Adjunct pelvic fixation in short-to-medium segment degenerative fusion constructs independently predicts readmission and morbidity

ABSTRACT

Context: Despite increasing utilization of fusion to treat degenerative pathology, few studies have evaluated outcomes with pelvic fixation (PF). This is the first large-scale database study to compare multilevel fusion with and without PF for degenerative lumbar disease.

Aim: The aim of this study was to compare the 30-day outcomes of multilevel lumbar fusion with and without PF.

Settings and Design: This was a retrospective cohort study.

Subjects and Methods: Lumbar fusion patients were identified using the National Surgical Quality Improvement Program database. Regression was utilized to analyze readmission, reoperation, morbidity, and specific complications and to evaluate for predictors thereof.

Statistical Analysis Used: Student's *t*-test was used for continuous variables and Chi-squared or Fisher's exact test was used for categorical variables. Variables significant in the univariate analyses ($P < 0.05$) and PF were then evaluated for significance as independent predictors and control variables in a series of multivariate logistic regression analyses of primary outcomes.

Results: We identified 38,413 patients. PF predicted 30-day readmission and morbidity. PF was associated with greater reoperation in univariate analysis, but not in multivariate analyses. PF predicted deep wound infections, organ-space infections, pulmonary complications, urinary tract infection, transfusion, deep venous thrombosis, and sepsis. PF was also associated with a longer hospital stay. Age, obesity, steroids, and American Society of Anesthesiologists (ASA) class 3 predicted readmission. Obesity, steroids, bleeding disorder, preoperative transfusion, ASA class ≥3, and levels fused predicted reoperation. Age, African American race, decreased hematocrit, obesity, hypertension, dyspnea, steroids, bleeding disorder, ASA class ≥3, levels fused, and interbody levels fused predicted morbidity. Male gender and inclusion of anterior lumbar interbody fusion (ALIF) were protective of reoperation. Hispanic ethnicity, ALIF, and computer-assisted surgery (CAS) were protective of morbidity.

Conclusions: Adjunctive PF was associated with a 1.5-times and 2.7-times increased odds of readmission and morbidity, respectively. ASA class and specific comorbidities predicted poorer outcomes, while ALIF and CAS were protective. These findings can guide surgical solutions given specific patient factors.

Keywords: Degenerative, fixation, fusion, lumbar spine, pelvic

INTRODUCTION

Adjunctive pelvic fixation (PF) has been utilized to provide greater sagittal and coronal correction and improve lumbar fusion construct stability and solid arthrodesis.[1,2] Given the growing elderly population and increasing utilization of PF in long constructs and deformity surgery, there is a need to evaluate the 30-day outcome profile of supplementary PF in degenerative lumbar fusion.[3,4] Thus, the purpose of this

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study was to compare multilevel adult degenerative lumbar fusion with and without PF based on 30-day readmission, reoperation, and morbidity and to explore predictors of primary outcomes.

SUBJECTS AND METHODS

Study design and population

This study is a retrospective analysis of data from the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database, from 2005 to 2018. This project is exempt from IRB review as this database is de-identified and no direct patient involvement occurred.

Patients ≥18 years old who underwent lumbar fusion were identified using current procedural terminology (CPT) codes for lumbar fusion and were stratified into groups with and without PF. Patients were excluded if they underwent single-level fusion; surgery for traumatic, deformity, nonelective, oncology, or revision purposes; had evidence of prior infection; or underwent additional procedures including osteotomy, arthroplasty, or cervical or thoracic procedures, including extension of fusion to the thoracic spine [Appendix A]. We evaluated patients with mid-length constructs (two-to-five segments) given that the topic of fusing to the pelvis in this group is controversial, with notably lacking literature. Further, by restricting analysis to mid-length constructs, we eliminated any potential morbidity associated with long constructs that could confound the association of fusion to the pelvis with morbidity.

Outcomes and variables

Primary outcomes were 30-day readmission, reoperation, and morbidity. Readmission includes any inpatient stay to the same or another hospital related to the surgical procedure. The NSQIP database did not collect readmission data until 2011. Reoperation includes all major surgical procedures requiring return to the operating room for intervention of any kind. Morbidity includes infectious, pulmonary, cardiac, renal, neurological, hematologic, and thromboembolic complications reported in the ACS-NSQIP dataset.

Primary outcomes, as well as specific complications, were compared between groups with and without PF. Predictors of primary outcomes were analyzed among the entire cohort. Variables evaluated as potential predictors included patient demographic, comorbidity, laboratory values, and procedural factors [Table 1]. Procedural factors specifically included anterior lumbar interbody fusion (ALIF) and computer-assisted surgery (CAS), given prior associations of ALIF and CAS with improved 30-day outcomes and the use of circumferential fusion to promote arthrodesis in patients with particularly poor bone quality.[5,6] Variables with <80% of data available, such as operative time, were excluded from the analysis to avoid skewing of results.

