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Clinical Studies

Underweight patients are an often under looked "At risk" population after undergoing posterior cervical spine surgery ☆

Taylor D. Ottesen*, Paul S. Bagi, Rohil Malpani, Anoop R. Galivanche, Arya G. Varthi, Jonathan N. Grauer

Department of Orthopaedics and Rehabilitation, Yale School of Medicine, 47 College Street, New Haven, 06511, CT, United States

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ABSTRACT

Background: Body Mass Index (BMI) is a weight-for-height metric that is used to quantify tissue mass and weight levels. Past studies have mainly focused on the association of high BMI on spine surgery outcomes and shown variable conclusions. Prior results may have varied due to insufficient power or inconsistent categorical separation of BMI groups (e.g. underweight, overweight, or obese). Additionally, few studies have considered outcomes of patients with low BMI. The aim of the current study was to analyze patients along the entirety of the BMI spectrum and to establish specific granular BMI categories for which patients become at risk for complication and mortality following posterior cervical spine surgery.

Methods: Patients undergoing elective posterior cervical spine surgery were abstracted from the 2005–2016 National Surgical Quality Improvement Program (NSQIP) databases. Patients were aggregated into pre-established WHO BMI categories and adverse outcomes were normalized to average risk of normal-weight subjects (BMI 18.5–24.9 kg/m^2). Risk-adjusted multivariate regressions were performed controlling for patient demographics and overall health.

Results: A total of 16,806 patients met inclusion criteria. Odds for adverse events for underweight patients (BMI < 18.5 kg/m^2) were the highest among any category of patients along the BMI spectrum. These patients experienced increased odds of any adverse event (Odds Ratio (OR) = 1.67, $p = 0.008$, major adverse events (OR=2.08, $p = 0.001$), post-operative infection (OR = 1.95, $p = 0.002$), and reoperation (OR = 1.84, $p = 0.020$). Interestingly, none of the overweight or obese categories were found to be correlated with increased risk of adverse event categories other than super-morbidly obese patients (BMI>50.0 kg/m^2) for post-operative infection (OR = 1.54, $p = 0.041$).

Conclusions: The current study found underweight patients to have the highest risk of adverse events after posterior cervical spine surgery. Increased pre-surgical planning and resource allocation for this population should be considered by physicians and healthcare systems, as is often already done for patients on the other end of the BMI spectrum.

Introduction

Cervical spondylosis is a common condition that can occur secondary to age-related degenerative changes of the cervical spine [1]. Cervical spondylosis can present in a diverse manner, with symptoms that can range from axial neck pain to radiculopathy to myelopathy [1,2]. In select cases, surgical intervention may be considered.

In terms of cervical spine surgical options, many pathologies can be addressed from anterior or posterior approaches. Potential advantages of posterior cervical laminectomy and fusion include the ability to decompress and instrument multiple segments and the ability to address some dorsal-based pathologies that are not as easily accessed from anterior cervical approaches [3]. As a result, the incidence of posterior cervical laminectomy and fusion increased by 102.7% from 2003 to 2013 [4].

Body mass index (BMI) has been widely studied as a risk factor for adverse outcomes after various surgical interventions. In relation

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* Corresponding author.
E-mail address: taylor.ottesen@yale.edu (T.D. Ottesen).

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to spine surgeries, mixed results have been found with such studies. For example, one study determined that patients with morbid obesity had a significantly higher risk of acute peri-operative complications following lumbar and cervical fusions [5]. To that end, other studies of patients undergoing anterior and posterior cervical spine surgery have found that high BMI patients have longer surgical times, longer hospital stays, higher postoperative complication rates, and lower satisfaction [6–8]. Conversely, other studies assessing the correlation of BMI on outcomes for patients undergoing posterior cervical fusions found that BMI did not affect a negative impact on post-operative outcomes [9,10].

In analyzing past studies, there are certain limitations that may have contributed to the variation in findings. For example, as with other administrative databases on obesity, limitations to the identification of patients with varying degrees of obesity can affect findings [11,12]. Also, many of the prior studies were done at single institutions with limited patient numbers [5,7,8,10,13].

Another potential explanation for the variation in conclusion about the effect of BMI on posterior cervical procedures may be due to the variation in boundaries set for various BMI category cut off values – often failing to separate BMI groups into smaller, more specific groups. For example, studies investigating the effect of BMI on posterior cervical fusion patients may indicate "obese" as any patient over 35 kg/m^2 without taking into account the considerable variation in BMI that may occur above this cutoff [9]. The aggregating of large groups across the BMI spectrum could potentially mask important findings pertaining to the effect of BMI that we are unable to detect due to the lack of granular classifications. Patients with BMI's of 35.5 kg/m^2 are significantly different from that of 45.5 kg/m^2 or even 55.5 kg/m^2, thus they may need to be more finely studied to detect potential differences in outcomes based on specific degree of obesity.

