Original Study

Complications following single-level interbody fusion procedures: an ACS-NSQIP study

Jamal N. Shillingford[1], Joseph L. Laratta[2], Joseph M. Lombardi[1], John D. Mueller[1], Meghan Cerpa[1], Hemant P. Reddy[1], Comron Saifi[3], Charla R. Fischer[4], Ronald A. Lehman Jr[1]

[1]Department of Orthopaedic Surgery, Columbia University Medical Center, The Spine Hospital at New York-Presbyterian, New York, NY, USA; [2]Norton Leatherman Spine Center, Louisville, KY, USA; [3]Penn Orthopaedics, University of Pennsylvania Perelman School of Medicine, Philadelphia, PA, USA; [4]Department of Orthopaedic Surgery, Hospital for Joint Diseases at New York University, New York, NY, USA

Contributions: (I) Conception and design: JN Shillingford, JL Laratta, CR Fischer, RA Lehman Jr; (II) Administrative support: CR Fischer, RA Lehman Jr; (III) Provision of study materials or patients: CR Fischer, RA Lehman Jr, C Saifi; (IV) Collection and assembly of data: JN Shillingford, JL Laratta; (V) Data analysis and interpretation: JN Shillingford, JL Laratta, M Cerpa, JD Mueller; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: Joseph L. Laratta, MD. Norton Leatherman Spine Center, 210 E Gray Street, Suite 900, Louisville, KY 40202, USA.
Email: larattaj@gmail.com.

Background: Controversy exists over the ability of various lumbar interbody fusion techniques to realign global and regional balance and their effect on patient outcomes. This is a retrospective cohort study to compare thirty-day postoperative outcomes between anterior and posterior interbody fusion techniques within a large national database.

Methods: A retrospective cohort study utilizing the National Surgical Quality Improvement Program (NSQIP) database included 2,372 (29.9%) single-level anterior/direct lateral interbody fusions (ALIF/DLIF) and 5,563 (70.1%) single-level posterior/transforaminal lateral interbody fusions (PLIF/TLIF) between 2013 and 2014. Emergent cases, fracture cases, and preoperative compromised wounds were not analyzed. Primary thirty-day outcomes included mortality, return to operating room, readmission, length of stay, and other major complications. Minor outcomes included urinary tract infection, superficial incisional site infection, and perioperative blood transfusion within 72 hours.

Results: ALIF/DLIF was performed more for degenerative lumbar disc disease (31.0% *vs.* 13.9%, P<0.001), whereas PLIF/TLIF was utilized more for spondylolisthesis (19.1% *vs.* 24.4%, P<0.001). Thirty-day mortality was significantly higher with ALIF/DLIF (0.3% *vs.* 0.1%, P=0.021) in the univariate analysis and persisted in the multivariate analysis (OR =12.8; 95% CI, 1.37–119.6; P=0.025). Significantly more PLIF/TLIF patients required blood transfusions within 72 hours of surgery (9.6% *vs.* 7.6%, P=0.005). This difference did not persist in the multivariate analysis after controlling for covariates. Elevated ASA physical status classification, age >60, prior bleeding disorder, and preoperative anemia were significantly associated with blood transfusion requirement. More deep venous thrombosis occurred (DVT) with ALIF/DLIF compared to PLIF/TLIF (1.0% *vs.* 0.6%, P=0.025), which persisted in the multivariate analysis (OR =2.03; 95% CI, 1.13–3.65; P=0.017).

Conclusions: Although numerous techniques can be utilized in the treatment approach to various lumbar pathologies, anterior approaches have an increased risk of developing a perioperative DVT and early mortality. Transfusion risk is more strongly associated with elevated American Society of Anesthesiologists (ASA) class, increased age, preoperative anemia, and patients with bleeding disorders.

Keywords: Interbody fusion; transforaminal lateral interbody fusion (TLIF); anterior lateral interbody fusion (ALIF); posterior lateral interbody fusion (PLIF); National Surgical Quality Improvement Program (NSQIP); American Society of Anesthesiologists (ASA)

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Introduction

Degenerative disk disease and spondylolisthesis are two of the most common causes of back pain and spinal instability in adults (1-3). Lower back pain accounts for approximately 2.3% of all office visits and greatly decreases the quality of life of affected patients (1,4). Both surgical and non-surgical treatments have been described to help alleviate back pain and improve spinal stability.

Surgical treatments typically involve a combination of neural decompression and spinal arthrodesis. In an effort to provide more rigid constructs, increase fusion rates, and provide indirect neural decompression, interbody fusions are being increasingly utilized in spine surgery. Anterior lumbar interbody fusion (ALIF), direct lateral interbody fusion (DLIF), transforaminal lumbar interbody fusion (TLIF), and posterior lumbar interbody fusion (PLIF) are the most commonly described procedures to achieve anterior column arthrodesis.