Statistical analysis

Analyses were completed in SPSS (IBM Corp., Armonk, New York, United States). Demographic, comorbidity, laboratory, and procedural factors were individually analyzed for baseline differences between lumbar fusion with and without PF using Student's *t*-test for continuous and Chi-squared or Fisher's exact test for categorical variables. The above factors were also individually analyzed for association with the primary outcomes using univariate logistic regression. Variables significant in the univariate analyses ($P < 0.05$) and PF were then evaluated for significance ($P < 0.05$) as independent predictors and control variables in a series of multivariate logistic regression analyses of primary outcomes.

RESULTS

We included 38,413 multilevel degenerative lumbar fusion patients, 818 with PF [Figure 1]. Baseline group differences and unadjusted primary outcomes are provided in Table 1. Patients with PF were significantly more likely to be older (mean 64 vs. 61 years), female (61.5 vs. 53.6%), and have an American Society of Anesthesiologists (ASA) class ≥3 (67.0 vs. 50.9%) ($P < 0.001$) compared to patients without PF [Table 1]. Patients with PF were significantly less likely to be obese (49.4 vs. 54.0%), African American (6.4 vs. 8.6%), or smokers (13.1 vs. 19.7%).

PF was associated with a significantly greater hospital stay (mean 7.8 vs. 4.6 days) and use of CAS (20.2 vs. 6.7%) and a significantly lower rate of inclusion of ALIF in the final construct (19.4 vs. 26.0%) ($P < 0.001$). Patients with

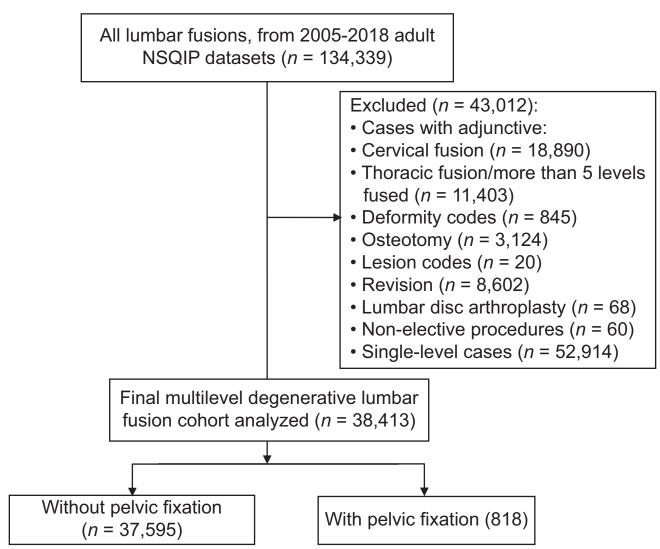

Figure 1: Flowchart demonstrating exclusion of patients. Adapted from the CONSORT 2010 Flow Diagram (original figure)

Table 1: Baseline differences in patient demographic, comorbidity, laboratory, and procedural factors and primary outcomes by presence or absence of pelvic fixation

	With pelvic fixation (n=818), n (%)	Without pelvic fixation (n=37,595), n (%)	P	Cases available (n=38,413)
Demographics				
Mean age (years)±SD	63.6±12.4	61.1±13.1	**<0.001**	38,413
Obese	401 (49.4)	20,187 (54.0)	**0.009**	38,213
African American race	49 (6.4)	3034 (8.6)	**0.034**	35,972
Hispanic ethnicity	38 (4.8)	2012 (5.7)	0.320	36,229
Male gender	315 (38.5)	17,457 (46.4)	**<0.001**	38,402
Comorbidities				
Smoker	107 (13.1)	7388 (19.7)	**<0.001**	38,413
Dyspnea	58 (7.1)	2293 (6.1)	0.242	38,413
Diabetes mellitus	135 (16.5)	6993 (18.6)	0.127	38,413
COPD	52 (6.4)	1695 (4.5)	**0.012**	38,413
Heart failure	11 (1.3)	138 (0.4)	**<0.001**#	38,411
Hypertension	514 (62.8)	22,031 (58.6)	**0.015**	38,413
Disseminated cancer	38 (4.6)	366 (1.0)	**<0.001**	38,413
Open wound infection	24 (2.9)	171 (0.5)	**<0.001**#	38,413
Chronic steroid use	59 (7.2)	1591 (4.2)	**<0.001**	38,413
Bleeding disorder	12 (1.5)	607 (1.6)	0.740	38,413
Preoperative transfusion	16 (2.0)	131 (0.3)	**<0.001**#	38,413
ASA class ≥3	548 (67.0)	19,106 (50.9)	**<0.001**	38,367
Lab values, mean±SD				
Creatinine	0.93±0.76	0.92±0.43	0.591	34,381
White cell count	7.43±2.62	7.40±2.47	0.687	35,645
Hematocrit	38.6±5.6	40.8±4.4	**<0.001**	36,103
Platelet	247±78	247±69	0.862	35,630
Procedural factors				
Length of stay, mean±SD	7.8±7.7	4.3±4.6	**<0.001**	38,386
Has ALIF	159 (19.4)	9770 (26.0)	**<0.001**	38,413
Has CAS	165 (20.2)	2519 (6.7)	**<0.001**	38,413
Mean levels fused, mean±SD	2.6±1.0	2.4±0.8	**<0.001**	38,413
Mean interbody fusions, mean±SD	0.8±1.1	1.2±1.1	**<0.001**	38,413
Unadjusted primary outcomes				
Readmission	84 (12.4)	2130 (6.8)	**<0.001**	32,022
Reoperation	60 (7.3)	1355 (3.6)	**<0.001**	38,413
Morbidity	465 (56.8)	8060 (21.4)	**<0.001**	38,413

