The effect of anterior lumbar interbody fusion staging order on perioperative complications in circumferential lumbar fusions performed within the same hospital admission

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OBJECTIVE Anterior lumbar interbody fusion (ALIF) is a powerful technique that provides wide access to the disc space and allows for large lordotic grafts. When used with posterior spinal fusion (PSF), the procedures are often staged within the same hospital admission. There are limited data on the perioperative risk profile of ALIF-first versus PSF-first circumferential fusions performed within the same hospital admission. In an effort to understand whether these procedures are associated with different perioperative complication profiles, the authors performed a retrospective review of their institutional experience in adult patients who had undergone circumferential lumbar fusions.

METHODS The electronic medical records of patients who had undergone ALIF and PSF on separate days within the same hospital admission at a single academic center were retrospectively analyzed. Patients carrying a diagnosis of tumor, infection, or traumatic fracture were excluded. Demographics, surgical characteristics, and perioperative complications were collected and assessed.

RESULTS A total of 373 patients, 217 of them women (58.2%), met the inclusion criteria. The mean age of the study cohort was 60 years. Surgical indications were as follows: degenerative disease or spondylolisthesis, 171 (45.8%); adult deformity, 168 (45.0%); and pseudarthrosis, 34 (9.1%). The majority of patients underwent ALIF first (321 [86.1%]) with a mean time of 2.5 days between stages. The mean number of levels fused was 2.1 for ALIF and 6.8 for PSF. In a comparison of ALIF-first to PSF-first cases, there were no major differences in demographics or surgical characteristics. Rates of intraoperative complications including venous injury were not significantly different between the two groups. The rates of postoperative ileus (11.8% vs 5.8%, $p = 0.194$) and ALIF-related wound complications (9.0% vs 3.8%, $p = 0.283$) were slightly higher in the ALIF-first group, although the differences did not reach statistical significance. Rates of other perioperative complications were no different.

CONCLUSIONS In patients undergoing staged circumferential fusion with ALIF and PSF, there was no statistically significant difference in the rate of perioperative complications when comparing ALIF-first to PSF-first surgeries.

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KEYWORDS lumbar fusion; anterior approach; circumferential fusion; complications

COMBINED anterior-posterior approaches to the lumbar spine play an important role in the treatment of degenerative disease, deformity, infection, tumor, and traumatic pathologies.^{1,2} These procedures can be performed as a single operation within one hospitalization, as

two stages within a single hospitalization, or as two stages across separate hospitalizations. Staging depends on a variety of factors including the surgical indication, patient comorbidities, and access surgeon availability. For patients requiring circumferential fusion, there are no consensus

ABBREVIATIONS ALIF = anterior lumbar interbody fusion; ASA = American Society of Anesthesiologists; CCI = Charlson Comorbidity Index; EBL = estimated blood loss; PSF = posterior spinal fusion; UTI = urinary tract infection.

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guidelines on whether an anterior lumbar interbody fusion (ALIF) should be performed before or after a posterior spinal fusion (PSF).

Few studies have investigated the effect of staging anterior-posterior approaches on perioperative complications and clinical outcomes. In an effort to understand whether ALIF-first or PSF-first procedures were associated with different perioperative complication profiles, we performed a retrospective review of our institutional experience in adult patients who had undergone circumferential lumbar fusions. Perioperative complications were classified as either intraoperative or postoperative; intraoperative events included vascular injury, bowel perforation, or medical/cardiac event, whereas postoperative complications included anterior-related wound complications, hematoma, ileus, neurological deficit, or medical complications.

Methods

Patient Identification

Patients were identified through a retrospective search of all ALIF cases performed from 2007 to 2016 at the University of California, San Francisco. All activities were approved by our institutional review board. Adult patients (age ≥ 18 years) who had undergone a PSF during the same admission were included in our analysis. Patients with an underlying diagnosis of tumor, infection, or trauma were excluded. Patients who had undergone ALIF-PSF on the same day were also excluded. All abdominal retroperitoneal exposures were performed by a fellowship-trained vascular surgeon.

