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Abstract

Study Design:

Retrospective.

Objective:

Identify patient risk factors for extended length of stay (LOS) and 90-day hospital readmissions following elective anterior cervical discectomy and fusion (ACDF).

Methods:

Included ACDF patients from 2013 to 2017 at a single institution. Eligible patients were subset into LOS <2 and LOS \geq 2 days, and no 90-day hospital readmission and yes 90-day hospital readmission. Patient and surgical factors were compared between the LOS and readmission groups. Multivariable logistic regression analysis was utilized to determine the association of independent factors with LOS and 90-day readmission rates.

Results:

Our sample included 1896 patients; 265 (14%) had LOS \geq 2 days, and 121 (6.4%) had readmission within 90 days of surgery. Patient and surgical factors associated with LOS included patient age \geq 65 years (odds ratio [OR] 1.72, 95% confidence interval [CI] 1.15-2.56), marriage (OR 0.57, 95% CI 0.43-0.79), private health insurance (OR 0.28, 95% CI 0.15-0.50), American Society of Anesthesiologists (ASA) score (OR 1.52, 95% CI 1.12-1.86), African American race (OR 1.95, 95% CI 1.38-2.72), and harvesting iliac crest autograft (OR 4.94, 95% CI 2.31-10.8). Patient and surgical factors associated with 90-day hospital readmission

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included ASA score (OR 1.81, 95% CI 1.32-2.49), length of surgery (OR 1.002, 95% CI 1.001-1.004), and radiculopathy as indication for surgery (OR 0.60, 95% CI 0.39-0.96).

Conclusions:

Extended LOS and 90-day hospital readmissions may lead to poorer patient outcomes and increased episode of care costs. Our study identified patient and surgical factors associated with extended LOS and 90-day readmission rates. In general, preoperative patient factors affected these outcomes more than surgical factors.

Introduction

Anterior cervical discectomy and fusion (ACDF) is the most common surgery performed for cervical spine pathology and is associated with improved health-related quality of life.¹⁻⁵ The total cost of ACDF surgery varies, and spine surgeons are under more pressure to minimize the cost of surgery.⁶⁻⁹ In a study investigating variability in the cost of ACDF surgery, the cost of surgery ranged from \$26 653 to \$129 220.¹⁰ Bundled repayment provides a fixed fee for service for the surgical hospitalization and for the 90-day postoperative period. In this model, the surgeon is incentivized to reduce the cost of both the index surgery and the postoperative global period. Extended length of stay (LOS) and 90-day hospital readmissions are 2 aspects of patient care that when minimized improve patient outcomes and decrease the overall cost of surgery.^{11,12}

Patient and surgical factors that are associated with LOS and 90-day hospital readmissions need to be recognized, and optimized when possible, to avoid postoperative complications. Risk factors previously associated with extended LOS or hospital readmissions include advanced age, gender, race, insurance status, medical comorbidities, preoperative opioid use, preoperative anemia, and multiple-level surgery.¹³⁻²⁵ The purpose of our study was to identify independent risk factors for extended LOS and 90-day readmission rates following ACDF surgery.

Methods

Institutional review board approval was obtained prior to initiating the current investigation. The cohort included all patients undergoing elective ACDF surgery at a single academic institution between July 2013 and March 2017. Patients were identified using relevant

Current Procedural Terminology (CPT) codes for ACDF surgery. The following CPT codes were used to identify patients undergoing ACDF surgery: 22 551, 22 554, 63 075, and 22 845. Exclusion criteria included posterior cervical fusion; traumatic, tumor, or infectious indication for surgery; and total disc replacement. Cases meeting inclusion criteria were subjected to chart review. The following data was obtained from the patient's record to be analyzed for its impact on LOS and 90-day hospital readmission rates: age, gender, race, body mass index (BMI), marital status, smoking status, payor status, American Society of Anesthesiologists (ASA) score, medical comorbidities, indication for surgery, number of levels fused, primary versus revision surgery, intraoperative estimated blood loss (EBL), length of surgery, type of interbody implant, iliac crest autograft harvest, intraoperative intravenous (IV) steroids, and indication for readmission. The following definitions were used when identifying patient variables. Psychologic illness was defined as an affective disorder, schizophrenia, or personality disorder. Indication for surgery was defined as either radiculopathy or myelopathy. Radiculopathy included patients without myelopathic symptoms or central cervical stenosis. For graft choice, autograft was selected as the graft choice only if iliac crest autograft was harvested. The combination of local autograft and allograft was considered in the allograft group. Intraoperative IV steroids were considered given if the patient received any dose of IV dexamethasone during the operative procedure.

