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Anterior Versus Transforaminal Lumbar Interbody Fusion: Perioperative Risk Factors and 30-Day Outcomes

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ABSTRACT

Background: Operative management of lower back pain often necessitates anterior lumbar interbody fusion (ALIF) or transforaminal lumbar interbody fusion (TLIF). Specific pathoanatomic advantages and indications exist for both approaches, and few studies to date have characterized comparative early outcomes.

Methods: Adult patients undergoing elective ALIF or TLIF operations were abstracted from the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) years 2011–2014. Univariate analyses were performed by surgery cohort for each outcome and adjusted for demographic/clinical variables (age ≥ 65, sex, race, body mass index, American Society of Anesthesiologists physical classification score, functional status, inpatient/outpatient status, smoking, hypertension, Charlson Comorbidity Index) using multivariable regression. Means, standard errors, mean differences (*B*), odds ratios (ORs), and associated 95% confidence intervals (CIs) are reported. Significance was assessed at $P < .05$.

Results: Of 8263 subjects (ALIF: 4325, TLIF: 3938), ALIF subjects were younger, less obese, less physically impaired, and had significantly lower rates of hypertension, diabetes, coagulopathy, and previous cardiac surgery. On multivariable analysis, ALIF associated with shorter operative time ($B = –11.80$ minutes, 95% CI [–16.48, –7.12]; $P < .001$). Transforaminal lumbar interbody fusion was associated with increased incidence of urinary tract infections (UTIs; OR = 1.57, 95% CI [1.10, 2.26]; $P = .013$) and of blood transfusions (OR = 1.19, 95% CI [1.04, 1.37]; $P = .012$). Multivariate analysis also demonstrated TLIF associated with shorter hospital length of stay ($B = –0.27$ days, 95% CI [–0.54, –0.01]; $P = .041$), and fewer cases of pneumonia (OR = 0.55, 95% CI [0.32, 0.94]; $P = .029$) and prolonged ventilator dependency (OR = 0.33, 95% CI [0.12, 0.84]; $P = .021$).

Conclusions: Comparatively, ALIF patients experienced decreased operative time and decreased incidence of postoperative UTIs and blood transfusions. Anterior lumbar interbody fusion patients were more likely to suffer postoperative pulmonary complications and longer hospital stays. Our data support the notion that both anterior and transforaminal surgical approaches perform comparably in context of 30-day perioperative outcomes.

Lumbar Spine

Keywords: anterior lumbar interbody fusion, ACS-NSQIP, posterior lumbar interbody fusion, lumbar spine surgery, early complications, surgical outcomes, transforaminal lumbar interbody fusion, degenerative disc disease, low back pain, operation time

INTRODUCTION

In the Western world, the annual prevalence of lower back pain is estimated to be as high as 65% and lifetime prevalence as high as 84%.[1] Sufferers often experience both a decrease in quality of life and a reduced workforce availability, with profound economic consequences. In the United States (US) alone, the annual direct (health care) and indirect (loss of work productivity) costs of back pain amount to over $100 billion.[2]

Lumbar spinal fusion is a viable option for patients with degenerative disc disease who fail aggressive nonsurgical management. Traditionally, surgical intervention with lumbar fusion is associated with improved acute and long-term outcomes compared with nonoperative treatment.[3]

Two primary surgical approaches to lumbar fusion in degenerative disease are anterior lumbar interbody fusion (ALIF) and transforaminal lumbar interbody fusion (TLIF). Anterior and posterior lumbar fusions were first described in the 1950s for the treatment of degenerative lumbar disease.[4,5] Transforaminal lumbar interbody fusion, a modification to the posterior fusion technique using circumferential fusion through a single posterolateral approach, was subsequently described in 1982.[6]

A meta-analysis of 7 comparative studies demonstrated that TLIF has potential advantages over traditional posterior fusion, specifically in reducing postsurgical complications.[7] Several studies highlight small relative advantages for TLIF over ALIF, including decreased operative time and lower complication rates.[8,9] However, comparative advantages between the anterior and posterior approaches lack a clear consensus.[10–12]

This paper analyzes the differences in 30-day perioperative outcomes in patients who have undergone anterior versus posterior or transforaminal fusion. In using data from the prospectively collected American College of Surgeons (ACS) National Surgical Quality Improvement Project (NSQIP),[13] we aim to provide insight into the comparative advantages and disadvantages between ALIF and TLIF surgical cohorts using population-wide data. In the present analysis, we assess the clinical presentation of patients and characterize key perioperative risk factors for each surgical cohort across outcome measures of operative time, mortality, early complications, hospital length of stay (HLOS), discharge destination, and unplanned reoperations.