To date, few studies exist on the risk profiles and outcomes of the various interbody fusion techniques. Moreover, much of our literature is based on the evidence obtained from industry-funded implant studies with pre-selected surgeons performed on small patient populations with varying levels of surgery and spinal pathologies. Therefore, the goal of our study was to investigate outcomes of single-level interbody fusion by use of anterior/lateral versus posterior approaches performed by the general population of spine surgeons. We conducted a retrospective analysis of the American College of Surgeon's National Surgical Quality Improvement Program (NSQIP) database to compare 30-day post-operative outcomes between ALIF/DLIF and PLIF/TLIF techniques. We hypothesized that ALIF/DLIF procedures would likely result in higher rates of deep venous thrombosis and catastrophic bleeding from manipulation of the great vessels leading to higher early mortality rates.

Methods

The American College of Surgeon's NSQIP database was retrospectively analyzed for this study. NSQIP is a national database that aggregates over 150 variables including preoperative factors, intraoperative factors, and thirty-day postoperative morbidity and mortality data from major surgical procedures, collected by trained surgical clinical reviewers. The database was developed in an attempt to improve surgical quality among hospitals on a national level. Data collection is of the highest quality, and participating sites undergo rigorous inter-rater reliability audits to ensure validity.

A total of 7,935 patients were identified by unique current procedural terminology (CPT) codes and divided into an ALIF/DLIF group (anterior lumbar, extreme lateral, direct lateral, and oblique lateral interbody fusion) and a PLIF/TLIF interbody fusion group (posterior lumbar and TLIF). The study included 2,372 (29.9%) patients that underwent a single-level ALIF/DLIF fixation (CPT 22558), with supplemental anterior or posterior fixation, and 5,563 (70.1%) that underwent a single-level PLIF/TLIF (CPT 22630 or 22633) between 2013 and 2014.

Emergent cases, fracture cases, and infection cases, including those with osteomyelitis or preoperative compromised wounds, were not included in the analysis. Patient demographics including age, gender, race/ethnicity, preoperative comorbidities, and overall preoperative health status as defined by the American Society of Anesthesiologists classification (ASA) were collected. The most common postoperative diagnoses were noted and included the following: degeneration of lumbar or lumbosacral intervertebral disc, acquired spondylolisthesis, lumbosacral spondylosis without myelopathy, displacement of lumbar intervertebral disc without myelopathy, spinal stenosis of the lumbar region and congenital spondylolisthesis. Patients were divided into four age groups: 60 years or younger, 61 to 70 years, 71 to 80 years, and 81 years and older. Preoperative comorbidities included diabetes requiring oral medication or insulin, hypertension requiring medication, congestive heart failure within 30 days before surgery, history of severe chronic obstructive pulmonary disease, current smoking within one year of surgery, renal disease currently on dialysis, bleeding disorders (e.g., hemophilia, thrombocytopenia, vitamin K deficiency, current chronic anticoagulation therapy), and corticosteroid use for chronic condition. Preoperative lab abnormalities were also included as covariates: albumin <3 g/dL, white blood count >12,000 cells/mcL, hematocrit <33%, platelets <100,000/mcL, and creatinine >1.5 mg/dL.

Primary outcomes included 30-day postoperative mortality, return to operating room, unplanned readmission within 30 days post-procedure, and length of stay greater than 30 days. Secondary outcomes were divided into major and minor complications. Major complications defined as: perioperative myocardial infarction, pulmonary embolism, deep venous thrombosis, sepsis, septic shock, deep infection, failure to wean or unplanned intubation,

cerebrovascular accident, acute renal failure, and progressive renal insufficiency. Minor complications included urinary tract infection, superficial incisional site infection, and perioperative blood transfusion within 72 hours.

Univariate analysis was conducted to determine the differences between outcomes utilizing Chi-squared or Fisher exact testing for categorical variables and independent student *t*-test for continuous variables. Additionally, a multivariate logistic regression was conducted to determine odds ratios and significant associations for several dependent outcomes while controlling for numerous covariates. Propensity score-matching was used to closely match the two groups in a 1:1 fashion to reduce pre-surgical differences in patient characteristics and create a more homogenous cohort for comparison. Findings were considered statistically significant when P<0.05. IBM SPSS Statistics Version 24 was utilized to conduct the analysis. The ACS NSQIP is de-identified and was therefore deemed exempt by our institutional review board.

Results

Degenerative disc disease was by far the most common post-operative diagnosis for which patients underwent interbody fixation, followed by acquired spondylolisthesis. ALIF/DLIF fusion techniques were performed more often in patients with degenerative lumbar disc disease (31.0% *vs.* 13.9%, P<0.001), whereas PLIF/TLIF techniques were utilized more for patients with spondylolisthesis (13.2% *vs.* 17.8%, P<0.001). Length of hospital stay and mean operation time were significantly longer statistically in the PLIF/TLIF group (3.6±4.3 *vs.* 3.4±4.2 days, P<0.05) and (200.2±94.4 *vs.* 192.0±112.8 minutes, P=0.001). These differences, however, are not clinically significant. Preoperative patient demographics and characteristics were similar between the two groups, but any preoperative differences are displayed in *Tables 1*,*2*.

