Original Article

Risk factors for 30-day outcomes in elective anterior versus posterior cervical fusion: A matched cohort analysis

ABSTRACT

Objective: Cervical spine fusion is the preferred treatment modality for a variety of degenerative and/or myelopathic disorders. Surgeons select between two approaches (anterior or posterior cervical fusion [ACF; PCF]) based on pathoanatomical features and spinal levels involved. Complications and outcome profiles between the approaches following elective surgery have not been systematically investigated.

Methods: Adult patients undergoing elective ACF or PCF were extracted from the American College of Surgeons National Surgical Quality Improvement Program years 2011–2014. Five hundred twenty-eight patients (264 ACF and 264 PCF) were matched 1:1 by age, sex, functional status, vertebral levels operated, and the American Society of Anesthesiologists classification. Multivariable regression was performed by surgical approach for operation time, complications, hospital length of stay (HLOS), and discharge destination, controlling for body mass index and comorbidities. Mean differences (*B*), odds ratios (ORs), and 95% confidence intervals (CIs) are reported.

Results: Compared to ACF, PCF was associated with increased odds of blood transfusions >1 unit (OR = 4.31, 95% CI [1.18–15.75]; $P = 0.027$) and failure to discharge to home (OR = 3.68 [2.17–6.25]; $P < 0.001$), and increased mean HLOS ($B = 1.72$ days [1.19–2.26]; $P < 0.001$). No differences in operation time, other complications, or reoperation rates were found by surgical approach.

Conclusions: In a matched cohort analysis by age, sex, functional and physical status, and vertebral levels, elective PCF is associated with increased HLOS and increased likelihood of failing to discharge to home compared to ACF without increased risk of 30-day complications. Increased blood transfusion volume is noted for patients undergoing PCF. Future prospective studies are warranted.

Keywords: American College of Surgeons National Surgical Quality Improvement Program, anterior cervical spine fusion, complications, outcome, posterior cervical spine fusion, risk factors, spine surgery

INTRODUCTION

Cervical spine decompression and fusions are widely indicated for the treatment of myelopathy, spondylosis, spondylolisthesis, deformity, and other compressive and noncompressive pathologies to provide functional recovery and improved quality of life. Spondylotic compression can arise anteriorly or posteriorly in the spinal canal, necessitating anterior or posterior decompression. Anterior decompression is performed commonly through anterior cervical discectomy and fusion (ACDF) and posterior decompression through laminectomy/laminoplasty and fusion.

Several large studies have been performed for the safety profiles comparing anterior and posterior approaches. In a meta-analysis of eight retrospective studies, Lawrence *et al*.

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report that anterior approaches have been associated with lower infection rates, while dysphagia and higher canal diameter changes have been associated with posterior surgeries.[1] Zhu *et al*. report in seven studies that postoperative complication and reoperations rates were higher in the anterior group.[2] Similarly, in another meta-analysis of six reports comparing ACDF and laminoplasty, the former was associated with increased complications; however, Cobb angle of C2–C7 compared to baseline was decreased.[3] Effects on outcome scores are conflicting across meta-analyses with some reporting improvement with anterior surgery, while others report no difference.[1-3] In a meta-analysis, exclusively on multilevel cervical compressive myelopathy, definitive conclusions on which surgical approach is more effective could not be reached.[4]

The evidence in prospective studies is comparable. In a prospective study of 302 patients for cervical spondylotic myelopathy, posterior approaches were associated with wound infections while combined anterior–posterior approaches were associated with dysphagia and overall increased perioperative complications; however, complications did not affect the overall outcome score, and on multivariate analysis, only age and operative time predicted complications.[5] A prospective multicenter observational trial by Fehlings *et al*. in 264 patients with cervical spondylotic myelopathy demonstrated comparable efficacy between anterior cervical fusion (ACF) and posterior cervical fusion (PCF). The authors noted that ACF was associated with younger, less complicated patients; however, when controlling for demographic factors, the two surgeries were performed comparably.[6] A related study by Fehlings *et al*. in 302 patients obtained from a multicenter prospective spine database also showed that across all perioperative outcomes and complications, PCF was only associated with increased rates of wound infection when compared to ACF.[5] Although meta-analyses and systematic reviews have looked into this issue, they are limited in the ability to fully control for the effects of comorbidities.[1-3] Similarly, there are challenges in randomizing prospective patients to the anterior or posterior approach without considering comorbidities and/or limitations on surgical approach.

