The impact of obesity on perioperative complications in patients undergoing anterior lumbar interbody fusion

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OBJECTIVE Anterior approaches to the lumbar spine provide wide exposure that facilitates placement of large grafts with high fusion rates. There are limited data on the effects of obesity on perioperative complications.

METHODS Data from consecutive patients undergoing anterior lumbar interbody fusion (ALIF) from 2007 to 2016 at a single academic center were analyzed. The primary outcome was any perioperative complication. Complications were divided into those occurring intraoperatively and those occurring postoperatively. Multivariate logistic regression was used to assess the association of obesity and other variables with these complications. An estimation table was used to identify a body mass index (BMI) threshold associated with increased risk of postoperative complication.

RESULTS A total of 938 patients were identified, and the mean age was 57 years; 511 were females (54.5%). The mean BMI was 28.7 kg/m², with 354 (37.7%) patients classified as obese (BMI ≥ 30 kg/m²). Forty patients (4.3%) underwent a lateral transthoracic approach, while the remaining 898 (95.7%) underwent a transabdominal retroperitoneal approach. Among patients undergoing transabdominal retroperitoneal ALIF, complication rates were higher for obese patients than for nonobese patients (37.0% vs 28.7%, $p = 0.010$), a difference that was driven primarily by postoperative complications (36.1% vs 26.0%, $p = 0.001$) rather than intraoperative complications (3.2% vs 4.3%, $p = 0.416$). Obese patients had higher rates of ileus (11.7% vs 7.2%, $p = 0.020$), wound complications (11.4% vs 3.4%, $p < 0.001$), and urinary tract infections (UTI) (5.0% vs 2.5%, $p = 0.049$). In a multivariate model, age, obesity, and number of ALIF levels fused were associated with an increased risk of postoperative complication. An estimation table including 19 candidate cut-points, odds ratios, and adjusted p values found a BMI ≥ 31 kg/m² to have the highest association with postoperative complication ($p = 0.012$).

CONCLUSIONS Obesity is associated with increased postoperative complications in ALIF, including ileus, wound complications, and UTI. ALIF is a safe and effective procedure. However, patients with a BMI ≥ 31 kg/m² should be counseled on their increased risks and warrant careful preoperative medical optimization and close monitoring in the postoperative setting.

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KEYWORDS lumbar fusion; anterior approach; anterior lumbar interbody fusion; body mass index; obesity; perioperative complications

OBESITY is a significant public health concern associated with increased risk of several long-term health problems, including disc degeneration and low-back pain.¹ In cases of severe degeneration, instability, or deformity, patients may require interbody fusion. A variety

of options exist, including posterior lumbar interbody fusion, transforaminal lumbar interbody fusion, direct lateral lumbar interbody fusion, oblique lumbar interbody fusion, and anterior lumbar interbody fusion (ALIF).² Obesity can increase the technical difficulty of these operations due to

ABBREVIATIONS ALIF = anterior lumbar interbody fusion; BMI = body mass index; BMP = bone morphogenetic protein; CCI = Charlson Comorbidity Index; DVT = deep venous thrombosis; EBL = estimated blood loss; LOS = length of stay; PE = pulmonary embolism; UTI = urinary tract infection.

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challenges associated with exposure, operative time, and blood loss.³⁻⁷ While the literature has established an association between increased complications and obesity in patients undergoing posterior spinal fusions,^{1,3,8-11} few have reported on surgical complications after ALIF.¹²⁻¹⁴

The ALIF procedure has become an increasingly popular technique because it provides wide access and visualization of the disc space, which facilitates a complete discectomy, and it can accommodate a large, lordotic interbody graft that is associated with high fusion rates.¹⁵ Additionally, several studies have reported improved restoration of lumbar lordosis and disc height compared to other interbody techniques.¹⁶⁻¹⁸ Disadvantages include the need for an access surgeon, increased risk of vascular injury, inability to easily access higher vertebral levels, and the frequent need for a secondary procedure for posterior stabilization.¹⁷ There are limited data on the effect of obesity and ALIF-related perioperative complications, with no studies focusing specifically on immediate postoperative complications.¹²

Given the increased popularity and utilization of ALIF, understanding the role obesity plays in the perioperative risk profile for this surgery is critical. To evaluate this effect, we performed a retrospective review of experience at a single tertiary care center, with a specific goal of determining potential associations between body mass index (BMI), obesity, and perioperative complications among patients undergoing ALIF. Furthermore, we distinguished intraoperative from immediate postoperative complications to control for the unique risks associated with the ALIF exposure.