MATERIALS AND METHODS

Data Source

This retrospective analysis uses the ACS-NSQIP database created with the purpose of improving surgical outcomes and techniques.[14] The NSQIP database focuses on demographic and clinical characteristics along with 30-day postoperative variables.[15,16] From medical and/or operative records, over 300 perioperative variables are cataloged and included, spanning a time period up to 30 days postoperation.[17] This analysis is exempt from institutional review board approval, as the ACS-NSQIP participant-use data files are in the public domain and contain no protected health information.

Study Population

This study analyzes the NSQIP database from the years 2011–2014 for all patients undergoing elective ALIF or TLIF. The ALIF and TLIF patients were identified using common procedural terminology (CPT) codes for single interspace procedures: 22558 ("Anterior Interbody Fusion, Lumbar") references the ALIF CPT code for a single interspace, and 22630 ("Posterior Interbody Fusion, Lumbar" [PLIF]) references CPT code for PLIF or TLIF for single interspaces. This grouping of posterior fusion techniques—PLIF and TLIF—has previously been used in literature to isolate differences between anterior and posterior fusion approaches.[18–21] It is also understood that PLIF procedures are coded by the same CPT codes used for TLIF procedures as both use a posterior approach with posterior instrumentation. Initially, 4490 ALIF and 4194 TLIF subjects were identified. Patients who underwent either emergent or nonelective surgeries (ALIF: 165, TLIF: 256) were removed to yield a final sample size of 8263 (ALIF: 4325, TLIF: 3938). Multilevel procedures were coded with additional CPT codes for each interspace: 22585 ("Anterior Interbody Fusion, Lumbar—Additional Interspace") and 22632 ("Posterior Interbody Fusion, Lumbar—Additional Interspace").

Outcome Measures

Six outcome measures were included in the current analysis: operation time, mortality, early complications, total HLOS, hospital discharge destination, and reoperation rate. Operation time is defined as the total length of surgery in minutes. Hospital length of stay is defined as the number of days between admission and postsurgery discharge. Both reoperation and complication were classified as a binary variables. If the patient had a reoperation, he or she was given a "yes"; otherwise, he or she was classified as a "no." For complications, a "yes" value was given if a patient experienced a complication as recorded by 1 or more of the following variables: cardiac arrest, myocardial infarction, coma >24 hours, cerebrovascular accident/stroke with neurological deficit, peripheral nerve injury, wound/surgical site infection, urinary tract infection (UTI), renal insufficiency or failure, blood transfusion >1 unit, unplanned intubation, incidence of deep vein thrombosis/thrombophlebitis, sepsis or septic shock, pneumonia, pulmonary embolism, and death. The merits and drawbacks of such an approach will be discussed in the limitation section.

Both HLOS and operation time were treated as continuous variables for univariate and multivariable analyses, and accordingly, linear regression was used. Hospital discharge destination was reclassified to either home or a facility of higher care (eg, rehabilitation center, skilled nursing facility, or acute care). Multivariable logistic regression was performed for reoperation, early complications, and discharge destination due to the categorical nature of the variables. Due to the confounding effects death may have on measures of HLOS and discharge destination, these analyses were performed on all patients not reported to have died within 30 days of operation (n = 8245).

STATISTICAL METHODS

All statistical analyses were performed using Python, an open source programming language. We thank the makers of the SciPy and StatsModels (source of materials), as all statistics were computed using these packages.[22–24] Continuous and categorical variables were compared between surgical cohorts using analysis of variance or χ^2 tests, respectively. Multivariable linear regression was performed for linear outcome variables (operation time, HLOS). Multivariable logistic regression was performed on categorical outcome variables (discharge destination, complications, reoperation). All multivariable models were adjusted for the following demographic characteristics: age, gender, race, comorbidities, body mass index (BMI), functional status, inpatient/outpatient status, American Society of Anesthesiologists (ASA) score, and levels of vertebral fusion. Conforming to standard cutoffs published by the US Census Bureau, age was treated as a binary variable with elderly classified as ≥65 years.[25] Body mass index (in kg/m^2) was stratified according to World Health Organization classifications: underweight (<18.5), nonobese (18.5–29.9), obese class I (30–34.9), obese class II/III (≥35). Medical comorbidities were categorized using the Charlson Comorbidity Index (CCI),[26] which has been widely used in retrospective spine studies as an summative indicator of baseline health burden.[27–29] Hypertension and smoking, both associated with negative outcomes in a number of previous lumbar spine studies,[30,31] were also analyzed independently. American Society of Anesthesiologists score was included as a validated indicator of physical morbidity in lumbar spine literature.[32,33] Number of vertebral levels spanned was ascertained using CPT codes. Each patient thus had a number between 1 (single interspace) and 5 (five interspaces) indicating the number of spaces across which their fusion occurred.

For linear regressions, mean difference (*B*) and 95% confidence intervals (CIs) are reported compared to reference values. For logistic regressions, odds ratios (ORs) and 95% CIs are reported. Significance was assessed at $P < .05$. Detailed information can be found in the tables section.