In the current study, the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database was utilized to identify the risk factors for 30-day medical and surgical complications following elective anterior versus posterior cervical spine fusion surgery using matched-cohorts for ACF and PCF surgical approaches. We characterize the incidence and predictors of individual complications, as well as outcome measures of hospital length of stay (HLOS) and discharge destination by surgical cohort.

METHODS

Data source

The ACS-NSQIP was created to improve surgical techniques and outcomes[7] and catalogs over 300 variables on comorbidities, intraoperative events, and 30-day outcomes using prospective random sampling.[8-10] This study is exempt from the institutional review board approval, as the ACS-NSQIP Participant-Use Data Files contain no protected health information.

Study population

The ACS-NSQIP database years 2011–2014 were selected because the variables "emergency" (coding whether surgery was emergent) and "dischdest" (coding whether the patient was discharged home, skilled nursing facility (SNF), rehabilitation unit, or other higher level of care) were added to ACS-NSQIP starting in 2011.[11] Elective CF and PCF surgeries were identified using common procedural terminology (CPT) codes. The CPT code for ACF was 22551 (arthrodesis anterior interbody decompression cervical below C2), and for PCF was 22600 (arthrodesis posterior/posterolateral cervical below C2 segment). A total of 17,732 elective ACF (n = 16,235) and PCF (n = 1497) patients were extracted. Patients were then included only if the surgical indication was due to a primary cervical spine disorder (spondylosis, spondylolisthesis, cervicalgia, disc degeneration, and/or disorder), leaving 13,903 ACF and 1,022 PCF patients. Included and excluded patients by CPT code are shown in Supplementary Table 1.

Patients were then matched 1:1 by age (years), sex (male vs. female), baseline functional status (independent vs. partially or totally dependent), vertebral levels operated, and the American Society of Anesthesiologists physical classification score, which is well-established as a predictor of poor outcome in the cervical spine literature,[12,13] which yielded a final matched sample of 264 elective ACF and 264 elective PCF patients.

Outcome measures

The primary outcome measures were operation time, 30-day complications, reoperations rates, HLOS, and discharge destination. Operation time was defined as the total surgical time in minutes. HLOS was defined as the number of days between admission and date of postsurgery discharge. For univariate and multivariable analyses, operation time and HLOS were treated as continuous variables. Hospital discharge destination was categorized to home, versus a facility of higher level of care, in all patients not reported to have died within 30 days. Due to the small numbers of deaths (n = 2), multivariable analysis was not performed for mortality.

Statistical analysis

Descriptive statistics were utilized to compare continuous and categorical variables by surgical approach cohort (ACF and PCF) using analysis of variance and Chi-squared tests, respectively. Complications with incidence amounting to >1% in the dataset ($n > 5$) were considered for analysis. Linear regressions were performed for operation time and HLOS, and logistic regressions were performed for complications and failure to discharge to home. Multivariable analyses were controlled for body mass index (BMI) stratified to the World Health Organization classifications (kg/m^2; <18.5 = underweight, 18.5–29.9 = nonobese, 30–34.9 = obese Class I, and ≥35 = obese Class II/III)[14,15] per association with increased risk of poor outcome (e.g., airway compromise, extubation challenges, and surgical site infection);[16-18] hypertension and smoking due to validated associations with negative outcomes in prior studies;[19-22] and baseline diabetes and dyspnea due to their high incidences in the dataset. Mean difference (*B*) was reported for linear regressions, and odds ratios (ORs) for logistic regressions, along with their associated 95% confidence intervals (CIs). Statistical significance was assessed at $P < 0.05$. All statistical analyses were performed using open source software in Python or R (SciPy, StatsModels, Sci-Kit-Learn and Resource Selection packages).[23-26]

RESULTS

Demographic and clinical characteristics

In the 1:1 matched cohort (ACF [$n = 264$]; PCF [$n = 264$]), subjects were 59.6 ± 12.0 years of age, 52.3% male, and 81.6% Caucasian. There was a nonsignificant statistical trend observed for obesity, with a higher incidence of nonobese patients in the PCF cohort (57.9% vs. 48.8%) [Table 1]. Baseline comorbidities were comparable between ACF and PCF, without significant differences [Table 2].