Methods

Patient Identification

We performed a retrospective review of consecutive patients who underwent ALIF from 2007 to 2016 at the University of California, San Francisco Medical Center. All activities were approved by our institutional review board. Exclusion criteria included patients under 18 years of age, patients with insufficient data to calculate BMI, and patients undergoing revision ALIF. Additionally, patients undergoing lateral transposas approaches were excluded. All transabdominal retroperitoneal or lateral transthoracic exposures were performed by a fellowship-trained vascular surgeon.

Data Collection

Patient demographics and surgical characteristics were collected through a review of the institutional electronic medical records system. Variables collected included age, sex, BMI, obesity (defined using the World Health Organization classification of BMI ≥ 30), Charlson Comorbidity Index (CCI), smoking status, and presence of diabetes. Surgical characteristics were collected, including surgical approach (transabdominal retroperitoneal or lateral transthoracic), number of levels fused, anterior uppermost level, procedure duration, estimated blood loss (EBL), presence of a second-stage surgery during the same admission, length of stay (LOS), and follow-up duration.

Surgical complications were categorized as intraopera-

tive or postoperative. Intraoperative complications were classified as arterial, venous, ureteral, bowel, or medical. Postoperative complications were classified as ileus, wound-related (dehiscence, hernia, or infection), neurological (new postoperative neurological symptom or deficit), ALIF-related hematoma, or medical. Postoperative medical complications were further subclassified as pulmonary (pneumonia, pleural effusion, pneumothorax, pulmonary edema, exacerbation of chronic obstructive pulmonary disease, hypoxia, or respiratory failure requiring intubation), cardiac (arrhythmia, congestive heart failure, myocardial infarction, or orthostatic hypotension), urological (urinary retention, incontinence, epididymitis, scrotal edema, or retrograde ejaculation), renal (acute kidney injury or acute renal failure), urinary tract infection (UTI), and thromboembolic events, including deep venous thrombosis (DVT) or pulmonary embolism (PE).

Statistical Analysis

Univariate analysis was performed using the chi-square test for categorical variables and the Student t-test for continuous variables. A multivariate model was generated using binary logistic regression. Variables with a p value < 0.10 on univariate analysis were included in the multivariate model with backward elimination. Statistical significance was defined as $p < 0.050$. To assess the associations of BMI with the risk of perioperative complications, several approaches were applied to find the optimal cut-points for BMI, including smoothing splines, grouped data plots, and an estimation table of optimal cut-points. The grouped data plot was created by grouping BMI into deciles and plotting the mean value of BMI within each decile against the proportion of patients with perioperative complications in that decile.

Results

Patient Demographics

A total of 938 patients met inclusion criteria (898 who underwent a transabdominal retroperitoneal approach and 40 who underwent a lateral transthoracic approach). The patients' mean age was 57 years (range 18–85 years), and 511 (54.5%) of the patients were women. The mean CCI score was 0.8, and the mean BMI was 28.7 kg/m² (range 16.4–49.7 kg/m²). Using BMI ≥ 30 kg/m², we identified 354 obese patients (37.7%). There were 117 smokers (12.5%), 99 diabetics (10.6%), and 540 patients (57.6%) with a history of spine surgery. The mean number of levels fused by ALIF was 1.9 (range 1–8), with a distribution of upper levels as follows: 8 (0.9%) at T10–12, 15 (1.6%) at L1, 35 (3.7%) at L2, 195 (20.8%) at L3, 412 (43.9%) at L4, and 273 (29.1%) at L5, including one case of S1–2 ALIF. A lateral transthoracic approach was used in 40 cases (4.3%), and a transabdominal retroperitoneal approach was used in the remaining 898 cases (95.6%). The mean operative duration was 253 minutes, and the mean EBL was 364 ml. Two-stage surgeries (anterior-posterior fusions performed on separate days) were performed in 778 cases (82.9%). The mean LOS was 7 days, and the mean follow-up duration was 27 months. Patient demographics are summarized in Table 1.