Patients were dichotomized into 2 groups: normal LOS and extended LOS. The extended LOS group was defined as patients who remained admitted for ≥ 2 days following surgery. The planned discharge date of patients at our institution is postoperative day (POD) 0 or 1. In addition, patients were dichotomized into those that did not require a 90-day hospital readmission and those that required a 90-day hospital readmission. The aforementioned patient and surgical variables were compared between the LOS groups and 90-day hospital readmission groups utilizing univariate analysis to determine which factors may influence LOS and hospital readmission rates. Patient and surgical factors that were discovered to be statistically different in the univariate analysis were then analyzed using a multivariable logistic regression model. Odds ratios (ORs) with 95% confidence intervals (CIs) were derived from the multivariable analysis. An OR serves as a way to describe the association between a covariate and an outcome, with the outcome in our study being either extended LOS or a 90-day readmission. The utility of an OR serves to compare levels of a covariate, meaning presence or absence of that covariate. An OR > 1 signifies that exposure or presence of the covariate increases odd of the given outcome, with an OR < 1 signifying that exposure or presence of the covariate decreases odd of the given outcome. Due to the high number of

individual variables investigated in this study, the ASA score was used as a surrogate in the multivariable model for individual medical comorbidities.

In the patients requiring a 90-day hospital readmission the indications for hospital readmission were identified and categorized into the following: wound complication, dysphagia, poorly controlled pain, neurologic complaint, cerebrospinal fluid leak, deep venous thrombosis/pulmonary embolus, ileus/abdominal pain, fall, and medical complications (respiratory complication, cardiovascular complication, acute kidney injury, meningitis, urinary tract infection, stroke, fever, altered mental status). In the setting of multiple indications for readmission, all indications for readmission were independently recorded. Therefore, the total number of indications for readmissions will be greater than the actual number of patient readmissions. Wound complications included superficial infections, deep infections, and wound dehiscence. Neurologic complications included weakness or radiculopathy. Respiratory complications included dyspnea, upper respiratory infections, and pneumonia. Cardiovascular complications included chest pain, tachycardia, and congestive heart failure (CHF) exacerbation. Fever was defined as patients admitted with a fever and an unclear source.

Statistical Analysis

Descriptive statistics were used to define the entire cohort and determine if there were any significant differences in the demographic or clinical features defining the LOS groups and the yes and no 90-day hospital readmission groups. Continuous variables were expressed as a mean and compared via the 2-tailed *t* test. Categorical variables were compared using the χ^2 test. Statistical significance for the *t* test and χ^2 test was set at $P < .05$. Significant factors in the univariate analysis were then entered into the multivariate logistic regression to determine the association of individual patient and surgical factors with LOS or 90-day hospital readmissions. Odds ratios with 95% confidence intervals were computed. Factors in the logistic regression model were deemed significant if $P < .05$. All statistical analyses were performed using R studio.

Results

The cohort consisted of 1896 patients that met inclusion criteria and were subsequently reviewed. In the cohort, 265 (14%) patients required an extended LOS following surgery. The remaining 1632 (86%) patients were discharged on POD 0 or 1. Patient factors that were significantly different between the extended LOS and normal LOS groups included patient

age, patient gender, patient race, marital status, BMI, payor status, tobacco use, ASA score, hypertension (HTN), diabetes mellitus (DM), coronary artery disease (CAD), congestive heart failure (CHF), chronic kidney disease (CKD), history of stroke, and psychologic illness ([Table 1](#)). The incidence of chronic obstructive pulmonary disease (COPD) was similar between the 2 groups. Surgical factors that were significantly different between the groups included EBL, length of surgery, iliac crest autograft harvest, and intraoperative IV steroid use ([Table 2](#)). The indication for surgery, number of levels fused, primary versus revision surgery, and choice of interbody implant were similar between the groups. In the multivariate logistic regression, the following factors were associated with LOS: patient age ≥ 65 (OR 1.72; 95% CI 1.15-2.56), marital status (OR 0.57; 95% CI 0.43-0.79), private health insurance (OR 0.28; 95% CI 0.15-0.50), ASA score (OR 1.52; 95% CI 1.12-1.86), intraoperative EBL (OR 1.003; 95% CI 1.001-1.005), and iliac crest autograft harvest (OR 4.94; 95% CI 2.31-10.8) ([Table 3](#)). Tobacco use, patient gender, BMI, indication for surgery, revision surgery, and intraoperative IV steroids were not independently associated with an extended LOS.