Table 1: Demographic and clinical characteristics by matched surgery cohort

Descriptive variable	ACF ($n=264$), *n* (%)	PCF ($n=264$), *n* (%)	Significant (*P*)
Age (years)			
Mean±SD	59.6±12.0	59.6±12.0	-
<65	170 (64.4)	170 (64.4)	
≥65	94 (35.6)	94 (35.6)	
Sex			
Male	138 (52.3)	138 (52.3)	-
Female	126 (47.7)	126 (47.7)	
Race			
Caucasian	215	216	0.980
African-American	24	25	
Other/unknown	25	24	
BMI (kg/m^2)			
Underweight (<18.5)	7 (2.6)	11 (4.2)	0.095
Nonobese (18.5-29.9)	129 (48.8)	153 (57.9)	
Obese Class I (30-34.9)	72 (27.3)	56 (21.2)	
Obese Class II/III (≥35)	56 (21.2)	44 (16.7)	
ASA classification			
ASA 1-2	113 (42.8)	113 (42.8)	-
ASA 3-4	151 (57.2)	151 (57.2)	
Functional status			
Independent	250 (94.7)	250 (94.7)	-
Partially or totally dependent	14 (5.3)	14 (5.3)	
Surgery team			
Attending without resident	46 (17.4)	17 (6.4)	<0.001
Attending with resident	22 (8.3)	28 (10.6)	
Attending status unknown	196 (74.2)	219 (82.9)	
Patient status			
Outpatient	35 (13.2)	24 (9.1)	0.128
Inpatient	229 (86.7)	240 (90.9)	
Number of surgical levels			
1-2 levels	257 (97.3)	257 (97.3)	-
3+ levels	7 (2.6)	7 (2.6)	

Distributions and proportions are shown for elective cervical spine fusion patients. ACF - Anterior cervical fusion; ASA - American Society of Anesthesiologists physical classification score; PCF - Posterior cervical fusion; SD - Standard deviation; BMI - Body mass index

Operation time

The overall operation time was 170.55 ± 91.34 min and did not differ by surgical approach [Table 3]. No predictors for operation time emerged on multivariable analysis [Table 5c].

30-day complications and reoperations

Overall, 10.6% of subjects suffered 30-day complications (ACF = 8.7%, PCF = 12.5%, $P = 0.158$) and 3.4% needed a reoperation within 30 days (ACF = 2.2%, PCF = 4.5%, $P = 0.150$) [Table 3]. Common complications in the ACF group were reintubation (3.4%), deep venous thrombosis (1.5%), ventilator dependency >24 h (1.5%), blood transfusion >1 unit (1.1%), and urinary tract infection (UTI; 1.1%). Common complications in the PCF group were blood transfusion >1 unit (4.5%), pneumonia (2.7%), wound infection (2.3%), UTI (2.3%), pulmonary embolus (1.1%), and ventilator dependency >24 h (1.1%) [Table 4].

On univariate analysis, PCF was associated with increased incidence of blood transfusion >1 unit (4.5% vs. 1.1%, $P = 0.033$). PCF showed a nonsignificant statistical trend for increased pneumonia (2.7% vs. 0.4%, $P = 0.068$) and decreased reintubation (0.8% vs. 3.4%, $P = 0.063$) [Table 4].

Multivariable analyses controlling for obesity, hypertension, smoking, diabetes, and dyspnea were performed

for all univariate complications with incidence >1%. Increased odds of blood transfusion >1 unit was demonstrated for PCF (OR = 4.31, 95% CI [1.18–15.75], $P = 0.027$) [Table 5b]. The nonsignificant statistical trends persisted for PCF and increased odds of pneumonia (OR = 7.64 [0.90–65.10], $P = 0.063$), and decreased odds of reintubation (OR = 0.22 [0.05–1.06], $P = 0.059$), compared to ACF [Table 5a and b]. Other predictors included baseline diabetes associating with increased odds of UTI (OR = 15.40 [3.13–74.89], $P = 0.001$), and being underweight associating with increased odds of pneumonia (OR = 8.82 [1.16–66.95], $P = 0.035$)] [Table 5a].