Major and minor complications were similar between the two groups with a few important differences. Thirty-day mortality was significantly higher for the ALIF/DLIF group (0.3% *vs.* 0.1%, P=0.021) in the univariate analysis. Similarly, significantly more patients developed deep venous thrombosis in the ALIF/DLIF group compared to the PLIF/TLIF (1.0% *vs.* 0.6%, P=0.025). Contrastingly, significantly more patients in the PLIF/TLIF group required blood transfusions within 72 hours of surgery (9.6% *vs.* 7.6%, P=0.005).

Upon multivariate analysis, numerous associations were noted between outcomes and covariates. The increase in mortality for the ALIF/DLIF group persisted in the multivariate analysis even after controlling for preoperative differences in comorbidities and other patient characteristics [odds ratio (OR), 12.79; 95% confidence interval (CI), 1.37–119.61; P=0.025]. No other preoperative variables were predictors for increased mortality in the multivariate model (*Table 3*). There were 7 deaths in the ALIF/DLIF group which included: postoperative cardiac arrest (n=2), massive pulmonary embolism (n=1), septic shock from an abdominal infection related to the anterior surgery (n=1), pneumonia (n=1), and unknown causes (n=2). There were 4 deaths in the posterior group which included: multi-organ failure from septic shock (n=1), pneumonia (n=1), respiratory complications (n=1), and unknown cause (n=1).

The difference in perioperative blood transfusion between the ALIF/DLIF and PLIF/TLIF groups did not persist in the multivariate analysis after controlling for covariates including preoperative laboratory values (*Table 4*). However, several other factors were predictive of perioperative transfusion. Patients with ASA scores ≥3 required more transfusions (OR, 1.46; 95% CI, 1.16–1.85; P=0.002). Older patients had an increased likelihood of requiring blood transfusions relative to younger patients under 60 years of age: 61–70 years (OR, 1.62; 95% CI, 1.25–2.10; P<0.001) and ≥71 years (OR, 1.71; 95% CI, 1.27–2.30, P<0.001). Similarly, patients with preoperative bleeding disorders were more likely to have perioperative blood transfusions relative to patients without a disorder (OR, 1.94; 95% CI, 1.00–3.76, P=0.05). Patient factors including female gender (OR, 1.42; 95% CI, 1.14–1.77; P=0.002) and preoperative anemia (OR, 5.63; 95% CI, 3.74–8.48; P<0.001) were also associated with an increased likelihood of blood transfusion. The multivariate analysis also showed that an ALIF/DLIF procedure is a predictor of developing a perioperative DVT (OR, 2.03; 95% CI, 1.13–3.65; P=0.017) (*Table 5*). Moreover, patients with preoperative bleeding disorders (OR, 4.73; 95% CI, 1.72–13.00; P=0.003) and low preoperative hematocrits (OR, 3.59; 95% CI, 1.32–9.78; P=0.012) were more likely to develop a DVT. Contrastingly, female patients were less likely to develop a perioperative DVT (OR, 0.49; 95% CI, 0.27–0.90; P=0.021).

An analysis of propensity score-matched groups was conducted producing a cohort of 4,738 patients, with 2,369 patients in each group. Preoperative patient characteristics were used to closely match the two groups in a 1:1 fashion, reducing pre-surgical patient characteristic differences. *Table 6* summarizes the univariate comparisons

Table 1 Univariate analysis of anterior/lateral interbody fusion (ALIF/DLIF) versus posterior/transforaminal lateral interbody fusion (PLIF/TLIF) procedures