Table 1. Patient Factors Between Length of Stay Groups.

Patient Factors	LOS <2 Group (n = 1631, 86%), n (%)	LOS ≥ 2 Group (n = 265, 14%), n (%)	P
Patient demographics			
Age (years)			<.001*
<48	408 (25%)	36 (13.6%)	
48-65 years	887 (54.4%)	127 (47.9%)	
>65 years	336 (20.6%)	102 (38.5%)	
Female gender	874 (53.6%)	164 (61.9%)	.014*
Race (%)			
Caucasian	1293 (79.2%)	171 (64.5%)	<.001*
African American	225 (13.8%)	80 (30.2%)	
BMI (kg/m ² , IQR)			<.001*

Patient Factors	LOS <2 Group (n = 1631, 86%), n (%)	LOS ≥2 Group (n = 265, 14%), n (%)	P
Underweight (<18.5)	11 (0.67%)	3 (1.1%)	
Normal (18.5-24.9)	393 (24.1%)	48 (18.1%)	
Overweight (25-29.9)	578 (35.4%)	81 (30.6%)	
Obese (30-34.9)	389 (23.8%)	58 (21.9%)	
Severe obesity (>34.9)	260 (15.9%)	72 (27.2%)	
Social history			
Marital status			<.001*
Single (%)	453 (27.8%)	125 (47.2%)	
Payor status			<.001*
Private insurance	976 (59.8%)	87 (32.8%)	
Medicare insurance	525 (32.2%)	142 (53.6%)	
Medicaid insurance	47 (2.9%)	26 (9.8%)	
Uninsured	61 (3.7%)	7 (2.6%)	
Smoker (%)	268 (16.4%)	36 (13.6%)	.019*
Medical comorbidities			
ASA score			<.001*
1	26 (1.6%)	4 (1.5%)	
2	759 (46.6%)	75 (28.3%)	
3	778 (47.7%)	154 (58.1%)	

Patient Factors	LOS <2 Group (n = 1631, 86%), n (%)	LOS ≥2 Group (n = 265, 14%), n (%)	P
4	68 (4.2%)	32 (12.1%)	
HTN (%)	643 (39.5%)	139 (52.5%)	<.001*
Diabetes mellitus (%)	219 (13.5%)	71 (26.8%)	<.001*
CAD (%)	72 (4.4%)	18 (6.8%)	<.001*
CHF (%)	10 (0.61%)	12 (4.5%)	<.001*
CKD (%)	32 (2.0%)	18 (6.8%)	<.001*
COPD (%)	55 (3.4%)	14 (5.3%)	.173
Psychologic illness (%)	280 (17.2%)	65 (24.5%)	.005*

Abbreviations: LOS, length of stay; BMI, body mass index; IQR, interquartile range; ASA, American Society of Anesthesiologists; HTN, hypertension; CAD, coronary artery disease; CHF, congestive heart failure; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease.

*Statistical significance.

Table 2. Surgical Factors Between Length of Stay Groups.

Surgical Factors	LOS <2 Group (n = 1631, 86%), n (%)	LOS ≥2 Group (n = 265, 14%), n (%)	P
Indication for surgery			.962
Myelopathy	1164 (71.3%)	188 (70.9%)	
Radiculopathy	468 (28.7%)	77 (29.1%)	
Levels fused			.786
1	461 (28.2%)	68 (25.7%)	
2	687 (42.1%)	115 (43.4%)	