Table 2: Comorbidities by matched surgery cohort

Comorbidity variable	ACF (*n*=264), *n* (%)	PCF (*n*=264), *n* (%)	Significant (*P*)
Cardiovascular			
Congestive heart failure	3 (1.1)	1 (0.4)	0.315
Myocardial infarction	0	0	-
Percutaneous coronary intervention	2 (0.8)	1 (0.4)	0.544
Prior cardiac surgery	0	2 (0.8)	0.156
Peripheral vascular disease	0	1 (0.4)	0.317
Malignancy			
Weight loss >10% (6 months)	0	1 (0.4)	0.317
Metastasis	1 (0.4)	1 (0.4)	0.317
Neurological			
Transient ischemic attack	1 (0.4)	1 (0.4)	-
Stroke	0	2 (0.8)	0.156
Paralysis			
Hemiparesis	1 (0.4)	0	0.317
Paraplegia	2 (0.8)	0	0.156
Quadriplegia	0	1 (0.1)	0.317
Pulmonary			
Dyspnea	48 (18.2)	43 (16.3)	0.564
Steroid use (inhaler)	13 (4.9)	12 (4.5)	0.838
COPD	12 (4.5)	19 (7.2)	0.195
Coagulopathy	5 (1.9)	4 (1.5)	0.736
Diabetes mellitus	59 (22.3)	42 (15.9)	0.059
Hypertension	138 (52.3)	146 (55.3)	0.485
Renal failure	0	0	-
Smoking	72 (27.1)	79 (29.9)	0.500

Distributions and proportions are shown for elective cervical spine surgery patients. ACF - Anterior cervical fusion; PCF - Posterior cervical fusion; COPD - Chronic obstructive pulmonary disease

Total hospital length of stay

The overall HLOS was 3.31 ± 3.22 days. On univariate analysis, HLOS was increased in PCF compared to ACF subjects (4.16 ± 3.28 days; 2.46 ± 2.91 days, $P < 0.001$) [Table 3], which persisted on multivariable analysis ($B = +1.72$ days, 95% CI [1.19, 2.26], $P < 0.001$) [Table 5c]. Other multivariable predictors for increased HLOS were baseline dyspnea ($B = +0.82$ days [0.12, 1.53], $P = 0.022$) and baseline diabetes ($B = +0.76$ days [0.05, 1.48], $P = 0.036$) [Table 5c]. Baseline hypertension showed a nonsignificant statistical trend for increased HLOS ($B = +0.55$ days [−0.02, 1.11], $P = 0.059$) [Table 5c].

Failing to discharge to home from hospital

In total, 438 (83.0%) of patients were discharged home from the hospital. On univariate analysis, PCF was associated with less incidence of discharge to home (ACF = 90.9%, PCF = 75.0%; $P < 0.001$) [Table 3]. The association between PCF and failure to discharge to home persisted on multivariable analysis (OR = 3.68, 95% CI [2.17–6.25], $P < 0.001$) [Table 5c]. Other multivariable predictors for failure to discharge to home included baseline diabetes (OR = 2.57 [1.43–4.64], $P = 0.002$) and baseline dyspnea (OR = 2.14 [1.19–3.85], $P = 0.011$). Obese Class II/II subjects showed decreased odds of failure to discharge to home compared to their nonobese counterparts (OR = 0.42 [0.20–0.88], $P = 0.022$).

