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Clinical Study

Obesity does not impact clinical outcome but affects cervical sagittal alignment and adjacent segment degeneration in short term follow-up after an anterior cervical decompression and fusion

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Abstract

BACKGROUND CONTEXT: Obesity increases complications and cost following spine surgery. However, the impact on sagittal alignment and adjacent segment degeneration (ASD) after anterior cervical decompression and fusion is less understood.
PURPOSE: To compare clinical and radiographic outcomes after anterior cervical decompression and fusion between obese and nonobese patients.
STUDY DESIGN: Retrospective cohort study.
PATIENT SAMPLE: In all, 467 patients that underwent an anterior cervical decompression and fusion procedure from January 2008 through December 2015 were assessed. Surgery indications were radiculopathy, myelopathy, or myeloradiculopathy that had failed nonoperative treatments. Exclusion criteria included patients who had postoperative follow-up less than 6 months. Of 467 patients originally identified, 399 fulfilled the inclusion and exclusion criteria.
OUTCOME MEASURES: The following patient-reported outcomes were obtained: Neck Disability Index and Visual Analog Scale scores for the neck and arm pain. Radiographic assessments included: C2−C7 lordosis, T1 angle, levels fused, sagittal vertical axis (SVA), fusion mass lordosis, proximal and distal adjacent segment lordosis, ASD, and presence of fusion.
METHODS: Plain radiographs were performed preoperatively, immediately postoperatively, and final follow-up. Demographic information was collected on all patients. Baseline patient characteristics were compared using chi-squared analysis and independent sample *t* tests for categorical and continuous data, respectively. For analysis, patients were divided into 4 groups based on obesity stratification as defined by Center for Disease Control: body mass index (BMI) <25 kg/m^2 (normal weight), BMI≥ 25 kg/m^2 to <30 kg/m^2 (overweight), ≥ 30 kg/m^2 to <35 kg/m^2 (Class I obesity), BMI≥ 35 kg/m^2 to <40 kg/m^2 (Class II obesity), and BMI≥ 40 kg/m^2 (Class III obesity). Additionally, obese (≥ 30 kg/m^2) and nonobese (<30 kg/m^2) patients were compared in a separate analysis. Multivariate analysis was used to compare clinical and radiographic outcomes among all BMI classes, as well as between BMI≥ 30 kg/m^2 versus BMI<30 kg/m^2 study groups. Multivariate analyses

FDA device/drug status: Not applicable.

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controlled for differences in baseline patient characteristics and included age, sex, smoking, American Society of Anesthesiologists Physical Status Score, diabetes mellitus, and number of levels.
RESULTS: Of the 399 patients assessed, 97 were identified as normal weight, 157 as overweight, 81 with Class I obesity, 45 with Class II obesity, and 19 with Class III obesity. On multivariate analysis, despite having similar SVA measurements on preoperative radiographs, increase in BMI was associated with increase in postoperative SVA (p=0.041) along with significantly larger SVA in immediate postoperative (p=0.004) and final follow-up radiographs (p=0.003) for patients with BMI≥30 kg/m^2 versus BMI<30 kg/m^2. Furthermore, patients with BMI≥30 kg/m^2 had smaller preoperative (p=0.012), immediate postoperative (p=0.017), and final lordosis (p<0.001) in addition to smaller immediate postoperative (p=0.025) and final fusion segment lordosis (p=0.015) and smaller preoperative (p=0.024) and final distal lordosis (p=0.021) compared with patients with BMI<30 kg/m^2. Additionally, greater BMI was associated with lower final Visual Analog Scale neck scores (p=0.008). Radiographic early ASD rates were higher in patients BMI≥30 kg/m^2 versus BMI<30 kg/m^2 (p=0.028).
CONCLUSIONS: Overall, obese patients who underwent anterior cervical decompression and fusion had similar patient-reported outcomes compared with nonobese patients but had worse radiographic parameters and higher rates of ASD development compared with nonobese patients. This underscores the importance of patient selection and surgical approach for both patient populations.

Keywords: Obesity; Clinical; Outcome; Cervical; Sagittal alignment; Adjacent segment degeneration; Anterior cervical decompression and fusion

Introduction

The prevalence of obesity continues to rise in the United States, according to the National Center for Health Statistics, and this rise increases the cost of healthcare management for this population [1]. Obesity has been identified as a significant comorbidity that may increase surgical risk, technical difficulty, and overall cost following spine surgery [2−6]. Djurasovic et al. found that obese patients had higher rates of wound-related complications than nonobese patients [7,8]. Similarly, Marquez-Lara et al. examined relative risk of complications postoperatively in 24,196 patients that underwent lumbar spine surgery and found that obese patients had increased risk of postoperative complications, but not mortality, compared with normal weight patients [9]. Despite the increased risk of complications, many studies have also found no difference in reported outcomes [9−11]. These studies have largely focused on the impact of obesity on various thoracic and lumbar surgeries, but few have examined the impact of obesity on cervical spine procedures, including anterior cervical decompression and fusions.

