

c Conflicts of Interest Statement for Alexander Parsons

d Conflicts of Interest Statement for Nisheka Vanjani

e Conflicts of Interest Statement for Elliot Cha

f Conflicts of Interest Statement for Conor Lynch

g Conflicts of Interest Statement for Michael Prabhu

h Conflicts of Interest Statement for Hanna Pawlowski

i Conflicts of Interest Statement for Dr. Singh

Conclusion

Highest rates of MCID achievement were 6-months following ACDF. Higher BMI, greater preoperative arm pain, smoking, and depression identified as significant risk factors for MCID drop-off for various PROMs. Male sex and anterior cervical plating were factors against regression of previously attained MCID for SF-12 PCS and VAS neck, respectively. Understanding the relationship between preoperative risk-inducing and protective variables for MCID drop-off may allow for earlier management of modifiable risk factors to maintain long-term clinical benefits following ACDF. Discussing factors influencing MCID drop-off with patients may allow for better matching of expectations among provider and patient and ultimately lead to improved satisfaction.

INTRODUCTION

Anterior Cervical Discectomy and Fusion (ACDF) is the most common spine procedure used for the management of cervical spondylolysis, with approximately 132,000 ACDFs performed each year (Kamalapathy et al. 2021; Saifi et al. 2018). Throughout the years, the parameters clinicians use to assess surgical outcomes have changed from objective physical metrics to subjective outcome measures grounded on patient perception, as commonly assessed by Patient Reported Outcome Measures (PROMs) (Finkelstein and Schwartz 2019; Deshpande et al. 2011; Field, Holmes, and Newell 2019). Commonly used PROMs for cervical spinal fusion surgery include: Visual Analog Scale (VAS) neck and arm, Neck Disability Index (NDI), 12-Item Short Form Survey (SF-12) Physical Composite Score (PCS), and Patient-Reported Outcome Measures Information System physical function (PROMIS-PF) (Finkelstein and Schwartz 2019; Vaishnav et al. 2020; Boody et al. 2018; Haws et al. 2019).

A drawback of PROM questionnaires is that they lack clinically significant meaning on their own (Parker et al. 2011; Mouelhi et al. 2020). To overcome this limitation, the concept of minimum clinically important difference (MCID) was developed (Parker et al. 2011; Mouelhi et al. 2020; Sedaghat 2019). MCID is defined as the minimum change in a patient reported outcome measure that is clinically significant and can justify implementation into medical practice (Parker et al. 2011; Paul et al. 2017). MCID values are unique to each individual PROM and spinal pathology (Parker et al. 2012).

Prior literature has demonstrated that the following preoperative risk factors can lead to poorer postoperative PROMs following ACDF: higher or lower age, increased duration of symptoms, depression, and comorbidity burden (determined by the Charlson Comorbidity Index (CCI) (Narain et al. 2019; Li et al. 2019; Rahman, Ibaseta, Reidler, et al. 2020; Omidi-Kashani, Ghayem Hasankhani, and Ghandehari 2014). While most patients achieve MCID for NDI and VAS neck following ACDF, a smaller subset of patients reach MCID for arm pain (Narain et al. 2019; Goldberg et al. 2002). Narain et al., one of few studies assessing the impact of preoperative variables on achievement of MCID, determined an association of increased CCI with failure to reach MCID for NDI (Narain et al. 2019). To better understand the long-term success of favorable postoperative outcomes, it is important to study how preoperative characteristics influence postoperative maintenance of previously attained MCID. The present study aims to identify risk factors for regressing below a level of meaningful clinical improvement for patients who already achieved MCID at an earlier time point following anterior cervical discectomy and fusion.

METHODS

PATIENT POPULATION

Informed patient consent and Institutional Review Board approval (ORA #14051301) were obtained prior to study onset. A prospectively maintained surgical registry was retrospectively reviewed to identify patients who received ACDF surgery between April 2008 and October 2020. All procedures were performed by a single attending spine surgeon at a single academic institution. Inclusion criteria were patients who underwent primary, elective, single- or multilevel ACDF. The following exclusion criteria were implemented: patients who did not complete preoperative PROM surveys or underwent surgery due to trauma, infection, or malignancy.