In addition to the need for more granular obese categories, prior studies often fail to investigate the other end of the BMI spectrum – the underweight population. To the best of our knowledge, there are no existing studies which specifically assess the impact of underweight BMI on outcomes following posterior cervical laminectomy and fusion [6,9,14,15]. Instead, prior studies have often opted to aggregate them with normal weight patients or exclude them from analysis. This could skew findings for normal weight patients and also fail to represent underweight patients as a distinct group with their own outcomes and risk factors.

The current study was thus performed to assess for correlations of 30-day adverse events after undergoing posterior cervical laminectomy using the internationally recognized incremental BMI categories as set forth by the World Health Organization (WHO).

Methods

Patient cohort

The National Surgical Quality Improvement Program database (NSQIP) database records and aggregates more than 150 variables on individual surgical cases from over 500 participating institutions. These variables, which include demographics, perioperative variables, and 30-day postoperative morbidity and mortality [16], are collected by trained reviewers from medical records, operative reports, and patient interviews [17]. Inter-rater reliability disagreement rates have been reported to be less than 2% [16].

Patients undergoing elective posterior cervical fusion and posterior cervical laminectomy or laminotomy cases were extracted from the 2005–2016 NSQIP datasets using Current Procedural Terminology (CPT) codes. CPT codes were used to identify posterior cervical fusion cases (22,595, 22,600) and posterior cervical laminectomy or laminotomy (63,015, 63,045, 63,265, 63,020, 63,040). Fracture, trauma, infection, and tumor cases were excluded.

Patient/Surgical characteristics

Body mass index, defined as weight/height^2, was calculated from recorded height (m) and weight (kg) and then cases were then binned into six different BMI group categories as outlined by the World Health Organization. These were: underweight (BMI<18.5 kg/m$^{2)}$, normal weight (BMI of 18.5–24.9 kg/m$^{2)}$, overweight (BMI 25.0–29.9 kg/m$^{2)}$, obese (BMI of greater than 30.0–39.9 kg/m$^{2)}$, morbidly obese (BMI of greater than 40.0–49.9 kg/m$^{2)}$, and super morbidly obese (BMI >50.0 kg/m$^{2)}$ [18].

Age, sex, functional status prior to surgery, American Society of Anesthesiologists (ASA) classification, smoking status (current and/or within 1 year), and presence of non-insulin-dependent or insulin-dependent diabetes were also directly extracted from the dataset. The ASA score was used to approximate the overall health of patients, as supported by past literature [19–26]. Prior studies have shown ASA to be a strong predictor of health and to outperform other comorbidity indices commonly used including the Modified Frailty Index and Modified Charlson Comorbidity Index [27].

Perioperative outcomes and readmission

NSQIP captures the occurrence of individual postoperative adverse outcome for every case through the 30th postoperative day, regardless of discharge status. Thus, occurrences of adverse events were extracted from NSQIP and investigated individually as well as in aggregated groups of any adverse, major adverse, and minor event and used for analyses.

Any adverse event (AAE) was defined as the occurrence of a minor adverse event (MAE) or serious adverse event (SAE). A MAE was defined as the occurrence of any of the following: superficial surgical site infection, wound dehiscence, pneumonia, urinary tract infection, and post-operative renal insufficiency. A SAE was defined as the occurrence of any of the following: deep infection, sepsis, failure to wean, unplanned intubation, post-operative renal failure, thromboembolic event, cardiac arrest, myocardial infarction, and stroke/cerebrovascular event.

In addition to being included in the above aggregated variables, postoperative infections (occurrence of superficial infection, deep infection, urinary tract infection, or sepsis) were separately assessed. Occurrence of death, reoperation, and readmission within 30 days of operation was also abstracted and assessed (noted that the readmissions data element was only available for cases that occurred in 2011–2016). Further, operative time (in minutes) and length of stay (in days) were collected. Incidence of all variables were investigated for each of the six BMI categories.

Data analysis

Univariate logistic regression models of BMI groups were calculated for surgical outcomes to estimate the relative risks of BMI on adverse events that occurred anytime during the 30-day postoperative period. Distribution of the patient population's BMI was then charted on a histogram which was overlaid with adverse event frequency and binomial outcomes data as a function BMI shown in Fig. 1 and Fig. 2, respectively.

