

Comparison of value per operative time between anterior lumbar interbody fusion and lumbar disc arthroplasty: A propensity score-matched analysis

ABSTRACT

Context: Despite the growing evidence demonstrating its effectiveness, lumbar disc arthroplasty (LDA) rates have not increased significantly in recent years. A likely contributing factor is uncertainties related to reimbursement and insurers' denial of coverage due to fear of late complications, reoperations, and unknown secondary costs. However, no prior study has compared the physician reimbursement rates of lumbar fusion and LDA.

Aim: The aim of this study was to compare the relative value units (RVUs) per min as well as 30-day readmission, reoperation, and morbidity rates between anterior lumbar interbody fusion (ALIF) and LDA.

Settings and Design: This was a retrospective cohort study.

Subjects and Methods: The current study utilizes data obtained from the National Surgical Quality Improvement Program database. Patients who underwent ALIF or LDA between 2011 and 2019 were included in the study.

Statistical Analysis Used: Propensity score matching analysis was performed according to demographic characteristics and comorbidities. Matched groups were compared through Fisher's exact test and independent t-test for categorical and continuous variables, respectively.

Results: Five hundred and two patients who underwent ALIF were matched with 591 patients who underwent LDA. Mean RVUs per min was significantly higher for ALIF compared to LDA. ALIF was associated with a significantly higher 30-day morbidity rate compared to LDA, while readmission and reoperation rates were statistically similar. ALIF was also associated with higher frequencies of deep venous thrombosis (DVT) and blood transfusions.

Conclusions: ALIF is associated with significantly higher RVUs per min compared to LDA. ALIF is also associated with higher rates of 30-day morbidity, DVT, and blood transfusions, while readmission and reoperation rates were statistically similar.

Keywords: Anterior lumbar interbody fusion, lumbar disc arthroplasty, lumbar disc replacement, outcomes, relative value units

INTRODUCTION

Fusion procedures have been the mainstay of surgical management of lumbar degenerative disc disease (DDD). Anterior lumbar interbody fusion (ALIF) is an effective surgical option for lumbar DDD which avoids damage to the paraspinal muscles and limits the manipulation of neural elements that occur in posterior approaches to the spine.^[1] In recent years, the utilization of ALIF has increased at an

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average of 24.07% annually, and its positive outcomes have been consistently demonstrated.^[2-4] However, a common criticism of fusion procedures is the associated disruption of motion at the surgical level, which increases stress and predisposes to degeneration at the adjacent levels.^[5,6] Total disc replacement is a relatively novel technique which has been shown to be a highly effective alternative to fusion for the treatment of lumbar DDD.^[7,8] It has been suggested that the motion-preserving nature of disc arthroplasty provides a unique benefit of reducing adjacent segment disease.^[9] Literature comparing the outcomes of fusion and lumbar disc arthroplasty (LDA) has largely been in support of the safety and efficacy of LDA.^[7,8,10-12]

Despite the growing evidence demonstrating its effectiveness, LDA rates have not increased significantly in recent years.^[13,14] Several possible explanations for the slow expansion have been proposed. A likely contributing factor is insurers' denial of coverage due to fear of late complications, reoperations, and unknown secondary costs.^[15,16] Although the cost analyses of LDA have been performed, no prior study has compared the physician reimbursement rates of lumbar fusion and LDA.^[17-19] Therefore, the aim of this study was to compare the relative value units (RVUs) per min of ALIF and LDA.

SUBJECTS AND METHODS

This study is exempt from the informed consent requirement and institutional review board review as it utilizes a de-identified national database and no direct patient involvement occurred.

Study design and population

This retrospective cohort study utilizes data obtained from the American College of Surgeons National Surgical Quality Improvement Program database (ACS-NSQIP) has been shown to have excellent validity, reliability, and a low rate of reporting the error.^[20,21] Patients ≥ 18 years old who underwent ALIF or LDA between 2011 and 2019 were identified and included based on Current Procedural Terminology codes 22,558 and 22,857, respectively. Exclusion criteria included multilevel, revision, emergency, nonelective, deformity procedures, intraspinal lesions, concomitant cervical procedures, laminectomy, laminotomy, and other posterior procedures. Patients with missing operation time, reoperation, and readmission data were also removed to prevent biases in the results.