DATA COLLECTION

Patient demographics including age, gender, body mass index (BMI), smoking status, diabetic status, American Society of Anesthesiologists (ASA) score, Ageless Charlson Comorbidity Index (CCI), American Society of Anesthesiologists physical status classification (ASA), and insurance (workers compensation or non-workers compensation) were collected. PROM scores were collected preoperatively and at 6-week, 12-week, 6-month, 1-year, and 2-year postoperative time points for VAS neck, VAS arm, NDI, SF-12 PCS, and PROMIS-PF. Perioperative characteristics, including mean operative duration, mean estimated blood loss (EBL), mean hospital length of stay (LOS), and utilization of a stand-alone cage vs. additional anterior cervical plating were recorded for both single- and multi-level patient cohorts. Preoperative spinal pathologies of patients were recorded and included herniated nucleus pulposus, central stenosis, and myeloradiculopathy.

STATISTICAL ANALYSIS

Data analysis was conducted with Stata 16.0 (StataCorp LP, College Station, TX). Mean PROM values were calculated, after which delta PROMs were computed as the improvement in PROMs from preoperative to each postoperative

time point. Delta PROMs were used to calculate the proportion of patients achieving MCID by comparison to previously established threshold values: 2.6 for VAS neck (Parker et al. 2013), 4.1 for VAS arm (Parker et al. 2013), 8.5 for NDI (Parker et al. 2013), 8.1 for SF-12 PCS (Parker et al. 2013), and 4.5 for PROMIS PF (Steinhaus et al. 2019). MCID "drop-off" for each PROM was calculated as the proportion of patients who achieved MCID postoperatively but then failed to maintain clinical improvement at any subsequent time point till 2-years. Poisson regression with robust error variance was employed to evaluate the relative risk of each collected demographic and perioperative variable for all PROMs. A p-value $\leqslant 0.05$ was used as a marker for statistical significance in all analyses performed.

RESULTS

DESCRIPTIVE ANALYSIS

351 patients who underwent either single-level or multi-level ACDF were studied (Table 1). Majority were male (57.3%), with an average age of 49.9 years and an average BMI of 29.3 kg/m^2 (Table 1). Within the single-level ACDF cohort, the most commonly observed spinal pathology was herniated nucleus pulposus (92.2%), followed by myeloradiculopathy (73.5%) and central stenosis (29.4%). Of the patients undergoing multi-level fusion, spinal pathologies were seen more uniformly, with 71.4% of patients with herniated nucleus pulposus, 76.2% with myeloradiculopathy, and 71.4% with central stenosis (Table 2).

The mean operative duration for single-level ACDF was 55.4 minutes with an average estimated blood loss of 40.0 mL (Table 2). Multi-level fusions took approximately 80.5 minutes to perform with an average estimated blood loss of 43.9 mL. Patients with both single- and multi-level ACDF experienced a hospital stay of one day or less (Table 2).

In each ACDF procedure, either a conventional stand-alone cage or additional anterior cervical plate was used. Within single-level ACDF procedures, 96 patients received a stand-alone cage and 108 patients received the cage-plate. On the contrary, nearly all multi-level patients received the cage-plate (139), while only 8 patients received a stand-alone cage (Table 2).

PRIMARY OUTCOME MEASURES

The proportion of patients achieving MCID across PROMs was highest for VAS neck at 12-weeks (56.5%), VAS arm at 6-months (38.5%), NDI at 6-months (68.1%), SF-12 PCS at 6-months (45.1%), and PROMIS-PF at 1-year (69.0%) (Table 3). MCID drop-off rates were highest for VAS arm (26.8%), followed by VAS neck (26.2%), SF-12 PCS (18.6%), NDI (17.0%), and PROMIS PF (16.3%) (Table 3).

Preoperative PHQ-9 (RR 1.1, p=0.011) significantly predicted MCID drop-off for VAS neck, while anterior plating (RR 0.6, p=0.029) was a significant protector of preventing drop-off for VAS neck (Table 4). Smoking status (RR 2.2, p=0.038) and preoperative VAS arm (RR 1.2, p=0.001) were significant risk factors for MCID drop-off for VAS arm (Table 5). No significant risk factors for MCID drop-off were observed in NDI (Table 6). Male sex was a significant protector of preventing MCID drop-off for SF-12 PCS (RR 0.4, p=0.025) (Table 7). BMI was a significant risk factor of MCID drop-off for PROMIS-PF (RR 1.1, p=0.006) (Table 8).

