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Preoperative factors affecting length of stay after elective ACDF with and without corpectomy: a multivariate analysis of an academic center cohort

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Abstract

Study Design—Retrospective cohort study of 183 patients who underwent elective anterior cervical discectomy and fusion (ACDF) at a single institution over a two-year period.

Objective—To determine which preoperative factors were independently associated with a prolonged hospital length of stay (LOS) following ACDF.

Summary of Background Data—ACDF has become the most common treatment modality for addressing cervical spine pathology. Extended LOS following ACDF is associated with increased costs and complications. There is a lack of conclusive data for factors affecting LOS after ACDF. This study aims to create a multivariate model to determine the association of various patient and operative characteristics with LOS after ACDF.

Methods—Patients who underwent elective ACDF at a single academic institution between January 2011 and February 2013 were identified using billing records. Their charts were reviewed to collect variables available preoperatively such as patient demographics, comorbidities, and surgery planned. Patients were categorized as normal or extended LOS, with extended LOS defined as LOS > 75th percentile. A multivariate logistic regression was used to determine which factors were independently associated with extended LOS.

Results—A total of 183 ACDF patients were identified. The average LOS for this cohort was 2.0 ± 2.5 days (Mean ± Standard Deviation). Extended LOS was defined as ≥ 3 days. Multivariate

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analysis revealed that preoperative factors independently associated with extended LOS were history of non-spinal malignancy (Odds Ratio [OR] = 4.9), history of pulmonary disease (OR = 4.0), and procedures that included corpectomy (OR = 4.5).

Conclusion—Patients with a history of non-spinal malignancy or pulmonary disease, as well as patients who underwent corpectomy, were more likely to have an extended LOS (ORs 4.0–4.9). Of significant note, other factors that one might expect to be associated with extended LOS did not independently predict extended LOS in this analysis.

Keywords

length of stay; acdf; anterior; cervical; discectomy; fusion; outcomes; malignancy; pulmonary; corpectomy; multivariate; preoperative

Introduction

The anterior cervical discectomy and fusion (ACDF) has become the most common treatment modality for addressing cervical spine pathology because of its efficacy and safety.^{1,2} Hospital length of stay (LOS) following the procedure is important to patients and providers for multiple reasons.

Longer hospital stays are associated with increased risk of complications such as postoperative infection, venous thromboembolism, and delirium.^{3,4} Additionally, LOS after any surgical procedure, including ACDF, can greatly affect total hospital charges for each procedure.⁵ Between 1990 and 2000, the number of ACDF procedures performed each year increased by 800%, while societal costs of cervical spine surgery rose from \$672 million to \$2.1 billion.^{6,7} It is critical to identify factors that affect LOS after ACDF in order to better understand how to reduce costs, improve outcomes, and set realistic expectations.

Previous studies have described factors associated with prolonged length of stay after ACDF such as age,^{8,9} gender,⁸ race/ethnicity,¹⁰ insurance status,¹⁰ geographic location,¹⁰ comorbidity index,¹⁰ heart disease,^{11,12} renal disease,^{11,12} pulmonary disease,¹² hypertension,¹² diabetes,^{9,12} functional status,⁹ preoperative anemia,⁹ preoperative opioid use,¹¹ presence of traumatic cervical spine injury,¹⁰ myelopathy,¹² multilevel decompression,¹² extended operating time,⁹ and postoperative complications.^{8,9}

The wide variation in study methodologies and results raise doubts about the validity of any one of these studies. Such results may be either out of date,¹² or skewed by inclusion of trauma patients¹⁰ or postoperative events.^{8,9} There is a need for further data in order to draw accurate conclusions about the contributions of each factor to LOS after ACDF.

This study aims to create a multivariate model to determine the association of various patient and operative characteristics with LOS after ACDF while controlling for potentially confounding variables. The purpose of using only variables available to the surgeon preoperatively is to create a model that is useful for preoperative counseling and planning, unlike a model that contains intraoperative and/or postoperative variables.

Materials and Methods

Data Source

Records of all patients who had undergone ACDF by 6 attending surgeons (3 orthopaedic surgeons and 3 neurosurgeons) at one academic institution between January 2011 to February 2013 were obtained from the institution's billing department using the Current Procedural Terminology (CPT) codes 22551 (anterior discectomy and fusion), 22554 (anterior fusion), and 63075 (anterior discectomy). CPT code 22551 largely replaced codes 22554 and 63075 in January 2011, and while all subjects underwent ACDF after January 2011, several additional ACDF patients were captured using CPT codes 22554 and 63075.