Outcomes and variables

The primary outcome of interest was RVUs per min, which was compared between the matched ALIF and LDA groups. Secondary outcomes were 30-day readmission, reoperation,

morbidity, and individual complication rates [Table 1]. Readmission includes any inpatient stay in the same or another hospital related to the surgical procedure. Reoperation includes all major surgical procedures requiring return to the operating room for the intervention of any kind. Morbidity includes the occurrence of one or more complications reported in the ACS-NSQIP dataset, including infectious, cardiopulmonary, renal, neurological, hematologic, and thromboembolic complications. The analyzed individual complications included superficial wound infections, pneumonia, pulmonary embolism, the requirement of ventilator >48 h, acute renal failure, urinary tract infection, stroke, cardiac arrest, deep venous thrombosis (DVT), sepsis, and blood transfusions [Table 1].

Statistical analysis

All statistical analyses were completed in SPSS version 28 (IBM Corp., Armonk, New York, United States). Propensity score matching analysis was performed with a match tolerance of 0.01 according to demographic characteristics, comorbidities, and preoperative laboratory values. Patients were then paired using the nearest neighbor approach, without replacement. Matched groups were compared through Fisher's exact test and independent *t*-test for categorical and continuous variables, respectively. The criterion for statistical significance was set at $P \leq 0.05$.

Table 1: Relative value units per minute and 30-day outcomes in propensity score matched groups

	ALIF, n (%)	LDA, n (%)	P
Total RVUs, mean \pm SD	41.1 \pm 16.5	33.9 \pm 13.9	<0.001*
RVUs per min, mean \pm SD	0.367 \pm 0.267	0.302 \pm 0.174	<0.001*
Operation time, mean \pm SD	155.0 \pm 100.5	132.3 \pm 67.6	<0.001*
30-day outcomes			
Readmission	21 (4.2)	20 (3.4)	0.488
Reoperation	14 (2.8)	12 (2.0)	0.412
Morbidity	40 (8.0)	21 (3.6)	0.002*
Complications			
Superficial wound infections	5 (1.0)	9 (1.5)	0.440
Deep incisional SSI	2 (0.4)	1 (0.2)	0.470
Organ/space SSI	0	1 (0.2)	0.356
Pneumonia	2 (0.4)	2 (0.3)	0.870
Pulmonary embolism	1 (0.2)	3 (0.5)	0.400
Ventilator >48 h	3 (0.6)	1 (0.2)	0.242
Acute renal failure	1 (0.2)	0	0.278
Urinary tract infection	5 (1.0)	2 (0.3)	0.174
Stroke	1 (0.2)	0	0.459
Cardiac arrest requiring CPR	2 (0.4)	0	0.211
DVT	10 (2.0)	1 (0.2)	0.003*
Sepsis	1 (0.2)	1 (0.2)	0.908
Blood transfusions	20 (4.0)	4 (0.7)	<0.001*

*Statistically significant ($P < 0.05$). Fisher's exact test performed for categorical variables; independent *t*-test performed for continuous variables.

SD - Standard deviation, RVUs - Relative value units, SSI - Surgical site infection, CPR - Cardiopulmonary resuscitation, DVT - Deep venous thrombosis, ALIF - Anterior lumbar interbody fusion, LDA - Lumbar disc arthroplasty

RESULTS

The total cohort before matching consisted of 6722 patients. Five hundred and two patients who underwent ALIF were matched with 591 patients who underwent LDA through propensity score matching. There were no significant differences in sex, race, and ethnicity ($P > 0.05$) between the matched groups, but patients in the ALIF group were significantly older on average (48.2 ± 14.8 years vs. 43.8 ± 12.6 years, $P < 0.001$). Hypertension requiring medication (32.1% vs. 25.4%, $P = 0.015$), chronic steroid use (2.0% vs. 0.3%, $P = 0.016$), and American Society of Anesthesiologists class of 3 or greater (26.7% vs. 21.0%, $P = 0.032$) were more common in the ALIF group compared to LDA group [Table 2].