TABLE 1. Demographics and surgical characteristics in 938 patients

Characteristic	Value
Age, yrs	
Mean (range)	57 (18–85)
Median (IQR)	59 (50–67)
No. of females	511 (54.5%)
BMI, kg/m ²	
Mean (range)	28.7 (16.4–49.7)
Median (IQR)	28.1 (24.3–32.3)
Obese (BMI ≥30)	354 (37.7%)
CCI score	
Mean (range)	0.8 (0–11)
Median (IQR)	0 (0–1)
Diabetic	99 (10.6%)
Current smoker	117 (12.5%)
Previous spine surgery	540 (57.6%)
Indication for surgery	
Degenerative/spondylolisthesis	470 (50.1%)
Deformity	317 (33.8%)
Infection	43 (4.6%)
Trauma	7 (0.7%)
Tumor	13 (1.4%)
Pseudarthrosis	88 (9.4%)
No. of anterior levels fused	
1	350 (37.3%)
2	396 (42.2%)
3	164 (17.5%)
≥4	28 (3.0%)
Lateral transthoracic approach	40 (4.3%)
Anterior upper level	
T10–12	8 (0.9%)
L1	15 (1.6%)
L2	35 (3.7%)
L3	195 (20.8%)
L4	412 (43.9%)
L5*	273 (29.1%)
Operative duration, mins	
Mean (range)	253 (58–823)
Median (IQR)	211 (137–341)
EBL, ml	
Mean (range)	364 (20–12,000)
Median (IQR)	200 (100–300)
Two-stage surgery	778 (82.9%)
Any surgical complication	311 (33.2%)
Intraoperative	40 (4.3%)
Postoperative	291 (31.0%)
LOS, days	
Mean (range)	7 (1–71)
Median (IQR)	6 (4–9)
Follow-up duration, mos	
Mean (range)	27 (0–155)
Median (IQR)	16 (8–9)

* One case of S1–2 ALIF.

Surgical Complications

Surgical complications were identified in 311 patients (33.2%). This included 40 patients with intraoperative complications (4.3%) and 291 patients with postoperative complications (31.0%). We compared patients with any perioperative complication to those without a perioperative complication. Patients with a complication were older (61 vs 56 years, $p < 0.001$) and had higher CCI score distributions ($p = 0.004$). There were no differences in sex or smoking status. Among patients with surgical complications, there was a higher rate of obesity (43.1% vs 35.1%, $p = 0.017$). Patients with any complication had a higher mean number of levels fused (2.1 vs 1.8, $p < 0.001$) and a higher rate of bone morphogenetic protein (BMP) use (57.6% vs 48.2%, $p = 0.007$). There was a higher proportion of patients who underwent a lateral transthoracic approach in the surgical complication group (8.0% vs 2.4%, $p < 0.001$). Operative duration was slightly longer for patients with a complication (262 vs 248 minutes, $p = 0.170$), with significantly higher EBL (556 vs 260 ml, $p < 0.001$). LOS was also longer for patients with a complication (10.4 vs 6.1 days, $p < 0.001$). There were no significant differences in rates of two-stage surgery or length of follow-up. Additional data are summarized in Table 2.

Comparison of Complications by Approach

We compared perioperative complications between transabdominal retroperitoneal and lateral transthoracic approaches. Patients with an indication of an infection (30.0% vs 3.5%, $p < 0.001$), trauma (10.0% vs 0.3%, $p < 0.01$), and tumor (17.5% vs 0.7%, $p < 0.001$) were more likely to undergo a lateral transthoracic approach, while transabdominal retroperitoneal approaches were more common among patients with degenerative disease (51.8% vs 12.5%, $p < 0.001$) or deformity (34.3% vs 22.5%, $p = 0.123$). Complications were more common among patients in whom lateral transthoracic approaches were used (62.5% vs 31.8%, $p < 0.001$), most notably higher rates of wound complications (17.5% vs 6.5%, $p = 0.017$), hematoma (7.5% vs 1.1%, $p = 0.015$), and pulmonary complications (20.0% vs 5.7%, $p = 0.002$). These results are summarized in Table 3.

Complications Among Obese Patients

We compared demographic and surgical characteristics among obese and nonobese patients who underwent transabdominal retroperitoneal ALIF. There were no significant differences in age, sex, smoking status, or history of spine surgery; however, there was a higher proportion of diabetic patients in the obese group (17.9% vs 5.7%, $p < 0.001$). The mean number of anterior levels fused and anterior upper level were not significantly different. There were no differences in BMP use, operative duration, EBL, use of two-stage surgery, LOS, or follow-up duration. These results are summarized in Table 4.

