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Relationship between body mass index and sagittal vertical axis change as well as health-related quality of life in 564 patients after deformity surgery

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OBJECTIVE Obesity, a condition that is increasing in prevalence in the United States, has previously been associated with poorer outcomes following deformity surgery, including higher rates of perioperative complications such as deep and superficial infections. To date, however, no study has examined the relationship between preoperative BMI and outcomes of deformity surgery as measured by spine parameters such as the sagittal vertical axis (SVA), as well as health-related quality of life (HRQoL) measures such as the Oswestry Disability Index (ODI) and Scoliosis Research Society–22 patient questionnaire (SRS-22). To this end, the authors sought to clarify the relationship between BMI and postoperative change in SVA as well as HRQoL outcomes.

METHODS The authors performed a retrospective review of a prospectively managed multicenter adult spinal deformity database collected and maintained by the International Spine Study Group (ISSG) between 2009 and 2014. The primary independent variable considered was preoperative BMI. The primary outcome was the change in SVA at 1 year after deformity surgery. Postoperative ODI and SRS-22 outcome measures were evaluated as secondary outcomes. Generalized linear models were used to model the primary and secondary outcomes at 1 year as a function of BMI at baseline, while adjusting for potential measured confounders.

RESULTS Increasing BMI (compared to BMI < 18) was not associated with change of SVA at 1 year postsurgery. However, BMIs in the obese range of 30 to 34.9 kg/m^2, compared to BMI < 18 at baseline, were associated with poorer outcomes as measured by the SRS-22 score (estimated change –0.47, 95% CI –0.93 to –0.01, p = 0.04). While BMIs > 30 appeared to be associated with poorer outcomes as determined by the ODI, this correlation did not reach statistical significance.

CONCLUSIONS Baseline BMI did not affect the achievable SVA at 1 year postsurgery. Further studies should evaluate whether even in the absence of a change in SVA, baseline BMIs in the obese range are associated with worsened HRQoL outcomes after spinal surgery.

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KEYWORDS sagittal vertical axis; body mass index; Oswestry Disability Index; Scoliosis Research Society–22 patient questionnaire; deformity

ABBREVIATIONS HRQoL = health-related quality of life; ISSG = International Spine Study Group; LL = lumbar lordosis; ODI = Oswestry Disability Index; PJK = proximal junctional kyphosis; PT = pelvic tilt; SRS-22 = Scoliosis Research Society–22 patient questionnaire; SSI = surgical site infection; SVA = sagittal vertical axis.

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Overall sagittal balance of the vertebral column is an important predictor of health-related quality of life (HRQoL) both before and after spine deformity surgery.[9] Previous studies have shown that sagittal malalignment in patients with spinal deformity is directly correlated with poor quality of life measures such as low-back pain and disability.[6,7,19] Postoperative improvement of the sagittal vertical axis (SVA) has been shown repeatedly to correlate with improved outcomes following deformity surgery.[1,2,10] Moreover, restoration of a normal SVA is often considered the single most important factor with regard to surgical efficacy.[1,2,8]

Obesity is an increasingly common problem in the United States, with recent estimates showing that roughly 35% of adults in the United States are either overweight or obese.[15] Spine surgeons in particular have been affected by this growing epidemic. Previously published studies have determined that patients with a higher BMI experience higher rates of perioperative complications related to spine surgery.[16,21] With interventions for spinal deformity, obesity was found to be an independent risk factor for both superficial and deep surgical site infections (SSIs).[17] The effectiveness of deformity surgery in obese patients, however, remains an unexplored area of research.

Many prior publications have explored the relationship between modifiable spinal parameters, such as lumbar lordosis (LL) and postoperative change of the SVA.[11] To our knowledge, however, no study to date has specifically addressed the relationship between preoperative BMI and the degree of achievable postoperative SVA. As such, we sought to define this relationship based on measurement of SVA performed 1 year postoperatively, thereby allowing enough time for potential complications such as proximal junctional kyphosis (PJK), which may occur in up to 20%–40% of patients and as early as 2 months postoperatively.[12] This in turn may enable deformity surgeons to predict surgical change based on baseline demographics, improve patient selection, and optimize outcomes.

Methods

Study Design and Population

A retrospective review was conducted in 2016 of a prospectively maintained multicenter adult spinal deformity database collected between 2009 and 2014 by the International Spine Study Group (ISSG). The database is composed of data from consecutively enrolled patients with adult spinal deformity (defined by age > 18 years and one of the following: scoliosis, Cobb angle > 20°, SVA > 50 mm, pelvic tilt [PT] > 25°, or thoracic kyphosis ≥ 60°). This study was conducted in accordance with the amended Declaration of Helsinki and reported following the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.[5,13] All study patients provided informed consent.