Readmission data is relative to 677 patients with pelvic fixation and 31,324 without. #Fisher's exact test. Bold values indicate significance (P<0.05). ASA: American Society of Anesthesiologists, ALIF: Anterior lumbar interbody fusion, CAS: Computer-assisted surgery, COPD: Chronic obstructive pulmonary disease, SD: Standard deviation

PF also had greater total mean levels fused (2.6 vs. 2.4) but fewer mean interbody levels fused (0.8 vs. 1.2) (P < 0.001). The mean operative times with and without PF were 352 ± 144 min and 227 ± 105 min, respectively.

Primary outcomes

Unadjusted analysis revealed that PF was associated with greater readmission (12.4 vs. 6.8%), reoperation (7.3 vs. 3.6%), and morbidity (56.8 vs. 21.4%) (P < 0.001) [Table 1]. After adjusting for significant demographic characteristics, patient comorbidities, and procedural factors, including levels fused and number of interbody fusions, multivariate analysis [Tables 2-4] revealed that PF was still significantly associated with greater readmission (odds ratio [OR] = 1.546, confidence interval [CI]: 1.183–2.019, P < 0.001) and morbidity (OR = 2.740, CI: 2.307–3.254, P < 0.001), but not reoperation (OR = 1.298, CI: 0.935–1.802, P = 0.119).

After adjusting for significant baseline characteristics in Table 1, multivariate analysis [Table 5] also revealed that PF independently predicted overall wound-related complications (OR = 1.533, CI: 1.087–2.160, P = 0.015), deep wound infection (OR = 2.915, CI: 1.827–4.651, P < 0.001), organ space infection (OR = 2.214, CI: 1.199–4.087, P = 0.011), overall pulmonary complications (OR = 1.490, CI: 1.018–2.181, P = 0.040), prolonged mechanical ventilation (OR = 3.840, CI: 2.031–7.261, P < 0.001), urinary

Table 2: Univariate and multivariate analysis of predictors of readmission

	Univariate			Multivariate	
	Readmitted (*n*=2214)	Not readmitted (*n*=29,808)	*P*	OR (95% CI)	*P*
Demographics					
Mean age (years)±SD	64±13	61±13	**<0.001**	1.016 (1.012, 1.021)	**<0.001**
Obese	1219 (58.8)	15,887 (53.5)	**<0.001**	1.210 (1.093, 1.340)	**<0.001**
African American race	215 (10.3)	2266 (8.1)	**<0.001**	1.209 (1.027, 1.423)	**0.022**
Hispanic ethnicity	123 (5.8)	1547 (5.5)	0.596		
Male gender	993 (44.9)	13,804 (46.3)	0.183	1.048 (0.946, 1.162)	0.368
Comorbidities					
Smoker	440 (19.9)	5889 (19.8)	0.894	1.157 (1.016, 1.318)	**0.028**
Dyspnea	175 (7.9)	1774 (6.0)	**<0.001**	1.034 (0.862, 1.240)	0.720
Diabetes mellitus	548 (24.8)	5337 (17.9)	**<0.001**	1.125 (1.000, 1.266)	0.050
COPD	148 (6.7)	1325 (4.4)	**<0.001**	1.169 (0.954, 1.433)	0.132
Heart failure	16 (0.7)	107 (0.4)	**0.008**	1.337 (0.748, 2.393)	0.327
Hypertension	1495 (67.5)	17,248 (57.9)	**<0.001**	1.015 (0.906, 1.137)	0.799
Disseminated cancer	68 (3.1)	267 (0.9)	**<0.001**	2.494 (1.835, 3.390)	**<0.001**
Open wound infection	20 (0.9)	153 (0.5)	**0.016**	0.982 (0.583, 1.652)	0.944
Chronic steroid use	179 (8.1)	1,204 (4.0)	**<0.001**	1.631 (1.360, 1.956)	**<0.001**
Bleeding disorder	58 (2.6)	465 (1.6)	**<0.001**	1.221 (0.904, 1.650)	0.194
Preoperative transfusion	17 (0.8)	107 (0.4)	**0.003**	1.023 (0.580, 1.804)	0.937
ASA class ≥3	1429 (64.6)	14,866 (49.9)	**<0.001**	1.297 (1.161, 1.449)	**<0.001**
Lab values, mean±SD					
Creatinine	1.0±0.5	0.9±0.4	**<0.001**	1.089 (1.003, 1.182)	**0.043**
White cell count	7.7±2.6	7.4±2.5	**<0.001**	1.035 (1.018, 1.052)	**<0.001**
Hematocrit	39.7±5.0	40.8±4.4	**<0.001**	0.965 (0.954, 0.976)	**<0.001**
Platelet	245±74	246±69	0.427		
Procedural factors					
Pelvic fixation	84 (12.4[a])	592 (2.0)	**<0.001**	1.546 (1.183, 2.019)	**0.001**
Has ALIF	546 (24.7)	7740 (26.0)	0.176		
Has ALIF (PF only)	12 (14.3)	115 (19.4)	0.259		
Has CAS	163 (7.4)	2,067 (6.9)	0.445		
Has CAS (PF only)	19 (22.6)	119 (20.1)	0.592		
Mean levels fused	2.5±0.9	2.4±0.9	0.199	0.999 (0.941, 1.061)	0.980
Mean interbody fusions	1.1±1.2	1.2±1.1	0.449	1.046 (0.985, 1.110)	0.140
Length of stay	5.2±4.8	4.3±4.9	**<0.001**	1.007 (1.000, 1.014)	0.059