Data Collection

Patient demographics, surgical characteristics, and postoperative data were collected through a review of electronic medical records. Demographic data included age, sex, American Society of Anesthesiologists (ASA) classification, Charlson Comorbidity Index (CCI), BMI, and smoking status. Surgical indications were classified as follows: degenerative disease or spondylolisthesis, deformity, and pseudarthrosis. Surgical characteristics included order of anterior and posterior approaches, number of levels fused, estimated blood loss (EBL), and procedure duration. Surgical complications associated with the ALIF portion of the case were classified as intraoperative or postoperative. Intraoperative complications included vascular injury, bowel injury, or medical/cardiac event. Postoperative complications included ileus, anterior abdominal hematoma requiring surgical evacuation, anterior-related wound complications (dehiscence, infection, seroma, or abdominal hernia), or medical complications including cardiac event (new arrhythmia, congestive heart failure, or myocardial infarction), pulmonary event (pneumonia, pneumothorax, pulmonary edema, pleural effusion, chronic obstructive pulmonary disease exacerbation, or respiratory failure requiring reintubation), renal event (acute kidney injury or renal failure), urinary tract infection (UTI), and deep venous thrombosis or pulmonary embolus. Surgeries were classified as “ALIF first” if the ALIF had been performed before the posterior fusion on

a separate day during the same hospitalization. Surgeries were classified as “PSF first” if the posterior fusion had been performed before the ALIF on a separate day during the same hospitalization.

Statistical Analysis

Univariate analysis was performed using the chi-square test or Fisher’s exact test for categorical variables and the independent samples t-test for continuous variables. Statistical significance was defined as $p < 0.05$. A multivariate model was generated using binary logistic regression with backward elimination. Variables included in the models were selected based on a significance of $p < 0.100$ on univariate analysis. All analyses were performed using SPSS version 25 (IBM Corp.).

Results

Patient Demographics

A total of 373 patients, 217 of them women (58.2%), underwent an ALIF and PSF on separate days during the same admission with a surgical indication of degenerative/spondylolisthesis, deformity, or pseudarthrosis. The mean patient age was 60 years. The mean BMI was 29.0 kg/m² for the 371 patients with available data. ASA classification was available for 317 patients, with a distribution as follows: 9 class I (2.8%), 200 class II (63.1%), 106 class III (33.4%), and 2 class IV (0.6%) patients. The CCI scores were calculated for all patients, with a score of 0 in 227 (60.9%) and a score of 1–2 in 120 (32.2%). There were 54 smokers (14.5%) and 230 patients (61.7%) with previous spine surgery. The mean follow-up was 25 months (range 0–115 months). Demographic data are summarized in Table 1.

Surgical Characteristics

Surgical indications were as follows: degenerative disease or spondylolisthesis, 171 (45.8%); deformity, 168 (45.0%); and pseudarthrosis, 34 (9.1%). The majority of patients underwent ALIF first (321 [86.1%]) compared to 52 (13.9%) who underwent PSF first. The mean time between stages was 2.5 days (median 2.0 days). The overwhelming majority of patients (368 [98.7%]) had a stage duration of 7 days or less. The remaining 5 patients were delayed because of cardiac events in 2 cases, severe ileus in 1 case, acute kidney injury in 1 case, and a planned stage duration of 8 days in 1 case. The mean number of levels fused by ALIF was 2.1 with 84 single-level fusions (22.5%), 179 two-level fusions (48.0%), 97 three-level fusions (26.0%), and 13 four-level fusions (3.5%). The mean EBL during ALIF was 269 ml (range 30–3200 ml), and the mean ALIF procedure duration was 161 minutes (range 58–539 minutes). The mean number of levels fused by the posterior approach was 6.8 (range 1–18 levels fused) with a mean EBL of 1456 ml (range 25–7500 ml) and a procedure duration of 277 minutes (range 52–714 minutes). Surgical characteristics are summarized in Table 2.

Effect of ALIF Order on Staged Surgeries

We performed a comparison of ALIF-first to PSF-first

TABLE 1. Summary of characteristics among 373 patients who underwent ALIF

Variable	Value
Mean age in yrs	60 ± 12
Female sex	217 (58.2)
Mean BMI in kg/m ² *	29.0 ± 5.7
ASA class†	
I	9 (2.8)
II	200 (63.1)
III	106 (33.4)
IV	2 (0.6)
CCI score	
0	227 (60.9)
1	89 (23.9)
2	31 (8.3)
3	7 (1.9)
4	9 (2.4)
5	4 (1.1)
6	5 (1.3)
7	0 (0)
8	1 (0.3)
Smoker	54 (14.5)
Previous spine surgery	230 (61.7)
Mean FU in mos (range)	25 (0–115)

FU = follow-up.