RESULTS

Demographic and Clinical Characteristics

A total of 8263 patient records for elective ALIF or TLIF were abstracted from the ACS-NSQIP database years 2011–2014. Overall, subjects were 56.3 ± 13.7 years of age, and 54.5% were female. Subjects undergoing TLIF were more likely to be elderly (≥65 years: 35.6% versus 27.4%; $P < .001$). A higher percentage of subjects undergoing TLIF were obese (BMI <30 kg/m^2: ALIF 49.9%, TLIF 47.2%; BMI >30 kg/m^2: ALIF 48.1%, TLIF 51.2%; $P = .001$). Transforaminal lumbar interbody fusion subjects were more likely to be physically impaired (ASA 3–4: ALIF 38.5%, TLIF 43.6%; $P < .001$). Also, a greater proportion of ALIF patients had multilevel surgery (29.3% versus 25.5%; $P = .003$; Table 1). Transforaminal lumbar interbody fusion patients demonstrated greater likelihood of medical comorbidities as reported in Table 2.

In total, 5994 (72.5%) underwent single-level interbody fusion by either anterior or posterior approaches. This included 3059 (70.7%) of the ALIF cohort and 2935 (74.5%) of the TLIF cohort. Only 391 (4.7%) total subjects had surgeries with >2 levels fused. Notably, in the ALIF group, 14.5% of subjects had nonsegmental posterior instrumentation used.

Operation Time and Hospital Length of Stay (HLOS)

The average operation time was 204.12 ± 110.51 minutes. On univariate analysis, ALIF showed significantly shorter operation times compared to TLIF cohort (ALIF: 198.36 ± 1.80 minutes, TLIF: 210.45 ± 1.60 minutes; $P < .001$; Table 3). This finding survived multivariable analysis with TLIF, showing a mean increase (*B*) of 11.80 minutes (95% CI [7.12, 16.48]; $P < .001$; Table 4). Male patients ($B = 7.94$ minutes; 95% CI [3.25, 12.62]; $P = .001$), obese patients (BMI >30: $B = 6.72$ minutes; 95% CI [1.09, 12.34]; $P = .019$), and ASA 3–4 ($B = 19.36$

Table 1. Demographic and clinical characteristics by surgery cohort. Distributions and proportions are shown for elective lumbar spine surgery patients.

Descriptive Variable	ALIF (n = 4325)	TLIF/PLIF (n = 3938)	Sig. (*P*)
Age			<.001
Mean (SD)	54.87 (13.67)	57.91 (13.63)	
<65 years	3141 (72.6%)	2536 (64.4%)	
≥65 years	1184 (27.4%)	1402 (35.6%)	
Sex			.340
Male	1942 (44.9%)	1816 (46.1%)	
Female	2383 (55.1%)	2122 (53.8%)	
Race[a]			<.001
Caucasian	3738 (86.4%)	3264 (82.9%)	
Hispanic	272 (6.3%)	199 (5.0%)	
African-American	276 (6.4%)	262 (6.6%)	
Other/unknown	311 (7.2%)	412 (10.4%)	
Body mass index (kg/m^2)			.010
Underweight (<18.5)	80 (1.8%)	60 (1.5%)	
Non-obese (18.5–29.9)	2162 (49.9%)	1859 (47.2%)	
Obese class I (30–34.9)	1159 (26.8%)	1072 (27.2%)	
Obese class II/III (≥35)	924 (21.3%)	947 (24.0%)	
ASA classification			<.001
ASA 1	217 (5.0%)	151 (3.8%)	
ASA 2	2443 (56.5%)	2071 (52.6%)	
ASA 3–4	1665 (38.5%)	1716 (43.6%)	
Functional status			.991
Independent	4226 (97.7%)	3848 (97.7%)	
Partially or totally dependent	99 (2.3%)	90 (2.3%)	
Surgery team			<.001
Attending without resident	321 (7.4%)	421 (10.7%)	
Attending with resident	117 (2.7%)	211 (5.3%)	
Attending status unknown	3887 (89.9%)	3306 (83.9%)	
Patient status			<.001
Outpatient	76 (1.7%)	134 (3.4%)	
Inpatient	4249 (98.2%)	3804 (96.6%)	
Number of surgical levels			.0003
Single level	3059 (70.7%)	2935 (74.5%)	
Two levels	1039 (24.0%)	839 (21.3%)	
>2 levels	227 (5.3%)	164 (4.2%)	

Abbreviations: TLIF/PLIF, transforaminal lumbar interbody fusion/posterior lumbar interbody fusion; ASA, American Society of Anesthesiologists physical classification score; ALIF, anterior lumbar interbody fusion; SD, standard deviation; Sig., Significance.
[a]The N for race is larger as Hispanic subjects were sometimes classified with another race.

minutes, 95% CI [13.98, 24.72]; $P < .001$) had longer operation times. In contrast, outpatients ($B =$ –21.36 minutes, 95% CI [–36.12, –6.59]; $P = .005$) and smokers ($B = –10.25$ minutes, 95% CI [–15.90, –4.59]; $P < .001$) had shorter operation times (Table 4).