Characteristic	ALIF/DLIF	PLIF/TLIF	P value
Total procedures	2,372 (29.9)	5,563 (70.1)	–
Post-operative diagnosis			<0.001
Degeneration of lumbar or lumbosacral intervertebral disc (ref)	735 (31.0)	774 (13.9)	
Acquired spondylolisthesis	314 (13.2)	992 (17.8)	
Lumbosacral spondylosis without myelopathy	229 (9.7)	624 (11.2)	
Displacement of lumbar intervertebral disc without myelopathy	223 (9.4)	790 (14.2)	
Spinal stenosis of lumbar region	253 (10.7)	853 (15.3)	
Spondylolisthesis congenital	141 (5.9)	366 (6.6)	
Operative characteristics			0.001
Operation time (min)	192.0±112.8	200.2±94.4	
ASA category			<0.001
ASA 1 (ref)	124 (5.2)	218 (3.9)	
ASA 2	1,329 (56.0)	2,894 (52.0)	
ASA 3	894 (37.7)	2,346 (42.2)	
ASA 4	25 (1.1)	105 (1.9)	
Age	54.8±13.9	58.1±13.4	<0.001
≤60 years (ref)	1,479 (62.4)	2,952 (53.1)	<0.001
61–70 years	556 (23.5)	1,585 (28.5)	
71–80 years	296 (12.5)	881 (15.8)	
>80 years	38 (1.6)	141 (2.5)	
Sex			0.274
Female	1,297 (54.7)	3,116 (56.0)	
Male	1,075 (45.3)	2,447 (44.0)	
Comorbidities			
Diabetes	296 (12.5)	930 (16.7)	<0.001
Hypertension	1,076 (45.4)	2,912 (52.3)	<0.001
Congestive heart failure	3 (0.1)	20 (0.4)	0.077
Chronic obstructive pulmonary disease	68 (2.9)	260 (4.7)	<0.001
Renal disease on dialysis	2 (0.1)	7 (0.1)	1.000
Corticosteroid use	70 (3.0)	186 (3.3)	0.365
Smoker	302 (12.7)	672 (12.1)	0.418
Bleeding disorder	32 (1.3)	75 (1.3)	0.998
Pre-operative lab abnormalities			
Albumin <3 g/dL	6 (0.7)	26 (1.1)	0.214
WBC >12×10^9/L	81 (3.7)	204 (4.0)	0.533
Hematocrit <33%	60 (2.7)	150 (2.9)	0.597
Platelets <100,000/mL	13 (0.6)	33 (0.7)	0.788
Cr >1.5 mg	43 (2.1)	119 (2.5)	0.424

Table 1 *(continued)*

Table 1 *(continued)*

Characteristic	ALIF/DLIF	PLIF/TLIF	P value
Race/ethnicity			0.183
Asian	24 (1.0)	67 (1.2)	
African American	173 (7.3)	424 (7.6)	
White (Hispanic and non-Hispanic)	2,038 (85.9)	4,694 (84.4)	
American Indian or Alaska Native	13 (0.5)	37 (0.7)	
Native Hawaiian or Pacific Islander	1 (0.04)	16 (0.3)	
Hispanic	137 (5.8)	288 (5.2)	0.278
Length of stay, days	3.35±4.18	3.56±4.34	0.049

Data are shown as mean ± SD or number (%).

Table 2 Frequency of in-hospital complications in anterior/lateral interbody fusion procedures (ALIF/DLIF) versus posterior/transforaminal lateral interbody fusion (PLIF/TLIF) procedures

Complication	ALIF/DLIF, n (%)	PLIF/TLIF, n (%)	P value
≥1 major complication	92 (3.9)	222 (4.0)	0.815
Unplanned readmission	84 (3.5)	194 (3.5)	0.905
Mortality	7 (0.3)	4 (0.1)	0.021
Deep venous thrombosis	24 (1.0)	31 (0.6)	0.025
Perioperative blood transfusion	180 (7.6)	532 (9.6)	0.005
30-day return to OR	20 (0.8)	72 (1.3)	0.086
Hospital stay >30 days	3 (0.1)	5 (0.1)	0.703
Perioperative myocardial infarction	4 (0.2)	12 (0.2)	0.790
Pulmonary embolism	8 (0.3)	21 (0.4)	0.786
Sepsis	7 (0.3)	31 (0.6)	0.122
Septic shock	2 (0.1)	15 (0.3)	0.102
Superficial incisional infection	23 (1.0)	60 (1.1)	0.662
Deep incisional surgical site infection	10 (0.4)	31 (0.6)	0.440
Organ/space infection	5 (0.2)	12 (0.2)	0.965
Unplanned reintubation	6 (0.3)	14 (0.3)	0.992
Ventilator >48 hours	9 (0.4)	9 (0.2)	0.062
Pneumonia	18 (0.8)	38 (0.7)	0.712
Urinary infection	27 (1.1)	83 (1.5)	0.217
Acute renal failure	1 (0.04)	3 (0.1)	1.000
Progressive renal insufficiency	4 (0.2)	6 (0.1)	0.498
Cardiac arrest requiring CPR	2 (0.1)	2 (0.04)	0.588
Stroke	0 (0.0)	9 (0.2)	0.066

Table 3 Independent risk factors for mortality by multivariate logistic regression analysis

Effect	Odds ratio	95% confidence limits	P
ALIF/DLIF	12.79	1.37–119.61	0.025
ASA ≥3	1.54	0.17–14.17	0.702
Age (reference: ≤60 years)			
61–70 years	0.42	0.04–4.7	0.484
≥71 years	0.65	0.05–7.92	0.738
Female	1.1	0.18–6.87	0.921
Diabetes	3.22	0.37–27.8	0.288
Hypertension	0.77	0.08–7.38	0.821
COPD	6.449	0.59–70.27	0.126
Corticosteroid use	0.771	0.08–7.38	0.821
Diagnosis (reference: degeneration of lumbar or lumbosacral intervertebral disc)			
Displacement of lumbar intervertebral disc without myelopathy	2.82	0.17–47.56	0.472
Spinal Stenosis of lumbar region	7.39	0.68–80.22	0.100

ALIF, anterior lateral interbody fusions; DLIF, direct lateral interbody fusions; COPD, chronic obstructive pulmonary disease.

