Effect of body mass index on surgical outcomes after posterior spinal fusion for adolescent idiopathic scoliosis

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OBJECTIVE Obesity is an increasing public health concern in the pediatric population. The purpose of this investigation was to examine the impact of body mass index (BMI) on 30-day outcomes after posterior spinal fusion for adolescent idiopathic scoliosis (AIS).

METHODS The American College of Surgeons National Surgical Quality Improvement Program Pediatric database (2013 and 2014) was reviewed. Patients 10–18 years of age who had undergone fusion of 7 or more spinal levels for AIS were included. Thirty-day outcomes (complications, readmissions, and reoperations) were compared based on patient BMI per age- and sex-adjusted growth charts as follows: normal weight (NW; BMI < 85th percentile), overweight (OW; BMI 85th–95th percentile), and obese (OB; BMI > 95th percentile).

RESULTS Patients eligible for study numbered 2712 (80.1% female and 19.9% male) and had a mean age of 14.4 ± 1.8 years. Average BMI for the entire cohort was 21.9 ± 5.0 kg/m²; 2010 patients (74.1%) were classified as NW, 345 (12.7%) as OW, and 357 (13.2%) as OB. The overall complication rate was 1.3% (36/2712). For NW and OW patients, the complication rate was 0.9% in each group; for OB patients, the rate was 4.2% ($p < 0.001$). The 30-day readmission rate was 2.0% (55/2712) for all patients, 1.6% for NW patients, 1.2% for OW patients, and 5.0% for OB patients ($p < 0.001$). The 30-day reoperation rate was 1.4% (39/2712). Based on BMI, this reoperation rate corresponded to 0.9%, 1.2%, and 4.8% for NW, OW, and OB patients, respectively ($p < 0.001$). After controlling for patient age, number of spinal levels fused, and operative/anesthesia time on multiple logistic regression analysis, obesity remained a significant risk factor for complications (OR 4.61), readmissions (OR 3.16), and reoperations (OR 5.33; all $p < 0.001$).

CONCLUSIONS Body mass index may be significantly associated with short-term outcomes after long-segment fusion procedures for AIS. Although NW and OW patients may have similar 30-day outcomes, OB patients had significantly higher wound complication, readmission, and reoperation rates and longer hospital stays than the NW patients. The findings of this study may help spine surgeons and patients in terms of preoperative risk stratification and perioperative expectations.

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KEY WORDS obesity; adolescent idiopathic scoliosis; complications; spinal deformity; NSQIP; pediatrics

OBESITY is a growing health concern worldwide, even within the pediatric population. Epidemiological studies have shown significant increases in the prevalence of obesity, and it is currently estimated that 1 in every 5 school-aged children in the United States suffers from this condition.¹³ Obese children suffer not only from chronic health conditions such as diabetes, asthma,

and bone and joint problems, but also from depression, low self-esteem, and social isolation.^{7,8,12}

Given the rise of obesity in the younger population, it is not uncommon for patients with adolescent idiopathic scoliosis (AIS) to present with concomitant obesity. Adolescent idiopathic scoliosis has an estimated prevalence of 1%–3% annually, mostly affecting young girls.^{3,15,17} AI-

ABBREVIATIONS ACS NSQIP Peds = American College of Surgeons National Surgical Quality Improvement Program Pediatric; AIS = adolescent idiopathic scoliosis; BMI = body mass index; NW = normal weight; OB = obese; OW = overweight.

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though many cases can be treated conservatively, surgery is usually offered for curves greater than 50° in skeletally mature patients.¹⁹ In the adult literature, obesity has been shown to increase the risk of perioperative complications after spinal surgery, particularly wound complications.^{4–6,16} Nonetheless, there are conflicting data in the pediatric population, with some studies finding a negative impact from obesity^{1,9–11} and others finding no significant difference in outcomes.^{2,18}

Thus, the purpose of this investigation was to examine the impact of obesity on 30-day outcomes after posterior spinal fusion for AIS, with an emphasis on complication rates based on body mass index (BMI).

Methods

This study used the multicenter, prospectively collected American College of Surgeons National Surgical Quality Improvement Program Pediatric (ACS NSQIP Peds) database for the years 2013 and 2014. This database comprises approximately 60,000 pediatric surgery cases per year, from over 100 participating hospitals in the United States. Surgical patients are randomly selected and their data are prospectively collected throughout their hospital stay and for the first 30 days after surgery (<https://www.facs.org/quality-programs/childrens-surgery/pediatric>).