Thus far, two studies have addressed the impact of obesity on patient-reported outcomes (PROs) after Anterior Cervical Decompression and Fusion (ACDF). Sielatycki et al. analyzed PROs for 80 obese patients and 219 nonobese patients at baseline and 1-year follow-up after ACDF and found that there was no difference in PROs [12]. Similarly, Narain et al. evaluated PROs between obese and nonobese patients, including narcotic use, hospital cost, and postoperative complications in their assessment and found no difference in outcomes between the two patient populations [13]. Although the aforementioned studies were novel additions to literature, they did not monitor morphological characteristics, such as sagittal parameters that can help guide patient selection and treatment course to minimize complications for obese patients undergoing ACDF [14].

Sagittal parameters reflect cervical sagittal alignment, which has been shown to be an important determinant in clinical outcomes for patients who have undergone an anterior cervical decompression and fusion [15]. Studies have indicated that maintenance of morphological sagittal alignment may be predictive of positive clinical outcomes [14,16]. In addition, restoration of sagittal alignment has been identified as an important surgical parameter to decrease the occurrence of symptomatic adjacent segment degeneration (ASD), which occurs in patients with ACDF at approximately 3% annually and 25.6% in 10 years [17−19]. ASD has been correlated with poor outcomes and an increased likelihood of reoperation [20]. To our knowledge, there are no studies that directly examine the impact of obesity on clinical and radiographic outcomes in patients who have undergone anterior cervical decompression and fusion. The goal of this study was to compare PROs along with cervical sagittal alignment parameters between obese and nonobese patients.

Material and methods

Patient identification

Following Institutional Review Board approval, we performed a retrospective cohort study of consecutive patients from January 2008 through December 2015 who underwent an anterior cervical decompression and fusion procedure. Surgery indications were radiculopathy, myelopathy, or myeloradiculopathy that had failed nonoperative treatments. Surgeries were performed by 1 of 2 senior orthopaedic spine surgeons (HSA, EG) at an academic medical center. Both surgeons exclusively used tricortical structural fresh-frozen Iliac crest bone graft (ICBG) allograft and plate/screw fixation for all cases. No intervertebral cages were used. Exclusion criteria were patients under 18 years of age at the time of surgery and those who had previous cervical fusion or concomitant posterior cervical surgery, postoperative follow-up less than 6 months, or an anterior cervical decompression and fusion for cervical spine fracture, tumor, or infection. Of 467 patients originally identified, 399 fulfilled the above criteria. For analysis, patients were divided into 4 groups based on obesity stratification as defined by Center for Disease Control using body mass index (BMI): <25 kg/m^2 (normal weight), ≥25 kg/m^2 to <30 kg/m^2 (overweight), ≥30 kg/m^2 to <35 kg/m^2 (Class I obesity), ≥35 kg/m^2 to 40 kg/m^2 (Class II obesity), and ≥40 kg/m^2 (Class III obesity).

Data collection

Demographic information such as age, sex, BMI, diabetes mellitus status, smoking status, and American Society of Anesthesiologists Physical Status Score (ASA) was collected for all patients. Patients followed up with the attending surgeon within the first 4 weeks postoperatively, and then again at 3 months, 6 months, and 12 months postoperatively. Anteroposterior and lateral cervical spine radiographs were taken at each postoperative visit.