[a]Percent of patients readmitted within pelvic fixation, #Fisher's exact test. Bold values indicate significance ($P<0.05$). ASA: American Society of Anesthesiologists, ALIF: Anterior lumbar interbody fusion, CAS: Computer-assisted surgery, COPD: Chronic obstructive pulmonary disease, SD: Standard deviation, PF: Pelvic fixation

tract infection (UTI) (OR = 1.811, CI: 1.243–2.637, $P = 0.002$), bleeding events requiring transfusion (OR = 3.299, CI: 2.797–3.891, $P < 0.001$), deep venous thrombosis (DVT)/thrombophlebitis (OR = 2.054, CI: 1.295–3.258, $P = 0.002$), and sepsis/septic shock (OR = 1.713, CI: 1.032–2.845, $P = 0.038$).

Predictor analysis

There were 2214 readmissions (6.9%) in 32,022 patients. On multivariate analysis, increased age ($P < 0.001$), obesity ($P < 0.001$), African American race ($P = 0.022$), smoking ($P = 0.028$), disseminated cancer ($P < 0.001$), chronic steroid use ($P < 0.001$), ASA class ≥ 3 ($P < 0.001$), and other laboratory parameters independently predicted readmission [Table 2].

There were 1415 reoperations (3.7%) in 38,413 patients. On multivariate analysis, obesity ($P = 0.021$), female gender ($P = 0.027$), disseminated cancer ($P = 0.004$), chronic steroid use ($P = 0.024$), bleeding disorder ($P = 0.028$), preoperative transfusion ($P = 0.037$), ASA class ≥ 3 ($P < 0.001$), increased white cell count ($P = 0.001$), increased length of stay ($P < 0.001$), and levels fused ($P = 0.003$) predicted reoperation [Table 3]. Inclusion of ALIF in the final construct was protective against reoperation ($P < 0.001$). Among PF patients only, CAS was protective against reoperation in univariate analysis ($P = 0.049$), but not in multivariate analysis.

Morbidity occurred in 8,525 patients (22.2%). On multivariate analysis, increased age ($P < 0.001$), obesity ($P = 0.041$), African American race ($P < 0.001$), baseline dyspnea ($P = 0.001$),