Data Collection and Radiographic Assessment

The database contains de-identified information regarding the demographics, medical comorbidities, clinical examinations, and diagnostic study results of adult patients with spinal deformity. For the purpose of the present analysis, data for each patient were collected preoperatively and 1 year after surgery. The Oswestry Disability Index (ODI) and the Scoliosis Research Society–22 patient questionnaire (SRS-22) were used to measure HRQoL.[4,14] Full-length 36-inch cassette radiographs were obtained and analyzed at a single center (New York University Hospital for Joint Disease).

Explanatory Variables and Outcomes

The primary outcome was change in global sagittal alignment at 1 year after surgery. The primary independent variable considered was baseline (preoperative) BMI. Additional important clinical predictors extracted included age, sex, smoking status, active malignancy, chronic lung disease, chronic arthritis, and major depression. Secondary outcomes included HRQoL determined by use of the ODI and SRS-22.

Statistical Analysis

Descriptive statistics were used to determine baseline patient characteristics. Quantitative variables were presented as mean and standard deviation, median and interquartile range, or proportion. The primary variable under consideration, BMI, was considered alongside other important a priori clinical predictors such as age, sex, current or past smoker, active malignancy, chronic lung disease, chronic arthritis, and major depression in order to predict the change in SVA during the follow-up period. We used generalized linear models in order to model the primary and secondary outcomes at 1 year as a function of BMI at baseline, while adjusting for potential measured confounders.

We used a 0.05 level to declare statistical significance and conducted two-sided tests to determine p values. All analyses were performed in STATA version 14.1 (StataCorp).

Results

A total of 1053 patients in the aforementioned database were assessed for eligibility (Fig. 1). Among the 590 patients who underwent surgical management, 26 patients were excluded due to incomplete baseline information regarding BMI. The remaining 564 patients were selected for inclusion in the present study.

The demographic information and baseline medical characteristics of patients selected for inclusion in the study are outlined in Table 1. The mean ± SD age of studied patients was 55.0 ± 15.5 years; 82.4% of the patients were male. The mean preoperative BMI was 26.9 ± 9.4. The most prevalent comorbidities among the study population were chronic arthritis (30.7%) and major depressive disorder (21.6%).

Results related to the primary outcome, postoperative SVA change at 1 year postsurgery, are presented in Table 2. Based on the results shown, it can be seen that no statistically significant relationship exists between preoperative BMI and change in SVA measured at 1 year postsurgery. For example, for patients with normal BMIs (18–24.9), the average SVA change observed was –5.33 mm (95% CI –35.3, 24.6) compared to the reference level of BMI <