Patients 10–18 years of age with a principal diagnosis of idiopathic scoliosis (ICD-9 code 737.30) who had undergone fusion of 7 or more spinal levels (CPT codes 22802, 22843, 22804, or 22844) were first identified. Patients with a concomitant diagnosis of neuromuscular disease, cerebral palsy, ventilator dependency, impaired cognition, or tracheostomy were excluded. The final analytical sample consisted of 2712 patients.

Examined Parameters

Collected patient data included age, sex, BMI, race, and comorbidities such as diabetes, asthma, chronic lung disease, cardiac disease (aortic valve disease, pulmonary hypertension, and so forth), seizure disorder, chronic steroid use, bleeding disorder (vitamin K deficiency, hemophilia, thrombocytopenia, or chronic anticoagulation use), or hematological disorder (sickle cell disease, thalassemia, hereditary spherocytosis, and so forth). Operative data included number of spinal levels fused (7–12 vs ≥ 13 levels), revision status, combined anteroposterior approach, use of decompression (laminectomy), use of pelvic fixation, use of osteotomy, use of blood transfusion, average operative time, and average length of hospital stay. Thirty-day outcomes included the development of at least 1 perioperative complication, readmission, and reoperation. Examined complications included coma, pneumonia, reintubation, stroke, pulmonary embolism, cardiac arrest, renal failure, sepsis, septic shock, superficial/deep/organ-space infection, wound dehiscence, deep vein thrombosis, or urinary tract infection.

Statistical Analysis

Patients were grouped into 3 cohorts based on their BMI and according to the Centers for Disease Control age- and sex-adjusted growth charts for children, with mi-

TABLE 1. Patient demographics stratified by BMI

Variable	NW	OW	OB	p Value
No. of cases	2010	345	357	
Average age in yrs	14.5 ± 1.7	14.1 ± 1.6	13.7 ± 1.9	<0.001*
Male sex	19.9	18.0	21.6	0.489
Female sex	80.1	82.0	78.4	
Race				0.140
White	71.2	71.6	71.2	
African American	16.3	15.9	20.2	
Other	11.6	12.5	8.6	
Comorbidity				
Diabetes	0.3	0.3	0.6	0.723
Asthma	6.3	6.4	6.4	0.996
Chronic lung disease	1.0	0.3	0.3	0.228
Cardiac disease	1.5	2.3	2.2	0.380
Seizure disorder	0.7	1.7	1.4	0.104
Chronic steroid use	0.6	0.3	1.1	0.316
Bleeding disorder	0.9	1.2	0.3	0.406
Hematological disorder	1.3	1.2	0.6	0.497

Normal weight (NW) = BMI < 85th percentile; Overweight (OW) = BMI 85th–95th percentile; Obese (OB) = BMI > 95th percentile.

* Significantly different ($p < 0.05$) and thus included in the multiple logistic regression analysis.

nor adjustments: normal weight (NW; BMI < 85th percentile), overweight (OW; BMI 85th–95th percentile), and obese (OB; BMI > 95th percentile; https://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html). Descriptive statistics were used to describe the study population. Comparisons between groups were made using the ANOVA and chi-square or Fisher's exact test, as appropriate. Factors significant on univariate analysis were included in a multiple logistic regression analysis to adjust for potential confounders and to identify the independent effect of obesity. Statistical significance was defined as a p value < 0.05.

Results

A total of 2712 patients—2173 females (80.1%) and 539 males (19.9%)—with a mean age of 14.4 ± 1.8 years were included in this study. Average BMI for the entire cohort was 21.9 ± 5.0 kg/m²; 2010 patients (74.1%) were classified as NW, 345 (12.7%) as OW, and 357 (13.2%) as OB. General demographics are summarized in Table 1. Although there was a significant difference in age ($p < 0.001$), there was no significant difference in sex, race, or comorbidities among the 3 groups.