DISCUSSION

Spinal surgery has primarily turned to patient reported outcome measures (PROMs) to assess the effectiveness of surgical procedures, including anterior cervical discectomy and fusion (ACDF) (Staartjes et al. 2019). Translating PROMs into clinical significance has proved more complex, with Jaeschke et al. noting a disconnect between statistically significant PROMs and clinical significance (Parker et al. 2011, 2012; Jaeschke, Singer, and Guyatt 1989; Jenkins et al. 2020). Minimally important clinical difference (MCID) was created to address this discrepancy and evaluate progression of PROMs following spinal surgery in a clinically significant context. Nonetheless, many times MCID is achieved at one time point, yet this achievement may not be maintained at successive time points. Our study aims to assess the predictive capability of preoperative and perioperative characteristics on a patient's ability to maintain a previously attained MCID at subsequent time points following ACDF.

PROMIS PF DROP-OFF: BMI

An increased body mass index (BMI) has been associated with development of degenerative disc disease due to greater mechanical load and stimulation of chronic inflammatory pathways, leading to increased risk for cervical myelopathy and radiculopathy (Zhang et al. 2020; Fatima et al. 2020). Interestingly, BMI has not significantly impacted postoperative PROMs, attainment of MCID across PROMs, patient satisfaction, narcotics consumption, length of hospital stay, or healthcare costs following ACDF (Narain et al. 2018; Sielatycki et al. 2016). Nevertheless, greater BMI has predicted significantly decreased Patient-Reported Outcomes Measurement Information System physical function (PROMIS-PF) scores following other surgical procedures, suggesting a potential relationship among the two variables (Katakam et al. 2021; Blanchett et al. 2019). Katakam et al. established that for each one-unit increase in BMI, there was an additional 2% risk of failure to attain MCID following total joint arthroplasty (Katakam et al. 2021). Our findings uniquely demonstrated that higher BMI is significantly associated with failure to maintain previously achieved MCID for PROMIS-PF. For this reason, surgeons should acknowledge the increased possibility of lack of maintainance of clinically meaningful physical funciton improvement among obese ACDF candidates. Early weight management education in the preoperative period may allow for obese patients to have a better chance of maintaining clinically meaningful improvements in their postoperative physical health.

Table 1. Patient Baseline Characteristics

	(n=351)
Age (mean±SD)	49.9 ± 10.1
Gender % (n)	
Female	42.7% (150)
Male	57.3% (201)
Body mass index (BMI)	29.3 ± 5.8
Smoking Status	
Non-Smoker	83.8% (294)
Smoker	16.2% (57)
Diabetes	
Non-Diabetic	88.9% (312)
Diabetic	11.1% (39)
ASA score	1.9 ± 0.6
Ageless CCI	1.1 ± 1.1
Insurance	
Non-WC	69.2% (243)
WC	30.8% (108)
Preoperative PROM Scores	
VAS Neck	6.1 ± 2.5
VAS Arm	5.9 ± 2.7
NDI	40.0 ± 19.2
SF-12 PCS	37.4 ± 9.5
PROMIS PF	39.6 ± 7.0
PHQ-9	7.2 ± 6.4

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; NDI= Neck Disability Index; PROMIS PF = Patient Reported Outcomes Measurement Information System physical function; PHQ-9 = Patient Health Questionnaire-9; SF-12 PCS = 12 Item Short Form Physical Component Summary; VAS = Visual Analog Scale

Table 2. Perioperative Characteristic

	Single Level (n=204)	Multi-Level (n=147)
Spinal Pathology		
Herniated Nucleus Pulposus	92.2% (188)	71.4% (105)
Central Stenosis	29.4% (60)	71.4% (105)
Myeloradiculopathy	73.5% (150)	76.2% (112)
Operative Duration (minutes)	55.4 ± 21.8	80.5 ± 23.8
EBL (mean ± SD; mL)	40.0 ± 36.3	43.9 ± 26.2
LOS (mean ± SD; hours)	18.5 ± 15.8	22.2 ± 15.8
Instrumentation		
Stand-Alone Cage	47.1% (96)	5.4% (8)
Anterior Cervical Plate	52.9% (108)	94.6% (139)