Surgical Factors	LOS <2 Group (n = 1631, 86%), n (%)	LOS ≥2 Group (n = 265, 14%), n (%)	P
3	401 (24.6%)	70 (26.4%)	
4	82 (5.0%)	12 (4.53%)	
Type of surgery			.577
Primary ACDF	1474 (90.3%)	236 (89.1%)	
Revision ACDF	157 (9.7%)	29 (10.9%)	
Median length of surgery (minutes)	131	133	.002*
EBL (mL)	52	78	.009*
Interbody implant			.568
PEEK interbody cage	467 (28.6%)	81 (30.6%)	
Structural graft	1165 (71.4%)	184 (69.4%)	
Graft type			<.001*
Allograft	1602 (98.2%)	251 (94.7%)	
Autograft	19 (1.2%)	14 (5.3%)	
Intraoperative IV steroids	1450 (88.8%)	219 (82.6%)	.004*

Abbreviations: LOS, length of stay; ACDF, anterior cervical discectomy and fusion; EBL, estimated blood loss.

*Statistical significance.

Table 3. Multivariate Analysis of Factors Associated With Length of Stay.

Patient Factor	OR (95% CI)	P
Patient demographics		
Age (years)		

Patient Factor	OR (95% CI)	P
48-64	Reference	
0-48	0.69 (0.43-1.02)	.090
>65	1.72 (1.15-2.56)	.007*
Male gender	0.75 (0.55-1.01)	.058
BMI (kg/m ²) (18.5-24.5 reference group)		
Normal weight (18.5-24.5)	Reference	
Underweight (<18.5)	1.61 (0.27-5.7)	.520
Overweight (24.5-29.9)	1.05 (0.70-1.60)	.790
Obese (30-34.9)	1.03 (0.68-1.66)	.860
Severe obesity (>35)	1.39 (0.91-2.26)	.140
Race		
Caucasian	Reference	
African American	1.95 (1.38-2.72)	<.001*
Asian	0.79 (0.04-4.39)	.82
Social history		
Marital status: married vs single	0.57 (0.43-0.79)	<.001*
Payor status		
Medicaid insurance	Reference	
Medicare insurance	0.44 (0.23-0.83)	.01*
Private insurance	0.28 (0.15-0.50)	<.001*
No insurance	0.33 (0.11-0.82)	.02*
Medical comorbidities		
ASA score	1.52 (1.12-1.86)	.001*

Patient Factor	OR (95% CI)	P
Surgical factors		
Graft type: iliac crest autograft vs allograft	4.94 (2.31-10.8)	<.001*
EBL	1.003 (1.001-1.005)	.001*
Intraoperative steroids: Yes	0.72 (0.49-1.07)	.10
Surgery length	1.001 (0.99-1.002)	.08

Abbreviations: OR, odds ratio; CI, confidence interval; BMI, body mass index; ASA, American Society of Anesthesiologists; EBL, estimated blood loss.

*Statistical significance.

The 90-day hospital readmission rate was 7.6% (144 readmissions). In total, 121 patients were responsible for 144 hospital readmissions. The reasons for hospital readmission are recorded in [Table 4](#). Dysphagia, pain control, and respiratory complications accounted for the most common indications requiring readmission. Patient and surgical factors that were statistically different between the yes and no 90-day hospital readmission groups included indication for surgery, length of surgery, payor status, ASA score, HTN, CAD, CHF, CKD, and COPD ([Tables 5](#) and [6](#)). In the multivariate logistic regression, the following factors were associated with 90-day readmissions: ASA score (OR 1.81; 95% CI 1.32-2.49), radiculopathy as the indication for surgery (OR 0.6; 95% CI 0.36-0.96), and length of surgery (OR 1.002; 95% CI 1.001-1.004) ([Table 7](#)).

Table 4. Indications for 90-Day Hospital Readmissions.

Complication	Number of Patients	Percent of Total Readmissions (n = 144)	Percent of Entire Cohort (n = 1896)
Wound complication	7	5%	0.4%
Dysphagia	26	18%	1.0%
Pain control	25	17%	1.0%

Complication	Number of Patients	Percent of Total Readmissions (n = 144)	Percent of Entire Cohort (n = 1896)
DVT/PE	8	6%	0.4%
Neurologic compromise	9	6%	0.5%
CSF leak	2	1%	0.1%
Ileus/abdominal pain	12	8%	0.6%
Fall	4	3%	0.2%
Psychiatric admission	2	1%	0.1%
Medical complications			
Cardiovascular	10	6.9%	0.5%
Respiratory	20	14%	1.0%
UTI	2	1%	0.1%
AKI	5	4%	0.3%
Meningitis	1	0.7%	0.05%
Fever	8	6%	0.4%
Altered mental status	4	3%	0.2%
Stroke	1	0.7%	0.05%

Abbreviations: DVT, deep vein thrombosis; PE, pulmonary embolism; CSF, cerebrospinal fluid; UTI, urinary tract infection; AKI, acute kidney disease.