In order to better control for potential demographic and health status differences between BMI categories, robust multivariate logistic regression models of BMI groups were fitted on the major surgical outcomes (AAEs, SAEs, MAEs, post-operative infections, reoperation, readmissions, and mortality). Demographic and health status factors controlled for included ASA class, functional status, age, sex, and number of levels affected as has modeled in previous publications [19,22,28,29]. Due to limitations with the NSQIP dataset, other confounding demographic factors such as albumin levels

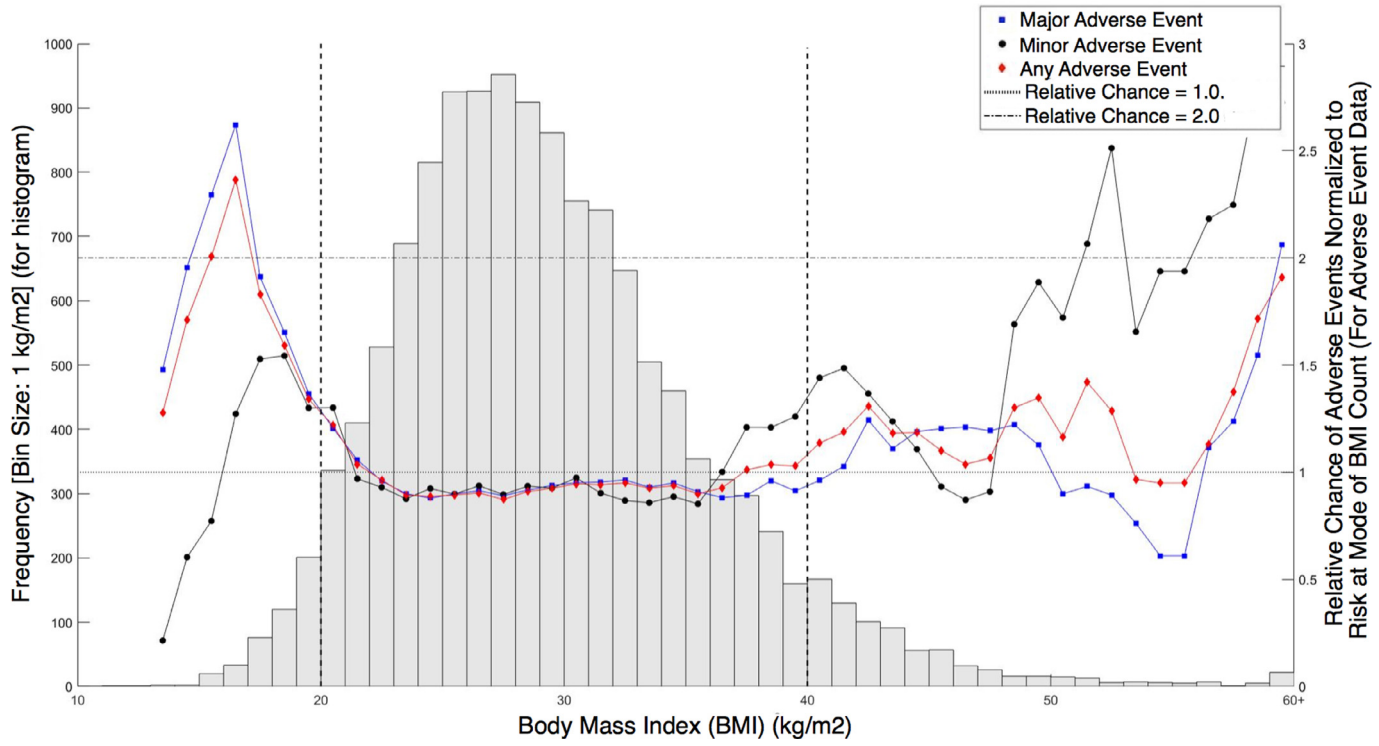

Fig. 1. Adverse event data as a function of BMI and BMI histogram for patients undergoing posterior cervical procedures.
Note: Left *y*-axis refers to the grey histogram in the figure. Right y-axis refers to the line and scatter plot of adverse event data. Horizontal lines denote relative risks of 1.0 and 2.0 as reference lines. Vertical lines bookend the stable BMI ranges. Blue squares represent major adverse events, black circles represent minor adverse events, red diamond represent any adverse events.