EBL = Estimated Blood Loss; LOS = Postoperative Length of Stay

VAS ARM MCID DROP-OFF: PREOPERATIVE VAS ARM, SMOKING STATUS

Patients with cervical radiculopathy often experience unilateral neck pain, arm pain, or a combination of both due to impingement of a nerve from a herniated disc or bony spurs (Eubanks 2010; Eubanks et al. 2011; Iyer and Kim 2016). Several studies have demonstrated a significant reduction in arm pain, measured by VAS arm, following ACDF (Massel et al. 2017; Laratta et al. 2018). Carreon et al. concluded that patients with a three-point decrease in arm pain achieved MCID, while those with a four-point decrease reached substantial clinical benefit (SCB) following cervical fusion (Carreon et al. 2010). Our findings uniquely demonstrate higher preoperative arm pain as a significant risk factor for loss of previously attained MCID for VAS arm. There-

Table 3. MCID Achievement

	% (n)
VAS Neck	
6-weeks	46.2% (104)
12-weeks	56.5% (117)
6-months	56.3% (103)
1-year	44.4% (44)
2-years	35.6% (16)
Drop-Off	26.2% (43)
VAS Arm	
6-weeks	38.2% (78)
12-weeks	36.6% (68)
6-months	38.5% (65)
1-year	30.6% (30)
2-years	24.4% (10)
Drop-Off	26.8% (30)
NDI	
6-weeks	43.8% (88)
12-weeks	58.2% (107)
6-months	68.1% (111)
1-year	58.5% (55)
2-years	57.1% (24)
Drop-Off	17.0% (27)
SF-12 PCS	
6-weeks	22.0% (37)
12-weeks	38.1% (75)
6-months	45.1% (50)
1-year	43.8% (35)
2-years	40.4% (21)
Drop-Off	18.6% (24)
PROMIS PF	
6-weeks	36.8% (35)
12-weeks	52.0% (39)
6-months	62.7% (42)
1-year	69.0% (40)
2-years	61.2% (30)
Drop-Off	16.3% (13)

fore, patients with more severe baseline arm pain should be informed that they will be more prone to losing previously achieved clinically significant long-term pain improvements. As alignment of provider and patient expectations has been associated with improved satisfaction (and thus clinical outcomes), relaying this evidence-based trend to this patient population is crucial, especially among those presenting with arm pain as their predominant symptom (Tabibian et al. 2017). To counteract this unfavorable trend, postoperative treatment modalities such as structured physiotherapy may be considered to increase expectation fulfillment, an association demonstrated by Wibault et al. (2018).

It is commonly understood that smoking is a risk factor for incomplete bone healing in spinal fusion procedures (Berman et al. 2017; Echt et al. 2018). Mangan et al. showed smokers had significantly decreased fusion rates compared to non-smokers, while other studies found similar fusion rates among the two cohorts following ACDF (Goldberg et al. 2002; Samartzis et al. 2005; Luszczyk et al. 2013). Nevertheless, clinical findings including fusion rates may not align with patients' perceived health status as measured by PROMs (Jaeschke, Singer, and Guyatt 1989). Our findings identified preoperative smoking as a significant predictor for loss of previously attained MCID for VAS arm following ACDF. In an effort to improve long-term clinical outcomes following ACDF for smokers, implementation of preoper-