Table 5. Patient and Social Factors Between 90-Day Readmission Groups.

Patient Factor	No Readmission (n = 1776, 93.6%), n (%)	90-Day Readmission (n = 121, 6.4%), n (%)	P
Patient demographics			
Age, years (IQR)			.332
<48	421 (23.7%)	23 (19%)	
49	949 (53.5%)	65 (53.7%)	
>64	405 (22.8%)	33 (27.3%)	
Female gender	973 (54.8%)	65 (53.7%)	.820
Race (%)			.480
Caucasian	1376 (77.5%)	87 (71.9%)	
African American	279 (15.7%)	26 (21.5%)	
BMI (kg/m ² , IQR)			.070
Underweight (<18.5)	13 (<1%)	1 (<1%)	
Normal (18.5-24.9)	418 (23.5%)	23 (19%)	
Overweight (25-29.9)	620 (34.9%)	41 (33.9%)	
Obese (30-34.9)	425 (23.9%)	23 (19%)	
Severe obesity (>34.9)	299 (16.8%)	33 (27.3%)	
Social history			
Marital status			.140
Single (%)	530 (29.9%)	47 (38.8%)	
Payer status			.042*
Private	1012 (57%)	51 (42.1%)	

Patient Factor	No Readmission (n = 1776, 93.6%), n (%)	90-Day Readmission (n = 121, 6.4%), n (%)	P
insurance			
Medicare insurance	606 (34.1%)	60 (49.6%)	
Medicaid insurance	67 (3.8%)	6 (5%)	
Uninsured	65 (3.7%)	3 (2.5%)	
Smoker (%)	282 (15.9%)	21 (17.4%)	.860
Medical comorbidities			
ASA score			<.001*
1	29 (1.6%)	1 (<1%)	
2	800 (45.1%)	34 (28.1%)	
3	861 (48.5%)	71 (58.7%)	
4	85 (4.8%)	15 (12.4%)	
HTN (%)	704 (39.7%)	78 (64.5%)	<.001*
Diabetes mellitus (%)	272 (15.3%)	18 (14.9%)	1.00
CAD (%)	86 (4.8%)	12 (9.9%)	.020*
CHF (%)	14 (<1%)	4 (3.3%)	.020*
CKD (%)	43 (2.4%)	7 (5.8%)	.040*
COPD (%)	56 (3.2%)	13 (10.7%)	<.001*
Psychologic illness (%)	319 (18%)	26 (21.5%)	.370

Abbreviations: BMI, body mass index; IQR, interquartile range; ASA, American Society of Anesthesiologists; HTN, hypertension; CAD, coronary artery disease; CHF, congestive heart failure; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease.

*Statistical significance.

Table 6. Surgical Factors Between 90-Day Readmission Groups.

Surgical Factors	No Readmission (n = 1775, 93.6%)	90-Day Readmission (n = 121, 6.4%)	P
Indication for surgery			.010*
Myelopathy	1252 (70.5%)	99 (81.8%)	
Radiculopathy	523 (29.5%)	22 (18.2%)	
Levels fused			.820
1	493 (27.8%)	36 (29.8%)	
2	756 (42.6%)	46 (38%)	
3	439 (24.7%)	32 (26.4%)	
4	87 (4.9%)	7 (5.8%)	
Median length of surgery (minutes)	130	147	.020*
Type of surgery			.070
Primary ACDF	1607 (90.5%)	103 (85.1%)	
Revision ACDF	168 (9.5%)	18 (14.9%)	
EBL (mL)	55	714	.060
Interbody implant			.060
PEEK interbody cage	508 (28.6%)	40 (33.1%)	
Structural graft	1267 (71.4%)	81 (66.9%)	
Graft type			.520
Allograft	1733 (97.6%)	120 (99.2%)	
Autograft	32 (1.8%)	1 (<1%)	

Surgical Factors	No Readmission (n = 1775, 93.6%)	90-Day Readmission (n = 121, 6.4%)	P
Intraoperative IV steroids	1560 (87.9%)	109 (90.1%)	.580

Abbreviations: ACDF, anterior cervical discectomy and fusion; IV, intravenous.