Table 4 Independent risk factors for transfusion by multivariate logistic regression analysis

Effect	Odds ratio	95% confidence limits	P
ALIF/DLIF	0.82	0.64–1.05	0.121
ASA ≥3	1.46	1.16–1.85	0.002
Age (reference: ≤60 years)			
61–70 years	1.62	1.25–2.10	<0.001
≥71 years	1.71	1.27–2.30	<0.001
Female	1.42	1.14–1.77	0.002
Diabetes	1.15	0.87–1.51	0.328
Hypertension	1.00	0.79–1.28	0.974
COPD	1.05	0.65–1.68	0.849
Corticosteroid use	0.88	0.5–1.54	0.651
Smoker	0.82	0.56–1.19	0.296
Bleeding disorder	1.94	1.00–3.76	0.05
WBC >12×10^9/L	0.84	0.48–1.47	0.543
Hematocrit <33%	5.63	3.74–8.48	<0.001
Platelets <100,000/mL	1.9	0.77–4.710	0.167
Cr >1.5 mg	1.04	0.56–1.92	0.897
Diagnosis (reference: degeneration of lumbar or lumbosacral intervertebral disc)			
Displacement of lumbar intervertebral disc without myelopathy	0.7	0.47–1.04	0.074
Spinal stenosis of lumbar region	1.16	0.84–1.61	0.372

ALIF, anterior lateral interbody fusions; DLIF, direct lateral interbody fusions; COPD, chronic obstructive pulmonary disease.

Table 5 Independent risk factors for deep venous thrombosis (DVT) by multivariate logistic regression analysis

Effect	Odds ratio	95% CI	P value
ALIF/DLIF	2.03	1.13–3.65	0.017
ASA ≥3	1.71	0.88–3.33	0.112
Age (reference: ≤60 years)			
61–70 years	1.51	0.73–3.12	0.269
≥71 years	1.68	0.76–3.73	0.198
Female	0.49	0.27–0.90	0.021
Diabetes	0.57	0.24–1.34	0.199
Hypertension	0.98	0.51–1.92	0.965
COPD	0.88	0.21–3.75	0.865
Corticosteroid use	2.21	0.77–6.36	0.141
Smoker	0.20	0.03–1.45	0.110
Bleeding disorder	4.73	1.72–13.00	0.003
Hematocrit <33%	3.59	1.32–9.78	0.012
Platelets <100,000/mL	1.31	0.16–10.63	0.801
Cr >1.5 mg	0.82	0.18–3.79	0.803

ALIF, anterior lateral interbody fusions; DLIF, direct lateral interbody fusions; COPD, chronic obstructive pulmonary disease.

of perioperative outcomes for the propensity score-matched groups. When compared to the PLIF/TLIF group in this analysis, the ALIF/DLIF group was found to have a higher rate of mortality (0.3% *vs.* 0.0%, P=0.016), DVT (1.0% *vs.* 0.3%, P=0.001), and perioperative blood transfusion (7.6% *vs.* 5.9%, P=0.018). A multivariate analysis again confirmed that procedure type was not significantly associated with need for transfusion, but rather age and preoperative hematocrit more significantly impacted transfusion risk.

Discussion

Carefully selected patients with degenerative disc disease and spondylolisthesis may benefit from surgical intervention with interbody fusion. Regardless of the interbody approach, the principles and technique remain the same. The intervertebral disc is removed and vertebral endplates are decorticated, followed by graft placement and supplemental instrumentation. The decision on approach depends on patient characteristics, surgeon familiarity, and analysis of the risk-benefit profile. This study is the first of its kind to comprehensively delineate the differences between single-level ALIF/DLIF and PLIF/TLIF performed by a general population of spine surgeons with respect to perioperative outcomes on a national level.

Anterior approaches afford improved visualization for disc space preparation but require mobilization of the peritoneum and great vessels (5,6). The greater access to the disk allows for the creation of a higher degree of distraction and lordosis while incurring a potential morbidity of vascular injury, ureteral damage, and retrograde ejaculation in males (6,7). The posterior approach circumvents the potential morbidity associated with the anterior approach but provides limited access to the disc space. The PLIF procedure requires significant retraction of the thecal sac and neural elements to access the disc space resulting in an increased risk of neurologic injury and incidental durotomy (8,9). The TLIF approach was developed to minimize thecal sac retraction during approach to the disc. Unfortunately, the TLIF procedure has known drawbacks including poor contralateral root decompression and incomplete disc removal as well as higher rates of graft extrusion and traversing nerve root irritation (7,10-15).