Values are reported as the mean ± standard deviation or number of patients (%), unless indicated otherwise.

* Among 371 patients.

† Among 317 patients.

cases. There was no significant difference in age between the PSF-first and ALIF-first groups (61 vs 60 years, respectively, $p = 0.871$), female sex (59.6% vs 57.9%, $p = 0.821$), or BMI (28.6 vs 29.0 kg/m², $p = 0.663$). ASA classification, CCI scores, surgical indications, and rates of smoking were not significantly different. The mean number of fused levels was slightly higher in the ALIF-first group (2.1 vs 1.9, $p = 0.047$). The ALIF procedure duration and EBL were similar between groups. The mean levels fused by PSF (7.2 vs 6.8, respectively, $p = 0.534$) and PSF EBL (1736 vs 1406 ml, $p = 0.151$) were similar between the PSF- and ALIF-first groups; however, PSF duration was higher for the PSF-first group (338 vs 267 minutes, $p < 0.001$).

Perioperative complications were defined as intraoperative or postoperative. Intraoperative complications included injury to a major artery or vein, the bowel, or the urethra or a major medical/cardiac event. Rates of intraoperative venous injury were similar between ALIF- and PSF-first cases (3.4% vs 5.8%, respectively, $p = 0.425$). Postoperative complications included ileus, hematoma, ALIF-related wound complications (dehiscence, infection, or hernia), neurological deficit, or medical event. There was no difference in the overall postoperative complication rate (PSF: 32.7% vs 37.1%, $p = 0.543$). Rates of ileus

TABLE 2. Surgical characteristics among 373 patients who underwent ALIF

Characteristic	Value
Surgical indication	
Degenerative/spondylolisthesis	171 (45.8)
Deformity	168 (45.0)
Pseudarthrosis	34 (9.1)
Order of stages	
Ant-pst	321 (86.1)
Pst-ant	52 (13.9)
Mean no. of days btwn stages (range)	2.5 (1–15)
ALIF upper level	
L2	18 (4.8)
L3	106 (28.4)
L4	178 (47.7)
L5	71 (19.0)
Mean no. of levels fused by ALIF (range)	2.1 (1–4)
No. of levels fused by ALIF	
1	84 (22.5)
2	179 (48.0)
3	97 (26.0)
4	13 (3.5)
ALIF procedure time in mins (range)	161 (58–539)
ALIF EBL in ml (range)*	269 (30–3200)
Mean no. of levels fused by PSF (range)	6.8 (1–18)
PSF procedure time in mins (range)	277 (52–714)
PSF EBL in ml (range)†	1456 (25–7500)
Length of stay in days (range)	9.5 (3–46)

ant = anterior; pst = posterior.

Values expressed as number (%), unless indicated otherwise.

* Among 243 patients.

† Among 250 patients.

(11.8% vs 5.8%, $p = 0.194$) and ALIF-related wound complications (9.0% vs 3.8%, $p = 0.283$) were slightly higher for the ALIF-first group. Rates of other postoperative complications were not significantly different. Length of stay and long-term follow-up were also not significantly different between the two groups. These results are summarized in Table 3.

Multivariate Analysis

Two multivariate models were generated to identify potential factors associated with intraoperative and postoperative complications. Variables were selected based on a significance of $p < 0.100$ on univariate analysis. Although not significant in the univariate analysis, ALIF-first was also included in the multivariate models. The model for intraoperative complications included age, ALIF EBL, ALIF duration, ASA class, and ALIF first. In this model, only ALIF EBL was associated with the presence of an intraoperative complication. The model for postoperative complications included age, BMI, ALIF procedure duration, PSF procedure duration, PSF EBL, surgical