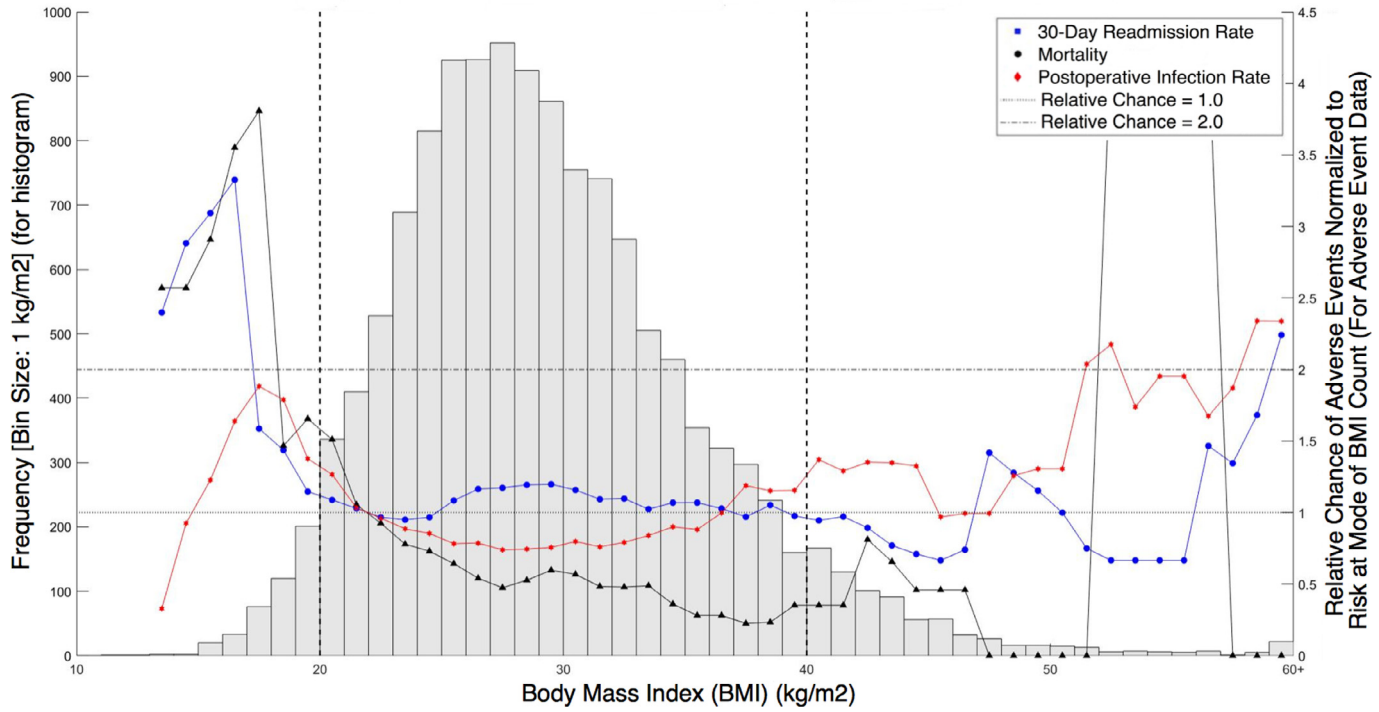

Fig. 2. Binomial outcomes data as a function of BMI and BMI histogram for patients undergoing posterior cervical procedures.
Note: Just as in Fig. 1, left *y*-axis refers to the grey histogram in the figure. Right y-axis refers to the line and scatter plot of adverse event data. Horizontal lines denote relative risks of 1.0 and 2.0 as reference lines. Vertical lines bookend the stable BMI ranges. In this figure, blue circles represent 30-day readmission rates, black triangles represent mortality, and red stars represent infection rates.

All statistical analyses were performed using STATA version 13 (StataCorp LP, College Station, TX). Our institutional review board granted an exemption for studies using the NSQIP dataset.

Results

Patient population

A total of 16,806 patients were selected that met the inclusion and exclusion criterion. In terms of the BMI category breakdowns: 'underweight' patients (BMI < 18.5 kg/m^2) were 1.40% (n = 235) of the study population, 'normal' weight patients (BMI 18.5–24.9 kg/m^2) were 23.06% (n = 3876), 'overweight' patients (BMI 25.0–29.9 kg/m^2) were 34.18% (n = 5744), 'obese' patients (BMI 30.0–39.9 kg/m^2) were 34.29% (n = 5763), 'morbidly obese' patients (BMI of 40.0–50.0 kg/m^2) were 5.36% (n = 901), and 'super morbidly obese' (>50.0 kg/m^2) were 1.71% (n = 287). Age, sex, functional status, ASA, smoking status, and diabetes category for each BMI category are shown in Table 1.

Perioperative outcomes

Of the entire study population, 8.16% (n = 1371) of patients experienced at least one adverse event in the 30 days following their procedure. Breaking this down, a major adverse event was noted for 4.86% (n = 817) of the study population, a minor adverse event was noted for 4.62% (n = 776), a reoperation was noted for 3.16% (n = 531), a readmission was noted for 5.55% (n = 933), and death was noted for 0.46% (n = 78). These rates are broken down by BMI category in Table 2.

Rates of adverse events followed a U-shaped curve with higher rates of any adverse event in the underweight cohort (17.0%) and the super morbidly obese cohort (13.2%) compared to the normal weight cohort (8.2%). Notably, risks of any adverse events were lower in the overweight cohort (7.4%) and the obese cohort (7.8%) as compared to the normal weight cohort (8.2%). A graphical representation of the varying rates of adverse event as a function of patient BMI category and the U-shaped relative risk curve is provided in Figs. 1 and 2 for various outcomes measures. The figures contain a histogram of patient BMI categories overlaid with adverse event data.