Given the well-matched surgical characteristics between obese and nonobese patients undergoing transabdominal retroperitoneal ALIF, we subsequently performed a comparison of complications between these groups. The cumulative intraoperative complication rate

TABLE 2. Comparison of patients with and without surgical complications

Variable	No Surgical Complication (n = 627)	Any Surgical Complication (n = 311)	p Value
Age, yrs	56	61	<0.001
Female sex	338 (53.9%)	173 (55.6%)	0.619
BMI, kg/m ²	28.3	29.3	0.013
Obese (BMI ≥30 kg/m ²)	220 (35.1%)	134 (43.1%)	0.017
CCI score			
0–2	585 (93.3%)	273 (87.8%)	0.004
3–5	29 (4.6%)	25 (8.0%)	0.035
≥6	13 (2.1%)	13 (4.2%)	0.064
Diabetic	63 (10%)	36 (11.6%)	0.473
Current smoker	71 (11.3%)	46 (14.8%)	0.130
Previous spine surgery	353 (56.4%)	187 (60.1%)	0.264
Surgical indication			
Degenerative/spondylolisthesis	352 (56.1%)	118 (37.9%)	<0.001
Deformity	185 (29.5%)	132 (42.4%)	<0.001
Infection	21 (3.3%)	22 (7.1%)	0.010
Trauma	3 (0.5%)	4 (1.3%)	0.176
Tumor	7 (1.1%)	6 (1.9%)	0.682
Pseudarthrosis	59 (9.4%)	29 (9.3%)	0.966
Mean no. of anterior levels fused	1.8	2.1	<0.001
Transthoracic approach	15 (2.4%)	25 (8.0%)	<0.001
Anterior upper level			
T10–12	4 (0.6%)	4 (1.3%)	0.451*
L1	3 (0.5%)	11 (3.5%)	0.001*
L2	17 (2.7%)	18 (5.8%)	0.019
L3	110 (17.5%)	86 (27.7%)	<0.001
L4	280 (44.7%)	132 (42.4%)	0.520
L5	213 (34.0%)	60 (19.3%)	<0.001
Use of BMP	302 (48.2%)	179 (57.6%)	0.007
Mean operative duration, mins	248	262	0.170
Mean EBL, ml	260	556	<0.001
Two-stage surgery	511 (81.5%)	267 (85.9%)	0.095
Mean LOS, days	6.1	10.4	<0.001
Mean follow-up, mos	25.9	28.1	0.221

Unless otherwise specified, values are presented as the number (%) of patients.

* Fisher's exact test.

was 3.9%, with no significant difference between obese and nonobese patients (3.2% vs 4.3%, $p = 0.416$). This included no difference in rates of intraoperative arterial, venous, ureteral, bowel, or medical complications. There were no cases of intraoperative bowel or ureteral injury. Among postoperative complications, the rate for the entire cohort was 29.8%, with a significantly higher rate among obese versus nonobese patients (36.1% vs 26.0%, $p = 0.001$). The most significant differences involved increased rates of ileus (11.7% vs 7.2%, $p = 0.020$), anterior wound-related complications (11.4% vs 3.4%, $p < 0.001$), and UTI (5.0% vs 2.5%, $p = 0.049$). Among wound-related complications, significant differences were found in rates of dehiscence (3.8% vs 0.5%, $p < 0.001$), hernia (5.3% vs 2.0%, $p = 0.007$), and infection (3.2% vs 1.1%, $p = 0.022$).

There were no significant differences in postoperative neurological deficits, hematomas, DVT/PE, or other medical complications, including pulmonary, cardiac, urological, and renal complications. We also performed a comparison of complications across obesity subgroups based on BMI classification, including obese (BMI 30–34.9 kg/m²), severely obese (BMI 35–39.9 kg/m²), and morbidly obese (BMI > 40 kg/m²). This included 203 obese, 102 severely obese, and 36 morbidly obese patients. Intraoperative complications were similar across groups. Postoperative complications were also similar across these groups. There was a trend toward increased rate of hematomas ($p = 0.052$) and DVT/PE ($p = 0.054$) in morbidly obese compared to obese and severely obese patients. These results are summarized in Table 5.