Cases involving trauma, excision of malignancy, previous infection, patients under 18 years old, total disc replacement, concomitant posterior cervical arthrodesis, thoracic or lumbar spine surgery, or other unrelated procedures were excluded from this study.

Data Collection

Once ACDF procedures were identified from billing records, patient information was abstracted from the electronic medical record for each case. Data collected included age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) classification, preoperative hematocrit, history of smoking, and history of major medical comorbidities (non-spinal malignancy, diabetes mellitus, pulmonary disease, hypertension, heart disease, or bleeding disorder/currently taking aspirin).

The ASA classification system is a method for anesthesiologists to assess preoperative risk in patients undergoing surgery.¹³ ASA class 1 indicates "a normal, healthy patient," ASA class 2 indicates "a patient with mild systemic disease," ASA class 3 indicates "severe systemic disease," ASA class 4 indicates "severe systemic disease that is a constant threat to life," ASA class 5 is "a moribund patient who is not expected to survive without the operation," and ASA class 6 is "a declared brain-dead patient whose organs are being removed for donor purposes."¹³ Patients with ASA classes 5 and 6 were excluded from the study. For analysis, ASA class was separated into 2 categories: ASA class 1–2 for healthy patients or those with mild systemic disease, and ASA class 3–4 for patients with severe systemic disease.

The Preoperative hematocrit was taken from patients' preoperative lab values, however it was not drawn on every patient (generally due to low suspicion of an abnormal value). Patients with hematocrit at or above 36.0 or not drawn were defined as having normal preoperative hematocrit, and hematocrit below 36.0 was defined as low. There were 40 patients (21.9% of all patients) that did not have a preoperative hematocrit value available. These patients were counted as having "normal preoperative hematocrit" and were included in both bivariate and multivariate analyses.

Non-spinal malignancy was defined as either a current or previous history of treatment with radiation, chemotherapy, or surgery for a malignant tumor that did not involve the spine. Diabetes and hypertension were determined by a history of treatment for these conditions or by findings during the preoperative assessment. Pulmonary disease was defined as asthma

requiring hospitalization, chronic obstructive pulmonary disease, chronic bronchitis, or a history of pulmonary embolism. Heart disease was defined as a history of arrhythmia, valvular abnormalities, coronary artery disease, myocardial infarction, or congestive heart failure. Bleeding disorder was defined as history of bleeding or clotting disorder such as factor deficiency, platelet disorder, antiphospholipid syndrome, or current aspirin use.

Planned procedural variables that were collected included number of levels to be fused, whether a corpectomy was performed, and use of iliac crest bone graft (ICBG). While these variables do not fall under the category of patient demographics or comorbidities, they are known preoperatively and thus would be useful to include in a model that uses preoperative data to predict LOS.

Length of Stay (LOS)

LOS in this analysis was defined as number of calendar days from the operation to hospital discharge. The primary outcome measure was extended LOS, a binary variable that we defined as positive when the LOS exceeded the 75th percentile for this cohort.

The 75th percentile LOS was chosen as a cutoff in order to account for normal variations in LOS and differing practices of surgeons while still capturing patients with abnormally extended LOS. It was determined that the effects of outliers on the results would be increased if the cutoff for extended LOS was at a greater percentile or if LOS was treated as a continuous variable for analysis.

Statistical Analysis

Statistical analyses were conducted using STATA[®] version 11.2 (StataCorp, LP, College Station, Texas, USA). All tests were two-tailed and the statistical difference was established at a two-sided α level of 0.05 ($p < 0.05$).

Demographic, comorbidity, and procedural variables were tested for association with extended length of stay using bivariate and multivariate logistic regression. Logistic regression was used because extended LOS was defined as a binary variable in this study. The final multivariate model was constructed using a backwards stepwise process that initially included all potential demographic and comorbidity variables and sequentially excluded variables with the highest p-value until only those with $p < 0.20$ remained. Variables with $0.05 < p < 0.20$ were left in the model to control for potential confounding, but were not considered to be statistically significant. Covariance tests were conducted for all independent variables and covariance between variables was accounted for in the multivariate model.

Patient Characteristics

A total of 183 cases were identified that met inclusion criteria. A summary of patient demographics and comorbidities can be found in Table 1. Average age was 51.8 ± 12.1 years (mean $\pm$ standard deviation [SD]), average BMI was 29.2 ± 6.1 kg/m², and 53% of patients were female. Among the patients with a history of non-spinal malignancy, two had breast cancer, two had prostate cancer, and two had lung cancer. There was one patient for

each of the following types of non-spinal malignancy: hepatic cancer, Hodgkin lymphoma, melanoma, thyroid cancer, tonsil cancer, and vocal cord cancer. Patient demographics, comorbidities, and procedural characteristics were all within expected ranges.