TABLE 3. Effect of ALIF order on staged procedures

Variable	PSF-First Group	ALIF-First Group	p Value
No. of patients	52	321	
Age in yrs	61	60	0.871
Female sex	31 (59.6)	186 (57.9)	0.821
BMI in kg/m ² *	28.6	29.0	0.663
ASA class*			
I–II	24 (57.1)	185 (67.3)	0.222
III–IV	18 (42.9)	90 (32.7)	0.222
CCI score			
0–2	48 (92.3)	299 (93.1)	0.771†
3–5	4 (7.7)	16 (5.0)	0.501†
6–8	0 (0)	6 (1.9)	0.99†
Surgical indication			
Degenerative/spondylolisthesis	19 (36.5)	152 (47.4)	0.147
Deformity	27 (51.9)	141 (43.9)	0.282
Pseudarthrosis	6 (11.5)	28 (8.7)	0.513
Smoker	8 (15.4)	46 (14.3)	0.841
Mean no. of ALIF levels fused	1.9	2.1	0.047
ALIF procedure time in mins	183	157	0.065
ALIF EBL in ml*	317	261	0.408
Mean no. of PSF levels fused	7.2	6.8	0.534
PSF procedure time in mins	338	267	<0.001
PSF EBL in ml*	1736	1406	0.151
Intraop complications, any	3 (5.8)	12 (3.7)	0.449†
Arterial injury	0 (0)	0 (0)	—
Venous injury	3 (5.8)	11 (3.4)	0.425†
Bowel/ureteral injury	0 (0)	0 (0)	—
Medical/cardiac event	0 (0)	1 (0.3)	0.99†
Postop complications, any	17 (32.7)	119 (37.1)	0.543
Ileus	3 (5.8)	38 (11.8)	0.194
Hematoma	0 (0)	3 (0.9)	0.99†
Ant wound complication	2 (3.8)	29 (9.0)	0.283†
Neurological deficit	0 (0)	1 (0.3)	0.99†
Medical event, any	13 (25.0)	76 (23.7)	0.835
Cardiac	4 (7.7)	23 (7.2)	0.779†
Pulmonary	3 (5.8)	26 (8.1)	0.781†
Renal	0 (0)	8 (2.5)	0.606†
UTI	3 (5.8)	17 (5.3)	0.749†
DVT/PE	1 (1.9)	4 (1.2)	0.530†
Length of stay in days	11.1	9.3	0.075
FU in mos	29.9	24.6	0.155

DVT = deep venous thrombosis; PE = pulmonary embolus.

Values expressed as number (%), unless indicated otherwise. Boldface type indicates statistical significance.

* Among patients with complete data.

† Fisher's exact test.

TABLE 4. Multivariate analysis of variables associated with postoperative complications

Variable	OR (95% CI)	p Value
Age	1.039 (1.018–1.061)	<0.001
BMI	1.041 (1.001–1.083)	0.047
PSF duration	1.002 (1.000–1.004)	0.027

Boldface type indicates statistical significance.

indication, and ALIF first. In this model, age (OR 1.039, 95% CI 1.018–1.061, $p < 0.001$), BMI (OR 1.041, 95% CI 1.001–1.083, $p = 0.047$), and PSF duration (OR 1.002, 95% CI 1.000–1.004, $p = 0.027$) were associated with a postoperative complication. These results are summarized in Table 4.

Discussion

ALIF is a versatile surgical technique with roles in the treatment of degenerative disease, deformity, tumor, infection, and pseudarthrosis. There are no consensus guidelines on the role of staging ALIF-PSF procedures, and data on the perioperative complications related to ALIF-first or PSF-first surgery are limited. In this study, we attempted to identify associations between the order of ALIF and ALIF-related perioperative complications.

The major notable finding of this study was that the ALIF order did not affect perioperative ALIF-related complications. The rates of intraoperative complications (arterial injury, venous injury, bowel injury, ureteral injury, and medical event) and postoperative complications (ileus, hematoma, wound complications, neurological deficit, and medical) were not significantly different between the PSF-first and ALIF-first cohorts. Therefore, ALIF order is unlikely to have a major impact on the perioperative risk profile for patients undergoing circumferential fusion and should not be a major factor in the decision-making process for staging the procedures.