Table 3: Univariate and multivariate analysis of predictors of reoperation

	Univariate			Multivariate	
	Reoperation (*n*=1415)	No reoperation (*n*=36,998)	*P*	OR (95% CI)	*P*
Demographics					
Mean age (years)±SD	62±13	61±13	**0.001**	1.000 (0.994-1.006)	0.988
Obese	823 (58.9)	19,765 (53.7)	**<0.001**	1.164 (1.023-1.326)	**0.021**
African American race	137 (10.4)	2946 (8.5)	**0.016**	1.185 (0.970-1.447)	0.097
Hispanic ethnicity	87 (6.5)	1963 (5.6)	0.160		
Male gender	601 (42.5)	17,171 (46.4)	**0.004**	0.861 (0.755-0.983)	**0.027**
Comorbidities					
Smoker	261 (18.4)	7234 (19.6)	0.302	0.888 (0.750-1.051)	0.168
Dyspnea	122 (8.6)	2229 (6.0)	**<0.001**	1.191 (0.953-1.489)	0.124
Diabetes mellitus	340 (24.0)	6788 (18.3)	**<0.001**	1.090 (0.937-1.268)	0.262
COPD	88 (6.2)	1659 (4.5)	**0.002**	1.094 (0.841-1.423)	0.502
Heart failure	7 (0.5)	142 (0.4)	0.510	1.695 (0.670-4.292)	0.265
Hypertension	880 (62.2)	21,665 (58.6)	**0.006**	1.105 (0.959-1.274)	0.169
Disseminated cancer	24 (1.7)	380 (1.0)	**0.015**	2.309 (1.316-4.065)	**0.004**
Open wound infection	19 (1.3)	176 (0.5)	**<0.001**	1.065 (0.573-1.980)	0.842
Chronic steroid use	91 (6.4)	1559 (4.2)	**<0.001**	1.324 (1.038-1.690)	**0.024**
Bleeding disorder	41 (2.9)	578 (1.6)	**<0.001**	1.495 (1.044-2.140)	**0.028**
Preoperative transfusion	18 (1.3)	129 (0.3)	**<0.001**	1.829 (1.037-3.226)	**0.037**
ASA class ≥3	896 (63.4)	18,758 (50.8)	**<0.001**	1.338 (1.162-1.540)	**<0.001**
Lab values, mean±SD					
Creatinine	1.0±0.6	0.9±0.4	**0.002**	1.021 (0.916-1.138)	0.708
White cell count	7.7±3.0	7.4±2.5	**<0.001**	1.033 (1.013-1.054)	**0.001**
Hematocrit	40.0±4.7	40.8±4.4	**<0.001**	0.994 (0.980-1.008)	0.411
Platelet	249±76	247±70	0.388		
Procedural factors					
Pelvic fixation	60 (7.3[a])	758 (2.0)	**<0.001**	1.298 (0.935-1.802)	0.119
Has ALIF	301 (21.3)	9,628 (26.0)	**<0.001**	0.759 (0.653-0.882)	**<0.001**
Has ALIF (PF only)	7 (11.7)	152 (20.1)	0.114	0.549 (0.219-1.378)	0.202
Has CAS	109 (7.7)	2575 (7.0)	0.282	1.012 (0.796-1.286)	0.924
Has CAS (PF only)	18 (30.0)	147 (19.4)	**0.049**	1.362 (0.598-3.102)	0.462
Mean levels fused	2.5 (0.9)	2.4 (0.8)	**<0.001**	1.108 (1.035-1.186)	**0.003**
Mean interbody fusions	1.1 (1.2)	1.2 (1.1)	0.158	0.982 (0.923-1.044)	0.557
Length of stay	8.0 (8.0)	4.2 (4.5)	**<0.001**	1.085 (1.074-1.096)	**<0.001**

[a]Percent of patients who required reoperation within pelvic fixation, #Fisher's exact test. Bold values indicate significance ($P<0.05$). ASA: American Society of Anesthesiologists, ALIF: Anterior lumbar interbody fusion, CAS: Computer-assisted surgery, COPD: Chronic obstructive pulmonary disease, SD: Standard deviation, PF: Pelvic fixation

hypertension ($P = 0.046$), chronic steroid use ($P = 0.001$), bleeding disorder ($P < 0.001$), ASA class ≥ 3 ($P < 0.001$), and decreased preoperative hematocrit ($P < 0.001$) and platelet count ($P = 0.001$) predicted morbidity [Table 4]. Levels fused ($P < 0.001$) and interbody levels fused ($P = 0.006$) also predicted morbidity. Hispanic ethnicity ($P < 0.001$), smoking ($P = 0.046$), inclusion of ALIF in the final construct ($P < 0.001$), and CAS ($P = 0.010$) were protective against morbidity.

DISCUSSION

Comparison of surgical solution

Literature comparing multilevel lumbar fusion with and without PF for adult degenerative disease is limited, with current studies restricted by small sample size, poor generalizability, and few patients with degenerative disease. In the present study, early outcomes were significantly worse with adjunctive PF. After adjusting for significant surrogates for poorer health status, which were worse at baseline in the PF group, including specific medical comorbidities and ASA class ≥3, PF was still associated with a 55% increase in odds of readmission and 174% increase in odds of morbidity.

In a combined degenerative and deformity study, Kasten *et al*. demonstrated an overall 54% complication rate with PF, which is in line with the 57% rate observed in the present study.[2] In comparison, the rate of morbidity in deformity surgery in general is about 31%,[7] while in the present study, the rate of morbidity for multilevel lumbar fusion without PF was