At preoperative, immediately postoperative, and last follow-up visits, the following radiographic parameters were measured on cervical spine radiographs: C2−C7 lordosis, T1 slope (T1S), sagittal vertical axis (SVA), fusion mass lordosis, proximal and distal adjacent segment lordosis, height of the fusion mass, ASD, and fusion. The Cobb angle between the inferior endplate of C2 to the inferior endplate of C7 was used to measure C2−C7 lordosis. Lordosis of the fusion mass was the Cobb angle between the inferior endplate of the rostral vertebral body to the inferior endplate of the caudal vertebral body encompassed into the fusion. Furthermore, the distance from the posterior−superior corner of C7 to a vertical line that bisected the C2 centroid was measured to obtain SVA. The T1S was the angle created from a line tangential to the superior endplate of T1 and a horizontal line. Distal adjacent segment lordosis was the angle between the inferior endplate of the vertebral body caudal to the fusion mass, or proposed fusion mass, and the superior endplate of the most caudal vertebral body of the fusion mass. Proximal adjacent segment lordosis was the angle between the superior endplate of the vertebral body cephalad to the fusion mass, or proposed fusion mass, and the inferior endplate of the most cephalad vertebral body of the fusion mass. Fusion was assessed independently and deemed present if anterior and posterior bone bridging was present on plain radiographs, no visible motion between the vertebral body and fusion adjunct on flexion/extension radiographs, and no visible radiographic halo surrounding the graft on both anteroposterior and lateral views. Radiographic diagnosis of ASD was determined by the presence of disc space narrowing >50%, new or enlarged osteophytes, endplate sclerosis, and/or increased calcification or ossification of the anterior longitudinal ligament as presented by previous published studies [19−21].

PROs were obtained in the form of Neck Disability Index (NDI) scores and Visual Analog Scales (VAS) scores for the neck and arm preoperatively and at the most recent follow-up. Charts were also reviewed for evidence of symptomatic pseudarthrosis and any reoperations in the cervical spine. Minimal clinically important difference (MCID) reported in current literature was used to determine the following thresholds: VAS neck pain 2.5, VAS arm pain 2.5, and NDI 7.5 [22].

Statistical analysis

Analysis was conducted using Stata version 13.1 (StataCorp LP, College Station, TX, USA). The level of significance was set at p<0.05. Baseline patient characteristics were compared using chi-squared analysis and analysis of variance (ANOVA) for categorical and continuous data, respectively. Multivariate analysis was subsequently used to compare clinical and radiographic outcomes between study groups. Patients were first compared using all BMI categories (normal BMI, overweight, Class I obesity, Class II obesity, and Class III obesity). Given the lower numbers of patients in the Class II and class III obesity groups, in order to maximize statistical power, a second multivariate analysis was performed by dividing patients into 2 groups based on BMI of 30 kg/m^2 (*obese* and *nonobese* groups). In a subgroup analysis, myelopathy was also assessed for association with clinical and radiographic outcomes using multivariate regression. Furthermore, performance of corpectomy was accounted for in all multivariate analyses and corpectomy was assessed in terms of radiographic outcomes as part of a subgroup analysis. Multivariate analyses controlled for differences in baseline patient characteristics and included age, sex, smoking, ASA, diabetes mellitus, and number of levels.

Results

For the 399 patients that were assessed, average follow-up was 28.6 months (range 6−113.8 months). There were 97 patients who were identified as <25 kg/m^2 (normal weight), 157 as ≥25 kg/m^2 to <30 kg/m^2 (overweight), 81 as ≥30 kg/m^2 to <35 kg/m^2 (Class I obesity), 45 as ≥35 kg/m^2 to <40 kg/m^2 (Class II obesity), and 19 as ≥40 kg/m^2 (Class III obesity) (Table 1). A total of 50 patients had fusions that included the C3−4 level (19 obese and 31 nonobese). The prevalence of patients with a diagnosis of diabetes (6.19% vs. 7.05% vs. 17.28% vs. 24.44% vs. 26.32%; p<0.001) and ASA class greater than three (9.28% vs. 14.65% vs. 25.93% vs. 35.56% vs. 42.11%; p<0.001) increase with the rise in BMI.

On multivariate analysis, differences were found among BMI classes in postoperative SVA (p=0.041), and final overall lordosis and fusion segment lordosis, and final overall lordosis and fusion segment lordosis patients had significantly larger SVA in immediate postoperative (p=0.004)