TABLE 3. Comparison of perioperative complications by ALIF approach

Variable	Anterior Retroperitoneal (n = 898)	Lateral Transthoracic (n = 40)	p Value
Surgical indication			
Degenerative/spondylolisthesis	465 (51.8%)	5 (12.5%)	<0.001
Deformity	308 (34.3%)	9 (22.5%)	0.123
Infection	31 (3.5%)	12 (30.0%)	<0.001*
Trauma	3 (0.3%)	4 (10.0%)	<0.001*
Tumor	6 (0.7%)	7 (17.5%)	<0.001*
Pseudarthrosis	85 (9.5%)	3 (7.5%)	1.000*
Any complication	286 (31.8%)	25 (62.5%)	<0.001
Intraoperative complication	35 (3.9%)	5 (12.5%)	0.024*
Arterial	2 (0.2%)	0 (0%)	1.000*
Venous	32 (3.6%)	3 (7.5%)	0.184*
Ureteral	0 (0%)	1 (2.5%)	0.043*
Bowel	0 (0%)	0 (0%)	NA
Medical	1 (0.1%)	1 (2.5%)	0.084*
Postoperative complication	268 (29.8%)	23 (57.5%)	<0.001
Ileus	80 (8.9%)	4 (10.0%)	0.776*
Wound	58 (6.5%)	7 (17.5%)	0.017*
Dehiscence	16 (1.8%)	0 (0%)	1.000*
Hernia	29 (3.2%)	3 (7.5%)	0.152*
Infection	17 (1.9%)	4 (10.0%)	0.010*
Neurological	3 (0.3%)	0 (0%)	1.000*
Hematoma	10 (1.1%)	3 (7.5%)	0.015*
Medical	168 (18.7%)	13 (32.5%)	0.031
Pulmonary	51 (5.7%)	8 (20.0%)	0.002
Cardiac	41 (4.6%)	4 (10.0%)	0.120*
Renal	16 (1.8%)	0 (0%)	1.000*
Urologic	42 (4.7%)	0 (0%)	0.252*
UTI	31 (3.5%)	1 (2.5%)	1.000*
DVT/PE	19 (2.1%)	2 (5.0%)	0.224*

NA = not applicable.

Values are presented as the number (%) of patients.

* Fisher's exact test.

Multivariate Analysis for Postoperative Complications

We performed multivariate binary logistic regression to determine the association of specific variables with postoperative complications using variables that demonstrated a significance ($p < 0.100$) by univariate analysis. Lateral transthoracic approaches were excluded. The model included age, obesity, CCI score of 3 or more, use of BMP, number of ALIF levels fused, EBL, use of a second-stage surgery, anterior upper level at L3 or above, and an indication of degenerative disease/spondylolisthesis, deformity, or osteomyelitis. Variables with a significant association with postoperative complications included age (OR 1.026, 95% CI 1.010–1.043, $p = 0.001$), obesity (OR 1.672, 95% CI 1.177–2.376, $p = 0.004$), number of levels fused (OR 1.319, 95% CI 1.046–1.663, $p = 0.019$), and surgical indication of degenerative disease/spondylolisthesis (OR 0.625, 95% CI 0.430–0.907, $p = 0.004$). These results are summarized in Table 6.

BMI Threshold for Postoperative Complications

In the univariate smoothing spline with BMI and odds ratio of postoperative complication, as well as the multivariate model including age, BMI, number of fused levels, CCI score, use of BMP, and operative duration, there was no identifiable BMI threshold associated with increase postoperative complications. No appropriate threshold was identified in the grouped data plot either. A subsequent estimation table was generated to include 19 candidate cut-points, odds ratios, and corresponding unadjusted and adjusted p values using Bonferroni correction. A BMI threshold of 31 had the lowest unadjusted p value ($p < 0.001$) and adjusted p value ($p = 0.012$) shown in the forest plot (Fig. 1).

Discussion

ALIF is an increasingly utilized technique for a variety of lumbar pathologies. As its use increases, it is important

TABLE 4. Comparison of obese and nonobese patients who underwent transabdominal retroperitoneal ALIF