*Statistical significance.

Table 7. Multivariate Analysis of Factors Associated With 90-Day Hospital Readmission.

Patient Factor	OR (95% CI)	P
Patient demographics		
BMI (kg/m ²) (normal comparison)		
Normal weight (18.5-24.5)	Reference	
Underweight (<18.5)	0.98 (0.05-5.56)	.98
Overweight (25-29.9)	1.08 (0.63-1.89)	.78
Obese (30-34.9)	0.86 (0.47-1.59)	.64
Severe obesity (>35)	1.39 (0.78-2.53)	.26
Medical comorbidities		
ASA score	1.81 (1.32-2.49)	<.001*
Surgical factors		
Indication: radiculopathy vs myelopathy	0.60 (0.36-0.96)	.04*
Graft type: iliac crest autograft vs allograft	0.46 (0.02-2.22)	.45
EBL	1.001 (0.99-1.002)	.16
Surgery length	1.002 (1.001-1.004)	.01*

Abbreviations: OR, odds ratio; CI, confidence interval; BMI, body mass index; ASA, American Society of Anesthesiologists; EBL, estimated blood loss.

*Statistical significance.

Discussion

Length of stay and 90-day readmission rates are 2 components of the variable cost between episodes of surgical care. In the total joint arthroplasty orthopedic literature, concerted efforts to decrease the rates of these measures have been shown to reliably decrease the total cost of surgery.¹⁰ In the spine literature, prolonged hospital stays have been associated with increased rates of delirium and surgical site infections.^{26,27} Additionally, 76% of the total cost of ACDF surgery is the hospitalization cost, and decreasing hospital LOS can decrease the total episode of care cost.^{9,10} In our cohort, independent variables associated with extended LOS included age ≥ 65 , single marital status, Medicaid insurance, African American race, ASA score, increased intraoperative EBL, and iliac crest bone graft harvest. The greatest OR for extended LOS was associated with iliac crest autograft harvest, and although EBL was statistically significant it had a clinically negligible OR of 1.003. Individual medical comorbidities that were more common in the extended LOS group included HTN, DM, CAD, psychologic illness, and tobacco use. The current study is unique in that it is a large cohort from a single institution. In previous database studies extended LOS is difficult to interpret due to variations in postoperative protocols. The patients in this study all followed the same postoperative protocol with planned discharge on POD 0 or 1.

The 90-day hospital readmission rate in our cohort was 7.6%, which is comparable to previous studies with readmission rates ranging from 2.5% to 7.9%.^{23,24,28} Reducing 90-day hospital readmission rates improves patient quality of life, decreases the total cost during the postoperative global period, and avoids penalization from the Medicare Hospital Readmission Reduction Program.^{7,9,23,29} In this cohort, ASA score, cervical myelopathy as the indication for surgery, and increased length of surgery were significantly associated with 90-day readmission rates. ASA score had the greatest association for requiring a readmission, and length of surgery although statistically significant had a negligible OR of 1.002.

Increased age has been reported as a risk factor for extended LOS, hospital readmissions, and adverse events following ACDF.^{14,16,20,22-24,30} The average age in our extended LOS group was greater than 60 years of age, and the average age in our normal LOS group was 55 years old. Age ≥ 65 was independently associated with extended LOS; however, it was not associated with 90-day readmission rates. Older patients generally have increased medical

comorbidities, lower physiologic reserve, and fewer resources where they live placing them at increased risk for extended LOS. Co-management of geriatric patients undergoing spinal surgery by a geriatric co-management service has been shown to decrease hospital LOS and decrease postoperative complications in this population.³¹ At our institution all patients older than 65 are now being referred preoperatively to a geriatric co-management medical service, Perioperative Optimization for Senior Health, in order to best prepare patients for their upcoming spinal surgery.