Advancements in minimally invasive surgical techniques have allowed increasing utilization of interbody fusion in the treatment of various lumbar pathologies. Newer lateral approaches afford unique advantages and disadvantages

Table 6 Propensity-score matched comparison of complications in ALIF/DLIF versus PLIF/TLIF procedures

Complications	ALIF/DLIF, n (%)	PLIF/TLIF, n (%)	P value
Total procedures	2369 (50.0)	2369 (50.0)	–
≥1 major complication	92 (3.9)	73 (3.1)	0.134
Unplanned readmission	84 (3.5)	72 (3.0)	0.333
Mortality	7 (0.3)	0 (0.0)	0.016
Deep venous thrombosis	24 (1.0)	6 (0.3)	0.001
Perioperative blood transfusion	180 (7.6)	139 (5.9)	0.018
30-day return to OR	20 (0.8)	25 (1.1)	0.451
Hospital stay >30 days	3 (0.1)	0 (0.0)	0.250
Perioperative myocardial infarction	4 (0.2)	5 (0.2)	0.754
Pulmonary embolism	8 (0.3)	11 (0.5)	0.489
Sepsis	7 (0.3)	8 (0.3)	0.794
Septic shock	2 (0.1)	2 (0.1)	1.000
Superficial incisional infection	23 (1.0)	29 (1.2)	0.400
Deep incisional surgical site infection	10 (0.4)	12 (0.5)	0.667
Organ/space infection	5 (0.2)	5 (0.2)	1.000
Unplanned reintubation	6 (0.3)	4 (0.2)	0.754
Ventilator >48 hours	9 (0.4)	3 (0.1)	0.083
Pneumonia	18 (0.8)	12 (0.5)	0.273
Urinary infection	27 (1.1)	21 (0.9)	0.386
Acute renal failure	1 (0.0)	0 (0.0)	1.000
Progressive renal insufficiency	4 (0.2)	1 (0.0)	0.375
Cardiac arrest requiring CPR	2 (0.1)	0 (0.0)	0.500
Stroke	0 (0.0)	3 (0.1)	0.125

ALIF, anterior lateral interbody fusion; DLIF, direct lateral interbody fusion; PLIF, posterior lumbar interbody fusion; TLIF, transforaminal lumbar interbody fusion.

when compared with more established approaches (16-26). Still, controversy exists over the effects of various lumbar interbody fusion techniques on global sagittal and coronal balance as well as on overall patient outcome, including mortality and transfusion rate.

In a retrospective analysis of 167 consecutive cases, Villavicencio *et al.* compared anterior-posterior fusion (APF) with TLIF. Anterior-posterior fusion (APF) was associated with a more than two times higher complication rate, significantly increased blood loss, and longer operative and hospitalization times than both percutaneous and open TLIF (12). Similarly, in an analysis of population-based national hospital discharge data collected for the National Inpatient Sample (NIS), Memtsoudis *et al.* (27) showed that both ALIFs and APFs are associated with increased morbidity and mortality in comparison to posterior spinal fusions. Unfortunately, the authors were unable to isolate their analysis to single-level procedures, which may significantly skew the results and conclusions. Additionally, there was no comparison of the complication and mortality rates between anterior interbody and posterior interbody techniques. Goz *et al.* expanded on this study and directly compared mortality rates in anterior and posterior interbody approaches utilizing the NIS database. The authors found an increased mortality in ALIFs compared to P/TLIFs (0.25% *vs.* 0.15%, P<0.0001), which persisted in

the multivariate regression (28).

The data from our study are consistent with previously published studies. Thirty-day mortality was significantly greater in the ALIF/DLIF group versus the PLIF/TLIF group (0.3% *vs.* 0.1%, P=0.025). This increase in mortality is consistent with the previously published studies and is likely attributable to the morbidity of the anterior approach. Deaths in the anterior group included cardiac arrest, massive pulmonary embolism, septic shock, pneumonia, and unknown causes in 2 patients. Mobilization of the great vessels has potential for catastrophic vascular injury and early mortality. Additionally, the increased incidence of DVT in the anterior group is likely due to this mobilization of the great vessels and the concomitant endothelial damage (1.0% *vs.* 0.6%, P=0.025). Similar to the incidence of DVT in the general population, the incidence of DVT was higher in men than women (OR, 0.49; 95% CI, 0.27–0.90; P=0.021) (29,30).