Table 4: Univariate and multivariate analysis of predictors of morbidity

	Univariate			Multivariate	
	Morbidity (*n*=8525)	No morbidity (*n*=29,888)	*P*	OR (95% CI)	*P*
Demographics					
Mean age (years)±SD	64 (12)	60 (13)	**<0.001**	1.011 (1.008-1.013)	**<0.001**
Obese	4634 (54.8)	15,954 (53.6)	0.055	1.065 (1.003-1.132)	**0.041**
African American race	705 (8.8)	2,378 (8.5)	0.339	1.212 (1.092-1.346)	**<0.001**
Hispanic ethnicity	399 (4.9)	1,651 (5.9)	**0.001**	0.761 (0.653-0.886)	**<0.001**
Male gender	3585 (42.1)	14,187 (47.5)	**<0.001**	0.949 (0.890-1.012)	0.114
Comorbidities					
Smoker	1393 (16.3)	6102 (20.4)	**<0.001**	0.921 (0.849-0.998)	**0.046**
Dyspnea	694 (8.1)	1657 (5.5)	**<0.001**	1.201 (1.074-1.343)	**0.001**
Diabetes mellitus	1879 (22.0)	5249 (17.6)	**<0.001**	1.048 (0.973-1.129)	0.217
COPD	458 (5.4)	1289 (4.3)	**<0.001**	1.076 (0.941-1.232)	0.281
Heart failure	64 (0.8)	85 (0.3)	**<0.001**	1.017 (0.662-1.565)	0.937
Hypertension	5601 (65.7)	16,944 (56.7)	**<0.001**	1.071 (1.001-1.146)	**0.046**
Disseminated cancer	211 (2.5)	193 (0.6)	**<0.001**	1.125 (0.864-1.464)	0.382
Open wound infection	104 (1.2)	91 (0.3)	**<0.001**	1.022 (0.693-1.511)	0.909
Chronic steroid use	526 (6.2)	1124 (3.8)	**<0.001**	1.238 (1.089-1.407)	**0.001**
Bleeding disorder	240 (2.8)	379 (1.3)	**<0.001**	1.516 (1.244-1.846)	**<0.001**
Preoperative transfusion	96 (1.1)	51 (0.2)	**<0.001**	1.455 (0.969-2.185)	0.070
ASA class ≥3	5288 (62.1)	14,366 (48.1)	**<0.001**	1.182 (1.108-1.261)	**<0.001**
Lab values, mean±SD					
Creatinine	1.0±0.5	0.9±0.4	**<0.001**	1.029 (0.963-1.099)	0.398
White cell count	7.4±2.6	7.4±2.4	0.823		
Hematocrit	39.2±5.0	41.2±4.2	**<0.001**	0.938 (0.931-0.944)	**<0.001**
Platelet	245±77	248±67	**0.003**	0.999 (0.999-1.000)	**0.001**
Procedural factors					
Pelvic fixation	465 (56.8[a])	353 (43.2)	**<0.001**	2.740 (2.307-3.254)	**<0.001**
Has ALIF	1628 (19.1)	8301 (27.8)	**<0.001**	0.644 (0.600-0.692)	**<0.001**
Has ALIF (PF only)	78 (16.8)	81 (22.9)	**0.027**	0.703 (0.461-1.071)	0.101
Has CAS	589 (6.9)	2095 (7.0)	0.748	0.855 (0.759-0.962)	**0.010**
Has CAS (PF only)	81 (17.4)	84 (23.8)	**0.024**	0.640 (.400-1.026)	0.064
Mean levels fused	2.6±1.0	2.4±0.8	**<0.001**	1.276 (1.232-1.321)	**<0.001**
Mean interbody fusions	1.1±1.2	1.2±1.1	**0.020**	1.042 (1.012-1.073)	**0.006**
Length of stay	6.4±6.6	3.7±3.8	**<0.001**	1.179 (1.167-1.190)	**<0.001**

[a]Percent of patients who experienced morbidity within pelvic fixation, #Fisher's exact test. Bold values indicate significance ($P<0.05$). ASA: American Society of Anesthesiologists, ALIF: Anterior lumbar interbody fusion, CAS: Computer-assisted surgery, COPD: Chronic obstructive pulmonary disease, SD: Standard deviation, PF: Pelvic fixation

21%. These findings suggest that PF provides a significantly greater element of morbidity to multilevel lumbar fusion.[7,8] Thus, PF should be utilized conservatively when treating degenerative lumbar pathology.

Moreover, the rate of readmission in deformity surgery is 6% and, with PF, is 7%.[4,7] For patients undergoing multilevel fusion for degenerative purposes without PF in the present study, the readmission rate was 7%. In light of the 12% readmission rate, we found with PF, these findings suggest that degenerative patients, who are inherently older on average, are less able to tolerate more invasive and morbid procedures, such as fixation to the pelvis, resulting in greater readmission and ultimately greater health-care costs.[9,10] This is particularly significant given the difference in length of stay we observed for patients with (8 days) and without PF (4 days).

Reoperation rates no longer statistically differed between the surgical techniques after multivariate analysis. Interestingly, in deformity surgery, PF has been associated with increased short-term reoperation, as well as readmission and morbidity.[1] PF has even been associated with high rates of 6-month postoperative mechanical failure in deformity surgery, ranging from 15% to 36%.[2,11] In the present degenerative study, the early reoperation rate with PF was 7.3%, considerably below that seen in deformity surgery. Therefore, the lack of a finding of a significant difference in early reoperation suggests that the mechanical stresses placed on the construct when treating

Table 5: Univariate and multivariate analysis of specific complications by presence or absence of pelvic fixation

