The Impact of Obesity on Perioperative Resource Utilization after Elective Spine Surgery for Degenerative Disease

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Abstract

Study Design Retrospective case series.
Objective To determine the effect of obesity on the resource utilization and cost in 3270 consecutive patients undergoing elective noninstrumented decompressive surgeries for degenerative spine disease at Mayo Clinic Rochester between 2005 and 2012.
Methods Groups were assessed for baseline differences (age, gender, and American Society of Anesthesiologists [ASA] classification, procedure type, and number of operative levels). Outcome variables included the transfusion requirements during surgery, the total anesthesia and surgical times, intensive care unit (ICU) admissions, standardized costs, as well as the ICU and hospital length of stay (LOS). Regression analysis was used to evaluate for strength of association between obesity and outcome variables.
Results Baseline differences between the groups (nonobese: $n = 1{,}853$; obese: $n = 1{,}417$) were found with respect to age, ASA class, gender, procedure type, and number of operative levels. After correcting for differences, we found significant associations between obesity and surgical ($p < 0.0001$) and anesthesia times ($p < 0.0001$) and hospital LOS ($p < 0.0001$). Additionally, ICU admission rates ($p = 0.02$) and requirement for postoperative ventilation ($p = 0.048$) were significantly higher in obese patients. Finally, mean difference in total cost ($1,632, $p < 0.0001$) was significantly higher for the obese cohort.
Conclusion Obesity is associated with increased resource utilization and cost in patients undergoing a noninstrumented decompressive surgery for degenerative spine disease.

Keywords
- obesity
- cost
- spine
- resource utilization
- decompression

Introduction

The prevalence of obesity has increased in the United States. As of 2009, 35% of U.S. adults, or 41 million American women and over 37 million American men, were obese.[1] Obesity is a risk factor for degenerative spine disease, and the number of obese patients undergoing elective spine surgery is increasing.[2] To prepare for changes in patient demographics, and to provide higher-quality perioperative care for these patients, understanding how obesity affects resource utilization and outcomes after surgery is essential.

Existing data on the impact of obesity on the outcomes and costs are limited. The majority of prior series are

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limited by the size and the quality of the data. Recent efforts have also been made to utilize inpatient databases,[3,4] which, although beneficial due to their large numbers and incorporation of multiple care centers, have inherent inaccuracy due to the methodology of data collection. Despite these limitations, there is a growing body of evidence that obesity may increase costs[3–5] and complication rates.[6–12] To better understand its impact on acute resource utilization in a tertiary referral center, we reviewed our institutional experience with obese patients undergoing elective decompression for a degenerative disease using an established electronic perioperative outcomes database and validated query algorithms.

Methods

In accordance with an approved Institutional Review Board protocol, operative reports between 2005 and 2012 were reviewed for patients undergoing elective procedures for a degenerative disease. Following an initial search, patients with incomplete data, undergoing fusion, refusing consent, or having surgery for different indications were excluded. A total of 3,270 patients were ultimately included. Patients were then grouped by body mass index (BMI), with obesity being defined as a BMI greater than or equal to 30.

Data collection was performed by querying an internal procedure database.[13] Baseline demographics including age, gender, procedure type, and American Society of Anesthesiologists (ASA) classification were reviewed.[14] Additionally, each operative note was individually reviewed to determine the number of operative levels and to classify each case as either a decompressive bilateral laminectomy or another procedure (i.e., diskectomy, unilateral hemilaminectomy, and foraminotomy). The outcome measures included the intraoperative vasoactive drug use, transfusion requirements, surgical and anesthesia times, intensive care unit (ICU) admission rates and length of stay, ventilator requirement, and hospital length of stay.

Standardized institutional costs were collected using another internal Mayo Clinic resource. The database collates a cumulative report of resources used during each patient visit and assigns a cost for each resource corresponding to its valuation in the current fiscal year. Costs were classified either as operating room costs (all costs recorded under the date of the spinal procedure excluding postoperative observation/hospital room rate) or hospital costs (the remainder of costs accrued over the patient visit including postoperative observation/hospital room rate).

Statistical analysis was performed using JMP software (SAS, Cary, North Carolina, United States) with assistance from an institutional statistician. Continuous variables were analyzed by *t* tests, and chi-square analysis was used to assess significance for the categorical variables. Multivariate linear and logistic regression analyses were performed when appropriate, to account for inherent baseline differences between the groups. Odds ratios were calculated using 95% confidence intervals, and *p* values less than or equal to 0.05 were considered significant.