Variable	Nonobese Patients (n = 557)	Obese Patients (n = 341)	p Value
Age, yrs	58	57	0.094
Female sex	319 (57.3%)	180 (52.8%)	0.189
Mean BMI, kg/m ²	25.0	34.7	<0.001
CCI score			
0–2	520 (93.4%)	314 (92.1%)	0.471
3–5	20 (3.6%)	24 (7.0%)	0.020
≥6	17 (3.1%)	3 (0.9%)	0.032
Diabetic	32 (5.7%)	61 (17.9%)	<0.001
Current smoker	77 (13.8%)	36 (10.6%)	0.152
Previous spine surgery	310 (55.7%)	207 (60.7%)	0.137
Surgical indication			
Degenerative/spondylolisthesis	280 (50.3%)	185 (54.3%)	0.246
Deformity	205 (36.8%)	103 (30.2%)	0.043
Infection	19 (3.4%)	12 (3.5%)	0.931
Trauma	3 (0.5%)	0 (0%)	0.175
Tumor	4 (0.7%)	2 (0.6%)	0.814
Pseudarthrosis	46 (8.3%)	39 (11.4%)	0.114
Mean no. of anterior levels fused	1.8	1.8	0.475
Anterior upper level			
L1	1 (0.2%)	0 (0%)	1.000*
L2	17 (3.1%)	6 (1.8%)	0.234
L3	113 (20.3%)	76 (22.3%)	0.475
L4	255 (45.8%)	157 (46.0%)	0.939
L5	171 (30.7%)	102 (29.9%)	0.803
Use of BMP	294 (52.8%)	174 (51.0%)	0.609
Mean operative duration, mins	246	256	0.295
Mean EBL, ml	321	348	0.665
Two-stage surgery	462 (82.9%)	283 (83.0%)	0.986
Mean LOS, days	7.1	7.4	0.473
Mean follow-up, mos	27.0	25.5	0.394

Unless otherwise specified, values are presented as the number (%) of patients.

* Fisher's exact test.

to characterize the factors that may increase the risk of surgical complications. Obesity has been a well-studied determinant of surgical complications in spinal surgery.³ Few have looked at the anterior approach exclusively and have been limited by their small sample sizes.^{12–14} Peng et al. examined 74 patients undergoing anterior lumbar surgery and found comparable rates of perioperative complications between obese and nonobese patients.¹³ Additionally, Lucas et al. reviewed 84 patients undergoing ALIF and found no increase in infectious or vascular complications among overweight and obese patients compared to normal-weight individuals. In our study of 898 patients who underwent transabdominal retroperitoneal ALIF, we found an increase in perioperative surgical complications in obese patients compared to nonobese patients (37.0% vs 28.7%, $p = 0.010$), a difference that was driven primarily by postoperative complications (36.1% vs 26.0%, $p = 0.001$), rather than intraoperative complications (3.2% vs 4.3%, $p = 0.416$). These findings remained consistent in

our multivariate analysis, as obesity demonstrated a significant association with postoperative complications (OR 1.672, 95% CI 1.177–2.376, $p = 0.004$). Since the goals of this study were to investigate transabdominal retroperitoneal ALIF, we excluded lateral transpsoas, prepsoas, and transthoracic approaches in our formal analysis given the significantly different surgical indications and risk profiles associated with these approaches.

The most common complication was ileus (8.9%), with a higher rate among obese patients (11.7% vs 7.2%). Durand et al. analyzed a cohort of 59,410 patients undergoing deformity correction surgery and found a similar increased risk of ileus with anterior surgical approaches.¹⁹ Patients are often on high doses of opioids in the perioperative period, thus exacerbating the risk of ileus. The risk is also likely higher in obese patients given the more extensive mobilization and forceful retraction of peritoneal contents in order to provide adequate exposure. Ileus can significantly prolong hospital stays, and although we were

TABLE 5. Summary of surgical complications among patients who underwent transabdominal retroperitoneal ALIF