Specific complications	With pelvic fixation, *n* (%)	Without pelvic fixation, *n* (%)	Univariate *P*	OR (95% CI)	Multivariate *P*
Wound-related complication	52 (6.4)	955 (2.5)	**<0.001**	1.533 (1.087-2.160)	**0.015**
Superficial site infections	10 (1.2)	432 (1.1)	0.846		
Deep wound infections	26 (3.2)	279 (0.7)	**<0.001**	2.915 (1.827-4.651)	**<0.001**
Organ space infections	15 (1.8)	185 (0.5)	**<0.001**#	2.214 (1.199-4.087)	**0.011**
Dehiscence	4 (0.5)	149 (0.4)	0.571#		
Pulmonary complication	40 (4.9)	769 (2.0)	**<0.001**	1.490 (1.018-2.181)	**0.040**
Pneumonia	9 (1.1)	345 (0.9)	0.589		
Re-intubation	11 (1.3)	179 (0.5)	**0.003**#	1.577 (0.748-3.325)	0.231
Pulmonary embolism	14 (1.7)	288 (0.8)	**0.002**	1.712 (0.957-3.062)	0.070
Prolonged ventilation	16 (2.0)	137 (0.4)	**<0.001**	3.840 (2.031-7.261)	**<0.001**
Renal complication	6 (0.7)	142 (0.4)	0.138		
Renal insufficiency	0	84 (0.2)	0.429		
Acute renal failure	6 (0.7)	59 (0.2)	**0.003**#	1.418 (0.400-5.029)	0.589
Urinary tract infection	37 (4.5)	718 (1.9)	**<0.001**	1.811 (1.243-2.637)	**0.002**
Stroke/CVA	3 (0.4)	78 (0.2)	0.248		
Myocardial infarction	2 (0.2)	140 (0.4)	0.773		
Cardiac arrest requiring CPR	4 (0.5)	83 (0.2)	0.115#		
Bleeding transfusions	402 (49.1)	6,132 (16.3)	**<0.001**	3.299 (2.797-3.891)	**<0.001**
DVT/thrombophlebitis	23 (2.8)	394 (1.0)	**<0.001**	2.054 (1.295-3.258)	**0.002**
Sepsis/septic shock	25 (3.1)	423 (1.1)	**<0.001**	1.713 (1.032-2.845)	**0.038**

#Fisher's exact test. Bold values indicate significance ($P<0.05$). CPR: Cardiopulmonary resuscitation, DVT: Deep venous thrombosis, CVA: Cerebrovascular accident, OR: Odds ratio, CI: Confidence interval

degenerative lumbar pathology are not severe enough to promote early device failure. On the contrary, it also suggests that PF does not offer an appreciable benefit to early construct integrity.

Specific complications

PF has been associated with severe sexual dysfunction, rates of which exceed 40%.[3] PF has even been posited as a risk factor for posterior hip dislocation after total hip arthroplasty; however, this has not been demonstrated beyond a single case report.[12] While the NSQIP database does not evaluate for the above complications, we did identify 3.3-times increased odds of transfusion, 1.5-times increased odds of a wound-related complication, and 2.1-times increased odds of DVT/thrombophlebitis.

The increased risk of blood loss with PF has been documented in deformity surgery.[4,7,8,13,14] Kothari *et al*. demonstrated a 74% transfusion rate for patients undergoing PF.[4] We observed a transfusion rate of 49%, likely lower than the 74% figure as that included larger constructs extending into the thoracic spine. However, this is notably higher than the 16% transfusion rate for patients without PF in the present study. In comparison, transfusion rates for up to two-level posterior and anterior interbody fusion are 12% and 10%, respectively.[15]

The associations between PF and wound-related complication and DVT are not surprising given the greater invasiveness and more extensive surgical dissection, operative time (352 vs. 227 min) and resultant release of inflammatory factors, and potential prominence of hardware.[4,16] We specifically observed a greater rate of deep wound and organ space infections with PF, which may be directly related to the effects of transfusion on immune system modulation as well as increased operative time.[4,17,18] Interestingly, Kothari *et al*. did not identify PF as a risk factor for wound-related complications or DVT.

In addition, we observed 1.5-times greater odds of pulmonary complication with PF. In deformity surgery, pulmonary complications have been shown to be significantly greater in long-segment fusions, which are more likely to have fixation to the pelvis, than short-segment fusions.[19] Further, Urban *et al*. demonstrated greater rates of pneumonia with PF.[1] Thus, the greater rates of pulmonary injury observed could be related to acute inflammatory events incited by embolization of sacral and iliac fat and marrow debris from the greater level of morbidity that PF adds to multilevel lumbar fusion.[20]

Predictor variables

No studies have reported on risk factors associated with poor early outcomes in patients with degenerative disease undergoing PF. In the deformity literature, age, elevated ASA class, and bleeding disorder have been associated with poor outcomes and postoperative complications.[7,8,11,14,18] In other spine research literature, diabetes and hypertension were significant risk factors for readmission.[21] While we did not identify diabetes as a risk factor for poor early outcomes, we did find that increased age, obesity, and ASA class ≥3 predicted poor 30-day outcomes. We also identified hypertension as a risk factor for morbidity. Thus, these findings suggest that preoperative patient factors should be strongly considered in patient selection and surgical planning, particularly when performing more morbid adjunct procedures such as PF.

Further, we observed that African American race predicted readmission and morbidity. African American race has previously been shown to predict poorer outcomes in spine surgery, with researchers noting an interplay between differences in postoperative care, socioeconomic factors, and greater baseline comorbidities playing a role.[22,23] Interestingly, we found that Hispanic ethnicity was protective against morbidity. These findings suggest that there are factors beyond the NSQIP dataset, such as variables related to geographic location, socioeconomic and insurance status, and hospital type, that would aid in understanding the relationship between race, ethnicity, and outcomes in spine surgery.