Socioeconomic factors including insurance status, marriage status, and race have been shown to affect surgical outcomes. In this cohort, payor status, marital status, and African American race affected LOS. Married patients undergoing all types of surgery have been shown to have improved mortality, reduced lengths of hospitalization, and reduced need for skilled nursing facilities.^{32,33} A study looking at all elective spinal surgery demonstrated shorter LOS in married patients compared with single patients.³⁴ To the best of our knowledge, no studies have specifically looked at the association of marital status and LOS in ACDF patients. In this cohort, married patients were associated with a shorter postoperative LOS compared with single patients.

Insurance status, specifically Medicaid insurance, has been associated with increased rates of adverse events and surgical site infections in spine surgery.^{35,36} In a study of 419 424 cervical fusion patients obtained from the Nationwide Inpatient Sample, patients with Medicaid insurance or no insurance were associated with increased adverse events.³⁷ In our patient cohort, patients with private insurance, Medicare insurance, and no insurance were associated with a decreased risk of extended LOS when compared with Medicaid insurance. One possibility as to the association of extended LOS and Medicaid insurance could be a delay in placement of patients into skilled nursing facilities following surgery as a result of delay in obtaining insurance approval. This is the first study to demonstrate a discrepancy in LOS following ACDF surgery with regard to insurance status. Independent to the socioeconomic impact of payor status on LOS, African American race was associated with extended LOS. Previous studies have reported inferior outcomes in African American patients following spinal surgery.^{38,39} However, the impact of race on surgical outcomes following spinal surgery is controversial, and other studies have found no disparity in outcome.⁴⁰

The ASA classification is used to evaluate the overall health and medical comorbidities of patients prior to surgery, and can be used to predict patient outcomes.⁴¹ ASA scores have been shown to affect mortality rates, LOS, and readmission rates in spine surgery.^{25,42,43} In a

review of 1701 elective ACDF cases from the National Surgical Quality Improvement Program (NSQIP) database, patients with an ASA score of 4 were at increased risk of 30-day readmissions (OR 5.7; $P = .04$).²⁵ In our patients, the ASA score was associated with both extended LOS and 90-day hospital readmissions. The ASA score can be a simple objective tool to assess the risk for extended LOS and 90-day readmission rates compared with assessing individual medical comorbidities. In a univariate model, HTN, DM, CAD, CKD, and psychologic illness were more common in the extended LOS group. Similarly, HTN, CAD, and COPD were more common in patients requiring a 90-day hospital readmission.

Obesity is a growing health epidemic in the United States. In our cohort, 41% of patients were obese having a BMI greater than or equal to 30 kg/m². Previous studies have reported the rate of obesity in patients undergoing cervical spine surgery to be approximately 35%.⁴⁴ Obesity in all-cause spine surgery increases operative times, EBL, total cost of care, infection rates, and thromboembolism.^{17,45} When investigating the impact of obesity in ACDF surgery, specifically more controversy exists. Two studies have demonstrated no difference in functional outcomes, LOS, total cost, and readmission rates following ACDF surgery in obese and nonobese patients.^{17,46} An additional study looked at 1384 patients diagnosed with metabolic syndrome undergoing ACDF and found an increased rate of LOS in this group.⁴⁷ Severe obesity trended to be associated with readmission rates and LOS; however, these variables did not reach statistical significance.

Degenerative cervical disease can result in radiculopathy or myelopathic symptoms requiring surgery. Our cohort consisted of a greater percentage of myelopathic patients compared to those with isolated radiculopathy undergoing surgery. In a review of 5256 patients from the NSQIP database, ACDF performed for cervical myelopathy compared with other indications was associated with an increased risk for adverse events, severe adverse events, and death.⁴⁸ Our study supports this previously reported association, and patients requiring ACDF for isolated radiculopathy compared with myelopathy or myeloradiculopathy were at a decreased risk of requiring a 90-day hospital readmission.