Table 1
Demographics

Overall	BMI<25 97	BMI≥25−<30 157	BMI≥30−<35 81	BMI≥35−<40 45	BMI≥40 19	All patients 399	p-value	BMI<30 vs. BMI≥30 p-value
Age	**47.4±10.5**	**49.8±11.7**	**52.8±10.9**	**50.5±10.9**	**50.4±8.7**	**49.9±11.1**	**0.030**	**0.028**
BMI	**21.9±1.8**	**27.0±1.5**	**31.6±1.4**	**36.8±1.4**	**45.7±5.2**	**28.7±6.2**	**<0.001**	**<0.001**
Female sex	**67.71%**	**39.49%**	**41.98%**	**51.11%**	**73.68%**	**49.75%**	**<0.001**	0.672
Smoking	18.56%	17.83%	23.46%	24.44%	10.53%	19.55%	0.590	0.728
Diabetes	**6.19%**	**7.05%**	**17.28%**	**224.44%**	**26.32%**	**11.81%**	**0.001**	**<0.001**
ASA≥3	**9.28%**	**14.65%**	**25.93%**	**35.56%**	**42.11%**	**19.30%**	**<0.001**	**<0.001**
Symptoms								
Radiculopathy	67.01%	75.16%	71.60%	71.11%	57.89%	71.61%	0.452	0.281
Myelopathy	5.15%	4.46%	6.17%	6.67%	15.79%	5.76%	0.384	0.100
Myeloradiculopathy	27.84%	19.75%	23.46%	22.22%	26.32%	23.06%	0.670	0.613
Number of levels							0.074	**0.017**
1	31.96%	33.76%	29.63%	35.56%	31.58%	32.58%		
2	58.76%	45.86%	41.98%	37.78%	42.11%	47.12%		
≥3	9.28%	20.38%	28.40%	26.67%	26.32%	20.30%		
Follow-up	27.4±26.8	28.2±27.1	30.8±28.3	24.8±23.4	38.1±30.1	28.6±27.05	0.411	0.842
Minimum	6.0	6.0	6.0	6.2	6.5	6.0		
Maximum	113.8	113.5	111.5	95.4	88.8	113.8		
Corpectomy	2.06%	5.10%	7.41%	8.89%	5.26%	5.26%	0.415	0.269

ASA, American Society of Anesthesiologists Physical Status Classification System.
Bolding indicates statistical significance (p<0.05).

and final follow-up radiographs (p=0.003). Furthermore, obese patients had smaller preoperative (p=0.012), immediate postoperative (p=0.017), and final lordosis (p<0.001) in addition to smaller immediate postoperative (p=0.025), and final fusion segment lordosis (p=0.015) and smaller preoperative (p=0.024) and final distal lordosis (p=0.021) compared with patients with BMI<30 kg/m^2 (Table 2). The obese group experienced a significant increase in SVA from preoperative to immediate postoperative radiographs (p=0.037) and a decreased T1S from postoperative to final follow-up radiographs (p=0.040, Table 3).

Whereas differences in final VAS neck scores were found across BMI classes (3.2±2.8 vs. 1.0±1.7 vs. 2.0±1.9 vs. 2.3+3.0 vs. 2.5+2.2; p=0.008), the comparison

Table 2
Sagittal parameters preoperatively and postoperatively

	BMI<25	BMI≥25−<30	BMI≥30−<35	BMI≥35−<40	BMI≥40	All patients	p-value	BMI<30 vs. BMI≥30 Beta	BMI<30 vs. BMI≥30 p-value
Preoperative									
Lordosis (deg)	5.4±12.4	4.6±11.0	3.7±11.7	2.7+11.3	5.0+9.9	4.4±11.5	0.197	**−3.22**	**0.012**
SVA (mm)	23.4±8.9	28.8±11.9	29.3±11.7	29.0+10.6	25.4+9.8	27.4±11.1	0.201	1.73	0.161
Fusion seg lordosis (deg)	−0.2±7.0	−0.0±8.1	−0.5±6.5	1.1+6.9	0.9+6.1	0.0±7.3	0.538	−0.29	0.727
T1 slope (deg)	25.6±8.3	26.3±8.7	25.0±8.7	25.5+8.4	27.1+5.9	25.8±8.4	0.900	−0.84	0.535
Proximal lordosis (deg)	1.7±9.5	1.8±8.5	2.3±6.4	0.4+6.3	1.3+6.4	1.7 ± 8.1	0.847	−0.83	0.344
Distal lordosis (deg)	4.2±4.3	3.8±4.5	3.2±3.7	2.0+4.1	4.9+5.0	3.7±4.5	0.178	**−1.59**	**0.024**
Immediate postoperative									
Lordosis (deg)	8.0±10.7	8.5±9.5	6.3±10.3	5.1+10.6	8.1+7.2	7.5±10.0	0.095	**−2.64**	**0.017**
SVA (mm)	25.6±8.8	30.0±11.3	32.5±10.6	33.0+10.2	29.6+9.3	29.7±10.6	**0.041**	**3.32**	**0.004**
Fusion seg lordosis (deg)	7.2±5.8	6.5±6.0	5.3±5.6	6.4+5.4	5.8+6.0	6.4±5.8	0.060	**−1.39**	**0.025**
T1 slope (deg)	28.1±7.8	28.2±7.3	27.3±8.1	26.2+7.2	29.4+9.4	27.9±7.6	0.593	−1.45	0.259
Proximal lordosis (deg)	1.1±9.8	1.4±8.4	1.6±8.1	0.3+7.7	1.8+8.3	1.3± 8.6	0.854	−0.31	0.733
Distal lordosis (deg)	2.9±4.3	2.7±4.8	1.8±5.4	0.9+4.7	3.5+3.5	2.5±4.7	0.162	−1.23	0.089
Final									
Lordosis (deg)	9.3±10.9	10.7±9.6	7.9±9.8	6.3+10.3	6.5+7.9	9.1+10.1	**0.035**	**−3.99**	**<0.001**
SVA (mm)	23.4±8.5	27.5±11.2	30.0±10.9	29.7+8.8	29.3+10.0	27.3+10.5	0.115	**3.24**	**0.003**
Fusion seg lordosis (deg)	6.3±6.0	6.5±6.1	4.1±5.4	6.3+5.5	5.5+4.8	5.9+5.8	**0.017**	**−1.54**	**0.015**
T1 slope (deg)	29.3±8.1	28.6±7.3	28.0±7.6	28.3+9.5	25.4+6.8	28.6+7.7	0.280	**−2.46**	**0.043**
Proximal lordosis (deg)	2.2±9.2	2.3±8.3	2.38±7.9	1.0+7.5	1.8+7.6	2.2±8.3	0.847	−0.22	0.803
Distal lordosis (deg)	3.9±4.7	4.0±5.3	3.4±5.2	1.4+4.9	1.9+5.3	3.5+5.1	0.177	**−1.76**	**0.021**