Table 4. Risk Factors for VAS Neck MCID Drop-Off

Characteristic	RR	SE	95% C.I.	p-value†
Age	1.0	0.0	(0.9-1.0)	0.160
Gender				
Female	reference			
Male	0.9	0.2	(0.5-1.5)	0.638
Body mass index (BMI)	1.0	0.0	(0.9-1.1)	0.340
Smoking Status				
Non-smoker	reference			
Smoker	1.4	0.5	(0.7-2.8)	0.370
Diabetes				
Non-Diabetic	reference			
Diabetic	1.4	0.5	(0.7-3.0)	0.364
Ageless CCI	1.1	0.2	(0.9-1.4)	0.696
ASA	1.3	0.3	(0.8-2.2)	0.340
Workers' Compensation Status				
Non-WC	reference			
WC	1.1	0.3	(0.6-1.9)	0.747
Preoperative PROM Scores				
VAS Neck	0.4	0.1	(0.3-0.8)	0.668
VAS Arm	1.0	0.1	(0.9-1.1)	0.822
NDI	1.0	0.0	(0.9-1.0)	0.313
SF-12 PCS	1.0	0.0	(0.9-1.0)	0.192
PROMIS PF	1.0	0.0	(0.9-1.1)	0.944
PHQ-9	**1.1**	**0.0**	**(1.0-1.1)**	**0.011**
Operative Duration	1.0	0.0	(0.9-1.0)	0.881
Estimated Blood Loss	1.0	0.0	(0.9-1.0)	0.520
Length of Stay	1.0	0.0	(0.9-1.0)	0.177
Number of Operative Levels				
Single	reference			
Multilevel	0.7	0.2	(0.4-1.2)	0.162
Anterior Cervical Plating				
Stand-Alone Cage	reference			
Anterior Plate	**0.6**	**0.2**	**(0.2-0.9)**	**0.029**
Spinal Pathologies				
HNP	0.9	0.3	(0.5-1.8)	0.759
Central Stenosis	0.7	0.2	(0.4-1.2)	0.183
Myeloradiculopathy	1.2	0.5	(0.5-2.6)	0.693

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; NDI= Neck Disability Index; PHQ-9= Patient Health Questionnaire-9; PROMIS PF = Patient-Reported Outcomes Measurement Information System physical function; RR = Relative Risk; SF-12 PCS = 12 Item Short Form Physical Component Summary; VAS = Visual Analog Scale; HNP = herniated nucleus pulposus
Boldface indicates statistical significance
†p-value calculated using poisson regression with robust error variance

ative education and recommendation of pre/postoperative smoking cessation resources may be beneficial. Preoperative medical education may include consultations with patients to inform them of the long-term postoperative implications of smoking on ACDF. Likewise, resources for smoking cessation can be discussed preoperatively and postoperatively to encourage patients to quit behaviors that may impede maintenance of clinical recovery in arm pain following ACDF.

SF-12 PCS MCID DROP-OFF: MALE SEX

The incidence of cervical radiculopathies is higher in males compared to females, putting them at greater risk for requiring ACDF management (Radhakrishnan et al. 1994;

Table 5. Risk Factors for VAS Arm MCID Drop-Off

Characteristic	RR	SE	95% C.I.	p-value†
Age (years)	1.0	0.0	(0.9-1.0)	0.208
Gender				
Female	reference			
Male	0.7	0.2	(0.4-1.4)	0.283
Body mass index (BMI)	1.0	0.0	(0.9-1.1)	0.111
Smoking Status				
Non-smoker	reference			
Smoker	**2.2**	**0.8**	**(1.0-4.6)**	**0.038**
Diabetes				
Non-Diabetic	reference			
Diabetic	1.1	0.6	(0.4-3.4)	0.838
Ageless CCI	1.1	0.2	(0.8-1.6)	0.488
ASA	0.7	0.2	(0.4-1.2)	0.227
Workers' Compensation Status				
Non-WC	reference			
WC	1.1	0.4	(0.6-2.3)	0.730
Preoperative PROM Scores				
VAS Neck	1.1	0.1	(0.9-1.2)	0.240
VAS Arm	**1.2**	**0.1**	**(1.1-1.3)**	**0.001**
NDI	1.0	0.0	(0.9-1.0)	0.138
SF-12 PCS	1.0	0.0	(0.9-1.0)	0.938
PROMIS PF	1.0	0.0	(0.9-1.0)	0.407
PHQ-9	1.0	0.0	(0.9-1.1)	0.986
Operative Duration (min)	1.0	0.0	(0.9-1.0)	0.732
Estimated Blood Loss (mL)	1.0	0.0	(0.9-1.0)	0.683
Length of Stay (hours)	1.0	0.0	(0.9-1.0)	0.560
Number of Operative Levels				
Single	reference			
Multilevel	0.6	0.2	(0.3-1.3)	0.227
Anterior Cervical Plating				
Stand-Alone Cage	reference			
Anterior Plate	1.0	0.4	(0.5-2.0)	0.955
Spinal Pathologies				
HNP	1.6	0.8	(0.6-4.2)	0.383
Central Stenosis	0.6	0.2	(0.3-1.2)	0.129
Myeloradiculopathy	1.0	0.4	(0.4-2.4)	0.943