Results

Upon statistical analysis of baseline characteristics (►**Table 1**), the average obese patient was significantly younger than the average nonobese patient (61.7 versus 63.2 years, respectively). The majority of patients in both cohorts were male, but males comprised a greater proportion of the obese than nonobese cohort (64.7% versus 60.4%). Of the cases meeting inclusion criteria, 78.2% were posterior decompressions primarily of thoracic or lumbar vertebrae ($n = 2{,}557$). With regard to ASA classification, both obese and nonobese patient cohorts were predominantly class II (51.0% versus 60.6%, respectively), although the obese cohort had a significantly greater percentage represented by ASA class III, indicating more severe systemic disease (44.3% obese versus 31.2% nonobese). Additionally, significant differences in procedure type and the number of operative levels were observed between groups. The obese cohort had an increased prevalence of bilateral decompressive laminectomies (56.3% obese versus 48.3% nonobese) as well as an increased percentage of all multiple-level procedures (►**Table 1**).

Vasoactive Drugs and Transfusion Requirements

Because dosing was expected to vary with weight, intraoperative vasoactive drug use was analyzed as a categorical variable. Transfusion requirements were also analyzed as categorical variables. Compared with the nonobese group, obese individuals required more frequent use of both atropine (odds ratio [OR] = 4.12; 95% confidence interval [CI] = 1.53 to 13.2; $p < 0.005$) and phenylephrine (OR = 1.22; 95% CI = 1.02 to 1.47; $p < 0.032$). No differences were found with respect to packed red cells, fresh frozen plasma, or platelets (►**Table 2**).

Intensive Care Unit Stays and Ventilator Requirements

A small number of patients (7.9%) were managed initially in the ICU following their procedures. The reasons for ICU admission included ventilator requirements, pre-existing cardiopulmonary comorbidities (e.g., chronic obstructive pulmonary disease), and postoperative arrhythmias. A significant association was found between obesity and ICU admission rates (OR = 1.47; 95% CI = 1.14 to 1.90; $p = 0.003$) and near significance for required mechanical ventilation in the postoperative period (OR = 3.50; 95% CI = 0.93 to 13.1; $p = 0.066$). Multivariate regression revealed no significant associations between the length of ICU stay ($p = 0.277$) or ventilator days ($p = 0.297$); however, the obese cohort had a slight edge over their nonobese counterparts for both variables (►**Table 3**). Eleven patients required prolonged ventilation postoperatively, three nonobese (0.18, 0.75, and 25.08 days) and eight obese (0.02, 0.09, 0.14, 0.18, 0.53, 0.56, 0.65, and 5.44 days). The nonobese patient requiring 25.08 days of ventilation suffered from amyotrophic lateral sclerosis and required assistance with many of his activities of daily living prior to decompression (although no respiratory aid was needed prior to surgery), and the obese patient requiring ventilation for 5.44 days developed significant angioedema postoperatively that eventually required a tracheostomy to

Table 1 Baseline characteristics

	Nonobese ($n = 1,853$)	Obese ($n = 1,417$)	p Value
Age (y)	63.2 ± 15	61.7 ± 14	0.0013[b]
Gender, % (n)			0.0006[b]
Male	60.6% (1123)	66.2% (1123)	
Female	39.4% (730)	33.8% (479)	
ASA class[a]			<0.0001[b]
1	5.8% (108)	2.2% (31)	
2	60.6% (1123)	51.0% (722)	
3	31.2% (578)	44.2% (627)	
4	0.2% (4)	0.4% (6)	
5	0 (0)	0 (0)	
6	0 (0)	0 (0)	
Unknown	2.2% (40)	2.2% (31)	
Procedure			<0.0001[b]
Bilateral decompressive laminectomy	48.3% (894)	56.3% (797)	
Other	51.8% (959)	43.8% (620)	
Operative levels			<0.0001[b]
1	53.0% (982)	45.1% (639)	
2	19.8% (366)	20.3% (288)	
3	14.9% (276)	17.8% (252)	
4	8.3% (154)	11.4% (162)	
5+	4.1% (75)	5.4% (76)	

Abbreviation: ASA, American Society of Anesthesiologists.
[a]ASA classification: 1 = healthy patient, 2 = mild systemic disease, 3 = severe systemic disease, 4 = severe systemic disease that is a constant threat to life, 5 = moribund/not expected to survive, 6 = brain dead/organ harvest.
[b]$p < 0.05$, significant.