A unique aspect of our study compared with large database reviews was the ability to review intraoperative factors. Intraoperative factors associated with extended LOS included increased EBL and iliac crest autograft harvest. The only intraoperative factor associated with 90-day hospital readmission rates was increased length of surgery. Despite EBL being statistically associated with LOS, the OR was 1.003 (95% CI 1.001-1.005) and is likely clinically negligible. Similarly, length of surgery was statistically associated with readmission rates, but the OR was 1.002 (95% CI 1.001-1.004) and is likely clinically negligible. In general,

intraoperative factors did not have as significant of an impact on LOS and 90-day hospital readmissions as patient factors did, and only harvesting iliac crest autograft was associated with LOS. However, our finding that increased length of surgery was statistically associated with 90-day readmission rates supports a recent NSQIP review demonstrating that for every additional 15 minutes of operating time the risk for an adverse event increased by 10%.⁴⁹

Iliac crest autograft (ICBG) is the gold standard graft choice to achieve spinal fusion, but with the advent of biologics and bone allograft the trend has moved away from harvesting ICBG. In our study period, ICBG was used in only 33 patients (2% of the entire cohort). Donor site pain associated with obtaining iliac crest autograft has been well reported and may be persistent after the immediate postoperative period.⁵⁰ In addition, similar fusion rates have been reported with biologics and allograft bone when compared with ICBG.⁵¹ The results of this study demonstrate that harvesting iliac crest bone, and the immediate donor site pain, can be associated with longer LOS. Despite the small number of individuals with ICBG harvest, this represented the largest OR in the study. In addition to ICBG harvest, increased EBL was associated with extended LOS. The recorded EBL was estimated at the conclusion of the case by the surgeon and anesthesia team. A limitation of the study was the lack of reporting on transfusion rates in the postoperative period. Despite EBL being associated with possible extended LOS, variability in EBL following ACDF has been previously shown to have minimal clinical significance.⁵²

The most common causes for hospital readmissions were dysphagia, pain control, and respiratory complications. In a review of 17 088 ACDF patients from the NSQIP database, these same factors were identified as the most common indications for hospital readmission.²⁴ Dysphagia was the most common cause for readmission and is a recognized complication following anterior spinal surgery. In our cohort, 26 patients required a 90-day readmission for dysphagia accounting for 18.1% of the readmissions, and 1.4% of the entire cohort. Previously reported risk factors for dysphagia include female gender, revision ACDF, and multiple-level ACDF.⁵³⁻⁵⁵ Several strategies have been proposed to mitigate dysphagia including perioperative steroid use, low-profile plate utilization, and endotracheal tube cuff pressure monitoring.⁵³ In our patient cohort, intraoperative IV steroids were administered in 1669 patients (88% of the cohort). In the patients readmitted with dysphagia, 23 of the 26 patients (88.5%) received intraoperative IV steroids. In this study, intraoperative IV steroid administration was not associated with decreased LOS or 90-day hospital readmission rates, and specifically did not appear to affect 90-day hospital readmissions specifically for dysphagia.

This study has a number of strengths and limitations compared with previous studies. This is the largest single-center review investigating risk factors for extended LOS and 90-day hospital readmissions following ACDF. Being a single-center study, all patients followed the same postoperative course with the same planned discharge date of POD 0 or 1. This study was able to assess intraoperative factors that cannot be analyzed in large database reviews. In this study, 90-day hospital readmission rates were obtained, compared with 30-day hospital readmission rates reported on in database reviews. The global period following spinal surgery is 90 days, and it is important to investigate complications during this entire period. A limitation of the study was that laboratory data was not reported along with specific clinical diagnoses. The reason for this was that too few patients undergoing elective ACDF at our institution had sufficient preoperative laboratory results to include.

Increased postoperative LOS and hospital readmissions can result in decreased perceived patient outcomes, decreased quality of care metrics, and increased total cost of surgery. At our institution, patient age ≥ 65 , Medicaid health insurance, single marital status, African American race, increased ASA scores, iliac crest bone graft harvest, and increased EBL were associated with extended LOS. The majority of surgical decisions including interbody cage selection, administration of IV steroids, choosing the number of fusion levels, and decision to perform revision ACDF were not associated with LOS or hospital readmission rates. Ninety-day hospital readmissions were associated with ASA scores, myelopathy as the indication for surgery, and increased length of surgery. ACDF remains an effective and predictable surgery with 86% of patients being discharged on POD 0 or 1, and a 90-day readmission rate of only 6.4%. The results of this study provide additional information as to which patients are at risk for postoperative complications and extended LOS. Patients identified as being at increased risk may benefit from additional preoperative education and support to prevent delayed discharge and may not be ideal candidate for same day surgery.

Declaration of Conflicting Interests

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ORCID iD

Brian L. Dial

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