Univariate / multivariate analyses

The univariate and multivariate analyses used the normal weight category as the baseline risk to which other outcomes were compared (Table 3). The underweight cohort had a statistically significant increased odds of any (OR = 2.31), major (OR = 2.91), postoperative infections (OR = 2.64), return to operating room within 30 days of operation (OR = 2.12) and mortality within 30 days of the procedure (OR = 3.49). Similarly, the super morbidly obese cohort had a statistically significant increased odds of any, major, minor adverse events, and postoperative infections.

Notably, the odds for patients developing any adverse event post-procedure was higher for underweight patients (OR=2.31) as compared to super morbidly obese patients (OR = 1.72) and this trend continues across many of the other outcome variables assessed. Furthermore, none of the BMI cohorts were associated with a statistically significant increased risk of readmission post-procedure.

On multivariate analysis controlling for patient demographic factors, those in the underweight category were noted to have a statistically significant odds of any adverse event (OR = 1.67) and major adverse events (OR = 2.08) along with an increased risk of post-operative infection (OR=1.95) and return to operating room (OR = 1.84) (Table 4, Fig. 3). Morbidly obese patients had increased risk of returning to the OR within 30 day of operation and super morbidly obese patients had an risk of post-operative infections.

Discussion

Obesity remains a growing problem in the United States and in developed countries around the world and its prevalence has driven research evaluating the impact of increasing BMI on post-operative outcomes. Importantly, malnutrition has also been increasingly associated with an elevated risk of postoperative infections, medical complications and increased mortality after varying surgical interventions [30,31]. While low body weight has been associated with poor nutritional status [32] and poor outcomes in other fields such as vascular surgery [33], there is minimal literature focusing directly on the effect of underweight BMI on orthopaedic spine patient outcomes.

The current study examined 30-day clinical outcomes of posterior cervical procedures in patients across the BMI spectrum from underweight to super morbidly obese. Following multivariate analysis to adjust for possible confounding variables, underweight patients (BMI<18.5 kg/m^2) were found to have significantly greater odds of any adverse event, major adverse event, post-operative infection and return to the operating room within 30 after posterior cervical surgery. Morbidly obese patients (BMI 40.0–49.9 kg/m^2) had significantly greater odds of returning to the operating room within 30 days of index procedure and super morbidly obese patients (BMI>50.0 kg/m^2) had significantly greater odds of post-operative infection relative to patients with a normal BMI (18.5–24.9 kg/m^2).

Although there is a paucity of literature evaluating the effect of low BMI in the adult cervical spine literature, the topic has been studied in the lumbar spine. Saleh et al. performed a retrospective review of 2320 elderly patients over the age of 80 years who underwent lumbar spine surgery between 2005 and 2013 using the NSQIP database [34]. They found that underweight patients had significantly greater odds of readmission relative to patients with a normal BMI (OR = 4.10; 95% CI = 1.08–15.48). Bono et al. performed a retrospective review of 31,763 patients who underwent lumbar spine surgery using the NSQIP database between 2011 and 2013 [35]. They did not find an increased risk of complications in underweight patients. They did find that patients with obesity class 2 or 3 (BMI>35 kg/m2) had significantly higher odds of any complication and infection relative to normal weight patients.

The effect of low BMI has also been previously studied in pediatric spine surgery patients. Minhas et al. evaluated children with cerebral palsy undergoing orthopedic surgery using the NSQIP database from 2012 to 2013 and found underweight patients to be at increased risk of complications [36]. Tarrant et al. retrospectively reviewed a cohort of 77 patients with adolescent idiopathic scoliosis that underwent posterior spinal fusion between 2010 and 2012 and found that low preoperative BMI was associated with the development of postoperative ileus [37].

The current study's findings may indicate that a more extensive preoperative and laboratory workup may be warranted in the identification of potentially reversible nutritional and/or metabolic concerns that should be addressed prior to surgery on a underweight patient. Further, many underlying medical and/or nutritional conditions can leads to a decrease in BMI such as cancer, alcoholism, vitamin disorders and others [38,39]. These pre-surgical conditions that result in weight loss can cause significant changes in albumin and protein levels thus impeding the patient from correctly forming various of the proteins of the body including bleeding factors, immune system components, and others which could increase a patient's risk of perioperative infection, bleeding, and other adverse surgical events. Future studies further exploring the preoperative blood values and conditions that may be the cause low BMI are merited to better understand the association between low BMI and increased surgical complications following posterior cervical spine procedures.

There are several limitations to our study. The NSQIP database does not report on outcomes after 30 days, thus adverse outcomes occurring beyond this time window could be missed. Additionally, although medical comorbidities were controlled for, many nutrition specific markers were not available such as albumin levels which have been shown to

Table 1
Demographic and comorbid characteristics of patients undergoing posterior cervical procedures with varying body mass index (BMI).