Table 2 Comparison of vasoactive drug use and transfusion requirements in obese and nonobese individuals

	Odds ratio[a]	Confidence interval (95%)	p Value
Vasoactive drugs			
Atropine	4.12	1.53–13.2	0.005[b]
Esmolol	1.04	0.87–1.26	0.640
Labetalol	1.12	0.94–1.32	0.197
Phenylephrine	1.22	1.02–1.47	0.032[b]
Transfusion			
RBCs	1.26	0.61–2.01	0.730
FFP	0	0–5.35	0.998
Platelets	1.43	0.36–6.13	0.609

Abbreviations: FFP, fresh frozen platelets; RBCs, red blood cells.
[a]Controlled for age, gender, American Society of Anesthesiologists class, procedure type, and operative levels.
[b]$p < 0.05$, significant.

alleviate. Categorizing ICU admissions into 1, 2, and 3 or more days (►**Table 4**) demonstrated no significant difference on ICU admissions between obese and nonobese patients on chi-square analysis ($p = 0.78$). Indications for ICU care are summarized in ►**Table 5**, and although there was a much higher percentage of obese patients admitted with a cardiac concern (45.8% versus 20.0%), there was again no statistical difference on chi-square analysis ($p = 0.17$).

Table 3 A comparison of time-oriented outcomes in obese and nonobese individuals using multivariate linear regression

	Nonobese ($n = 1,853$)	Obese ($n = 1,417$)	p Value	Adjusted R^2
Mean anesthesia time (h)	3.6	4.0	<0.0001[a]	0.23
Mean operative time (h)	2.3	2.7	<0.0001[a]	0.20
Mean ICU LOS (d)	1.4 ($n = 123$)	1.3 ($n = 134$)	0.277	0.001
Mean time on ventilator (d)	8.67 ($n = 3$)	0.95 ($n = 8$)	0.297	<0.0001
Mean hospital LOS (d)	2.4	2.7	0.002[a]	0.20

Abbreviations: ICU, intensive care unit; LOS, length of stay.
[a] $p < 0.05$, significant.

Table 4 Days in the intensive care unit for obese versus nonobese patients admitted

Days	Nonobese	Obese
1	103 (83.7%)	110 (82.1%)
2	15 (12.2%)	16 (11.9%)
3+	5 (4.1%)	8 (6.0%)

Table 5 Intensive care unit admission indications

	Myocardial infarction or arrhythmia	Respiratory distress	Other (neurologic weakness, renal, pain, blood pressure)	Total
Obese	11 (45.8%)	5 (20.8%)	8 (33.3%)	24
Nonobese	4 (20.0%)	5 (25.0%)	11 (55.0%)	20

Procedure Times and Length of Stay

Multivariate linear regression analysis demonstrated significant associations between obesity and the total anesthesia, surgical times, and hospital length of stay (►**Table 3**). The mean difference in the surgical and anesthesia times was 0.4 hours higher in obese individuals. Further separation of procedures into categories also demonstrates similar statistically significant differences between the cohorts for both the surgical and anesthesia times (►**Table 6**). The difference between the length hospital stay was minimal, albeit significant, at 2.7 versus 2.5 days for obese and nonobese patients, respectively.

Cost Analysis

The relationship between cost and obesity was evaluated with both univariate and multivariate analyses. On univariate analysis the obese cohort had demonstrated significantly increased cost. Operating room cost ($1,022, $p < 0.0001$), hospitalization cost ($610, $p < 0.0001$), and total cost ($1,632, $p < 0.0001$) were globally higher compared with the nonobese group. Similar results were observed on multivariate analysis, also validating that costs were significantly increased across all categories (►**Table 7**).

Discussion

The results presented here aimed to determine the true impact of obesity on outcomes after spine surgery and costs in nonfusion cases. Prior studies have primarily focused on the effect of obesity on infection rates, which in general have shown that obesity increases the rate of surgical site infections (superficial and deep).[6–11] However, the effect on perioperative morbidity, resource utilization, costs, and long-term outcomes has remained unclear. Here, we show that obese patients had higher rates of pre- and perioperative comorbidities. Additionally, obesity increased the risk of ICU admission and resulted in increased length of stay and cost.