There are limited data investigating the role of ALIF-first compared to PSF-first procedures in circumferential fusion. In a review of the National Inpatient Sample (NIS) from 1998 to 2006, Memtsoudis et al. found that patients undergoing anterior-posterior fusion were younger than those undergoing posterior approaches and had longer stays, higher procedure-related complications, higher rates of blood transfusions, and higher mortality, although the latter was primarily related to patients with metastatic disease and trauma.³ The highest rates of fatal outcomes and complications were associated with an anterior thoracic approach, consistent with other reports in the literature;⁴ however, the ALIF carries a significantly lower risk profile than the transthoracic approach.^{5,6} Hassanzadeh et al. reviewed 63 patients undergoing combined anterior-posterior fusion for adult deformity and compared those with surgeries staged less than 21 days apart to those with procedures greater than 21 days apart.⁷ There were no statistically significant differences in total EBL, major complications, or total hospital stay; however, a longer staging time was associated with fewer blood transfusions. These

authors did not assess differences in anterior-first versus posterior-first surgical plans.

Tsirikos et al. analyzed a cohort of 45 pediatric patients undergoing anterior-posterior fusion and found increased intraoperative blood loss, operative time, and medical complications in the single-stage cohort.⁸ In adult deformity, Rhee et al. utilized a staged approach for high-risk revision cases by separating the posterior surgery into two smaller procedures in order to limit hemodynamic risk.⁹ Hassanzadeh et al. demonstrated that staging anterior and posterior procedures by 21 days resulted in reductions in combined EBL, perioperative complications, and total hospital stay; however, none of these factors met statistical significance.⁷ None of these studies specifically addressed the role of ALIF-first or PSF-first procedures with respect to blood loss and perioperative complication risk profile. We showed that among patients undergoing circumferential lumbar fusion during a single hospital admission, ALIF stage order is not associated with the presence of a perioperative complication. In a multivariate model assessing factors associated with an intraoperative complication, the only significant association was with ALIF EBL, which was expected given the blood loss associated with an intraoperative venous injury. No other variables were associated with the presence of an intraoperative complication. In a separate model assessing postoperative complications, only age, BMI, and PSF duration were associated with the presence of a postoperative complication. Age and procedure duration are well-recognized risk factors,^{10–16} and our group has previously identified obesity as a risk factor for postoperative complications after ALIF, particularly with respect to ileus, wound-related complications, and UTI.¹⁷

Our typical institutional practice is to utilize an ALIF-first approach, particularly for complex cases. There are several advantages to this approach such as maximizing graft size without the need to overpower posterior instrumentation. This allows the surgeon to assess post-ALIF lordosis and determine the need for additional posterior column osteotomies. In patients with radicular symptoms who do not improve with ALIF, additional foraminotomies can be performed during the posterior stage. In this series, a PSF-first approach was most commonly used in cases in which a planned transforaminal or lateral lumbar interbody fusion had been aborted, an ALIF had been recommended based on intraoperative findings after PSF, or there had been limited access surgeon availability. Given the design of this study, it was not possible to identify the reason for PSF-first approaches in each individual case; however, we do not believe such knowledge would have altered our results. There are several limitations to this study, most notably its retrospective design and primary focus on perioperative complications rather than long-term complications such as pseudarthrosis, proximal junctional failure, graft subsidence, or rod fracture.

Conclusions

Among patients undergoing circumferential lumbar fusion with ALIF and PSF, there was no significant difference in perioperative complications between those who had undergone ALIF-first procedures and those who had

undergone PSF-first procedures. In a multivariate model, age, BMI, and PSF procedure duration were associated with the presence of a postoperative complication. In appropriately selected patients, the perioperative risk profile of ALIF does not change when performed before or after a PSF.

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Author Contributions

Conception and design: Clark, Safae, Tenorio, Ames. Acquisition of data: all authors. Analysis and interpretation of data: Clark, Safae, Tenorio. Drafting the article: Clark, Safae, Tenorio. Critically revising the article: Clark, Safae, Tenorio. Reviewed submitted version of manuscript: Clark, Safae, Tenorio, Osorio, Hu, Tay, Burch, Berven, Deviren, Dhall, Chou, Mummaneni, Eichler, Ames. Approved the final version of the manuscript on behalf of all authors: Clark. Statistical analysis: Clark, Safae, Tenorio. Administrative/technical/material support: Clark. Study supervision: Clark.

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