Variable	All Patients (n = 898)	Nonobese Patients w/ BMI <30 kg/m ² (n = 557)	All Obese Patients w/ BMI >30 kg/m ² (n = 341)	p Value	Obese Patients w/ BMI 30–34.9 kg/m ² (n = 203)	Severely Obese Patients w/ BMI 35–39.9 kg/m ² (n = 102)	Morbidly Obese Patients w/ BMI >40 kg/m ² (n = 36)	p Value
Any complication	286 (31.8%)	160 (28.7%)	126 (37.0%)	0.010	74 (36.5%)	39 (38.2%)	13 (36.1%)	0.949
Intraop complication	35 (3.9%)	24 (4.3%)	11 (3.2%)	0.416	6 (3.0%)	2 (2.0%)	3 (8.3%)	0.136*
Arterial	2 (0.2%)	2 (0.4%)	0 (0%)	0.528*	0 (0%)	0 (0%)	0 (0%)	NA
Venous	32 (3.6%)	21 (3.8%)	11 (3.2%)	0.669	6 (3.0%)	2 (2.0%)	3 (8.3%)	0.136*
Ureteral	0 (0%)	0 (0%)	0 (0%)	NA	0 (0%)	0 (0%)	0 (0%)	NA
Bowel	0 (0%)	0 (0%)	0 (0%)	NA	0 (0%)	0 (0%)	0 (0%)	NA
Medical	1 (0.1%)	1 (0.2%)	0 (0%)	1.000*	0 (0%)	0 (0%)	0 (0%)	NA
Postop complication	268 (29.8%)	145 (26.0%)	123 (36.1%)	0.001	73 (36.0%)	39 (38.2%)	11 (30.6%)	0.711
Ileus	80 (8.9%)	40 (7.2%)	40 (11.7%)	0.020	25 (12.3%)	14 (13.7%)	1 (2.8%)	0.189*
Wound	58 (6.5%)	19 (3.4%)	39 (11.4%)	<0.001	24 (11.8%)	12 (11.8%)	3 (8.3%)	0.935*
Dehiscence	16 (1.8%)	3 (0.5%)	13 (3.8%)	<0.001	10 (4.9%)	3 (2.9%)	0 (0%)	0.446*
Hernia	29 (3.2%)	11 (2.0%)	18 (5.3%)	0.007	9 (4.4%)	8 (7.8%)	1 (2.8%)	0.444*
Infection	17 (1.9%)	6 (1.1%)	11 (3.2%)	0.022	8 (3.9%)	1 (1.0%)	2 (5.6%)	0.252*
Neurological	3 (0.3%)	3 (0.5%)	0 (0%)	0.293*	0 (0%)	0 (0%)	0 (0%)	NA
Hematoma	10 (1.1%)	6 (1.1%)	4 (1.2%)	1.000*	2 (1.0%)	0 (0%)	2 (5.6%)	0.052*
Medical	168 (18.7%)	97 (17.4%)	71 (20.8%)	0.204	44 (21.7%)	20 (19.6%)	7 (19.4%)	0.895
Pulmonary	51 (5.7%)	32 (5.7%)	19 (5.6%)	0.913	10 (4.9%)	9 (8.8%)	0 (0%)	0.133*
Cardiac	41 (4.6%)	27 (4.8%)	14 (4.1%)	0.605	10 (4.9%)	3 (2.9%)	1 (2.8%)	0.778*
Renal	16 (1.8%)	8 (1.4%)	8 (2.3%)	0.317	5 (2.5%)	2 (2.0%)	1 (2.8%)	1.000*
Urologic	42 (4.7%)	26 (4.7%)	16 (4.7%)	0.987	13 (6.4%)	2 (2.0%)	1 (2.8%)	0.212*
UTI	31 (3.5%)	14 (2.5%)	17 (5.0%)	0.049	9 (4.4%)	4 (3.9%)	4 (11.1%)	0.218*
DVT/PE	19 (2.1%)	9 (1.6%)	10 (2.9%)	0.183	3 (1.5%)	4 (3.9%)	3 (8.3%)	0.054*

Values are presented as the number (%) of patients.

* Fisher's exact test.

not able to calculate its effect in this cohort, it is an important consideration in future studies.

ALIF-related wound complications in our cohort occurred in 6.5% of all patients, with a higher rate among obese patients (11.4% vs 3.4%, $p < 0.001$). This was driven primarily by dehiscence (3.8% vs 0.5%, $p < 0.001$), hernia (5.3% vs 2.0%, $p = 0.007$), and wound infections (3.2% vs 1.1%, $p = 0.022$). Obesity has been previously shown to be associated with increased wound complications, including postoperative infection, dehiscence, seroma, and hematoma formation in patients undergoing elective spine surgery.^{20,21} Obesity is also a well-known risk factor for the development of hernias and infections.^{1,22} The increased rate of wound complications in our cohort can be partially explained by increased mechanical stress placed on the anterior incision. Diabetes was also more common among our obese patients (17.9% vs 5.7%, $p < 0.001$) and is associated with increased risk of impaired wound healing and infection.²³

Among postoperative medical complications, UTI was the only category that was associated with an increased risk among obese patients (5.0% vs 2.5%, $p = 0.049$). Previous studies have reported an association between obesity and UTIs.^{24,25} Diabetes is also a well-recognized risk factor for UTI and the proportion of diabetic patients was

significantly higher among the obese patients in our cohort.²⁶ Another important consideration is urinary catheter duration, which we were unable to determine in this study given its retrospective nature.