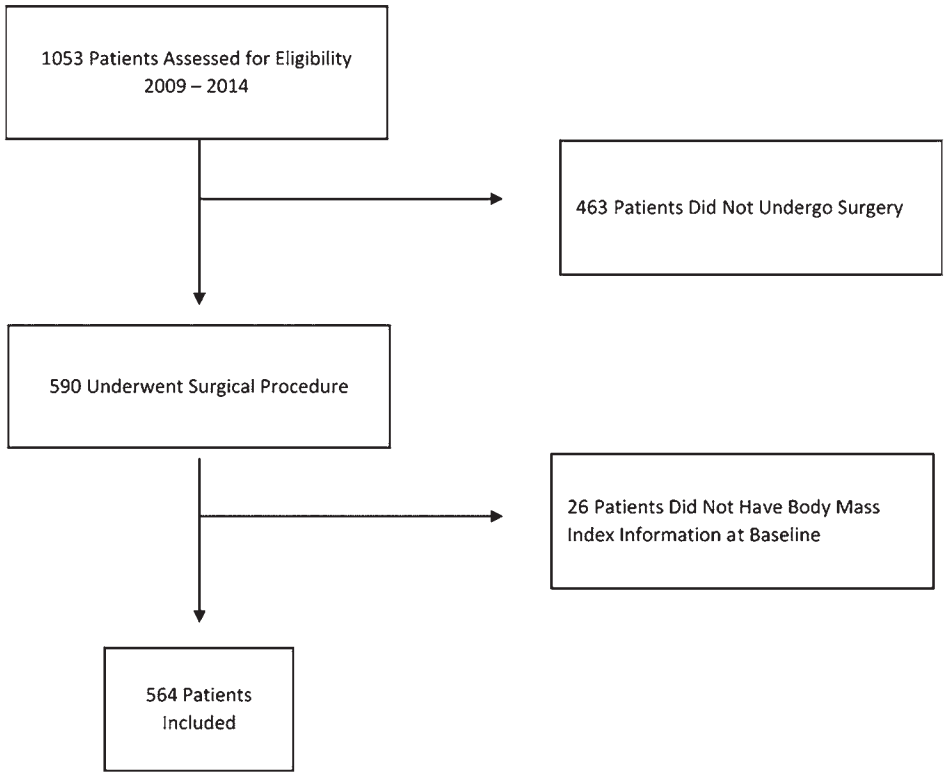

FIG. 1. Flowchart showing methodology utilized to obtain study cohort.

18. In addition, morbidly obese patients (e.g., BMI > 35) experienced an average SVA increase of +0.35 mm (95% CI –32.3, 33.0) compared to the reference value. Additionally, no relationship was found between preoperative BMI and the incidence of PJK.

Secondary outcome data are illustrated in Table 3. Unlike the previous data showing no correlation between BMI and postoperative SVA change, the data here illustrate a statistically significant correlation between obese BMIs in the range of 30–34.9 and negative HRQoL outcomes as measured by the SRS-22. While BMIs > 30 appeared to be associated with poorer outcomes as determined by the ODI, this correlation did not reach statistical significance.

Discussion

The findings of this study suggest that while increasing preoperative BMIs do not affect the degree to which the SVA can be corrected during deformity surgery, they may result in worse postoperative HRQoL outcomes—particularly as measured by the SRS-22.

Several prior studies have explored the relationship between baseline BMI and long-term outcomes and complications after deformity surgery. For instance, in an analysis of adults who experienced proximal junctional vertebral fractures following deformity surgery, Watanabe et al. demonstrated that patients who experienced upper instrumented vertebral collapse and adjacent vertebral subluxation, as opposed to simple fracture of the supra-adjacent vertebra, had higher preoperative BMIs (30.5 vs 23.0, $p < 0.05$).[22] These types of fractures were theorized to be a result of concentrated mechanical stress on the uppermost instrumented vertebra. Moreover, upper instrumental vertebral collapse carried a higher risk of severe neurological deficits due to spinal cord compression secondary to the severe angular kyphotic deformities associated with these types of fractures. Conversely, in our study no correlation was found between BMI and the occurrence of PJK following a multiple regression analysis.

Regarding outcomes following scoliosis surgery, Smith et al. found that increasing BMI was a predictor of poor outcomes for both younger (age 18–45 years) and older (age 46–85 years) patients with scoliosis.[20] In this study, both the younger and older patient subgroups demonstrated that higher BMIs were statistically associated with poorer scores on both the ODI and SRS-22—a finding that echoes the outcomes demonstrated in the present study.

Other studies have investigated the relationship between increasing BMI and perioperative complications during and after spine deformity surgery. Pull ter Gunne et al. demonstrated that patients with obese-range BMIs (> 30) were at higher risk for both deep and superficial SSIs following deformity surgery. The authors of that study theorized that the increased force necessary to retract the increased subcutaneous fat layer in obese patients leads to increased tissue necrosis, thus increasing the risk for both deep and superficial SSIs.[17] Patel et al. performed a logistic regression which demonstrated that obese patients were at increased risk for "significant complications" related to spine surgery, such as myocardial

TABLE 1. Study cohort demographics and radiographic characteristics (n = 564)

	Value
Age, yrs	55.0 ± 15.5
BMI, kg/m^2	26.9 ± 9.4
Male sex	465 (82.4)
Charlson Comorbidity Index, median [IQR]	1.0 [0–2]
Medical history	
Current smoker	53 (9.7)
Chronic heart failure	49 (8.69)
Chronic pulmonary disease	31 (5.5)
Chronic renal failure	15 (2.7)
Chronic arthritis	173 (30.7)
Malignancy	51 (9.0)
Osteoporosis	61 (10.8)
Anemia	52 (9.2)
Major depressive disorder	122 (21.6)
Plain radiograph findings	
Cervical lordosis C2–7, °	8.0 ± 14.5
Cervical lordosis C2–T3, °	6.5 ± 15.9
Plumb line C2–7, mm	31.9 ± 17.2
Plumb line C2–T3, mm	59.3 ± 23.4
T1 slope, °	25.8 ± 12.6
Sacral slope, °	32.9 ± 11.9
PT, °	22.1 ± 11.0
Pelvic incidence, °	55.0 ± 12.9
LL L1–S1, °	43.9 ± 20.5
Pelvic incidence – LL, °	11.1 ± 20.2

