Increasing Body Mass Index is Associated with Worse Perioperative Outcomes and Higher Costs in Adult Spinal Deformity Surgery

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ABSTRACT

Study Design. Retrospective review.

Objective. To investigate associations of obesity with outcomes and costs of adult spinal deformity (ASD) surgery.

Summary of Background Data. Increasing body mass index is a risk factor for complications after nondeformity spine surgery, but its effect on ASD surgery is unknown.

Methods. We reviewed records of 244 ASD patients who underwent spinal arthrodesis of ≥5 levels from 2010–2014 and categorized them by World Health Organization body mass index (BMI) groups: <30, nonobese (64%); 30–34.99, class-I obese (21%); and ≥35, class-II/III obese (15%). We used multivariate logistical regression to determine odds of transfusion, inpatient complications, prolonged intensive care unit (ICU) stay (>2 days), prolonged total length of hospital stay (LOS) (>1 week), and high episode-of-care costs (>80,000).

Results. Preoperative characteristics were similar among groups, except sex, preoperative hemoglobin concentration, and performance/type of osteotomy (all, P = 0.01). On univariate analysis, the groups differed in rates of prolonged ICU stay (P < 0.001), prolonged total LOS (P = 0.016), and high episode-of-care costs (P = 0.013). Inpatient complication rates were similar among groups (P = 0.218). On multivariate analysis, compared with nonobese patients, class I obese patients had greater odds of prolonged ICU stay (OR = 2.24, 95% CI = 1.06, 4.71). Class II/III obese patients also had greater odds of prolonged total LOS (OR = 2.21, 95% CI: 1.03, 4.71), and high episode-of-care costs (OR = 2.91, 95% CI: 1.31, 6.50).

Conclusion. In ASD surgery, BMI ≥35 is associated with significantly worse perioperative outcomes and higher costs compared with those of nonobese patients.
Key Words: adult spinal deformity; class-I obesity; class-II obesity; class-III obesity; costs; intensive care unit length of stay; length of stay; morbid obesity; obesity; operative time; predictive model; scoliosis; spinal arthrodesis

Level of Evidence. 3
INTRODUCTION

Surgery has become an increasingly common treatment for the functional limitations associated with adult spinal deformity (ASD).\textsuperscript{1,2} Although outcomes have been favorable, ASD surgery is associated with substantial postoperative complications and requires judicious patient selection.\textsuperscript{1}

However, optimal patient selection has become increasingly difficult as the increased incidence of obesity has paralleled the rise in ASD surgery rates during the past three decades.\textsuperscript{3} The medical, perioperative anesthesia, and surgical complications associated with obesity in non-ASD surgery are well known.\textsuperscript{4,5,6-10} Obese patients undergoing spine surgery are at greater risk for preintubation hypoxia, reintubation, and positioning-based peripheral nerve palsies.\textsuperscript{5} Moreover, positioning time is longer for morbidly obese patients compared with non–morbidly obese patients.\textsuperscript{5,11}

With respect to outcomes, in the non-ASD population, obesity has been associated with decreased surgical benefit, greater blood loss, greater risk of postoperative complications, and higher 30-day readmission rates compared with those of nonobese patients.\textsuperscript{7-10,12} In ASD patients, obesity is associated with worse perioperative and long-term outcomes.\textsuperscript{2}

The association of increasing World Health Organization (WHO) obesity class with perioperative outcomes of spine surgery is poorly understood in the non-ASD population, and to our knowledge, is unreported in the ASD population. The WHO categorizes obesity according to BMI as follows: 30–34.9, class I; 35–39.9, class II; and $\geq$40, class III.\textsuperscript{13} Among all spine surgery patients, class-III obesity has been associated with longer operative time, longer hospital stay, more postoperative complications, and higher episode-of-care costs compared with nonobese status.\textsuperscript{6,14} Given the independent risks of ASD surgery and obesity, an understanding of whether these 2 factors in combination lead to suboptimal perioperative outcomes is necessary for optimal patient care. We sought to determine the association of obesity with perioperative outcomes and costs in ASD surgery and to
stratify the risk of suboptimal outcomes according to WHO obesity class. We hypothesized that class-II/III obese patients would have longer hospital stays and higher episode-of-care costs compared with class-I obese and nonobese patients.

PATIENTS AND METHODS

We retrospectively reviewed a surgical registry at our academic tertiary care center to identify records of adults undergoing spine surgery between 2010 and 2014. Patients who underwent posterior arthrodesis of ≥5 spinal levels were classified as having ASD and were eligible for the study. All patients underwent surgery by the senior author. Institutional review board approval was obtained for this study. Patients were excluded from analysis if complete information regarding number of spinal levels fused, BMI, and perioperative outcomes was unavailable.