	BMI < 18.5 Underweight		BMI 18.5–24.9 Normal weight		BMI 25.0–29.9 Overweight		BMI 30.0–39.9 Obese		BMI 40.0–49.9 Morbidly obese		BMI > 50.0 Super morbidly obese	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total Number of Patients (n = 16,806)	235	1.40%	3876	23.06%	5744	34.18%	5763	34.29%	901	5.36%	287	1.71%
Age	Median: 61	IQR: 52–70	Median: 60	IQR: 51–70	Median: 60	IQR: 52–70	Median: 59	IQR: 51–67	Median: 57	IQR: 49–64	Median: 55	IQR: 44–61
≤ 40	14	5.96%	281	7.25%	335	5.83%	289	5.01%	65	7.21%	20	6.97%
41–50	28	11.91%	560	14.45%	822	14.31%	957	16.61%	170	18.87%	60	20.91%
51–60	61	25.96%	1038	26.78%	1589	27.66%	1693	29.38%	303	33.63%	86	29.97%
61 - 70	70	29.79%	1012	26.11%	1552	27.02%	1699	29.48%	254	28.19%	71	24.74%
71–80	42	17.87%	705	18.19%	1068	18.59%	935	16.22%	93	10.32%	40	13.94%
> 80	20	8.51%	280	7.22%	378	6.58%	190	3.30%	16	1.78%	10	3.48%
Sex												
Male	86	36.60%	1960	50.57%	3766	65.56%	3407	59.12%	412	45.73%	146	50.87%
Female	149	63.40%	1915	49.41%	1973	34.35%	2356	40.88%	489	54.27%	141	49.13%
Functional status prior to surgery												
Independent	207	88.09%	3625	93.52%	5460	95.06%	5490	95.26%	843	93.56%	250	87.11%
Partially/Totally Dependent	28	11.91%	251	6.48%	284	4.94%	273	4.74%	58	6.44%	37	12.89%
ASA	Median: 3	IQR: 2–3	Median: 3	IQR: 2–3	Median: 3	IQR: 2–3	Median: 3	IQR: 2–3	Median: 3	IQR: 3–3	Median: 3	IQR: 3–3
1	4	1.70%	166	4.28%	222	3.86%	95	1.65%	3	0.33%	9	3.14%
2	69	29.36%	1707	44.04%	2765	48.14%	2268	39.35%	181	20.09%	67	23.34%
3	133	56.60%	1821	46.98%	2510	43.70%	3172	55.04%	654	72.59%	172	59.93%
4	29	12.34%	179	4.62%	246	4.28%	228	3.96%	63	6.99%	39	13.59%
5	0	0.00%	3	0.08%	1	0.02%	0	0.00%	0	0.00%	0	0.00%
Smoker												
Yes	98	41.70%	1294	33.38%	1380	24.03%	1264	21.93%	182	20.20%	71	24.74%
No	137	58.30%	2582	66.62%	4364	75.97%	4499	78.07%	719	79.80%	216	75.26%
Diabetes Mellitis												
No diabetes mellitus	220	93.62%	3501	90.33%	4935	85.92%	4354	75.55%	596	66.15%	214	74.56%
Non-insulin-dependent diabetes mellitus	6	2.55%	232	5.99%	542	9.44%	903	15.67%	182	20.20%	50	17.42%
Insulin-dependent diabetes mellitus	9	3.83%	143	3.69%	267	4.65%	506	8.78%	123	13.65%	23	8.01%

Note: Underlined values represent the median of each demographic category.
* = Chi-square statistically significant at $p < 0.05$; IQR = Interquartile Range.

Table 2
Number of adverse events, return to operating room, readmissions and mortality for patients of varying body mass index (BMI).