Operative Parameters

All patients had undergone fusion of 7 or more spinal levels. Operative parameters are summarized in Table 2, showing no significant differences among the groups in terms of revision status, use of combined anteroposterior approach, use of decompression (laminectomy), use of pelvic fixation, use of osteotomy, or use of blood transfu-

TABLE 2. Operative characteristics stratified by BMI

Variable	NW	OW	OB	p Value
No. of cases	2010	345	357	
Fusion of 13+ levels	27.3	26.7	34.2	0.023*
Revision procedure (%)	1.0	0.6	1.1	0.723
Combined approach (%)	1.3	1.2	1.4	0.960
Decompression (%)	0.4	0.6	0.6	0.696
Pelvic fixation (%)	0.4	0.0	1.1	0.068
Osteotomy (%)	30.6	31.9	29.1	0.728
Transfusion (%)	69.3	66.1	65.8	0.269
Average op time (hrs)	4.5 ± 1.6	4.7 ± 1.6	4.9 ± 1.7	<0.001*
Average anesthesia time (hrs)	6.1 ± 1.8	6.3 ± 1.8	6.6 ± 2.0	<0.001*
Average length of stay (days)	4.6 ± 2.5	4.7 ± 1.7	5.1 ± 5.1	0.015*

* Significantly different ($p < 0.05$) and thus included in the multiple logistic regression analysis.

sion. However, the larger proportion of patients in the OB group who had undergone fusion of 13 or more levels ($p = 0.023$) and had a longer average operative time ($p < 0.001$), longer anesthesia time ($p < 0.001$), and longer length of stay ($p = 0.015$) was statistically significantly different compared with the other 2 groups.

Thirty-Day Outcomes

The overall complication rate was 1.3% (36/2712). For NW and OW patients, the complication rate was 0.9% for each group; for the OB patients, the rate was 4.2% ($p < 0.001$; Fig. 1). Specific complications and outcomes are summarized in Table 3. When examining individual complications, we noted that deep wound infection ($p = 0.002$), wound dehiscence ($p = 0.010$), and urinary tract infection

TABLE 3. Thirty-day outcomes stratified by BMI

Variable	NW	OW	OB	p Value
No. of cases	2010	345	357	
≥1 complication (%)	0.9	0.9	4.2	<0.001*
Coma	0.0	0.0	0.0	—
Pneumonia	0.2	0.6	0.3	0.130
Reintubation	0.1	0.0	0.6	0.166
Stroke	0.0	0.0	0.0	—
Pulmonary embolism	0.0	0.0	0.0	—
Cardiac arrest	0.0	0.0	0.0	—
Renal failure	0.0	0.0	0.3	0.259
Sepsis	0.0	0.0	0.0	—
Septic shock	0.0	0.0	0.0	—
Superficial wound infection	0.2	0.3	0.0	0.578
Deep wound infection	0.2	0.0	1.7	0.002*
Organ-space infection	0.0	0.0	0.0	—
Wound dehiscence	0.1	0.0	1.1	0.010*
Deep vein thrombosis	0.0	0.0	0.3	0.259
Urinary tract infection	0.2	0.0	1.4	0.007*
30-day readmission	1.6	1.2	5.0	<0.001*
30-day reoperation	0.9	1.2	4.8	<0.001*

— = not applicable.

* Significantly different ($p < 0.05$).

($p = 0.007$) occurred more frequently in the OB group. In a multiple logistic regression analysis, after controlling for patient age, number of fused spinal levels, and operating/anesthesia time (all significant on univariate analysis), the OB patients were significantly more likely to develop a complication (OR 4.61, 95% CI 2.24–9.46, $p < 0.001$) than were the NW patients. However, the OW patients had

FIG. 1. Thirty-day complication rates stratified by body weight ($p < 0.001$).

FIG. 2. Thirty-day readmission rates stratified by body weight ($p < 0.001$).

complication rates similar to those in the NW patients (OR 0.97, 95% CI 0.28–3.33, $p = 0.966$).

The 30-day readmission rate was 2.0% (55/2712) for all patients, 1.6% for NW patients, 1.2% for OW patients, and 5.0% for OB patients ($p < 0.001$; Fig. 2). Among the 55 patients who experienced a readmission, the reasons included wound disruption (10 cases), deep/organ-space surgical site infection (5), nerve injury (1), systemic infection (1), and other or unknown causes (39). On multiple logistic regression analysis, the OW patients did not have higher odds of readmission than the NW patients (OR 0.72, 95% CI 0.25–2.07, $p = 0.553$). On the other hand, the OB patients were more likely to be readmitted than the NW and OW patients (OR 3.16, 95% CI 1.73–5.80, $p < 0.001$).