BMI Categories

The primary independent variable was BMI. Patients were stratified according to the following WHO obesity classification: BMI < 30, nonobese; BMI 30–34.9, class-I obese; and BMI ≥ 35, class-II/III obese.

Data

We reviewed preoperative data on patient age at time of surgery, sex, BMI, pre-existing diagnosis of osteoporosis, Charlson Comorbidity Index score, hemoglobin concentration, and platelet count. We reviewed intraoperative data on number of spinal levels fused, primary versus revision.
surgery, and performance and type of osteotomy (posterior versus 3-column). We reviewed inpatient data on postoperative complications (vascular, thromboembolic, neurologic, pulmonary, renal, cardiac, infectious), transfusion, length of ICU stay, total LOS, and total episode-of-care costs. Inpatient care costs were obtained through in-hospital billing record review.

Statistical Analysis

Preoperative and intraoperative variables were compared among BMI groups. Analysis of variance and $\chi^2$ test were used for comparing continuous and categorical variables, respectively. Transfusion and postoperative inpatient medical complications were treated as binary variables. Total episode of care costs, total LOS, and length of ICU stay were transformed into binary variables given the positively skewed nature of their distribution (Shapiro-Wilk test for normality, $P < 0.001$ for all). These continuous variables were transformed into binary variables by defining the medians as the cutoff points for each. Factors with a $P$ value less than 0.10 were included in the multivariate logistic regression. Significance was set at a $P$ value less than 0.05. Analysis was performed using Stata, version 14.0, software (StataCorp LP, College Station, TX).

RESULTS

Preoperative Patient Characteristics

Of 273 patients undergoing arthrodesis of $\geq 5$ spinal levels from 2010–2014, 16 were excluded for incomplete BMI data. An additional 13 patients were excluded for lack of perioperative data outcomes, resulting in inclusion of 89% of eligible patients. Overall, 244 patients (175 women) with a mean age $\pm$ standard deviation of 60 $\pm$ 13 years met inclusion criteria (Table 1). Sixty-four percent of patients ($n =$
were nonobese, 21% (n = 52) were class-I obese, and 15% (n = 37) were class-II/III obese. The mean Charlson Comorbidity Index score was 1.1 ± 1.3, and 21% of patients (n = 51) had a diagnosis of osteoporosis. With respect to preoperative hematologic parameters, the mean hemoglobin concentration was 13±1.7 g/dL, and the mean platelet count was 246 x 10^9 ± 88 x 10^9 cells/L, respectively.

### Intraoperative and Postoperative Outcomes

The mean number of spinal levels fused per patient was 9 ± 3. Fifty-six percent of surgical procedures (n = 137) were revisions, and 47% of patients (n = 105) had a 3-column osteotomy. With respect to postoperative outcomes, 9% of patients (n = 22) had an in-hospital complication. The mean length of ICU stay was 2 ± 3 days, and the mean total LOS was 8 ± 5 days. The mean episode-of-care cost was $83,000 ± $30,000. The median length of ICU stay, total LOS, and total episode of care costs used as cutoffs were 2 days, 1 week, and $80,000 US, respectively.

### Group Comparisons

Of the baseline characteristics, only the percentage of women (P = 0.002), preoperative hemoglobin (P = 0.010) and performance/type of osteotomy (P = 0.018) differed significantly among the 3 groups. There were significant differences among the nonobese, class-I obese, and class-II/III obese groups in rates of prolonged ICU stay (17%, 37%, and 35%, respectively; P = 0.003), prolonged total LOS (41%, 58%, and 62%, respectively; P = 0.016), and high episode-of-care cost (44%, 54%, and 70%, respectively; P = 0.013).

On multivariate logistic regression analysis, class-I obese patients had significantly higher odds of prolonged ICU stay (odds ratio [OR] = 2.24, 95% confidence interval [CI]: 1.07, 4.71) compared with nonobese patients (Table 2). Class-I obese patients did not have significantly higher odds of
prolonged total LOS (OR = 1.78, 95% CI: 0.91, 3.47) or high episode-of-care cost (OR = 1.26, 95% CI: 0.65, 2.48) compared with nonobese patients. However, class-II/III obese patients had significantly higher odds of prolonged ICU stay (OR = 2.35, 95% CI: 1.02, 5.40), prolonged total LOS (OR = 2.21, 95% CI: 1.03 4.71), and high episode-of-care cost (OR = 2.91, 95% CI: 1.31, 6.50) compared with class-I obese patients.

DISCUSSION

Understanding the effect of obesity on outcomes in ASD surgery is critical given the prevalence of obesity among patients undergoing spine surgery. We found that both class-I and class-II/III obesity were independently associated with prolonged ICU stay. Class-II/III obesity was also independently associated with prolonged total LOS and high total episode-of-care cost.