Values are presented as number (%) of patients or mean ± SD unless otherwise indicated.

infarction, pneumonia, deep vein thrombosis (DVT), and durotomy ($p < 0.04$).[16]

The findings we report here echo those of previous studies which have demonstrated poorer overall outcomes following spinal deformity surgery in overweight and obese patients. Though we have demonstrated that higher baseline BMIs do not prevent operative change of the SVA, we have shown that outcomes of surgery in overweight and obese patients tend to be worse despite adequate restoration of a proper SVA. This information may aid spine surgeons in the process of selecting candidates for deformity surgery.

Future Directions

Further validation of our results is warranted in the form of a prospective trial with a longer follow-up period. This is especially true given that statistical significance was not achieved in the obese groups for ODI or the BMI > 35 group for SRS-22. In the context of assessing the impact of patient characteristics on the change of spinopelvic parameters and outcomes, future studies should also account for bone mineral density (BMD) and preoperative nutritional status. Decreased BMD in patients with osteoporosis affects approximately 4 to 6 million women and 1 to 2 million men in the United States. Not only can osteoporosis accelerate the progress of degenerative scoliosis in elderly patients, but also it can lead to worse perioperative outcomes secondary to complications such as instrumentation failure.[3] Along with BMI and BMD, any preoperative assessment should include the patient's nutritional status.[23] Nutritional status is known to affect outcomes in several health conditions. To this end, Salvetti et al. have demonstrated that preoperative prealbumin levels correlate with the risk of SSIs in elective spine surgery.[18] Overall, prehabilitation before spine surgery to optimize baseline patient characteristics such as BMI, BMD, and nutritional status may improve outcomes.

Limitations

This study was limited by its retrospective design, which may have introduced significant selection bias in terms of patients selected to undergo spine surgery versus those who were medically managed. Furthermore, the follow-up period was limited to 1 year, which may not have adequately captured postoperative changes in SVA or HRQoL outcomes. In addition, this 1-year timeframe may not be adequate to assess for all postoperative complications and subsequent rates of reoperation. Overall, however, we believe that these limitations are balanced by the strengths of the study, which include the use of a prospectively collected and managed cohort, the standardized assessment of radiographic measurements, and the large study cohort.

TABLE 2. Estimated change in SVA at 1 year after surgery for each BMI category at baseline

BMI, kg/m^2	Total No. of Pts in BMI Category	Mean SVA at Baseline, mm	Mean SVA at 1 Yr, mm	Change in SVA (95% CI), mm	p Value*
<18	10	70.48 ± 110.24	32.49 ± 59.51	Ref	—
18–24.9	248	20.43 ± 62.59	13.22 ± 52.85	−5.33 (−35.3, 24.6)	0.72
25–29.9	175	54.47 ± 71.18	29.32 ± 54.60	−11.0 (−41.3, 19.3)	0.48
30–34.9	79	74.01 ± 68.16	43.55 ± 50.77	−6.9 (−38.2, 24.4)	0.67
>35	52	78.01 ± 67.97	50.85 ± 62.30	0.35 (−32.3, 33.0)	0.98

Pt = patient.
Mean values are shown ± SD.
* p values based on a generalized linear model including the main exposure in addition to age, Charlson Comorbidity Index, arthritis, BMI, smoking, cancer, sex, cervical lordosis C2–7, cervical lordosis C2–T3, cervical SVA C2–T3, T1 slope, LL L1–S1, and sacral slope.

TABLE 3. Estimated change of HRQoL (SRS-22) at 1 year after surgery for each BMI category at baseline

BMI, kg/m²	Mean SRS Score at Baseline	Mean SRS Score at 1 Yr	Estimated SRS Score Change (95% CI)	p Value*
<18	3.81 ± 0.51	4.00 ± 0.78	Ref	—
18–24.9	3.38 ± 0.73	3.78 ± 0.66	−0.19 (−0.63, 0.24)	0.39
25–29.9	2.99 ± 0.70	3.64 ± 0.77	−0.26 (−0.71, 0.18)	0.24
30–34.9	2.92 ± 0.71	3.45 ± 0.73	−0.47 (−0.93, −0.01)	**0.04**
>35	2.70 ± 0.59	3.39 ± 0.68	−0.39 (−0.86, 0.09)	0.11

Boldface type indicates statistical significance. Mean values are shown ± SD.