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; NDI= Neck Disability Index; PHQ-9= Patient Health Questionnaire-9; PROMIS PF = Patient-Reported Outcomes Measurement Information System physical function; RR = Relative Risk; SF-12 PCS = 12 Item Short Form Physical Component Summary; VAS = Visual Analog Scale; HNP = herniated nucleus pulposus

Boldface indicates statistical significance

†p-value calculated using poisson regression with robust error variance

Robinson et al. 2014). Prior literature has also demonstrated that male sex is associated with a significantly greater risk for any adverse event and numerous specific adverse events (e.g. pneumonia, sepsis, death) following ACDF (Radhakrishnan et al. 1994; Basques et al. 2018). While aforementioned studies have evaluated the impact of sex on incidence and surgical complications of ACDF, the relationship between sex and PROMs or MCID achievement/drop-off across PROMs has yet to be assessed. Our study found that male sex was a significant protective factor for regression of previously attained MCID for SF-12 PCS. While males are more prone to cervical radiculopathy and post-surgical complications following ACDF, improved physical functioning is likely to remain through a minimum of 2-years following fusion, which may provide comfort and positively influence a patient's decision to undergo surgery.

Table 6. Risk Factors for NDI MCID Drop-Off

Characteristic	RR	SE	95% C.I.	p-value†
Age (years)	1.0	0.0	(0.9-1.0)	0.153
Gender				
Female	reference			
Male	1.5	0.6	(0.7-3.1)	0.329
Body mass index (BMI)	1.0	0.0	(0.9-1.1)	0.096
Smoking Status				
Non-smoker	reference			
Smoker	1.2	0.6	(0.5-3.2)	0.695
Diabetes				
Non-Diabetic	reference			
Diabetic	1.7	0.8	(0.7-4.4)	0.276
Ageless CCI	1.1	0.3	(0.6-1.9)	0.687
ASA	1.2	0.4	(0.6-2.4)	0.679
Workers' Compensation Status				
Non-WC	reference			
WC	0.8	0.3	(0.4-1.9)	0.655
Preoperative PROM Scores				
VAS Neck	1.0	0.1	(0.9-1.1)	0.920
VAS Arm	1.0	0.1	(0.9-1.1)	0.745
NDI	1.0	0.0	(.9-1.0)	0.209
SF-12 PCS	1.0	0.0	(0.9-1.0)	0.199
PROMIS PF	1.0	0.0	(0.9-1.0)	0.472
PHQ-9	0.9	0.1	(0.8-1.1)	0.298
Operative Duration (min)	1.0	0.0	(0.9-1.0)	0.560
Estimated Blood Loss (mL)	1.0	0.0	(0.9-1.0)	0.661
Length of Stay (hours)	1.0	0.0	(0.9-1.0)	0.190
Number of Operative Levels				
Single	reference			
Multilevel	0.9	0.3	(0.4-1.8)	0.718
Anterior Cervical Plating				
Stand-Alone Cage	reference			
Anterior Plate	0.5	0.2	(0.3-1.1)	0.084
Spinal Pathologies				
HNP	0.7	0.3	(0.3-1.6)	0.399
Central Stenosis	0.9	0.3	(0.4-1.9)	0.795
Myeloradiculopathy	0.7	0.3	(0.3-1.6)	0.359

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; NDI= Neck Disability Index; PHQ-9= Patient Health Questionnaire-9; PROMIS PF = Patient-Reported Outcomes Measurement Information System physical function; RR = Relative Risk; SF-12 PCS = 12 Item Short Form Physical Component Summary; VAS = Visual Analog Scale; HNP = herniated nucleus pulposus
†p-value calculated using poisson regression with robust error variance

Further studies on the impact of male vs. female sex on PROMs, MCID attainment, and MCID drop-off in patients undergoing cervical fusions would add invaluable insight on the relationship between sex and postoperative success following ACDF. Future implications of these findings will allow for appropriate preoperative and postoperative measures to be taken so that optimal patient outcomes following ACDF can be achieved for both genders.