Overall mean HLOS was 3.75 ± 0.06 days. Both univariate and multivariate analyses demonstrated a nonsignificant statistical trend to longer HLOS for ALIF subjects (Table 3). Both male ($B = –0.62$ days, 95% CI [–0.88, –0.35]; $P < .001$) and outpatient ($B = –1.56$ days, 95% CI [–2.39, –0.74]; $P < .001$) subjects had shorter hospital stays. Higher ASA score (ASA 3–4: $B = 0.92$ days, 95% CI [0.62, 1.22]; $P < .001$) and greater number of vertebral segments fused ($B = 0.87$, 95% CI [0.66, 1.09]; $P < .001$) were associated with increased HLOS (Table 5).

Failure of Hospital Discharge to Home and Mortality

A total of 7127 patients or 86.4% of our dataset was discharged home. No significant difference was observed for surgery cohort and failure to be discharged home (ALIF: 12.9%, TLIF: 14.2%; $P = .104$; Table 3). Multivariable analysis further demonstrated this nonsignificant relationship (TLIF: OR 0.98, 95% CI [0.85, 1.12]; $P = .720$). Of note, 8 out of 12 independent variables were significant predictors on multivariable analysis. Age ≥65 years was associated with an OR of 3.40 for discharge to a facility of higher care (95% CI [2.92, 3.96]; $P < .001$). The ASA score (ASA 3–4: OR 2.06, 95% CI [1.77, 2.40]; $P < .001$) and CCI were associated with increased odds of failure to be discharged home (per-unit OR 1.26, 95% CI [1.09, 1.46]; $P < .001$). Multilevel surgery was associated with increased odds of failure to be discharged home (per-interspace OR 1.52, 95% CI [1.38, 1.67]; $P <$ .001). Preoperative physical dependence (OR 2.03, 95% CI [1.41, 2.92]; $P < .001$) and hypertension (OR 1.26, 95% CI [1.08, 1.47]; $P < .001$) were associated with increased odds of failure to return home (Table 6). In contrast, male patients (OR 0.55, 95% CI [0.48, 0.63]; $P < .001$) and smokers (OR 0.73, 95% CI [0.61, 0.89]; $P < .001$) were less likely to fail to be discharged to home (Table 6).

No significant univariate difference was observed for mortality by surgery cohort, as 9 patients died in each the anterior and posterior cohorts (ALIF 0.22%, TLIF 0.22%; $P = .842$); hence, multivariable analysis was not performed.

Early Complication and Reoperation Rates

A greater proportion of patients undergoing TLIF suffered early complications (ALIF: 15.0%, TLIF: 16.9%; $P = .016$). This finding did survive multivariable analysis (TLIF: OR: 1.14, 95% CI [1.01, 1.29]; $P = .034$). As seen with discharge destination, older age, ASA score, functional dependency, hypertension, and number of vertebral levels all significantly increased patient likelihood of experiencing complications. Outpatient status (OR 0.47, 95% CI [0.28, 0.81]; $P = .006$) and male gender (OR 0.68, 95% CI [0.60, 0.77]; $P < .001$) were associated with lower odds of early complications (Table 7).

To further characterize differences observed in early complication rates, individual complications

Table 2. Comorbidities by surgery cohort. Distributions and proportions are shown for elective lumbar spine surgery patients.

Comorbidity Variable	ALIF (n = 4325)	TLIF/PLIF (n = 3938)	Sig. (*P*)
Charlson Comorbidity Index			
Mean (SD)	0.16 (0.40)	0.19 (0.42)	.004
Cardiovascular			
Congestive heart failure	5 (0.1%)	11 (0.2%)	.090
Myocardial infarction	0 (0.0%)	0 (0.0%)	—
Percutaneous coronary intervention	10 (0.2%)	30 (0.7%)	<.001
Prior cardiac surgery	6 (0.1%)	17 (0.4%)	.011
Peripheral vascular disease	3 (0.07%)	5 (0.1%)	.400
Malignancy			
Weight loss >10% (6 mo)	8 (0.1%)	7 (0.1%)	.938
Metastasis	8 (0.1%)	6 (0.1%)	.718
Neurological			
Transient ischemic attack	8 (0.1%)	7 (0.1%)	.958
Stroke	2 (0.04%)	5 (0.1%)	.207
Paralysis			
Hemiparesis	1 (0.02%)	1 (0.02%)	.976
Paraplegia	6 (0.1%)	7 (0.1%)	.654
Quadriplegia	0 (0.0%)	0 (0.0%)	—
Pulmonary			
Dyspnea	227 (5.2%)	235 (5.9%)	.155
Steroid use (inhaler)	119 (2.7%)	130 (3.3%)	.144
Chronic obstructive pulmonary disease	148 (3.4%)	164 (4.1%)	.077
Coagulopathy	47 (0.1%)	67 (0.1%)	.016
Diabetes mellitus	514 (11.8%)	539 (13.7%)	.014
Hypertension	1918 (44.3%)	2034 (51.6%)	<.001
Renal failure	1 (0.02%)	0 (0.0%)	.339
Smoking	1043 (22.7%)	894 (24.1%)	.129