* p values based on a generalized linear model including the main exposure in addition to age, Charlson Comorbidity Index, depression, arthritis, BMI, smoking, cancer, sex, cervical lordosis C2–7, cervical lordosis C2–T3, cervical SVA C2–T3, T1 slope, LL L1–S1, and sacral slope.

Conclusions

In this study, we performed a retrospective analysis of a database of spine deformity patients in order to explore the relationship between preoperative BMI and postoperative outcomes of deformity surgery, such as SVA change and HRQoL outcomes. We show that baseline BMI does not affect the degree of change achievable in SVA at 1 year postsurgery. However, we also show that greater baseline BMIs may be correlated with worsened HRQoL outcomes regardless of the degree of change achieved in the SVA. Further validation of our results is warranted in the form of a prospective trial with a longer follow-up period.

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Disclosures

Dr. Okonkwo reports being a consultant for NuVasive, Zimmer Biomet, and Stryker. Dr. Passias reports being a consultant for Spinewave, Zimmer Biomet, and Medicrea and being a scientific advisory board member for AlloSource. Dr. V. Lafage reports direct stock ownership in Nemaris Inc.; receiving support of non–study-related clinical or research effort overseen by author from DePuy Spine, NuVasive, K2M, and Stryker (grants paid through ISSGF); and being a consultant (receiving payment for lectures) for DePuy Spine, AOSpine, and K2M. Dr. Schwab reports direct stock ownership in Nemaris Inc.; being a consultant for Zimmer Biomet, K2M, NuVasive, Medicrea, and Medtronic; receiving support of non–study-related clinical or research effort overseen by author from DePuy Spine, K2M, Stryker, and NuVasive (grants paid through ISSGF); and speaking/teaching arrangements with Zimmer Biomet, K2M, NuVasive, and Medtronic. Dr. Bess reports being a consultant for EOS, K2 Medical, Misonix, and AlloSource; being a patent holder for K2 Medical; receiving clinical or research support for the study described (includes equipment or material) from the ISSGF; and receiving support of non–study-related clinical or research effort overseen by author from the ISSGF. Dr. Ames reports being an employee of UCSF; being a consultant for DePuy Synthes, Medtronic, Stryker, Medicrea, K2M, and Zimmer Biomet; receiving royalties from Stryker, Zimmer Biomet, DePuy Synthes, NuVasive, Next Orthosurgical, and K2M; ownership and receiving royalties from Medicrea; ownership and conducting research for Titan Spine, DePuy Synthes, and ISSG; ownership and being on the editorial board of *Operative Neurosurgery*; ownership and receiving grant funding from SRS; ownership and being on the executive committee for ISSG; and ownership and being the director of Global Spinal Analytics. Dr. Smith reports being a consultant for NuVasive, Zimmer Biomet, K2M/Stryker, AlloSource, and Cerapedics; receiving clinical or research support for the study described (includes equipment or material) from DePuy Synthes/ISSG; receiving support of non–study-related clinical or research effort overseen by author from DePuy Synthes/ISSG and AOSpine; receiving royalties from Zimmer Biomet and NuVasive; and receiving fellowship funding from NREF and AOSpine. Dr. Shaffrey reports being a consultant for Medtronic, NuVasive, and EOS; direct stock ownership in NuVasive; and being a patent holder for Medtronic, NuVasive, and Zimmer Biomet. Dr. Burton reports being a consultant for DePuy and AlloSource; being a patent holder for DePuy; and receiving clinical or research support for the study described (includes equipment or material) from DePuy and Pfizer.

Author Contributions

Conception and design: Hamilton, Agarwal, Goldschmidt. Acquisition of data: Angriman, Goldschmidt. Analysis and interpretation of data: Hamilton, Agarwal, Angriman, Goldschmidt. Drafting the article: Hamilton, Agarwal, Angriman, Goldschmidt, Zhou. Critically revising the article: Hamilton, Agarwal, Kanter, Okonkwo, Passias, Protopsaltis, V Lafage, R Lafage, Schwab, Bess, Ames, Smith, Shaffrey, Burton. Reviewed submitted version of manuscript: all authors. Statistical analysis: Angriman. Administrative/technical/material support: Hamilton. Study supervision: Hamilton.

Supplemental Information

Previous Presentations

Data from this study were presented at the 35th Annual Meeting of the AANS/CNS Section on Disorders of the Spine and Peripheral Nerves, Spine Summit, Spinal Deformity Breakout, March 14–17, 2019, Miami, Florida.

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