Total Number of Patients (n = 16,806)	BMI < 18.5 Underweight n = 235		BMI 18.5–24.9 Normal weight n = 3876		BMI 25.0–29.9 Overweight n = 5744		BMI 30.0–39.9 Obese n = 5763		BMI 40.0–49.9 Morbidly obese n = 901		BMI > 50.0 Super morbidly obese n = 287	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Any Adverse Event (AAE)	40	17.02%	316	8.15%	427	7.43%	450	7.81%	100	11.10%	38	13.24%
Major Adverse Event (SAE)	32	13.62%	199	5.13%	240	4.18%	265	4.60%	58	6.44%	23	8.01%
Deep Infection	15	46.88%	55	27.64%	55	0.96%	84	1.46%	11	1.22%	10	3.48%
Sepsis	6	18.75%	62	31.16%	64	1.11%	54	0.94%	13	1.44%	7	2.44%
Failure to Wean	13	40.63%	41	20.60%	49	0.85%	44	0.76%	17	1.89%	5	1.74%
Reintubation	9	28.13%	44	22.11%	45	0.78%	48	0.83%	11	1.22%	3	1.05%
Renal Failure	0	0.00%	44	22.11%	41	0.71%	30	0.52%	2	0.22%	2	0.70%
Thromboembolic Events	4	12.50%	27	13.57%	64	1.11%	68	1.18%	17	1.89%	8	2.79%
Cardiac Arrest	2	6.25%	14	7.04%	13	0.23%	17	0.29%	3	0.33%	1	0.35%
MI	3	9.38%	13	6.53%	18	0.31%	27	0.47%	3	0.33%	2	0.70%
Stroke	0	0.00%	11	5.53%	13	0.23%	13	0.23%	0	0.00%	0	0.00%
Minor Adverse Event (MAE)	17	7.23%	175	4.51%	254	4.42%	250	4.34%	58	6.44%	22	7.67%
Superficial Infection	4	23.53%	32	0.83%	62	1.08%	69	1.20%	23	2.55%	6	2.09%
Dehiscence	1	5.88%	19	0.49%	24	0.42%	29	0.50%	10	1.11%	3	1.05%
Pneumonia	9	52.94%	63	1.63%	83	1.44%	78	1.35%	14	1.55%	3	1.05%
UTI	5	29.41%	67	1.73%	89	1.55%	77	1.34%	15	1.66%	11	3.83%
Post Renal Insufficiency	0	0.00%	1	0.03%	7	0.12%	7	0.12%	0	0.00%	0	0.00%
Post-operative Infections	31	13.19%	226	5.83%	280	4.87%	311	5.40%	65	7.21%	16	5.57%
Return to operating room within 30 days of operation	12	5.11%	119	3.07%	154	2.68%	189	3.28%	43	4.77%	14	4.88%
Readmission within 30 days of operation ‡	15	6.38%	192	4.95%	330	5.75%	325	5.64%	55	6.10%	16	5.57%
Mortality within 30 days of operation	5	2.13%	24	0.62%	22	0.38%	23	0.40%	2	0.22%	2	0.70%

Table 3
Univariate odds ratio for adverse events, return to operating room, readmissions and mortality for patients of varying body mass index (BMI).

Total Number of Patients (n = 16,806)	Underweight n = 235		Normal weight n = 3876		BMI 25.0–29.9 Overweight n = 5744		BMI 30.0–39.9 Obese n = 5763		BMI 40.0–49.9 Morbidly obese n = 901		BMI > 50.0 Super morbidly obese n = 287	
	Odds ratio	*p-value	Odds ratio	*p-value	Odds ratio	*p-value	Odds ratio	*p-value	Odds Ratio	*p-value	Odds Ratio	*p-value
Any Adverse Event (AAE)	**2.31**	**0.000**	1.00	1.000	0.90	0.195	0.95	0.540	**1.41**	**0.005**	**1.72**	**0.003**
Major Adverse Event (SAE)	**2.91**	**0.000**	1.00	1.000	0.81	0.028	0.89	0.228	1.27	0.119	**1.61**	**0.038**
Minor Adverse Event (MAE)	1.65	0.058	1.00	1.000	0.98	0.828	0.96	0.678	1.46	0.016	**1.76**	**0.017**
Post-operative Infections	**2.64**	**0.000**	1.00	1.000	0.85	0.086	0.95	0.583	1.28	0.095	**2.10**	**0.000**
Return to operating room within 30 days of operation	**2.12**	**0.004**	1.00	1.000	0.92	0.434	1.04	0.730	**1.62**	**0.003**	**2.17**	**0.023**
Readmission within 30 days of operation	1.31	0.332	1.00	1.000	1.17	0.093	1.15	0.143	1.25	0.161	1.13	0.641
Mortality within 30 days of operation	**3.49**	**0.012**	1.00	1.000	0.62	0.103	0.64	0.131	0.36	0.162	**1.13**	**0.872**

Bolding indicates statistical significance at $p < 0.05$.

Table 4
Multivariable odds ratio for adverse events, return to operating room, readmissions and mortality for patients of varying body mass index (BMI).

Total Number of Patients (n = 16,806)	Underweight n = 235		Normal weight n = 3876		BMI 25.0–29.9 Overweight n = 5744		BMI 30.0–39.9 Obese n = 5763		BMI 40.0–49.9 Morbidly obese n = 901		BMI > 50.0 Super morbidly obese n = 287	
	Odds Ratio	*p-value	Odds Ratio	*p-value	Odds Ratio	*p-value	Odds Ratio	*p-value	Odds Ratio	*p-value	Odds Ratio	*p-value
Any Adverse Event (AAE)	**1.67**	**0.008**	1.00	1.000	0.97	0.095	0.98	0.773	1.24	0.089	1.31	0.162
Major Adverse Event (SAE)	**2.08**	**0.001**	1.00	1.000	0.85	0.108	0.90	0.294	1.11	0.505	1.17	0.514
Minor Adverse Event (MAE)	1.25	0.328	1.00	1.000	1.06	0.563	0.99	0.908	1.30	0.103	1.40	0.168
Post-operative Infections	**1.95**	**0.002**	1.00	1.000	0.92	0.377	0.96	0.684	1.07	0.679	**1.54**	**0.041**
Return to operating room within 30 days of operation	**1.84**	**0.020**	1.00	1.000	0.93	0.518	0.99	0.914	**1.40**	**0.042**	1.85	0.740
Readmission within 30 days of operation	1.19	0.532	1.00	1.000	1.15	0.164	1.10	0.312	1.04	0.802	1.57	0.183
Mortality within 30 days of operation	2.23	0.128	1.00	1.000	0.61	0.100	0.66	0.169	0.37	0.183	0.85	0.831