Results

LOS ranged from 1 day to 21 days. The average postoperative LOS was 2.0 ± 2.5 days. Figure 1 is a survivorship curve for LOS, depicting the percentage of patients remaining in the hospital per day after the procedure. The 75th percentile LOS was 2 days. LOS of 3 days or greater was thus considered extended LOS. The dashed vertical line separates cohorts of normal and extended LOS.

As seen in Table 2, 18.6% of all patients had extended LOS. Percentage of patients with extended LOS is given for each demographic, comorbidity, and procedural category. Covariance was tested for each combination of independent variables. There were 15 total independent variables, yielding 105 unique combinations of variables. Of these 105 combinations, 77 did not show significant covariance ($p > 0.05$). Ten combinations of variables showed covariance with $p < 0.001$: age and ASA class, age and hypertension, age and history of bleeding disorder or current aspirin use, age and history of malignancy, BMI and hypertension, ASA class and diabetes, ASA class and hypertension, ASA class and heart disease, smoking and iliac crest bone graft use, and diabetes and hypertension.

Bivariate logistic regressions were performed to test the association of each variable with extended LOS. These results can be found in the bivariate analyses columns of Table 2. As extended LOS was treated as a binary variable for analysis, results are reported as odds ratios in Table 2 in order to show the magnitude of each variable's association with LOS after ACDF.

Bivariate analyses showed significant association between extended LOS and ASA class, preoperative hematocrit < 36.0 , history of non-spinal malignancy, history of pulmonary disease, history of hypertension, history of heart disease, number of levels fused, and corpectomy (bivariate analyses columns of Table 2).

Multivariate logistic regression was then used to control for potential confounding variables and determine which factors were independently associated with extended LOS. The results of this analysis are reported as odds ratios in the multivariate analysis columns of Table 2. Multivariate analysis found a significant association between extended LOS and history of non-spinal malignancy (Odds Ratio [OR] = 4.9, 95% Confidence Interval [CI] = 1.2 – 20.9, $p = 0.031$), history of pulmonary disease (OR = 4.0, 95% CI = 1.6 – 9.7, $p = 0.002$), and procedures that included corpectomy (OR = 4.5, 95% CI = 1.3 – 16.2, $p = 0.020$). Sex, history of hypertension, history of heart disease, and number of levels fused were left in the final model to control for potential confounding ($p < 0.20$), but they were not considered to be statistically significant ($p > 0.05$).

Table 3 summarizes the effect of all variables on LOS (summarizes data from Table 2) and additionally reports standard error and 95% confidence intervals for the odds ratio of each variable significant on multivariate analysis. Several factors were significant predictors of

increased LOS in bivariate analysis, but not on multivariate analysis: ASA class, preoperative hematocrit < 36.0, history of hypertension, history of heart disease, and number of levels fused. This indicates covariance between these variables and the significant variables from the multivariate model. Age, sex, BMI, history of smoking, history of diabetes, history of bleeding disorder or current aspirin use, and use of ICBG were not found to be significant predictor of extended LOS by either bivariate or multivariate analysis.

Discussion

Hospital LOS after ACDF is important to patients and providers for multiple reasons,^{1-6,14} however there is inconsistent information regarding which factors are associated with extended LOS. While other studies have used multivariate analysis to describe factors affecting LOS after ACDF, their methods and results vary widely.⁸⁻¹²

We looked at elective ACDF patients, excluding procedures performed for trauma or tumor indications, and evaluated the effects of factors that could have been known preoperatively. The goal of this analysis was to identify factors that could be used preoperatively to define surgical expectations.

We found that history of non-spinal malignancy, history of pulmonary disease, and corpectomy were independent risk factors for increased LOS with odds ratios between 4.0 and 4.9. Age, sex, BMI, ASA class, preoperative hematocrit < 36.0, smoking history, diabetes, hypertension, history of heart disease, history of bleeding disorder or current aspirin use, number of levels fused, and use of iliac crest bone graft were not significantly associated with extended LOS after ACDF in the final multivariate model.

To our knowledge, no previous study has identified history of non-spinal malignancy as associated with increased odds of extended LOS after ACDF. However, this variable is probably associated with increased overall comorbidity due to underlying illness. Further, specific postoperative complications, such as venous thromboembolism^{15,16} may be a driver for this variable's effect on LOS.