To date, the literature has been inconsistent with regards to blood loss and transfusion after various interbody techniques. Villavicencio and colleagues showed a decrease in blood loss with TLIF compared to APF, while Dorward *et al.* showed an increase in blood loss with TLIF compared to ALIF (7,12). This discrepancy could be due in part to the multi-level nature of the corrections performed in the Dorward *et al.* study (7). Nevertheless, the overall effect of approach on blood loss and transfusion remains unclear. Our analysis demonstrated a significantly greater need for blood transfusions within 72 hours of surgery in the PLIF/TLIF group in the univariate analysis. However, when controlling for confounding variables, the difference in blood transfusion rate between anterior and posterior interbody approaches was insignificant. It is important to note that elevated ASA status, age >60 years, presence of a prior bleeding disorder, and pre-operative anemia were shown to predict a need for blood transfusion regardless of the surgical approach. Because patient selection and preoperative risk stratification is essential when delivering safe and effective spinal surgery, this information is invaluable to surgeons.

The strength of this study is derived from the use of the NSQIP database, which not only contains a large number of patients, but also provides a significantly larger number of outcome variables when compared to other databases like the Nationwide Inpatient Sample. The outcome data is collected at a national level, so the analysis and results can be extrapolated to the population as a whole.

Many of limitations of this study are secondary to the inherent limitations of large patient databases. The NSQIP database is limited in its operative details and is restricted to outcomes and complications that occur within 30 days of surgery. Functional measures, imaging data, and long-term outcomes are not captured. The description of diagnoses is limited to only postoperative diagnoses, without inclusion or comparison to preoperative diagnoses. Furthermore, the CPT coding system prevents separation and isolation of the individual interbody approaches. All lateral and anterior approaches are coded similarly, and all posterior and transforaminal approaches are coded similarly. The inherent risks are somewhat different in open ALIF cases compared to percutaneous XLIF/DLIF approaches where there is no visualization of the great vessels. Future subgroup analyses should be done to distinguish the pros and cons of newly developed anterior, lateral, and posterior approaches. Unavoidable with a study of this magnitude, the surgeries were performed by a large variety of surgeons, allowing for significant variation in surgical technique as well as potential indication bias. Prospective studies with long-term follow-up are essential to give further insight into the differences between interbody fusion approaches.

Conclusions

Lumbar interbody fusion continues to be a vital surgical tool for treating a variety of conditions recalcitrant to conservative management. Rapid advances in minimally invasive surgical techniques offering new advantages have prevented surgeons from ascertaining a definitive standard of care for performing lumbar interbody fusions. In this study of a large national database, ALIF/DLIF techniques were associated with an increased risk of thirty-day mortality and perioperative DVT. The increased risk of transfusion was related to elevated ASA grade, increased age, preoperative anemia, and preoperative bleeding disorders. Although more prospective studies are needed to elucidate the safety profile and differences in patient outcomes between anterior and posterior interbody techniques, the mortality and transfusion data presented in this study is integral to surgeons designing a patient-customized treatment plan.

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Footnote

Conflicts of Interest: Dr. Ronald Lehman Jr reports grants

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Ethical Statement: The study is exempt from ethics approval by Institutional Review Board at Columbia University. The National Surgical Quality Improvement Program (NSQIP) database contains all de-identified patient information and data, which is exempt from ethics review at Columbia University.