Bolding indicates statistical significance at $p < 0.05$.

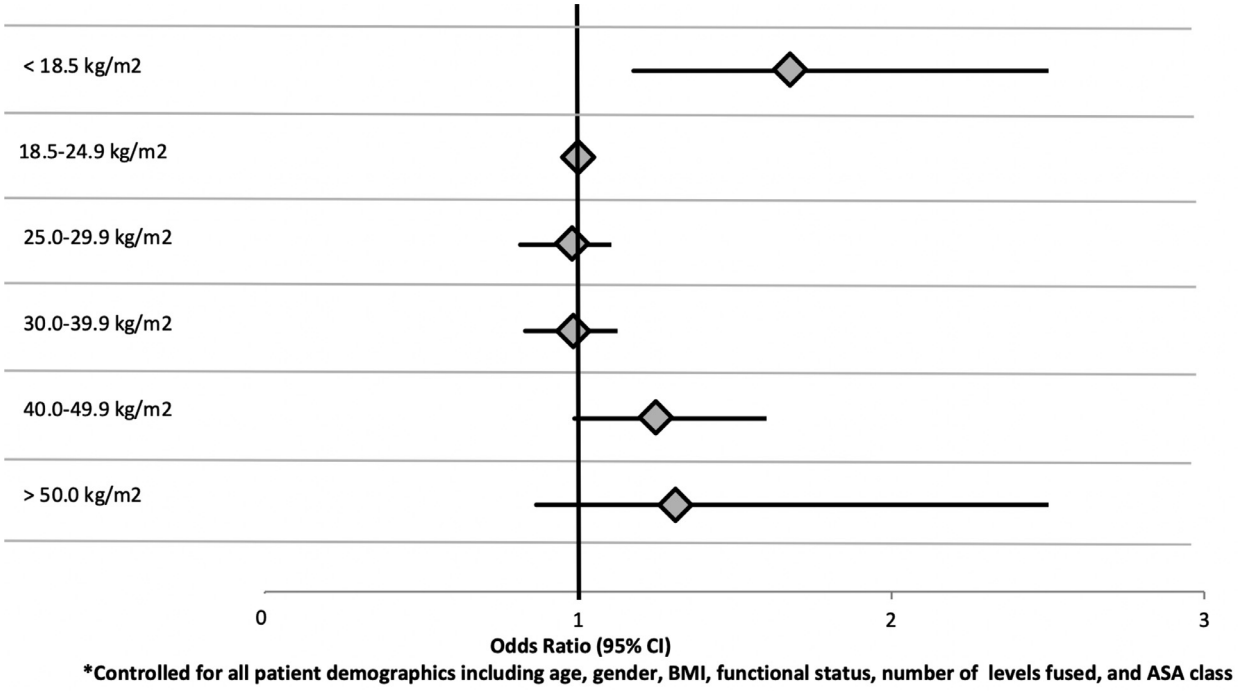

Fig. 3. Multivariate odds ratio of experiencing any adverse event for patients of varying body mass index (BMI) following a posterior cervical procedure.

be associated with increased risk of wound infection when at low levels and are often altered in underweight patients [40,41]. This represents a potential confounding factor. Further, this database does not capture disease or operation-specific variables such as neurologic deficits or implant characteristics. Despite these limitations, there are also several strengths inherent to the current study. The NSQIP data is robust for the collected data elements / time frame and the large number of patients (16,806) provide substantial statistical power for assessing smaller subcohorts such as the underweight patients.

Overall, the most notable results of the current study are that underweight patients are at significantly increased risk of multiple postoperative complications after undergoing posterior cervical spine surgery. These increased risks were actually higher than noted for the overweight/obese groups of patients. These data provide surgeons performing posterior cervical surgery with important information that can be used preoperatively to appropriately counsel and risk stratify patients, and possibly prophylactically treat reversible nutritional or metabolic derangements.

Declaration of Competing Interest

No conflicts of interest or external sources of funding for this study are reported.

IRB Approval

This study received exemption by our institution's Human Investigations Committee.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2020.100041.

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