SVA, sagittal vertical axis; OR, odds ratio.
Bolding indicates statistical significance (p<0.05).

Table 3
Change in parameters at different time points

	BMI<25	BMI≥ 25−<30	BMI≥ 30−<35	BMI≥ 35−<40	BMI≥40	All patients	p-value	BMI<30 vs. BMI≥30	
								Beta	p-value
Change Preoperative to Postoperative									
Lordosis (deg)	2.6±8.5	3.9±8.0	2.8±7.9	2.1+8.2	3.1+7.5	3.1±8.1	0.757	0.58	0.537
SVA (mm)	2.4±6.9	1.1±7.9	4.1 ±7.4	3.8+8.7	4.1+8.2	2.5±7.7	0.183	**1.95**	**0.037**
Fusion seg lordosis (deg)	7.3±6.6	6.6±6.4	5.9±6.8	5.3+6.2	5.0+6.1	6.4±6.5	0.473	−0.97	0.176
T1 slope (deg)	2.4±5.9	2.1±5.5	2.8±4.8	0.9+5.7	2.3+3.5	2.2±5.5	0.862	0.25	0.808
Proximal lordosis (deg)	−0.4±4.1	−0.5±3.5	−0.4±4.8	−0.7+3.4	0.5+4.1	−0.4±4.0	0.812	0.33	0.468
Distal lordosis (deg)	−1.2±3.8	−1.4±4.2	−1.1±5.0	−0.8+3.9	−1.3+4.6	−1.3±4.3	0.778	0.52	0.43
Change Postoperative to Final									
Lordosis (deg)	1.3±5.8	2.2±5.6	1.2±6.0	1.2+5.0	−1.6+3.3	1.5±5.6	0.087	−1.22	0.058
SVA (mm)	−2.5±5.9	−2.9±8.0	−3.0±7.4	−3.5+6.9	−0.4+8.1	−2.8±7.3	0.741	0.05	0.951
Fusion seg lordosis (deg)	−1.0±3.9	−0.1±3.6	−1.2±3.7	−0.1+3.5	−0.3+3.5	−0.6±3.7	0.143	−0.05	0.909
T1 slope (deg)	−0.7±7.7	0.3±4.5	−0.1±4.76	−0.3+5.1	−1.4+2.9	−1.4±5.7	0.954	**−2.30**	**0.040**
Proximal lordosis (deg)	1.0±4.6	1.0±3.8	1.2±3.3	0.7+3.2	0.0+2.8	1.0±3.8	0.793	0.12	0.784
Distal lordosis (deg)	1.1±3.8	1.1±3.9	1.6±4.0	0.5+4.3	−1.6+3.2	1.0±3.9	0.128	−0.42	0.488
Change Preoperative to Final									
Lordosis (deg)	4.0±8.4	6.0±7.8	4.4±7.1	3.5+7.7	1.5+6.9	4.7±7.8	0.060	−0.86	0.350
SVA (mm)	0.0±7.2	−1.6±8.7	1.0±8.0	0.4+6.3	3.5+6.7	−0.2±7.9	0.170	1.78	0.058
Fusion seg lordosis (deg)	6.3+6.7	6.4±7.0	4.7±6.5	5.2+6.8	4.5+4.2	5.8±6.7	0.402	−1.07	0.141
T1 slope (deg)	1.9±8.1	2.5±6.8	2.9±4.7	2.5+5.3	−0.6+4.5	2.2±6.8	0.799	−2.11	0.092
Proximal lordosis (deg)	0.6±5.1	0.7±4.5	0.7±4.5	−0.1+4.1	0.6+3.3	0.6±4.6	0.943	0.30	0.582
Distal lordosis (deg)	−0.4±4.1	−0.2±4.5	0.5±4.7	−1.0+4.1	−3.0+3.7	−0.3±4.4	0.324	0.04	0.953