Table 3: Univariate distribution of outcomes by matched surgery cohort

Comorbidity variable	ACF (*n*=264), *n* (%)	PCF (*n*=264), *n* (%)	Overall (*n*=528), *n* (%)	Significant (*P*)
Operation time (min)				
Mean±SD	171.22±99.14	169.88±82.62	170.55±91.34	0.866
HLOS (days)				
Mean±SD	2.46±2.91	4.16±3.28	3.31±3.22	<0.001
Reoperation				
Overall	6 (2.2)	12 (4.5)	18 (3.4)	0.150
30-day complications				
Overall	23 (8.7)	33 (12.5)	56 (10.6)	0.158
Hospital discharge to home				
Home	240 (90.9)	198 (75.0)	438 (82.9)	<0.001
SNF/rehabilitation	24 (9.1)	66 (25.0)	90 (17.0)	

Distributions and proportions are shown for elective cervical spine surgery patients. Hospital discharge to home analyses have a lower N due to excluding patients who expired in hospital and/or within 30 days of operation. ACF - Anterior cervical fusion; PCF - Posterior cervical fusion; SD - Standard deviation; SNF - Skilled nursing facility; HLOS - Hospital length of stay

Table 4: Univariate comparison of major 30-day complications by surgery cohort

Complication variable	ACF (*n*=264), *n* (%)	PCF (*n*=264), *n* (%)	Significant (*P*)
Univariate			
Pulmonary embolism	1 (0.38)	3 (1.13)	0.623
Renal failure	0	0	1.00
Pneumonia	1 (0.38)	7 (2.65)	0.068
Deep venous thrombosis	4 (1.51)	1 (0.38)	0.373
Peripheral nerve injury	0	0	1.00
Urinary tract infection	3 (1.13)	6 (2.27)	0.504
Stroke	1 (0.38)	0	1.00
Myocardial infarction	1 (0.38)	2 (0.75)	1.00
Cardiac arrest	0	2 (0.75)	0.499
Blood transfusion >1 unit	3 (1.13)	12 (4.54)	0.033
Wound infection	2 (0.75)	6 (2.27)	0.285
Ventilator dependency >24 h	4 (1.51)	3 (1.13)	1.00
Reintubation	9 (3.41)	2 (0.75)	0.063
Death	1 (0.38)	1 (0.38)	1.00

Proportions are shown for elective cervical spine surgery patients. ACF - Anterior cervical fusion; PCF - Posterior cervical fusion

DISCUSSION

ACF and PCF are effective treatment modalities for primary cervical spine disorders. Both techniques can provide significant improvement of the neurological, functional, and quality-of-life measures.[1,6,27] Using a matched cohort analysis of 264 ACF and 264 PCF patients from the ACS-NSQIP, we demonstrate that ACF is associated with increased risk for reintubation and PCF is associated with increased blood transfusion, pneumonia, longer hospitalization, and discharge to a nursing/rehabilitation facility, while no differences in operation time, reoperation, mortality, and overall complication rates are observed.

Operation time and reoperation

Our matched analysis shows no difference between ACF and PCF in mean operation times (ACF = 171.22 min; PCF = 169.88 min, $P = 0.866$) or reoperation rates (ACF = 2.2%; PCF 4.5%, $P = 0.150$), although the familiarity and comfort level of the surgeon for each technique is critical. Expert opinion emphasizes the cause of the compression, whether the primary compression site is ventral or dorsal, number of involved levels, sagittal alignment of spine, and baseline functional status of the patient to determine an optimal surgical strategy. The anterior approach is indicated for the restoration of cervical lordosis. The pre-matched difference in overall complication rate between the anterior and posterior approaches (ACF = 2.4%; PCF = 13.5%, $P < 0.001$) is not unexpected, as PCF patients have a greater tendency for increased baseline burden.[6,28] Anterior techniques are usually indicated in patients who are younger, with less neurological and functional impairment, and more focal cervical pathology. Of note, the current dataset of the ACS-NSQIP database only includes patients undergoing elective spine surgery and not the acute cases requiring urgent surgical decompression; therefore, our findings are selectively generalizable to the lower-risk and chronic degenerative cervical adult patients being treated at qualified surgical centers.