Abbreviations: TLIF/PLIF, transforaminal lumbar interbody fusion/posterior lumbar interbody fusion; ALIF, anterior lumbar interbody fusion; SD, standard deviation; Sig., Significance.

were compared using multivariable analysis. On univariate analysis, the TLIF cohort was associated with a nonsignificant statistical trend in decreased rates of pneumonia (ALIF: 0.9% versus TLIF: 0.5%; $P = .090$) and need for prolonged ventilation (>24 hours) (ALIF: 0.4% versus TLIF: 0.1%, $P = .062$); these associations were both statistically significant on multivariable analysis (pneumonia: TLIF OR 0.55, 95% CI [0.32, 0.94]; $P = .029$; ventilatory assistance: TLIF OR 0.33, 95% CI [0.12, 0.84]; $P = .021$). The TLIF cohort had a greater incidence of UTIs (ALIF: 1.2% versus TLIF: 1.8%, $P = .004$) and blood transfusions >1 unit (ALIF: 10.9% versus TLIF: 11.5%, $P = .014$). Multivariable analysis demonstrated increased odds of UTI in the TLIF cohort (OR 1.57, 95% CI [1.10, 2.26]; $P = .013$), and a statistically significant trend persisted for patients requiring blood transfusions >1 unit (OR 1.19, 95% CI [1.04, 1.37]; $P = .012$; Table 8).

No significant differences in reoperation rates were observed between surgery cohorts (TLIF OR 1.04, 95% CI [0.80, 1.35]; $P = .758$).

DISCUSSION

The present analysis uses the NSQIP database for patients undergoing elective lumbar fusion surgeries from years 2011–2014. We show that, in general, TLIF patients have a higher preoperative health burden. While controlling for a number of demographic and clinical factors, we demonstrate that patients undergoing elective ALIF were less likely to suffer prolonged operative time, postoperative UTIs, or require blood transfusions. However, ALIF patients were at increased risk of pneumonia and prolonged ventilatory support.

A primary consideration is how disc disease presents anatomically. In the healthy, young spine, 80% of the axial load is borne on the anterior portion of the vertebral body. Accordingly, ALIF provides surgeons with increased capacity to access and augment this load bearing portion of the spine with instrumentation.[34] Visualization of the anterior spinal column allows for efficient discectomy and vertebral body distraction with minimal neurological insult. A major consideration in the anterior approach is the navigation through the peritoneal and retroperitoneal space. Not surprisingly, ALIF subjects were generally healthier and presented with fewer prior comorbidities, eg, cardiac surgery, diabetes, hypertension, obesity, and coagulopathy. The risk, however small, for serious bleeding

Table 3. Univariate distribution of outcomes by surgery cohort. Distributions and proportions are shown for elective lumbar spine surgery patients. Mean hospital length of stay and hospital discharge to home analyses have a lower N due to excluding patients who expired in hospital and/or within 30 days of operation (ALIF: n = 4316; TLIF/PLIF: n = 3929).

Comorbidity Variable	ALIF (n = 4325)	TLIF/PLIF (n = 3938)	Sig. (*P*)
Operation time, min, mean (SE)	198.36 (1.80)	210.45 (1.60)	<.001
HLOS, d, mean (SE)	3.83 (0.07)	3.65 (0.11)	.176
Reoperation, overall N (%)	123 (2.8%)	117 (2.9%)	.731
Early complications, overall N (%)	650 (15.0%)	668 (16.9%)	.016
Hospital discharge			
Home	3756 (87.0%)	3371 (85.8%)	.104
Skilled nursing facility/rehabilitation	560 (12.9%)	558 (14.2%)	

Abbreviations: TLIF/PLIF, transforaminal lumbar interbody fusion/posterior lumbar interbody fusion; ALIF, anterior lumbar interbody fusion; SD, standard deviation; SE, standard error; HLOS, hospital length of stay; Sig., Significance.

Table 4. Multivariable linear regression for operation time. Mean increase or decrease (*B*) and associated 95% confidence intervals (CIs) are shown for each predictor.