SVA, sagittal vertical axis; OR, odds ratio.

between obese and nonobese patients yielded no difference (Table 4). Additionally, no differences were found based on BMI for achievement of MCID for VAS neck, VAS arm, or NDI.

Radiographic ASD, defined by Arbeitsgemeinschaft für Osteosynthesefragen (AO) Spine as radiographic adjacent segment pathology (RASP), rates were significantly higher in the obese group (OR 1.8, p=0.028) particularly at the adjacent distal segment (OR 2.3, p=0.025) (Table 5). Statistical differences in reoperation rates were found across BMI categories, however when comparing all obese patients together compared with nonobese patients, there were no difference in reoperation. No differences in graft subsidence or fusion rates were found across BMI categories. On subgroup analysis, presence of myelopathy was not found to be significantly associated with differing clinical

Table 4
Comparing clinical outcomes

	BMI<25	BMI≥25−<30	BMI≥30−<35	BMI≥35−<40	BMI≥40	All patients	p-value	BMI<30 vs. BMI >30	
								Beta	p-value
Preoperative									
VAS neck	6.6±2.9	6.9±3.6	7.3±3.2	6.7+3.7	9.0+1.0	7.1±3.2	0.546	0.36	0.648
VAS arm	5.5±3.6	6.1±3.8	4.3±4.1	5.5+3.5	7.2+3.6	5.6±3.8	0.476	−0.44	0.625
NDI	40.6±19.8	46.8±20.0	45.4±22.2	57.8+20.5	49.8+12.7	46.4±20.3	0.502	4.03	0.346
Final									
VAS neck	3.2±2.8	1.0±1.7	2.0±1.9	2.3+3.0	2.5+2.2	2.1±2.4	**0.008**	0.36	0.526
VAS arm	2.7±3.3	1.4±2.4	1.1±2.4	1.3+2.5	1.7+2.7	1.7±2.5	0.371	−0.66	0.298
NDI	27.2±22.2	15.9±17.8	18.3±18.0	23.6+28.8	27.8+20.8	20.9+20.6	0.267	3.01	0.493
Change preoperative to final									
VAS neck	3.5±3.5	6.2±3.8	5.3±3.9	4.4+4.4	7.0+1.8	5.1±3.8	0.064	0.10	0.92
VAS arm	2.9±3.7	5.0±4.0	3.2±3.8	4.4+3.1	6.0+3.4	4.1±3.8	0.079	0.55	0.547
NDI	13.3±26.0	32.8±23.5	30.9±	34.4+24.4	24.0+25.9	26.7+24.2	0.052	3.18	0.567
MCID									
VAS neck	60.0%	78.1%	75.0%	80.0%	100.0%	74.7%	0.565	1.38	0.581
VAS arm	48.0%	68.8%	45.0%	80.0%	87.5%	61.5%	0.094	1.54	0.410
NDI	56.0%	84.4%	90.0%	90.0%	75.0%	77.9%	0.197	2.00	0.299

ASD, radiographic evidence of adjacent segment degeneration; VAS, visual analog scale score; NDI, neck disability index score; MCID, minimal clinically important difference.