Complications

When the baseline characteristics are closely matched, we demonstrate that the surgical approach does not impact overall complications (ACF = 8.7%; PCF = 12.5%, $P = 0.158$). Posterior surgery was associated with a nonsignificant trend for decreased incidence of reintubation compared to anterior surgery (OR = 0.22 [0.05–1.06], $P = 0.059$). A rare but potentially lethal complication following anterior cervical spine surgery is airway compromise from a postoperative hematoma or soft-tissue edema that typically occurs 24–72 h postsurgery.[29,30] The risk factors include operation time over 5 h, multilevel cases involving C2, C3, or C4, and blood loss >300 ml.[29] The long-term outcomes are unavailable, but Nagoshi *et al*. reported that patients who experienced reintubation do not achieve as much functional and quality of life improvement as expected following anterior surgery.[30] Other risks associated with the anterior approach include dysphagia and hoarseness because of injury to the glossopharyngeal, hypoglossal, and recurrent laryngeal nerves, which can be asymptomatic or resolve within 1 week following surgery.[31-33] As such, these patients are also at the risk for aspiration during the first few days following surgery.

In contrast, the posterior surgical approach may be associated with greater risks for increased blood transfusion (OR = 4.31 [1.18–15.75], $P = 0.027$) and pneumonia (OR = 7.64 [0.90–65.10], $P = 0.063$) compared to anterior surgery. While revision surgery has a greater risk for increased bleeding,[34] our matched analysis shows no difference in the reoperation rate for the two surgical techniques (ACF = 2.2%; PCF = 4.5%, $P = 0.150$). A number of reasons that cause increased surgical blood loss include the exposure of the spine via stripping of the muscle off bone, osteoporotic bone with wider vascular channels, epidural bleeding following laminectomy, and multilevel pathology. Of note, the PCF patients exhibit higher prevalence of cardiovascular and pulmonary diseases, along with malignancy (weight loss >10% over 6 months), coagulopathy, hypertension, and diabetes mellitus. They cannot tolerate decreased perfusion to critical organs during surgery and are more likely to need transfusion.[35] Nuttall *et al*. found that the history of

Table 5a: Infectious complications

Predictor	Pneumonia (OR)	Significant (*P*)	Urinary tract infection (OR)	Significant (*P*)	Wound infection (OR)	Significant (*P*)
Surgery						
ACF	Reference	-	Reference	-	Reference	-
PCF	7.64 (0.90-65.10)	0.063	2.14 (0.48-9.56)	0.321	3.18 (0.61-16.59)	0.170
BMI						
Nonobese	Reference	-	Reference	-	Reference	-
Underweight	8.82 (1.16-66.95)	0.035	-	-	-	-
Obese I	2.53 (0.49-13.21)	0.270	2.76 (0.68-11.3)	0.157	1.48 (0.31-6.94)	0.621
Obese II-III	-	-	-	-	0.53 (0.05-5.17)	0.586
Hypertension	1.37 (0.29-6.37)	0.688	0.51 (0.11-2.41)	0.394	5.93 (0.69-50.96)	0.105
Smoking	0.24 (0.03-2.16)	0.204	1.09 (0.20-6.06)	0.923	1.10 (0.21-5.94)	0.908
Diabetes	0.59 (0.06-5.61)	0.646	15.43 (3.13-74.89)	0.001	2.25 (0.49-10.39)	0.300
Dyspnea	3.01 (0.6-15.2)	0.826	0.88 (0.1-7.99)	0.908	-	-

Table 5b: Critical care complications

Predictor	Blood transfusion >1 unit (OR)	Significant (*P*)	Failure to wean off ventilator (OR)	Significant (*P*)	Reintubation (OR)	Significant (*P*)
Surgery						
ACF	Reference	-	Reference	-	Reference	-
PCF	4.31 (1.18-15.75)	0.027	0.68 (0.15-3.17)	0.627	0.22 (0.05-1.06)	0.059
BMI						
Nonobese	Reference	-	Reference	-	Reference	-
Underweight	-	-	5.65 (0.53-60.22)	0.151	5.22 (0.48-56.43)	0.174
Obese I	0.75 (0.20-2.90)	0.680	1.46 (0.24-9.00)	0.683	2.71 (0.59-12.55)	0.201
Obese II-III	0.69 (0.17-2.82)	0.603	1.03 (0.10-10.89)	0.982	2.36 (0.42-13.16)	0.327
Hypertension	2.05 (0.61-6.97)	0.248	1.44 (0.29-7.24)	0.657	1.66 (0.41-6.69)	0.478
Smoking	0.63 (0.17-2.38)	0.495	1.93 (0.39-9.44)	0.417	2.81 (0.77-10.18)	0.116
Diabetes	1.42 (0.41-4.93)	0.577	0.68 (0.07-6.41)	0.738	1.25 (0.28-5.67)	0.768
Dyspnea	1.95 (0.58-6.55)	0.282	0.63 (0.07-5.58)	0.679	0.82 (0.17-3.97)	0.800