Predictor Variable	B	95% CI	Sig. (P)
Surgery cohort			
ALIF	Reference	—	—
TLIF/PLIF	11.80	7.12, 16.48	<.001
Age			
<65 years	Reference	—	—
≥65 years	−2.38	−8.02, 3.27	.41
Sex			
Female	Reference	—	—
Male	7.94	3.25, 12.62	.001
Race			
Caucasian	Reference	—	—
Hispanic	−3.86	−13.96, 6.24	.454
African-American	2.03	−7.47, 11.53	.676
Other/unknown	19.89	11.53, 28.24	<.001
Body mass index			
Nonobese	Reference	—	—
Obese class I	6.72	1.09, 12.34	.019
Obese class II/III	15.85	9.60, 22.08	<.001
Underweight	10.66	−7.42, 28.75	.248
ASA classification score			
ASA 1	Reference	—	—
ASA 3–4	19.36	13.98, 24.72	<.001
Functional status			
Independent	Reference	—	—
Partially or totally dependent	−9.45	−24.96, 6.06	.232
Patient type			
Inpatient	Reference	—	—
Outpatient	−21.36	−36.12, −6.59	.005
Hypertension			
No	Reference	—	—
Yes	3.26	−2.02, 8.54	.226
Smoking			
No	Reference	—	—
Yes	−10.25	−15.90, −4.59	<.001
Charlson Comorbidity Index per unit	−3.67	−9.71, 2.37	.234
Number of vertebral levels per interspace	34.91	31.07, 38.74	<.001

Abbreviations: TLIF/PLIF, transforaminal lumbar interbody fusion/posterior lumbar interbody fusion; ALIF, anterior lumbar interbody fusion; ASA, American Society of Anesthesiologists physical classification score; Sig., Significance.

complications with ALIF is another serious consideration.

Benefits of a posterior approach include minimizing risk of serious vascular injury present when mobilizing the inferior vena cava and abdominal aorta to access the spine and potential cost saving due to eliminating the need to bill for an anterior access general surgeon. Even so, anterior approaches have been associated with reduced blood loss and decreased operative time,[35,10,36] likely due to the lack of needing to dissect the paraspinous musculature required by posterior and posterolateral approaches. Increased operation time is known to associate with increased risk of infection, blood loss, and postoperative respiratory complications. Thus, operative time must be minimized in patients with significant health burden. As such, after clinical presentation and patient pathology are taken into account, decreased operative time associated with ALIF procedures may be another factor that can inform surgical decision making. Significant difference in demographic characteristics between our 2 cohorts suggests the TLIF cohort has more advanced pathology. Difficult anterior access due to morbid obesity or body habitus may be 1 factor that skews ALIF demographic characteristics towards healthier individuals.

No difference was seen in discharge destination between ALIF and TLIF cohorts. Both surgeries also performed comparably on rates of most postoperative complications. Anterior lumbar interbody fusion subjects were more likely to require ventilatory assistance and/or develop pneumonia. This may be due to postoperative atelectasis related to the anterior approach. Urinary tract infections (1–2%) and the need for blood transfusions (10–11%) were the 2 most common complications following both surgeries and at higher likelihood following TLIF—important considerations for the dependent or coagulopathic patient. Notably, the number of vertebral levels fused was a significant predictor of all outcomes. This finding, while intuitive, highlights the importance of instrumentation and pathology in outcome prediction.

Reported costs per procedure found that, across a 10-year sample of over 900 000 lumbar interbody fusions, ALIF procedures cost on average over $10 000 more.[37] This increased cost can be accounted for in a highly specialized surgical team responsible for anterior approach surgeries and the cost of spinal implants. A previous meta-analysis has shown ALIF to be associated with increased HLOS when compared to TLIF.[38] This was thought to be due to increased rates of postoperative complications such as ileus.[39] Although our dataset did not specifically account for ileus, the lack of a significant difference between HLOS in ALIF and TLIF cohorts suggests similar rates of discharge preventing complications. This is reflected in the increasing trend of surgeons to choose posterior/posterolateral fusion techniques.[37] In contrast, spine surgeons with fellowship training were 4 times as likely to choose ALIF over TLIF.[19]

The findings outlined in our paper are corroborated by a small study of 21 individuals in which ALIF surgeries significantly decreased operative time compared to TLIF.[40] The current literature,

Table 5. Multivariable linear regression for hospital length of stay (HLOS). Mean increase or decrease (*B*) and associated 95% confidence intervals (CI) are shown for each predictor.