Mean RVUs per min was significantly higher for ALIF compared to LDA (0.367 ± 0.267 vs. 0.302 ± 0.174 , $P < 0.001$). ALIF was also associated with higher total RVUs (41.1 ± 16.5 vs. 33.0 ± 13.9 , $P < 0.001$) and operation time (155.0 ± 100.5 vs. 132.3 ± 67.6 , $P < 0.001$). In regard to 30-day outcomes, ALIF was associated with significantly higher rates of morbidity (8.0% vs. 3.6%, $P = 0.002$), DVT (2.0% vs. 0.2%, $P = 0.003$), and blood transfusions (4.0% vs.

0.7%, $P < 0.001$). Readmission and reoperation rates were statistically similar. There were no differences in rates of other individual complications, which included wound infections, pneumonia, pulmonary embolism, prolonged ventilator requirement, acute renal failure, urinary tract infection, stroke, cardiac arrest, and sepsis ($P > 0.05$) [Table 1].

DISCUSSION

The purpose of the current study was to compare the RVUs per min between ALIF and LDA. In addition, we evaluated for differences in 30-day outcomes between the two procedures. Our results showed that ALIF was associated with significantly higher mean RVUs per min. ALIF was also associated with higher rates of 30-day morbidity, DVT, and blood transfusions.

RVU was created for the Centers for Medicare and Medicaid to provide a measure of productivity for physician services. RVU is widely used to determine physician payments nationally and considers the physician's work, expenses of the physician's practice, and professional liability insurance.^[22] In general, higher RVU is assigned to procedures associated with higher complexity and difficulty.^[23] Recently, a number of studies in spine and arthroplasty literature have found disparities

Table 2: Demographic and clinical characteristics before and after propensity score matching

	Total cohort			Propensity matched cohort		
	ALIF, n (%)	LDA, n (%)	P	ALIF, n (%)	LDA, n (%)	P
Number of subjects	6131	591		502	591	
Age (years), mean±SD	54.7±13.5	43.8±12.6	<0.001*	48.2±14.8	43.8±12.6	<0.001*
Female sex	3189 (52.0)	226 (38.2)	<0.001*	196 (39.0)	226 (38.2)	0.803
Black race	508 (8.3)	47 (8.0)	0.876	50 (9.9)	47 (8.0)	0.245
Hispanic ethnicity	415 (6.8)	30 (5.1)	0.281	32 (6.4)	30 (5.1)	0.781
BMI (kg/m ²), mean±SD	30.2±6.1	28.8±5.7	<0.001*	29.2±5.8	28.8±5.7	0.131
Comorbidities						
Diabetes mellitus	823 (13.4)	47 (8.0)	<0.001*	46 (9.2)	47 (8.0)	0.475
Current smoker within 1 year	1402 (22.9)	134 (22.7)	0.959	108 (21.5)	134 (22.7)	0.645
Dyspnea	259 (4.2)	6 (1.0)	<0.001*	6 (1.2)	6 (1.0)	0.776
Functional dependence	89 (1.5)	7 (11.8)	0.718	4 (0.8)	7 (11.8)	0.561
Severe COPD	245 (4.0)	6 (1.0)	<0.001*	11 (2.2)	6 (1.0)	0.143
Hypertension requiring medication	2704 (44.1)	150 (25.4)	<0.001*	161 (32.1)	150 (25.4)	0.015*
Open wound/wound infection	12 (0.2)	0	0.616	1 (0.2)	0	0.459
Chronic steroid use	188 (3.1)	2 (0.3)	<0.001*	10 (2.0)	2 (0.3)	0.016*
Bleeding disorders	60 (1.0)	1 (0.2)	0.041	2 (0.4)	1 (0.2)	0.597
ASA ≥3	2396 (39.1)	124 (21.0)	<0.001*	134 (26.7)	124 (21.0)	0.032*
Wound class ≥2	80 (1.3)	9 (1.5)	0.575	9 (1.85)	9 (1.5)	0.727
Preoperative laboratory values						
Elevated creatinine	540 (8.8)	48 (8.1)	0.647	37 (7.4)	48 (8.1)	0.653
Elevated white blood cells	320 (5.2)	34 (5.8)	0.563	31 (6.2)	34 (5.8)	0.798
Low hematocrit	340 (5.5)	18 (3.0)	0.007*	12 (2.4)	18 (3.0)	0.580
Low platelet count	223 (3.6)	17 (2.9)	0.416	19 (3.8)	17 (2.9)	0.497