Patients with a history of pulmonary disease were also found to have increased odds of an extended LOS. History of pulmonary disease was also found to be significantly associated with extended LOS after ACDF in studies by Harris et al.¹² and Walid et al.¹⁷ Pulmonary disease such as COPD or asthma could affect LOS by increasing postoperative care requirements and/or the risk of postoperative pulmonary complications.¹⁸

Finally, patients who underwent ACDF that included a corpectomy were also found to have increased odds of extended LOS. Similar to our results, Song et al. found that anterior cervical corpectomy is associated with increased LOS compared to ACDF alone.¹⁹ This relationship of corpectomy with LOS is likely independent of intraoperative and postoperative complications, as several studies have found no difference in complications such as postoperative infection and dysphagia between ACDF with corpectomy and ACDF without corpectomy.²⁰⁻²⁴

While it may not be surprising that history of non-spinal malignancy, pulmonary disease, or corpectomy is associated with increased LOS after ACDF, variables that were not associated with extended LOS are of significant note. In particular, age, elevated BMI, ASA class, smoking history, diabetes, heart disease, number of levels fused, and use of iliac crest bone graft, all of which one might expect to be associated with longer LOS, did not correlate with extended LOS in this model.

Among those variables not found to predict extended LOS, number of levels was surprising. Although significant on bivariate analysis, number of levels did not reach statistical significance in the multivariate model. One possible explanation is that corpectomy procedures were counted as multi-level procedures for this analysis, so the contribution of corpectomy could have been a driving variable for the number of levels finding on the bivariate analysis. In fact, if the analysis is repeated comparing one- and two-level cases to three- and four-level cases, the number of levels still did not prove to be a significant predictor of extended LOS in the multivariate analysis.

Our results differ from previous studies that have described a significant association between increased LOS after ACDF and age, obesity, hypertension, diabetes, heart disease, and number of levels fused.^{8–10,12,17} Differences between studies are most likely due to inclusion of different predictive factors in the multivariate models of other studies (such as intraoperative and postoperative factors), differences in inclusion criteria or populations studied, and differences in surgical technique and discharge criteria. The fact that findings can differ so greatly between studies underlines the importance of using multiple patient samples, drawn from different populations, in order to best characterize factors affecting LOS after ACDF.

Limitations of this study include its retrospective nature and differences in surgeon practices. The retrospective nature of the study, however, may actually be appropriate to avoid observer effect (surgeons pushing for earlier discharge due to an ongoing study). Regarding the multiple surgeons involved in the study, there may be some variations in discharge criteria, but this is true for any center. Furthermore, by studying a single institution, institutional variables should have been controlled. It is important to note that while outpatient ACDF procedures have become more common in recent years,²⁵ no patient in this study was discharged the same day after undergoing an ACDF procedure. This is attributable to surgeon practice at our institution and thus these results may be less applicable to planned outpatient ACDF procedures.

Overall, this study helps to establish which factors affect LOS after ACDF. We found three factors associated with increased odds of extended LOS, two of which (history of pulmonary disease and corpectomy) have been identified in previous studies. Other factors including age, sex, BMI, smoking history, history of most major medical comorbidities, number of levels fused, and use of iliac crest bone graft (ICBG) were found to not be associated with increased odds of extended LOS after ACDF. We hope that this information will be of use to patients and providers to facilitate discussion and set appropriate expectations about hospital LOS following elective ACDF procedures.

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Figure 1.

Length of stay (LOS) after anterior cervical discectomy and fusion (ACDF). Extended LOS was defined as one greater than the 75th percentile LOS, which was 2 days. LOS of 3 days or greater was thus considered extended LOS. Patients discharged to the right of the vertical dashed line had an extended LOS.

Table 1

Demographics and comorbidities of the patient population.

	Number	Percent
Overall	183	100%
Age		
18–39	24	13.1%
40–49	57	31.2%
50–59	57	31.2%
60	45	24.6%
Sex		
Female	97	53.0%
Male	86	47.0%
Body mass index *		
18–25	41	22.7%
25–30	66	36.5%
30–35	43	23.8%
35	31	17.1%
ASA class		
1–2	116	63.4%
3–4	67	36.6%
Preoperative hematocrit		
36.0 or not drawn	167	91.3%
<36.0	16	8.7%
History of smoking		
No	98	53.6%
Yes	58	46.5%
History of non-spinal malignancy		
No	171	93.4%
Yes	12	6.6%
History of diabetes		
No	157	85.8%
Yes	26	14.2%
History of pulmonary disease		
No	136	74.3%
Yes	47	25.7%
History of hypertension		
No	110	60.1%

	Number	Percent
Yes	73	39.9%
History of heart disease		
No	156	85.3%
Yes	27	14.8%
History of bleeding disorder or on aspirin		
No	167	91.3%
Yes	16	8.7%
Number of levels		
1	91	49.7%
2	76	41.5%
3	15	8.2%
4	1	0.6%
Corpectomy		
No	166	90.7%
Yes	17	9.3%
Use of iliac crest bone graft		
No	120	82.0 %
Yes	32	18.0%

ASA = American Society of Anesthesiologists.