Predictor Variable	*B*	95% CI	Sig. (*P*)
Surgery cohort			
ALIF	Reference	—	—
TLIF/PLIF	−0.22	−0.49, 0.04	.097
Age			
<65 years	Reference	—	—
≥65 years	0.11	−0.21, 0.43	.501
Sex			
Female	Reference	—	—
Male	−0.62	−0.88, −0.35	<.001
Race			
Caucasian	Reference	—	—
Hispanic	0.2	−0.36, 0.77	.478
African-American	0.24	−0.3, 0.77	.384
Other/unknown	1.13	0.66, 1.59	<.001
Body mass index			
Nonobese	Reference	—	—
Obese class I	0.02	−0.29, 0.34	.894
Obese class II/III	0.07	−0.29, 0.42	.715
Underweight	0.25	−0.76, 1.27	.626
ASA classification score			
ASA 1	Reference	—	—
ASA 3–4	0.92	0.62, 1.22	<.001
Functional status			
Independent	Reference	—	—
Partially or totally dependent	0.33	−0.54, 1.2	.459
Patient status			
Inpatient	Reference	—	—
Outpatient	−1.56	−2.39, −0.74	<.001
Hypertension			
No	Reference	—	—
Yes	0.27	−0.02, 0.57	.069
Smoking			
No	Reference	—	—
Yes	−0.12	−0.44, 0.2	.452
Charlson Comorbidity Index per unit	0.12	−0.22, 0.46	.477
Number of vertebral levels per interspace	0.87	0.66, 1.09	<.001

Abbreviations: TLIF/PLIF, transforaminal lumbar interbody fusion/posterior lumbar interbody fusion; ALIF, anterior lumbar interbody fusion; ASA, American Society of Anesthesiologists physical classification score; Sig., Significance.

Table 6. Multivariable logistic regression for hospital discharge to home. Odds ratios (ORs) and associated 95% confidence intervals (CIs) are shown for each predictor. Patients who expired in hospital and/or within 30 days of operation were excluded from the analysis.

Predictor Variable	OR	95% CI	Sig. (*P*)
Surgery cohort			
ALIF	Reference	—	—
TLIF/PLIF	0.98	0.85, 1.12	.720
Age			
<65 years	Reference	—	—
≥65 years	3.40	2.92, 3.96	<.001
Sex			
Female	Reference	—	—
Male	0.55	0.48, 0.63	<.001
Race			
Caucasian	Reference	—	—
Hispanic	0.94	0.68, 1.29	.68
African-American	1.37	1.06, 1.78	.02
Other/unknown	0.84	0.64, 1.09	.19
Body mass index			
Nonobese	Reference	—	—
Obese class I	1.07	0.91, 1.26	.43
Obese class II/III	1.03	0.86, 1.22	.78
Underweight	1.34	0.82, 2.19	.24
ASA classification score			
ASA 1–2	Reference	—	—
ASA 3–4	2.06	1.77, 2.4	<.001
Functional status			
Independent	Reference	—	—
Partially or totally dependent	2.03	1.41, 2.92	<.001
Patient status			
Inpatient	Reference	—	—
Outpatient	0.53	0.28, 0.99	.05
Hypertension			
No	Reference	—	—
Yes	1.26	1.08, 1.47	<.001
Smoking			
No	Reference	—	—
Yes	0.73	0.61, 0.89	<.001
Charlson Comorbidity Index per unit	1.26	1.09, 1.46	<.001
Number of vertebral levels per interspace	1.52	1.38, 1.67	<.001

Abbreviations: TLIF/PLIF, transforaminal lumbar interbody fusion/posterior lumbar interbody fusion; ALIF, anterior lumbar interbody fusion; ASA, American Society of Anesthesiologists physical classification score; Sig., Significance.

however, has no clear consensus on outcomes when comparing anterior and posterior lumbar interbody fusion. Phan et al[38] describe a meta-analysis using weighted means to compare ALIF and TLIF. They found ALIF was associated with longer hospitalizations, lower dural injuries, and higher blood vessel injuries.[38] A recent meta-analysis comparing PLIF, ALIF, and TLIF between 30 studies found similar fusion rates and similar complication rates between the various methods for lumbar fusion.[41] A retrospective study using the NSQIP database comparing single-level ALIF to single-level TLIF in a propensity matched cohort found no difference on any 30-day perioperative outcomes.[42] In contrast to the results outlined in our study, Jiang et al[43] found ALIF to be associated with increased operative time and blood loss than TLIF. In contrast, a meta-analysis of 651 patients found ALIF is associated with comparable or superior performance for operative time, blood loss, and fusion rates.[36] The current paper offers a more detailed look at what specific complications are impacted by surgical approach while also having the largest sample size for determining differences in operative time, HLOS, and other perioperative outcomes.

Limitations

Retrospective database studies have inherent limitations. Discrepancies between data collection and entry are of primary concern. The NSQIP

Table 7. Multivariable logistic regression for early complication rates. Odds ratios (ORs) and associated 95% confidence intervals (CIs) are shown for each predictor. Patients who expired in hospital and/or within 30 days of operation were excluded from the analysis.