Table 5
Comparison of ASD, reoperations, fusion, and subsidence

								BMI<30 vs. BMI≥30	
	BMI<25	BMI≥25−<30	BMI≥30−<35	BMI≥35−<40	BMI≥40	All patients	p-value	Odds Ratio*	p-value
Any ASD	17.53%	16.56%	33.33%	24.40%	15.80%	21.05%	0.071	**1.8**	**0.028**
Proximal	13.40%	12.74%	23.46%	17.80%	10.50%	15.54%	0.263	1.5	0.176
Distal	7.22%	7.01%	17.28%	11.10%	15.80%	10.03%	0.304	2.3	**0.025**
Proximal and Distal	3.09%	3.18%	7.41%	4.40%	10.50%	4.51%	0.571	2.0	0.189
Reoperations	**5.15%**	**3.82%**	**4.94%**	**8.90%**	**0.00%**	**4.76%**	**0.047**	1.3	0.665
Fusion	91.80%	94.90%	90.10%	97.80%	94.80%	97.24%	0.973	2.4	0.293
Subsidence	5.20%	3.80%	4.90%	8.90%	0.00%	6.52%	0.604	1.3	0.600

ASD, radiographic evidence of adjacent segment degeneration
Subsidence as measured by a decrease in intervertebral disc height of ≥2 mm from immediate postoperative radiographs to final follow-up radiographs.
Bolding indicates statistical significance (p<0.05).
* Odds ratio represents odds of ASD per one-unit increase in each sagittal parameter.

or radiographic outcomes compared with patients with nonmyelopathic symptoms. Of note, our study population included patients that underwent corpectomy but there was no statistically significant difference in the rate of corpectomy between groups. However, when corpectomy was assessed in terms of radiographic outcomes as part of a subgroup analysis, there were decreased postoperative (=−2.7, p=0.037), final (=−2.8, p=0.037), change from preoperative to postoperative (=−2.9, p=0.048) fusion segment lordosis compared with anterior cervical discectomy and fusion (Supplemental 2).

Discussion

Obesity is a growing problem in the United States and has been shown to increase complications and costs following spine surgery, however the impact on sagittal alignment and ASD after anterior cervical decompression and fusion is less understood [2−6,9]. The present study therefore compared radiographic and clinical outcomes after anterior cervical decompression and fusion between obese and nonobese patients. Although, clinical outcomes, except final VAS neck score, were similar between all study cohorts, rise in BMI was positively associated with increase in postoperative SVA and decrease in final lordosis and final fusion segment lordosis. Obese patients with BMI≥30 kg/m^2 had worse postoperative and final SVA, overall cervical lordosis, fusion segment lordosis, distal lordosis and had significantly greater rates of radiographic ASD compared with nonobese patients with BMI<30 kg/m^2. Additionally, prevalence of patients with a diagnosis of diabetes and ASA class greater than 3 rose with the increase in BMI.

Despite poorer radiographic outcomes for obese patients, there were no significant differences in PROs between obese and nonobese patients except lower final VAS back scores for patients with higher BMI. Our results are in agreement with previous studies that evaluated the impact of obesity on PROs after undergoing anterior cervical decompression and fusion [12,13]. However, prior studies were limited to PROs and clinical outcomes and, thus, lacked an analysis of radiographic parameters. The correlation between radiographic and clinical outcomes has sparse evidence in the cervical spine literature, and inconsistent evidence in the lumbar spine literature [7,11,23]. Biomechanical studies have found that alteration in the sagittal alignment, such as SVA or cervical lordosis distorts physiological loading which may result in functional disorders and affect clinical outcomes [15,24]. Furthermore, the presence of radiographic degenerative changes without symptoms, such as radiculopathy or myelopathy, can be classified as RASP which differs from clinical adjacent segment pathology according to AO Spine's proposed subcategories for adjacent segment pathology. The rate of RASP developing to clinical adjacent segment pathology is unclear, which impresses the need for vigilant follow-up for all patients, especially obese patients caused by an increased risk of complications [25,26]. Although, myelopathy has been associated with worse clinical outcomes following anterior cervical decompression and fusion previously, in the current study, myelopathic patients did not have differing clinical or radiographic outcomes compared with nonmyelopathic patients [27]. Further research is necessary to understand the role of radiographic parameters in clinical outcomes in order to use these parameters for proper patient selection for operative management.

Increased SVA postoperatively in obese patients indicates sagittal misalignment and possible presence of progressive degenerative changes [15]. To our knowledge, greater cervical SVA in obese patients has not been previously described in the literature, and may be caused by alterations in posture or distribution of adipose tissue in these patients. This information may be useful during the assessment of preoperative and postoperative radiographs of obese anterior cervical decompression and fusion patients. Further vigilance may be required by the providers to properly position obese patients in the operating room with specific attention to sagittal parameters to avoid hypolordosis or hyperkyposis of the cervical spine [15,24]. Unlike the MCID for PROs, current literature does not define changes in

SVA, lordosis, fusion segment lordosis, and TIS that would be deemed as clinically significant. The presence of statistically significant difference in sagittal parameters without associated difference in clinical outcomes suggests that these differences may not be clinically significant. Additional studies are indicated to better explore the etiology of this finding in obese patients, and possible strategies for correction.