Table 5c: Perioperative outcomes

Predictor	Operation time (B)	Significant (*P*)	Discharge destination (OR)	Significant (*P*)	HLOS (B)	Significant (*P*)
Surgery						
ACF	Reference	-	Reference	-	Reference	-
PCF	−1.11 (−16.95-14.72)	0.89	3.68 (2.17-6.25)	<0.001	1.72 (1.19-2.26)	<0.001
BMI						
Nonobese	Reference	-	Reference	-	Reference	-
Underweight	−11.72 (−55.80-32.36)	0.602	2.38 (0.82-6.94)	0.113	0.58 (−0.89-2.06)	0.440
Obese I	15.82 (−3.53-35.17)	0.109	0.77 (0.42-1.41)	0.400	0.14 (−0.50-0.79)	0.661
Obese II-III	−1.39 (−23.25-20.46)	0.900	0.42 (0.20-0.88)	0.022	−0.37 (−1.10-0.36)	0.321
Hypertension	0.016 (−16.92-16.95)	0.999	1.45 (0.86-2.45)	0.166	0.55 (−0.02-1.11)	0.059
Smoking	4.22 (−13.75-22.18)	0.645	0.84 (0.48-1.48)	0.552	0.04 (−0.56-0.65)	0.888
Diabetes	−12.82 (−34.11-8.45)	0.237	2.57 (1.43-4.64)	0.002	0.76 (0.05-1.48)	0.036
Dyspnea	4.79 (−16.27-25.87)	0.655	2.14 (1.19-3.85)	0.011	0.82 (0.12-1.53)	0.022

Multivariable predictors of 30-day complications with >1% incidence in dataset, divided into infection (Table 5a) and critical care (Table 5b) type complications. OR, B, and 95% CI (in brackets) are displayed for categorical and continuous outcome variables, respectively. For hypertension, smoking, diabetes, and dyspnea, the OR and/or B is listed for the group with the baseline condition. ACF - Anterior cervical fusion; BMI - Body mass index; PCF - Posterior cervical fusion; OR - Odds ratios; B - Mean differences; CI - Confidence intervals; HLOS - Hospital length of stay

pulmonary disease and surgery for tumors near the spinal column predict increased blood transfusion.[36] Since being underweight (BMI <18.5) is associated with the greatest odds of developing pneumonia (OR = 8.82 [1.16–66.95]; $P = 0.035$) compared to being nonobese, it may be that the PCF cohort is more likely to develop postoperative pneumonia due to a relatively more frail body profile, and less so from the surgical strategy. On the other end of the spectrum, we also confirm previous reports that obesity is not associated with increased complications after cervical spine fusion.[37] As is the case with any major operation, the odds of UTI greatly increase with the preoperative diagnosis

of diabetes (OR = 15.4 [3.13, 74.89]; $P = 0.001$), irrespective of the cervical approach.

The literature reports trends of increased wound infection rates in the posterior cohort.[6,38] We find no difference in the rate of wound infection between the two surgical cohorts (ACF = 0.75%; PCF = 2.27%, $P = 0.285$). These results, along with the similar odds of failure to wean from mechanical intubation between ACF and PCF patients (OR 1.47 [0.32–6.67], $P = 0.627$), may indicate the effects of 1:1 matching which eliminates confounding baseline factors, rather than true incidence in the population.