Procedural factors

The inclusion of ALIF in the final construct predicted reduced reoperation and morbidity. The utilization of CAS also predicted reduced morbidity. Given the significantly higher rate of bleeding events requiring transfusion observed with PF, the reduced early morbidity seen with ALIF is most likely related to a lower rate of blood loss and subsequently fewer transfusions and other associated complications.[15] This is because the anatomic dissection in ALIF is through an avascular plane. Minimizing blood loss and surgical dissection have also been postulated as mechanisms for reduced morbidity seen with CAS.[5] This also raises the point of different operational approaches as being more or less beneficial for blood loss. While only 4.8% of patients with ALIF had CAS, the use of CAS with ALIF may have also bolstered the strong protective effect seen with ALIF. However, a more in-depth analysis would be beyond the scope of this study.

In addition, supplementary ALIF provides a restorative effect on reducing biomechanical strain at the lumbosacral junction when used in PF. O'Brien *et al*. noted that supplementary ALIF particularly augments fusion construct strength at the sacropelvic region from L4 to the S1 vertebral body and cephalad aspects of the sacral ala, thereby delivering a significant biomechanical advantage to counter lumbosacral junctional bending moments and dorsal pullout forces seen with PF.[6] Therefore, it is possible that this protective effect of ALIF against screw pullout and instrumentation failure contributed to the reduction in reoperations.

While operative time has been shown to be a highly influential factor in determining outcomes,[14] the data were only available for <80% of patients and therefore were not included in univariate or multivariate analyses. In addition, meaningful interpretation of operative time in the present study would be limited by the variability of procedures included in the present study that cannot be accounted for by the NSQIP dataset (i.e., surgical approaches, fixation to the pelvis, patient positioning, and so forth).

Limitations

While the NSQIP database provides for surrogates of bone quality, such as smoking status and chronic steroid use, the database does not provide history of osteoporosis. The database also does not provide patient-reported outcomes or radiographic parameters. Having these variables would provide additional points of discussion but ultimately would not impact our conclusions. In the context of PF, the NSQIP dataset cannot distinguish between S2-alar-iliac screw and traditional iliac screw fixation, which may have different outcome profiles. Finally, the database lacks adequate and complete ICD codes to verify whether each patient truly had degenerative lumbar disease. However, our carefully planned series of CPT-based exclusions, restriction of analysis to the lumbar spine, and overall results helped to minimize inclusion of patients with solely deformity pathology or those with infectious or spine-oncologic diagnoses.

CONCLUSION

In this national database study of 38,413 patients who underwent multilevel lumbar fusion for degenerative disease, we found that supplementary PF was associated with a 1.5-times increase in odds 30-day readmission and a 2.7-times increase in odds of morbidity compared to lumbar fusion without PF, with significantly greater rates of transfusion, DVT/thrombophlebitis, sepsis, UTI, prolonged mechanical ventilation, and wound-related complications. These findings held true despite controlling for patient- and procedural-related factors, including surrogates for increased invasiveness such as total number of levels fused and number of interbody fusions. After controlling for patient-related factors, there were no technique-based differences in 30-day reoperation. Increased age, ASA class ≥3, obesity, and other demographic factors and medical comorbidities predicted poorer 30-day outcomes, while anterior column support was protective against reoperation and morbidity, and CAS was protective against morbidity.

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Conflicts of interest

There are no conflicts of interest.

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Appendix A: Inclusion and exclusion CPT codes

	CPT codes
Stratified by	
Pelvic fixation	22848
Included	
Standalone PLIF/TLIF	Primary code: 22630; additional level code: 22632
Posterolateral fusion	Primary code: 22612; additional level code: 22614
PLIF/TLIF bundled with posterolateral fusion	Primary code: 22633; additional level code: 22634
Standalone ALIF/LLIF	Primary code: 22558; additional level code: 22585
Excluded	
Cervical fusion	22600, 22590, 22551, 22552, 22554
Thoracic fusion	22610, 22556
Non-elective	10140, 11305, 20661, 22010, 22305, 22315, 22326, 22327
Deformity	22800, 22802, 22804, 22806, 22808, 22810, 22812, 22818
Revision	20680, 22830, 22849, 22850, 22852, 22855
Osteotomy	22210, 22212, 22214, 22216, 22220, 22222, 22224, 22226
Intraspinal lesion	63300, 63301, 63304, 63308
Other procedures	22858

Multilevel (≥2-level) fusion was identified by ≥1 entry of additional level code for a specific primary code, or ≥2 entries of separate primary codes with or without their respective additional level codes. Patients who did not meet this criteria were considered to have single level fusion and were excluded. Because thoracic fusion extending into the lumbar spine can be coded for using lumbar CPT codes, we also excluded patients who had >4 additional level codes. ALIF: Anterior lumbar interbody fusion. LLIF: Lateral lumbar interbody fusion. PLIF: Posterior lumbar interbody fusion. TLIF: Transforaminal lumbar interbody fusion.