Predictor Variable	OR	95% CI	Sig. (*P*)
Surgery cohort			
ALIF	Reference	—	—
TLIF/PLIF	1.14	1.01, 1.29	.034
Age			
<65 years	Reference	—	—
≥65 years	1.25	1.09, 1.44	.002
Sex			
Female	Reference	—	—
Male	0.68	0.60, 0.77	<.001
Race			
Caucasian	Reference	—	—
Hispanic	0.55	0.40, 0.76	<.001
African-American	0.75	0.58, 0.98	.033
Other/unknown	0.97	0.78, 1.22	.806
Body mass index			
Nonobese	Reference	—	—
Obese class I	1.00	0.86, 1.16	.998
Obese class II/III	0.98	0.83, 1.15	.795
Underweight	1.07	0.67, 1.71	.772
ASA classification score			
ASA 1–2	Reference	—	—
ASA 3–4	1.69	1.47, 1.94	<.001
Functional status			
Independent	Reference	—	—
Partially or totally dependent	1.87	1.34, 2.63	<.001
Patient status			
Inpatient	Reference	—	—
Outpatient	0.47	0.28, 0.81	.006
Hypertension			
No	Reference	—	—
Yes	1.22	1.06, 1.4	.005
Smoking			
No	Reference	—	—
Yes	0.98	0.84, 1.15	.826
Charlson Comorbidity Index per unit	1.10	0.95, 1.26	.209
Number of vertebral levels per interspace	1.81	1.66, 1.97	<.001

Abbreviations: TLIF/PLIF, transforaminal lumbar interbody fusion/posterior lumbar interbody fusion; ALIF, anterior lumbar interbody fusion; ASA, American Society of Anesthesiologists physical classification score; Sig., Significance.

implementation of standardized data collector training and ongoing edits of data reliability have decreased errors to less than 1%.[44,45] Also, CPT codes, International Classification of Diseases, Ninth Revision, diagnoses are still broad and often do not capture the full scope of clinical presentation. More specifically, the potential grouping of PLIF and TLIF procedures in our TLIF group offers another potential confounder to our data. Also, grouping of TLIF and minimally invasive TLIF procedures could impact outcome measures of HLOS and blood loss.[46] Much specificity is lost by such broad groupings. Accordingly, conclusions between posterior and anterior approaches can be drawn, but specific conclusions between ALIF and TLIF should be tempered. The rates of posterior instrumentation in the ALIF group is another potential confounder. It stands to reason that this could make outcomes worse in the ALIF group because of increased operative time and chance for complications. Physician training, surgical cost, and regional differences may be important confounders requiring further study. Individual complications are disparate and may have different impacts on patient outcomes. A lack of data granularity, specifically the inability to account for different pathology and patient presentation, remains a shortcoming of retrospective studies. As described above, ALIF patients are more likely to present with stenosis as compared to TLIF patients who primarily present with degenerative disc disease. Due to the retrospective nature of this study, it is not possible to determine to what degree this difference in pathology impacted outcomes stud-

Table 8. Univariate and multivariate comparison of major early complications.

Complication Variable	ALIF (n = 4325)	TLIF/PLIF (n = 3938)	Univariate Sig. (*P*)	Multivariate Sig. (*P*)
Univariate, N (%)				
Pulmonary embolism	30 (0.69%)	27 (0.62%)	.929	.941
Renal failure	1 (0.02%)	1 (0.02%)	.521	—
Pneumonia	39 (0.9%)	22 (0.51%)	.091*	.029*
Deep venous thrombosis	31 (0.72%)	25 (0.58%)	.749	.714
Peripheral nerve injury	0 (0%)	2 (0.05%)	.438	.996
Urinary tract infection	52 (1.20%)	79 (1.83%)	.004*	.012*
Stroke	2 (0.05%)	5 (0.12%)	.378	.297
Myocardial infarction	10 (0.23%)	11 (0.25%)	.829	—
Cardiac arrest	7 (0.16%)	9 (0.21%)	.661	.530
Blood transfusion >1 unit	471 (10.89%)	498 (11.51%)	.014	.011*
Superficial wound infection	49 (1.13%)	36 (0.83%)	.381	.272
Deep wound infection	25 (0.58%)	18 (0.42%)	.541	.383
Ventilator dependency >24 h	17 (0.39%)	6 (0.14%)	.062	.021*
Reintubation	12 (0.28%)	11 (0.25%)	.847	.879
Death	9 (0.21%)	9 (0.21%)	.970	.968

Abbreviations: TLIF/PLIF, transforaminal lumbar interbody fusion/posterior lumbar interbody fusion; ALIF, anterior lumbar interbody fusion; Sig., Significance.
*All values that are significant to *P*.

ied. While important, we hope that this is at least partially compensated through the large sample size afforded by the retrospective dataset.

CONCLUSIONS

In summary, both ALIF and TLIF were relatively safe, and both performed comparably on measures of mortality and most postsurgical complications. Patients undergoing elective single-level TLIF are generally older and present with increased comorbidities compared to single-level ALIF. Anterior lumbar interbody fusion is associated with decreased operative time, decreased incidence of UTI and blood transfusions, and increased incidence of respiratory complications. Hence, ALIF and TLIF may be of benefit to specific surgical subpopulations based on comorbidities and pathology.

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