Previous spine studies have identified obesity as being independently associated with increased rates of dural tears, early postoperative complications, venous thromboembolic complications, adjacent segment disease, and sagittal imbalance, as well as reduced surgical benefit and higher in-hospital cost. However, few spine studies have evaluated the differences in perioperative outcomes between obese and nonobese patients. To our knowledge, no studies have evaluated the effect of increasing obesity class on outcomes of ASD surgery while accounting for operative details such as length of arthrodesis, and performance/type of osteotomy.

The applicability of studies evaluating the effect of obesity on non-ASD surgery to ASD patients is limited by several factors. First, most studies have used large national databases that lack detailed surgical data. Data on the performance of osteotomies and the length of arthrodesis constructs are critical when assessing ASD outcomes. Second, a spine study found that the comorbid diagnosis of obesity was coded inaccurately in the same large national databases used in previous
Third, spinal deformity surgery is considerably more complex and has a higher perioperative complication rate than nondeformity spine surgery.

With respect to length of stay, we found that both class-I and class-II/III obese groups had significantly higher rates of long ICU stay, and the class-II/III obese group had significantly longer total LOS compared with the nonobese group. To our knowledge, an association between obesity and length of ICU stay has not been reported in deformity spine surgery. In our study, class-I obesity was associated with 2.24 times greater odds of prolonged ICU stay compared with nonobese patients. Class-II/III obesity was associated with 2.35 times greater odds of prolonged ICU stay compared with nonobese patients. ICU stays may be longer for obese patients, whose vital signs may need to be monitored for a longer period because of limitations in postoperative pulmonary function and higher doses of narcotics required for pain control. The literature also demonstrates that in patients with degenerative spine disease, obesity is a significant risk factor for ICU admission and postoperative ventilation requirement. Furthermore, among all orthopedic surgery patients, obstructive sleep apnea (OSA) and chronic obstructive pulmonary disease, which are known sequelae of morbid obesity, have been shown to increase the odds of a patient being transferred to the ICU. In our population, the overall rate of OSA was 2.9%. When assessed by category, the rates of OSA were 1.3%, 3.6% and 8.1% in the nonobese, class-I, and class-II/III groups, respectively. An understanding of typical immediate postoperative disposition (e.g., to the ICU or to non-monitored inpatient floor) and the typical length of ICU stay is critical for adequate preoperative resource allocation.

Few studies of ASD surgery have evaluated the associations of obesity and obesity class with length of hospital stay. Klineberger et al. performed a comprehensive review of factors predicting extended hospital stay but did not report on an association between BMI and prolonged hospital stay. Studies of nondeformity spine surgery have shown that class-III obesity (BMI ≥40) is significantly associated with length of hospital stay. These studies, however, did not find an association.
between length of hospital stay and class-I or class-II obesity. However, in the study by Kalanithi et al., only 2% (n = 1455) of the cohort (n = 84,607) were in the class-III obesity category. Patients without BMI data were presumed to be nonobese, and class-I and class-II obese patients were excluded. The study by Buerba et al. included patients who underwent lumbar spine surgery only, and thus highlights the difference between nondeformity and ASD surgery.

With respect to costs of ASD, higher adjusted Charlson Comorbidity Index value, long fusions, prolonged LOS, surgical site infection, venous thromboembolic complication, and 30-day readmission have been implicated as drivers of high cost. A recent study of patients with ASD found that frailty was also predictive of outcomes associated with high costs, including postoperative complications and reoperation. Research of the nondeformity spine surgery population shows that higher cost is associated with older age, higher comorbidity burden, and surgeon preference. Planchard et al. found that obesity was associated with a mean of $1,632 higher hospital costs compared with nonobese patients for nondeformity spine surgery.

Our data suggest that class-II/III obesity is significantly associated with high cost of ASD surgery. Other variables known to contribute to costs of care, including comorbidities, transfusion status, and in-hospital complications, were not significantly different among the 3 groups on initial analysis. In addition, physician preferences (e.g., related to treatment methods, implant types) have been shown to be the largest determinant of higher total episode-of-care cost in the ASD surgery population. Our study mitigates this variable because all surgeries were performed by the same surgeon, who also provided care through the perioperative period.

It has been suggested that outcomes of thoracolumbar arthrodesis for degenerative conditions are equivalent between obese and nonobese patients. Few studies have evaluated the effect of obesity on postoperative outcomes of ASD patients. Soroceanu et al. performed a robust perioperative and 2-year follow-up study of obese ASD surgery patients. Their findings suggest that
obese patients are at greater risk of complications after ASD surgery and show less clinical improvement at 2-year follow-up compared with nonobese patients. This finding was supported by that of Manoharan et al.26, who found in their large national database study that obesity was predictive of 30-day readmission after ASD surgery. In contrast, a study of 77 ASD patients36 and a study of 84 adult scoliosis patients24 did not detect higher complication rates or worse clinical outcomes after surgery in obese versus nonobese patients. These findings may be related to small sample sizes.