* For one patient, height was not available in the medical record; hence, body mass index could not be calculated.

Table 2

Percent of cases with extended length of stay, by demographics and comorbidities.

	Bivariate analyses [†]		Multivariate analysis ^{†‡}	
	Percent of cases with an extended length of stay [*]	OR	P-value	P-value
Overall	18.6			
Age			0.104	
18–39	8.3	Ref.		
40–49	12.3	1.5		
50–59	21.1	2.9		
60	28.9	4.5		
Sex			0.452	.180
Female	20.6	Ref.		Ref.
Male	16.3	0.7		0.5
Body mass index			0.842	
18–25	22.0	Ref.		
25–30	15.2	0.7		
30–35	20.9	1.0		
35	19.4	0.9		
ASA class			0.031	
1–2	13.8	Ref.		
3–4	26.9	2.3		
Preoperative hematocrit			0.050	
36.0 or not drawn	16.8	Ref.		
< 36.0	37.5	3.0		
History of smoking			0.401	
No	16.3	Ref.		
Yes	21.2	1.4		
History of non-spinal malignancy			0.008	0.031

	Bivariate analyses [†]			Multivariate analyses ^{†,‡}		
	Percent of cases with an extended length of stay*			OR	P-value	P-value
No	16.4	Ref.		Ref.		
Yes	50.0	5.1		4.9		
History of diabetes			0.526			
No	17.8	Ref.				
Yes	23.1	1.4				
History of pulmonary disease			<0.001			0.002
No	11.8	Ref.		Ref.		
Yes	38.3	4.7		4.0		
History of hypertension			0.037			0.195
No	13.6	Ref.		Ref.		
Yes	26.0	2.2		1.8		
History of heart disease			0.037			0.118
No	16.0	Ref.		Ref.		
Yes	33.3	2.6		2.4		
History of bleeding disorder or on aspirin			0.181			
No	17.4	Ref.				
Yes	31.3	1.2				
Number of levels			0.004			0.095
1	9.9	Ref.		Ref.		
2	23.7	2.8		1.8		
3-4	43.8	7.1		5.1		
Corpectomy			<0.001			0.020
No	14.5	Ref.		Ref.		
Yes	58.8	8.5		4.5		
Use of iliac crest bone graft			0.733			
No	19.2	Ref.				

	Percent of cases with an extended length of stay [*]		Bivariate analyses [†]		Multivariate analyses ^{†,‡}	
			OR	P-value	OR	P-value
Yes		21.9	1.2			

OR = Odds ratio; ASA = American Society of Anesthesiologists.

^{*} Unadjusted percent of cases with extended length of stay (length of stay ≥ 3 days).

[†] Bolding indicates statistical significance (p < 0.05).

[‡] The final multivariate model was constructed using a backwards stepwise process that initially included all potential predictor variables and sequentially excluded variables with the highest p-value until only those with p < 0.20 remained. Variables with 0.05 < p < 0.20 are left in the model to control for potential confounding, but are not considered to be statistically significant.

Table 3

Summary of effects of factors on LOS after ACDF

	Odds Ratio	Standard Error	95% Confidence Interval	P-value
Significant in multivariate analysis*				
History of non-spinal malignancy	4.9	3.6	1.2 – 20.9	0.031
Corpectomy	4.5	2.9	1.3 – 16.2	0.020
History of pulmonary disease	4.0	1.8	1.6 – 9.7	0.002
Not significant in multivariate analysis, but significant in bivariate analysis				
ASA class				
Preoperative hematocrit < 36.0				
History of hypertension				
History of heart disease				
Number of levels				
Not significant in multivariate analysis or bivariate analysis				
Age				
Sex				
Body mass index				
History of smoking				
History of diabetes				
History of bleeding disorder or on aspirin				
Use of iliac crest bone graft				

ASA = American Society of Anesthesiologists

* Variables significant in the multivariate analysis are listed in order of descending odds ratio.