The 30-day reoperation rate was 1.4% (39/2712 patients). Based on BMI, the reoperation rates were 0.9%, 1.2%, and 4.8% for NW, OW, and OB patients, respectively ($p < 0.001$; Fig. 3). Causes of reoperation included wound complication (infection or dehiscence, 15 cases), progressive deformity (7), implant failure (3), and other or unknown (14). As with complications and readmissions, obesity remained a risk factor for reoperation after adjustment for significant covariates on multiple logistic regression analysis (OR 5.33, 95% CI 2.66–10.70, $p < 0.001$). The OW patients did not have higher odds of reoperation than the NW patients (OR 1.30, 95% CI 0.43–3.90, $p = 0.631$).

Subanalysis Based on Number of Spinal Levels Fused

There were 1950 patients (71.9%) who had undergone fusion of 7–12 spinal levels. Among this group, complication rates for the NW, OW, and OB patients were 0.8%, 0.8%, and 3.4%, respectively ($p = 0.002$). Thirty-day readmission rates were 1.4% for NW patients, 0.8% for OW patients, and 3.8% for OB patients ($p = 0.011$). Lastly, 30-day reoperation rates were 1.0%, 1.2%, and 3.0% for the NW, OW, and OB patients, respectively ($p = 0.033$).

On the other hand, 762 patients had undergone fusion

of 13 or more spinal levels. Among this group, complication rates were 1.1% for NW patients, 1.1% for OW patients, and 5.7% for OB patients ($p = 0.002$). Thirty-day readmission rates were 2.4%, 2.2%, and 7.4% for the NW, OW, and OB patients, respectively ($p = 0.014$). Reoperations occurred in 0.7% of the NW patients, 1.1% of the OW patients, and 8.2% of the OB patients ($p < 0.001$).

Discussion

As the prevalence of obesity increases in children, the proportion of patients who undergo surgery for AIS with a concomitant diagnosis of obesity will most likely also increase. In 2011–2014, the prevalence of obesity among patients 2–19 years of age was 17% and the prevalence of “extreme” obesity (defined as BMI at or above 120% of the sex-specific 95th percentile) was 5.8%. Furthermore, obese patients have been shown to have more severe major curves at presentation, preoperative minor curves, and preoperative thoracic kyphosis compared with normal-weight patients.¹¹

In the present study, we used a large multicenter prospective database to examine 30-day outcomes after AIS surgery, finding that the OB patients had significantly longer operative/anesthesia times, higher 30-day complication, readmission, and reoperation rates, and longer hospital stays. It is interesting to note that the OB patients were the youngest on average (13.7 vs 14.5 years for NW patients vs 14.1 years for OW patients, $p < 0.001$). This has been shown previously¹¹ and may be attributable to the fact that obese patients can present with worse curves initially, or to the decreased effectiveness of brace treatment.¹⁴ Likewise, the OB patients were more likely to undergo fusion of 13 or more spinal levels, suggesting that they, in fact, may present with more severe curves, as has been postulated previously.

Hardesty et al. reviewed the outcomes of 236 patients

FIG. 3. Thirty-day reoperation rates stratified by body weight ($p < 0.001$).

surgically treated for AIS and found, similar to our results, that obese patients had longer operative times (324 vs 293 minutes), larger amounts of intraoperative fluids given (3077 vs 2756 ml), and higher levels of intraoperative blood loss (910 vs 764 ml).⁹ Likewise, when reviewing 207 AIS cases, Katyal et al. showed that the duration of anesthesia was significantly longer for obese patients than for controls.¹⁰ The obese patients have a greater skin-to-lamina distance, which can definitely impact operative time. Additionally, positioning is more challenging and emerging from deep sedation may take longer.¹⁰