Our study has several limitations. Our data were obtained retrospectively and thus have the inherent limitations of this research method. Although we had fewer patients compared with large national database studies, we included operative details known to confound outcomes and had complete data for 89% of patients. Additionally, our study cannot assess the effect of increasing BMI on long-term outcomes; we evaluated the presence of in-hospital outcomes known to influence long-term results. Lastly, because our study evaluated only in-hospital outcomes, further research is necessary to evaluate the correlation between higher obesity class and long-term outcomes, including infection and hardware failure rates.

CONCLUSION

Surgery is an effective but challenging treatment for ASD. Given that an increasing number of patients present with class-II or class-III obesity, it is critical to understand the effect of this comorbidity on postoperative outcomes. We found that compared with thenonobese patients, class-I and class-II/III obese patients have higher odds of prolonged ICU stay after ASD surgery. Moreover, increasing class of obesity is associated with prolonged total LOS, and high episode-of-care cost.
REFERENCES


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<table>
<thead>
<tr>
<th>Variable</th>
<th>No. (%) of Patients</th>
<th>Nonobese (n = 155)</th>
<th>Class-I Obese (n = 52)</th>
<th>Class-II/III Obese (n = 37)</th>
<th>P</th>
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<td>Age (yr)</td>
<td></td>
<td>60± 14†</td>
<td>61± 13†</td>
<td>61± 13†</td>
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<td>Hemoglobin concentration (g/dL)</td>
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<td>13± 1.7†</td>
<td>14 ± 1.3†</td>
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<td>Platelet count (x 10⁹/L)</td>
<td></td>
<td>251 ± 92†</td>
<td>238±92†</td>
<td>238 ±59†</td>
<td>0.552</td>
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<td><strong>Intraoperative factors</strong></td>
<td></td>
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<td></td>
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<tr>
<td>No. of levels fused</td>
<td></td>
<td>9 ± 3†</td>
<td>9 ±3†</td>
<td>9 ±3†</td>
<td>0.91</td>
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<td>Revision surgery</td>
<td></td>
<td>82 (53)</td>
<td>30 (58)</td>
<td>25 (68)</td>
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<td>Osteotomy</td>
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<td>9 (17)</td>
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**Postoperative outcomes**

<table>
<thead>
<tr>
<th></th>
<th>Transfusion</th>
<th>In-hospital complication</th>
<th>Prolonged ICUstay (&gt;2 days)</th>
<th>Prolonged total LOS (&gt;1 week)</th>
<th>High episode-of-care costs (&gt; $80,000)</th>
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<tr>
<td></td>
<td>151 (97)</td>
<td>14 (9.0)</td>
<td>26 (17)</td>
<td>63 (41)</td>
<td>68 (44)</td>
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<td>51 (98)</td>
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<td>19 (37)</td>
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<td>34 (92)</td>
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<td>13 (35)</td>
<td>23 (62)</td>
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<td></td>
<td></td>
<td></td>
<td>0.003</td>
<td>0.016</td>
<td>0.013</td>
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</tbody>
</table>

CCI indicates Charlson Comorbidity Index; ICU, intensive care unit; LOS, length of stay.

* Patients were stratified according to the following World Health Organization obesity classification: nonobese (body mass index < 30), class-I obese (body mass index 30–34.9), and class-II/III obese (body mass index ≥ 35).

† Expressed as mean ± standard deviation.
TABLE 2. Odds of Adverse Perioperative Outcomes from Multivariate Regression Analysis in 244 Patients after Adult Spinal Deformity Surgery, 2010 to 2014

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Class-I Obese[^1] (n = 52)</th>
<th>Class-II/III Obese[^1] (n = 122)</th>
</tr>
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<tbody>
<tr>
<td>Prolonged ICU stay (&gt;2 d)</td>
<td>2.24 (1.06, 4.71)</td>
<td>2.35 (1.02, 5.40)</td>
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<tr>
<td>Prolonged total LOS (&gt;1 week)</td>
<td>1.78 (0.91, 3.47)</td>
<td>2.21 (1.03, 4.71)</td>
</tr>
<tr>
<td>High episode-of-care costs (&gt;80,000)</td>
<td>1.26 (0.65, 2.48)</td>
<td>2.91 (1.31, 6.50)</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; ICU, intensive care unit; LOS, length of hospital stay; OR, odds ratio.

[^1] Patients were stratified according to the following World Health Organization Obesity Classification: class-I obese (body mass index 30–34.9) or class-II/III obese (body mass index ≥35).

[^1] Versus 155 nonobese patients (body mass index <30).