Overall cervical lordosis and fusion segment lordosis was found to be decreased at immediate postoperative and final follow-up, whereas distal lordosis decreased from preoperative to final follow-up in obese patients compared with nonobese patients. This finding also has not been previously described in the literature but may be caused by technical challenges in obese patients undergoing anterior cervical decompression and fusion. Positioning and surgical exposure is often more difficult in obese patients, and these may affect the surgeon's ability to maximize correction of cervical lordosis intraoperatively. The concomitant finding of increased SVA in obese patients may also be related to a decrease in cervical lordosis. Although, further studies of these relationships are needed, these findings regarding differences in radiographic parameters for obese patients may be useful considerations for surgeons operating on this patient population. Additionally, clinical and basic science studies have reported that obesity is associated with the presence, and severity of degenerative disc disease [28−30]. However, the majority of these studies focus on the lumbar spine. Further research is necessary to evaluate the influence of obesity on the rate of degenerative disc disease.

Obese patients in the study population also had significantly increased rates of early RASP [13−31]. ASD occurred mostly at the distal adjacent levels and not at the proximal adjacent levels. Although the pathogenesis of ASD has not been fully characterized, it has been hypothesized that the biomechanical changes resulting from fusion may accelerate the degenerative process [32]. Higher prevalence of early ASD for obese patients may result from failure to restore normal sagittal alignment as seen by larger postoperative SVA and smaller lordosis, leading to postoperative complications such as pseudoarthrosis [33]. The incidence of ASD following ACDF is reported as approximately 3% annually and 25.6% at 10 years [17,18]. In our sample, the overall rate of ASD (21.05%) falls within this range, with mean follow-up of 28 months. With the range of available options for cervical spine procedures, it is important that further studies are conducted to investigate whether reoperation rates are influenced by obesity in alternative procedures [17].

The present study had several limitations. Firstly, as a retrospective study, possible selection bias is an inherent limitation. However multivariate analyses controlled for baseline demographics between groups in an attempt to reduce any effects of this possible bias. Postoperative follow-up is another possible weakness. Although average postoperative follow-up was approximately 2 years, minimum follow-up was 6 months in order to maintain sufficient power for analysis. Nonetheless, this study provides important insight into early radiographic and clinical outcomes that can be expected in obese (vs. nonobese patients) following an anterior cervical decompression and fusion. Further long-term follow-up can aid in determining longer-term fate of this patient population. Additionally, as both surgeons used tricortical structural fresh-frozen ICBG allograft and plate/screw fixation for all cases, these results may not be fully generalizable to constructs using intervertebral cages, synthetic graft materials, stand-alone cages, or other constructs. Another limitation is that severity of myelopathy was not consistently recorded and was therefore not included in analyses. Also, dysphagia was not assessed in the present study. Obese patients undergoing anterior cervical decompression and fusion may require wider exposure and more forceful soft tissue retraction, and future studies designed to directly assess this outcome should be performed. Of note, our study population included patients that underwent corpectomy but there was no statistically significant difference in the rate of corpectomy between groups. Nonetheless, performance of corpectomy was accounted for in all multivariate analyses. When corpectomy was assessed in terms of radiographic outcomes as part of a subgroup analysis, there was a decreased fusion segment lordosis compared with anterior cervical discectomy and fusion, which has been previously reported [34]. Lastly, although BMI is the most commonly used marker for obesity, there may be variations in body mass distribution, and patients with similar BMI may have varying amounts of soft tissue at the neck. Future studies could consider measuring additional factors such as neck circumference which may affect anterior cervical decompression and fusion outcomes. Despite these limitations, we believe that our sample provides valuable information about anterior cervical decompression and fusion procedures in the obese population and raises new questions for further exploration.

Conclusion

This present study found that obese patients who underwent anterior cervical decompression and fusion had no differences in PROs except for lower final VAS neck scores, but had worse radiographic parameters and higher rates of reoperations and ASD compared with nonobese patients. Overall, these findings for obese patients underscore the importance of proper selection of patients for surgery combined with meticulous surgery for both patient populations. Hence, these results provide additional support toward the importance of weight discussions and expectations before surgery. Further research is warranted to further characterize the etiology of these differences in sagittal alignment for obese patients undergoing anterior cervical decompression and fusion, as well as to explore the relative efficacy of nonfusion procedures in this patient population.

Supplementary materials

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.spinee.2019.02.016.

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