References

1. Hart LG, Deyo RA, Cherkin DC. Physician office visits for low back pain. Frequency, clinical evaluation, and treatment patterns from a U.S. national survey. Spine (Phila Pa 1976) 1995;20:11-9.
2. Bono CM, Lee CK. Critical Analysis of Trends in Fusion for Degenerative Disc Disease over the Past 20 Years: Influence of Technique on Fusion Rate and Clinical Outcome. Spine (Phila Pa 1976) 2004;29:455-63.
3. Kalichman L, Kim DH, Li L, et al. Spondylolysis and spondylolisthesis: Prevalence and association with low back pain in the adult community-based population. Spine (Phila Pa 1976) 2009;34:199-205.
4. Deyo RA, Mirza SK, Martin BI. Back pain prevalence and visit rates: Estimates from U.S. national surveys, 2002. Spine (Phila Pa 1976) 2006;31:2724-7.
5. Ishihara H, Osada R, Kanamori M, et al. Minimum 10-year follow-up study of anterior lumbar interbody fusion for isthmic spondylolisthesis. J Spinal Disord 2001;14:91-9.
6. Brau SA, Delamarter RB, Schiffman ML, et al. Vascular injury during anterior lumbar surgery. Spine J 2004;4:409-12.
7. Dorward IG, Lenke LG, Bridwell KH, et al. Transforaminal versus anterior lumbar interbody fusion in long deformity constructs: A matched cohort analysis. Spine (Phila Pa 1976) 2013;38:E755-62.
8. Okuda S, Miyauchi A, Oda T, et al. Surgical complications of posterior lumbar interbody fusion with total facetectomy in 251 patients. J Neurosurg Spine 2006;4:304-9.
9. Hee HT, Castro FP, Majd ME, et al. Anterior/posterior lumbar fusion versus transforaminal lumbar interbody fusion: analysis of complications and predictive factors. J Spinal Disord 2001;14:533-40.
10. Faundez AA, Schwender JD, Safriel Y, et al. Clinical and radiological outcome of anterior-posterior fusion versus transforaminal lumbar interbody fusion for symptomatic disc degeneration: A retrospective comparative study of 133 patients. Eur Spine J 2009;18:203-11.
11. Aoki Y, Yamagata M, Nakajima F, et al. Posterior migration of fusion cages in degenerative lumbar disease treated with transforaminal lumbar interbody fusion: A report of three patients. Spine (Phila Pa 1976) 2009;34:E54-8.
12. Villavicencio AT, Burneikiene S, Bulsara KR, et al. Perioperative complications in transforaminal lumbar interbody fusion versus anterior-posterior reconstruction for lumbar disc degeneration and instability. J Spinal Disord Tech 2006;19:92-7.
13. Hackenberg L, Halm H, Bullmann V, et al. Transforaminal lumbar interbody fusion: A safe technique with satisfactory three to five year results. Eur Spine J 2005;14:551-8.
14. Grob D. Surgery for degenerative lumbar disease: transforaminal lumbar interbody fusion. Eur Spine J 2009;18:1991-2.
15. Hsieh PC, Koski TR, O'Shaughnessy BA, et al. Anterior lumbar interbody fusion in comparison with transforaminal lumbar interbody fusion: implications for the restoration of foraminal height, local disc angle, lumbar lordosis, and sagittal balance. J Neurosurg Spine 2007;7:379-86.
16. Winder MJ, Gambhir S. Comparison of ALIF vs. XLIF for L4/5 interbody fusion: pros, cons, and literature review. J Spine Surg 2016;2:2-8.
17. McAfee PC, Shucosky E, Chotikul L, et al. Multilevel extreme lateral interbody fusion (XLIF) and osteotomies for 3-dimensional severe deformity: 25 consecutive cases. Int J Spine Surg 2013;7:e8-19.
18. Arnold PM, Anderson K, McGuire R. The lateral transpsoas approach to the lumbar and thoracic spine: A review. Surg Neurol Int 2012;3:S198.
19. Meredith DS, Kepler CK, Huang RC, et al. Extreme Lateral Interbody Fusion (XLIF) in the Thoracic and Thoracolumbar Spine: Technical Report and Early Outcomes. HSS J 2013;9:25-31.
20. Caputo AM, Michael KW, Chapman TM, et al. Clinical Study Clinical Outcomes of Extreme Lateral Interbody Fusion in the Treatment of Adult Degenerative Scoliosis. ScientificWorldJournal 2012;2012:680643.
21. Malham GM, Ellis NJ, Parker RM, et al. Clinical Outcome and Fusion Rates after the First 30 Extreme Lateral Interbody Fusions. ScientificWorldJournal 2012;2012:246989.

22. Kim JS, Lee HS, Shin DA, et al. Correction of Coronal Imbalance in Degenerative Lumbar Spine Disease Following Direct Lateral Interbody Fusion (DLIF). Korean J Spine 2012;9:176-80.
23. Lee YS, Kim YB, Park SW, et al. Comparison of transforaminal lumbar interbody fusion with direct lumbar interbody fusion: clinical and radiological results. J Korean Neurosurg Soc 2014;56:469.
24. Mobbs RJ, Phan K, Malham G, et al. Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. J Spine Surg 2015;1:2-18.
25. Pawar AY, Hughes AP, Sama AA, et al. A comparative study of lateral lumbar interbody fusion and posterior lumbar interbody fusion in degenerative lumbar spondylolisthesis. Asian Spine J 2015;9:668-74.
26. Waddell B, Briski D, Qadir R, et al. Lateral lumbar interbody fusion for the correction of spondylolisthesis and adult degenerative scoliosis in high-risk patients: early radiographic results and complications. Ochsner J 2014;14:23-31.
27. Memtsoudis SG, Vougioukas VI, Ma Y, et al. Perioperative morbidity and mortality after anterior, posterior and anterior/posterior spine fusion surgery. Spine (Phila Pa 1976) 2011;36:1867-77.
28. Goz V, Weinreb JH, Schwab F, et al. Comparison of complications, costs, and length of stay of three different lumbar interbody fusion techniques: an analysis of the Nationwide Inpatient Sample database. Spine J 2014;14:2019-27.
29. Andreou ER, Koru-Sengul T, Linkins L, et al. Differences in clinical presentation of deep vein thrombosis in men and women. J Thromb Haemost 2008;6:1713-9.
30. Bauersachs RM, Riess H, Hach-Wunderle V, et al. Impact of gender on the clinical presentation and diagnosis of deep-vein thrombosis. Thromb Haemost 2010;103:710-7.

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