Complication rates were found to be similar between the NW and OW patients in our study. However, there was a significantly increased risk of complication occurrence in the OB patients as compared with the nonobese patients (Fig. 1). These complications included reintubation, deep wound infection, wound dehiscence, deep vein thrombosis, and urinary tract infection—the latter, interestingly, developing almost exclusively in the OB group. Katyal et al. also found a higher rate of postoperative wound infection in overweight (12%) and obese (10.5%) patients than in normal-weight adolescents (2.7%, $p = 0.030$); however, overall complication rates in that study were not significantly different between groups ($p = 1.000$).¹⁰ Interestingly, other studies have not found higher complication rates in obese patients undergoing AIS surgery.^{9,11,18} Although Hardesty et al. showed a difference in operative times and blood loss, their complication rate was not significantly different between normal-weight (15%) and obese (14%) patients ($p = 0.950$). Li et al. retrospectively analyzed the outcomes of 588 patients (454 normal weight, 63 overweight, and 71 obese patients), finding no significant differences in intraoperative or postoperative complications between the normal-weight and overweight patients (postoperative: 21.8% vs 23.9%, $p = 0.612$) or between the normal-weight and obese patients (postoperative: 21.8% vs 28.2%, $p = 0.234$).¹¹ Similarly, Upasani et al. showed that among 241

patients, there was no difference in operative time, estimated blood loss, or postoperative complications.¹⁸ These authors hypothesized that the absence of chronic comorbidities (such as in the adult population) could account for the similar complication rates between healthy and overweight patients.

The present study showed that the OB patients had higher reoperation and readmission rates than the OW or NW patients, even after adjustment for potential confounding variables such as age or number of instrumented levels. Wound-related complications (dehiscence or infection requiring washout) were the most common unique causes for readmission or reoperation, a finding that concurs with that of Katyal et al.¹⁰ One possible explanation for this finding is the “increased force needed for intraoperative retraction, leading to increased dead space and tissue necrosis.”¹⁰ Lastly, the hospital stay was also shown to be longer for OB patients in our study. Although the exact cause cannot be fully elucidated, this finding warrants further research and contrasts with the findings of previous studies showing no difference in the length of stay between weight groups.^{9,10}

Although there are conflicting data regarding perioperative outcomes after AIS surgery in obese patients, findings in the present study suggest that there is a negative impact of increased body weight in the first 30 postoperative days. One of the most interesting findings, however, was that NW and OW patients had similar outcomes. Although future studies are required to corroborate those findings, it may be reasonable to encourage weight reduction in OB patients before they undergo scoliosis surgery, even if it is moderate enough to drop to the OW subgroup. This finding was present in both instrumented level subgroups (that is, 7–12 and ≥ 13 levels), suggesting that obesity remains a risk factor for adverse outcomes of both short- and long-segment fusions. Patients and surgeons may benefit from these findings in terms of preoperative risk stratification, as well as in surgical planning and expectation setting be-

fore surgery. Nonetheless, future prospective studies may better define the impact of BMI on both short- and long-term outcomes after AIS surgery.

Study Strengths and Limitations

This study has several strengths and limitations. The data presented herein stem from a national prospective database that allows analysis of a large number of patients (over 2700) treated by multiple surgeons, potentially reducing selection bias. Additionally, most patient characteristics were very similar, also minimizing bias. On the other hand, the ACS NSQIP Peds database does not include parameters such as curve type or presenting symptomatology. However, by including only those patients who underwent fusion of 7 or more spinal levels and controlling for potential confounding variables on our multiple logistic regression analysis, we attempted to decrease the effect of variability in treatment and potential confounding factors.

Conclusions

In the past decades, obesity has become an enormous public health concern in the pediatric population. In this study, OB patients showed significantly higher rates of postoperative complications, as well as higher rates of 30-day readmission and reoperation after surgery for AIS, even after controlling for age, number of spinal levels fused, and anesthesia/operative time. On the other hand, NW and OW patients showed similar outcomes, suggesting that encouraging weight loss in children whose BMI is above the 95th percentile, even if the loss is moderate enough to drop them to the OW level (85th–95th percentile group), is a reasonable strategy before deformity surgery.

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Disclosures

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Conception and design: Yassari, De la Garza Ramos. Acquisition of data: De la Garza Ramos, Nakhla, Nasser, Schulz, Purvis, Sciubba, Kinon. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: Yassari, De la Garza Ramos, Schulz, Sciubba, Kinon. Reviewed submitted version of manuscript: Yassari, Schulz, Sciubba. Statistical analysis: De la Garza Ramos. Administrative/technical/material support: Sciubba. Study supervision: Yassari, Schulz, Kinon.

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