VAS NECK MCID DROP-OFF: PHQ-9, ANTERIOR PLATE FIXATION

In 2016, neck and back pain accounted for the largest amount of healthcare expenditure at $134.5 billion, with neck pain affecting over 20% of the representative population in the US (Dieleman et al. 2020; Genebra et al. 2017). Multiple studies have confirmed the effectiveness of ACDF in significantly improving several PROMs, includ-

Table 7. Risk Factors for SF-12 PCS MCID Drop-Off

Characteristic	RR	SE	95% C.I.	p-value†
Age (years)	1.0	0.0	(0.9-1.0)	0.780
Gender				
Female	reference			
Male	**0.4**	**0.2**	**(0.2-0.9)**	**0.025**
Body mass index (BMI)	1.0	0.0	(0.9-1.1)	0.599
Smoking Status				
Non-smoker	reference			
Smoker	2.1	0.9	(0.9-4.7)	0.083
Diabetes				
Non-Diabetic	reference			
Diabetic	2.1	1.0	(0.8-5.2)	0.112
Ageless CCI	1.1	0.2	(0.8-1.6)	0.444
ASA	1.1	0.3	(0.6-1.9)	0.839
Workers' Compensation Status				
Non-WC	reference			
WC	1.2	0.5	(0.5-2.7)	0.733
Preoperative PROM Scores				
VAS Neck	0.9	0.1	(0.8-1.1)	0.497
VAS Arm	1.0	0.1	(0.9-1.1)	0.983
NDI	1.1	0.0	(0.9-1.0)	0.517
SF-12 PCS	1.0	0.0	(0.9-1.0)	0.089
PROMIS PF	1.0	0.0	(0.9-1.1)	0.707
PHQ-9	1.0	0.1	(0.9-1.1)	0.683
Operative Duration (min)	1.0	0.0	(0.9-1.0)	0.756
Estimated Blood Loss (mL)	1.0	0.0	(0.9-1.0)	0.499
Length of Stay (hours)	1.0	0.0	(0.9-1.0)	0.800
Number of Operative Levels				
Single	reference			
Multilevel	1.1	0.4	(0.5-2.4)	0.779
Anterior Cervical Plating				
Stand-Alone Cage	reference			
Anterior Plate	1.6	0.8	(0.6-4.2)	0.309
Spinal Pathologies				
HNP	0.5	0.2	(0.2-1.1)	0.082
Central Stenosis	1.4	0.6	(0.7-3.1)	0.356
Myeloradiculopathy	0.8	0.3	(0.3-1.7)	0.495

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; NDI= Neck Disability Index; PHQ-9= Patient Health Questionnaire-9; PROMIS PF = Patient-Reported Outcomes Measurement Information System physical function; RR = Relative Risk; SF-12 PCS = 12 Item Short Form Physical Component Summary; VAS = Visual Analog Scale; HNP = herniated nucleus pulposus

Boldface indicates statistical significance

†p-value calculated using poisson regression with robust error variance

ing neck pain, through extended follow-ups (Massel et al. 2017; Oliver et al. 2018; Song et al. 2009). Recent advancements in ACDF have led to an increase in use of anterior plate fixation in addition to conventional stand-alone interbody cage for enhanced stability (Cheung et al. 2019). While the anterior plating can significantly improve radiographic outcomes following fusion by restoring lordosis and decreasing subsidence, a meta-analysis by Cheung et al. demonstrated no differences among cage-plate vs. cage-only cohorts for PROMs, including Odom's criteria, VAS neck, VAS arm, Japanese Orthopaedic Association (JOA) score, and NDI (Oliver et al. 2018; Cheung et al. 2019). Notably, the cage-plate cohort demonstrated increased surgical complications, including dysphagia and adjacent segment disease, highlighting potential drawbacks of anterior fixation (Cheung et al. 2019). Prior research has yet to eval-