Vascular injury is a frequently cited risk of anterior spine exposure, with reported rates ranging from 1.9% to 6.1%.^{27–29} Intraoperative vascular injuries in our series occurred in 3.8% of cases, with venous injuries being more common (3.6%). Rates were similar among obese and nonobese patients (3.2% vs 3.8%, $p = 0.669$). Fantini et al. identified osteomyelitis/discitis and previous anterior

TABLE 6. Multivariate analysis for variables associated with postoperative complications in patients who underwent transabdominal retroperitoneal ALIF

Variable	OR (95% CI)	p Value
Age	1.026 (1.010–1.043)	0.001
Obesity	1.672 (1.177–2.376)	0.004
No. of levels fused	1.319 (1.046–1.663)	0.019
Degenerative disease or spondylolisthesis	0.625 (0.430–0.907)	0.004

FIG. 1. Identification of a BMI threshold for increased risk of postoperative complication. An estimation table was generated to include candidate cut-points, odds ratios, and corresponding unadjusted and adjusted p values using Bonferroni correction. A BMI threshold of 31 kg/m² had the lowest unadjusted p value ($p < 0.001$) and adjusted p value ($p = 0.012$).

spine surgery, but not obesity, as factors associated with an increased risk of vascular surgery in ALIF surgery.²⁸ All of our retroperitoneal exposures were performed by experienced vascular surgeons, which contributes to a low rate of vascular injury. In a subgroup analysis of our cohort, we found that osteomyelitis/discitis, noted in 43 patients (4.6%), was associated with a nearly fourfold increase in intraoperative venous injury (17.1% vs 4.1%, $p < 0.001$), but no difference in other postoperative complications. Additionally, rates of osteomyelitis/discitis were not significantly different between obese and nonobese patients in our cohort (5.1% vs 4.3%, $p = 0.568$).

Another risk of the anterior approach is related to urological complications. The cohort had a rate of 4.7%, and there was no difference between obese and nonobese (4.7% vs 4.7%, $p = 0.987$). The most commonly reported complications were urinary retention or incontinence related to medication side effects, not neurological injury, and scrotal edema. Several retrospective analyses and systematic reviews have reported a wide range of rates of retrograde ejaculation in patients who underwent anterior spine surgery.^{30–33} There were no identifiable cases of retrograde ejaculation in our series, but we suspect that this is an underestimate of the true rate given the retrospective nature of this study. We did not identify any cases of intraoperative ureteral injury in patients undergoing transabdominal retroperitoneal ALIF, which is related to two important factors. First, all exposures were performed by experienced vascular surgeons. Second, in high-risk cases, ureteral stents were placed preoperatively to allow for identification of the ureter intraoperatively.

In the 898 patients who underwent transabdominal retroperitoneal ALIF, we identified an increased risk of postoperative complications among obese patients. These differences were driven primarily by higher rates of ileus, wound complications, and UTI. This study is limited by

its retrospective design and focuses specifically on perioperative complications rather than long-term complications such as pseudarthrosis, proximal junctional failure, and others. These data suggest a role for careful medical optimization of obese patients prior to transabdominal retroperitoneal ALIF and special attention to their recovery during the postoperative period, with a particular focus on meticulous wound closure, normalizing bowel function, and decreasing urinary catheter duration. It is important to note that despite an increased perioperative risk among obese patients undergoing transabdominal retroperitoneal ALIF, the long-term benefits provided by this approach likely outweigh the short-term risk. Improved restoration of disc height and segmental lordosis^{17,34} may decrease rates of long-term complications and the need for revision surgery, thus justifying this temporary increase in complication profile. Future studies are warranted to determine the long-term benefits of ALIF in obese patients.

Conclusions

Obesity is associated with an increased rate of postoperative complications in patients undergoing ALIF. This is driven primarily by postoperative, rather than intraoperative, events. Obese patients are at an increased risk of ileus, wound complications, and UTIs compared to non-obese patients. Patients with a BMI ≥ 31 kg/m² should be counseled on their increased risk and warrant careful preoperative medical optimization and close monitoring in the postoperative period.

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

Supplemental Information

Previous Presentations

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