Hospitalization length and relative costs

We demonstrate that PCF is associated with longer hospitalization times than ACF by approximately 1.72 days. While previous investigations have attributed the prolonged hospital stay to the conventional wisdom that the PCF patients are elderly and more comorbid,[39] our findings are independent of baseline characteristics or overall complication rates. The posterior approach is often preferred by the surgeon for cervical degenerative diseases involving more than two vertebral body levels,[40,41] as was the case in our prematched cohort (ACF = 0.2%; PCF = 22.6%, data not shown). In the context of multilevel degenerative cervical disease, Cole *et al*. recently concluded that the anterior approach may provide clinical and economic advantages.[38] Beyond demonstrating no difference in the clinical efficacy between the two surgical approaches, our findings confirm that a patient undergoing PCF would require increased resource utilization and can therefore be less cost-effective than ACF when the latter approach is feasible.

Discharge to home

A higher proportion of PCF patients were discharged to SNF/rehabilitation facilities (ACF = 9.1%; PCF = 25.0%, $P < 0.001$), possibly because the posterior approach results in a longer recovery and/or more perceived deficit. Similarly, Romano *et al*. found that posterior fusion patients stayed in the hospital an average of 0.7 days longer and were 4.6 times more likely discharged to a nursing home compared to anterior fusion patients.[42] The same reasons causing increased blood loss and longer hospitalization may be associated with more frequent transfer to a high-level care facility with physical and occupational health services. It is important, however, to keep in mind that the posterior surgical approach is at times pursued by the surgeon in patients with contraindications to anterior surgery. Therefore, even in a matched cohort, the outcomes are not perfectly comparable. We report that baseline dyspnea (OR 2.14 [1.19–3.85], $P = 0.011$) and diabetes (OR 2.57 [1.43–4.64], $P = 0.002$) are associated with increased likelihood of discharge to a rehabilitation facility. This is expected in major cervical surgery for patients who have preexisting difficulties with ventilation and/or systemic wound healing.

Our results suggest that obesity (BMI ≥30) does not associate with increased adverse outcomes after cervical spine surgery. One explanation from recent investigations is that BMI does not predict wound-related complications; rather, the thickness of the subcutaneous fat is an independent predictor, for stability of the cervical spine.[37,43,44] Other studies on thoracic and lumbar fusion have reported an association between obesity and complications.[45,46] It is not unreasonable to expect low-risk obese (BMI 30-34.9) patients to have similar odds of going directly home from the hospital compared to nonobese patients, as is the case in our study. Interestingly, moderate and high-risk obesity (BMI ≥35) is associated with better odds of going home (OR = 2.38, $P = 0.022$). One possible explanation for patients with moderate and high-risk obesity is the availability of prearranged home care services following elective surgery.

Limitations

Our study has several limitations that should to be considered. The ACS-NSQIP database restricts patient's follow-up to 30 days, and thus cannot report on the academic status of the selected hospitals, total in-hospital costs, and the hospital readmissions. As a result, only acute complications are analyzed while long-term complications and functional status are not readily generalizable from our findings. Second, the current analysis focused on patients undergoing elective cervical surgery and does not capture patients requiring cervical spine surgery due to emergent neurologic decline. ACS-NSQIP contains a variety of operations and does not possess the fine granular variables on cervical spine-specific complications, such as particular neurologic deficits and mechanical complications related to the graft and/or hardware. Finally, the ACS-NSQIP database does not include a number of clinical data variables that can influence perioperative outcomes, such as medication types and dosages, or other nonsurgical interventions during hospitalization. For example, in patients with obesity undergoing cervical spine surgery, data on antibiotic use and dosage would be important in clarifying conflicting findings in the literature. While the ACS-NSQIP database provides a large retrospective sample size to allow for accurate identification of risk factors, it is important to note that additional variables other than those identified in this study may also influence outcomes following cervical spine surgery and would best be studied through a large, well-designed randomized trial.

CONCLUSIONS

In a matched cohort analysis by age, sex, functional and physical status, and vertebral levels, elective PCF is

associated with increased HLOS and increased likelihood of failing to discharge to home compared to ACF, although without increased risk of 30-day complications. Increased blood transfusion volume and trending increase in risk for pneumonia are noted for patients undergoing PCF, and a trending increase in reintubation for patients undergoing ACF. Dyspnea and diabetes are associated with failure to discharge home, and diabetes with developing UTI. Obesity is not associated with increased adverse outcomes following cervical spine surgery. Future prospective studies are warranted.

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Conflicts of interest

There are no conflicts of interest.

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