*Statistically significant ($P < 0.05$). Fisher's exact test performed for categorical variables; independent *t*-test performed for continuous variables. SD - Standard deviation, COPD - Chronic obstructive pulmonary disease, ASA - American Society of Anesthesiologists, ALIF - Anterior lumbar interbody fusion, LDA - Lumbar disc arthroplasty, BMI - Body mass index

between assigned RVUs and procedure complexity, indicating the prevalence of inappropriate RVU assignments.^[24-27] Thus, the assessment of RVUs assigned to specific orthopedic procedures is critical.

Sodhi *et al.* compared RVUs between ALIF and posterior lumbar interbody fusion (PLIF) and found that ALIF was associated with lower mean operative times but higher mean RVUs compared to PLIF. The authors extrapolated that performing ALIF as opposed to PLIF may potentially increase annual compensation by nearly \$80,000 for spinal surgeons.^[26] Although RVU for ALIF has been previously analyzed, no prior study has evaluated the RVU assigned to LDA. Our findings showed that, on average, ALIF is assigned significantly higher total RVUs compared to LDA. Furthermore, despite requiring higher mean operation time, ALIF was associated with significantly higher RVUs per min. This demonstrates that for spinal surgeons, performing ALIF over LDA may provide greater value for time, which is a particularly important distinction given the clinically similar outcomes reported in the literature.^[7,10,28]

Although previous studies have demonstrated LDA to be an effective treatment for DDD, the data regarding short-term clinical outcomes of LDA and its comparison to fusion procedures remains controversial. The current study found that there were no differences in readmission and reoperation rates between ALIF and LDA. However, LDA was found to be associated with lower rates of 30-day morbidity and complications, with significant differences observed for DVT and blood transfusions. Eliasberg *et al.* found that reoperation was more common following lumbar fusion compared to LDA.^[29] Shultz *et al.* reported no difference in rates of readmission or adverse events between ALIF and LDA.^[8] While our findings suggest a more favorable 30-day outcome safety profile for LDA compared to ALIF, the paucity of literature comparing their clinical outcomes and the substantial disparity within the previous studies warrant further investigation.

The lower rate of morbidity associated with LDA compared to ALIF may be secondary to the fact that fewer and more experienced surgeons are performing LDAs in the United States that are being reported by the NSQIP database. Contrastingly, there is greater nationally represented variability in the ALIF group. In addition, it is likely that patients undergoing ALIF have more significant surgical pathology requiring correction, such as significant spondylolisthesis, which can explain why the transfusion and DVT rates are higher in the ALIF group. One factor potentially contributing to the difference in DVT rates is the earlier return to activity following LDA.^[11] In

addition, LDA patients are typically younger and have less severe pathology, which also likely contributes to lower DVT rates.

This study is not without limitations. The retrospective design of the study limits the level of evidence and the conclusions that can be drawn. The study findings may be impacted by generalizability bias given that the ACS-NSQIP database is comprised mainly of academic medical centers. There was a disproportionately smaller number of patients who underwent LDA compared to those who underwent ALIF. Although propensity score matching analysis allows for the balancing of the measured baseline covariates between the two groups, unmeasured characteristics would remain unbalanced, potentially producing a confounding effect. In addition, given that stand-alone ALIF is highly uncommon, it is likely that the ALIF patients included in the study underwent a staged posterior fusion during the same admission, which could not be accounted for using the NSQIP database. Despite these limitations, the current study provides valuable evidence regarding the reimbursement rates and outcomes of LDA and ALIF, which is currently lacking in the literature.

CONCLUSIONS

ALIF was associated with significantly higher RVUs per min compared to LDA. ALIF was associated with higher rates of 30-day morbidity, DVT, and blood transfusion. These findings provide valuable evidence for assessing the physician reimbursement and outcomes of the available surgical treatment options for lumbar DDD

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Conflicts of interest

There are no conflicts of interest.

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