Table 8. Risk Factors for PROMIS PF MCID Drop-Off

Characteristic	RR	SE	95% C.I.	p-value†
Age (years)	1.0	0.0	(0.9-1.1)	0.150
Gender				
Female	reference			
Male	1.2	0.6	(0.4-3.4)	0.750
Body mass index (BMI)	**1.1**	**0.0**	**(1.0-1.1)**	**0.006**
Smoking Status				
Non-smoker	reference			
Smoker	-	-	-	
Diabetes				
Non-Diabetic	reference			
Diabetic	1.7	1.0	(0.5-5.7)	0.366
Ageless CCI	1.1	0.4	(0.5-2.1)	0.835
ASA	2.1	1.0	(0.8-5.2)	0.118
Workers' Compensation Status				
Non-WC	reference			
WC	0.9	0.5	(0.2-2.9)	0.795
Preoperative PROM Scores				
VAS Neck	1.0	0.1	(0.8-1.4)	0.742
VAS Arm	0.8	0.1	(0.7-1.0)	0.062
NDI	1.0	0.0	(0.9-1.0)	0.805
SF-12 PCS	1.0	0.0	(0.9-1.1)	0.459
PROMIS PF	1.0	0.0	(0.9-1.1)	0.901
PHQ-9	0.9	0.1	(0.7-1.2)	0.529
Operative Duration (min)	1.0	0.0	(0.9-1.0)	0.375
Estimated Blood Loss (mL)	1.0	0.0	(0.9-1.1)	0.244
Length of Stay (hours)	1.0	0.0	(0.9-1.0)	0.268
Number of Operative Levels				
Single	reference			
Multilevel	0.8	0.4	(0.3-2.2)	0.607
Anterior Cervical Plating				
Stand-Alone Cage	reference			
Anterior Plate	0.6	0.3	(0.2-1.6)	0.282
Spinal Pathologies				
HNP	0.4	0.2	(0.1-1.1)	0.083
Central Stenosis	0.6	0.3	(0.2-1.7)	0.353
Myeloradiculopathy	0.5	0.3	(0.2-1.6)	0.248

ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; NDI= Neck Disability Index; PHQ-9= Patient Health Questionnaire-9; PROMIS PF = Patient-Reported Outcomes Measurement Information System physical function; RR = Relative Risk; SF-12 PCS = 12 Item Short Form Physical Component Summary; VAS = Visual Analog Scale; HNP = herniated nucleus pulposus

Boldface indicates statistical significance

†p-value calculated using poisson regression with robust error variance

uate the impact of anterior plating on MCID achievement and drop-off for PROMs, including VAS neck. Our study established that anterior plating was protective against the loss of previously gained MCID in patients with neck pain. While there are many potential benefits to using anterior plate fixation technique during ACDF, there are numerous risks. Physicians ought to discuss the evidence-based advantages and disadvantages of anterior plating with patients considering ACDF treatment (Viswanathan and Manoharan 2017).

Prior literature has demonstrated chronic neck pain as a significant risk indicator for preoperative depression, which in turn is a well-established predictor of poorer postoperative outcomes following ACDF (Elbinoune et al. 2016; Harris et al. 2020; Phan et al. 2017). Alvin et al. found that increasing preoperative PHQ-9 was significantly asso-

ciated with inferior Quality-of-Life (QOL) outcomes following ACDF (Alvin et al. 2016). Our results distinctly highlight preoperative PHQ-9 as a significant risk factor for loss of previously achieved MCID for neck pain. Appreciation of this finding emphasizes the interrelatedness of mental health and postoperative surgical outcomes. In an effort to allow for greater longevity of neck pain improvement following ACDF, it may be beneficial for surgeons to preoperatively console patients about the importance of depression management and recommend guidance from mental health providers.

LIMITATIONS

There are numerous limitations to this study. External validity was weakened due to all fusions being performed at one academic center by a single surgeon. Our results were based on outcomes collected from patient perception and thus prone to subjectivity and recall bias. Many individuals did not complete PROMs to full follow-up at 2-years, resulting in selection bias that skewed results to represent outcomes of remaining patients more accurately. Finally, the lack of control in the number of levels for ACDFs studied (single- and multi-level included) may introduce a confounder and limit the generalizability of our findings.

CONCLUSION

Our findings revealed a number of risk factors predictive of regression from initially achieved MCID for various PROMs following ACDF including: higher BMI, greater preoperative arm pain, smoking, and depression. Interestingly, male sex and anterior plating were significant protective factors for long-term retention of clinically significant improvements following ACDF. By identifying and addressing preoperative risk-inducing and protective factors for MCID drop-off, providers can help patients achieve greater longevity of benefits associated with cervical fusion. Furthermore, by communicating these evidence-based trends to patients in the preoperative period, surgeon and patient expectations may become better aligned, allowing for greater likelihood of patient satisfaction.

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