Resource Utilization

The impact of obesity on operative times and length of stays has been variable in the literature. Vaidya et al found that obese and morbidly obese patients undergoing lumbar fusion had longer surgical times ranging from 26 to 81 minutes depending on the number of levels (one versus two) and type of fusion (posterolateral versus transforaminal lumbar interbody fusion).[15] Peng et al also noted longer exposure times during anterior interbody lumbar fusions.[16] In contrast, no differences in surgical times were found in a small cohort of patients undergoing lumbar decompressions and/or fusions by Andreshak et al[17] or during minimally invasive approaches.[18,19] Although null findings in that instance may be in part explained by lack of statistical power, likely the extent of surgery and the approach used also account for the variability between studies. A convincing association between longer length of stays and morbid obesity was found in the review by Kalanithi et al of 84,607

Table 6 Mean surgical and anesthesia times by procedure type

	Surgical times (h)			Anesthesia times (h)		
	Nonobese	Obese	*p* Value	Nonobese	Obese	*p* Value
Bilateral laminectomy (1 or 2 levels)	2.32	2.55	<0.0001[a]	3.59	3.81	0.0007[a]
Bilateral laminectomy (3+ levels)	2.81	3.17	<0.0001[a]	4.17	4.66	<0.0001[a]
Other procedures	2.07	2.36	<0.0001[a]	3.31	3.67	<0.0001[a]

[a] $p < 0.05$, significant.

Table 7 Mean differences in costs among obese and nonobese individuals

Comparison	Operating room cost ($)	Hospitalization cost ($)	Total cost ($)
Univariate analysis			
Obese (BMI > 30) vs. nonobese (BMI < 30)	$1,022 ($p < 0.0001$[b])	$610 ($p < 0.0001$[b])	$1,632 ($p < 0.0001$[b])
Multivariate analysis[a]			
Obese (BMI > 30) vs. nonobese (BMI < 30)	$282 ($p = 0.0003$[b])	$227 ($p = 0.0006$[b])	$508 ($p < 0.0001$[b])

Abbreviation: BMI, body mass index.
[a] Controlled for age, gender, American Society of Anesthesiologists class, procedure type, and operative levels.
[b] $p < 0.05$, significant.

spinal fusions gathered from the inpatient California database.[3] Paradoxically, Shamji et al reviewed an even larger sample ($n = 244{,}170$) of patients undergoing thoracolumbar fusions and found no difference in length of stay, but did ultimately conclude that obesity is associated with increased resource utilization as evidenced by increased costs and higher transfusion requirements.[4] Although the aforementioned series are heterogeneous and do not specifically examine resource utilization in obese patients undergoing spinal decompressions without fusion, they do support a trend toward increased resource utilization and obesity that seems to vary depending on the type and extent of surgery. To our knowledge, no prior studies have examined the utilization of vasoactive drugs between obese and nonobese patients during spine surgery or ICU admission rates. The present series demonstrates that obesity is associated with higher resource utilization after elective nonfusion procedures for degenerative disease. Specifically, obese patients had increased vasoactive drug requirements during surgery, longer anesthetic and operative times, higher ICU admission rates, and increased hospital lengths of stay. Although there were a higher mean number of ventilator days and length of ICU stays for the nonobese cohort, obese patients were more likely to stay longer than 3 days and be admitted to the ICU for cardiac concerns. Unfortunately, our study may not be adequately powered to elucidate the true difference in the length of ICU admission and ventilator days, and single observations had a large effect on this result.

Vasoactive Drug Requirements

The more frequent use of atropine (an anticholinergic drug used to treat bradycardia and/or its associated hypotension) and phenylephrine (an α-adrenergic receptor agonist used to increase blood pressure) in spine surgery cases involving individuals who are obese indicates that there was a significant increase in the need for the anesthesia team to need to treat bradycardia and/or hypotension in this population. The reason for the increased use of these drugs cannot be directly determine by these data. However, it is known that obesity increases resting sympathetic activity and that there is a greater contribution of the sympathetic nervous system to resting blood pressure in obese individuals.[20] Most anesthetic drugs dramatically reduce sympathetic activity and the compensatory baroreflex-mediated responses associated with hypotension.[21] Therefore, it is likely that the greater need for drugs to increase heart rate and/or blood pressure reflects abnormal sympathetic tone in the obese patients and an increased incidence of hypotension during administration of anesthetic agents. Additionally, the increased need for intervention may be related to the increased risk of cardiovascular disease in patients who are obese, including cardiac arrhythmias.[22] Finally, there is an increased incidence of hypertension in obese individuals, and because there may be resetting of the brain blood flow autoregulatory curve in patients with hypertension, some anesthesiologists advocate maintain blood pressure within 10 to 20% of preanesthesia baseline values through the use of direct-acting vasoconstrictors such as phenylephrine.

Costs

A recent census by the Centers for Disease Control estimated that obesity increases overall health care costs by nearly $1,429 per capita.[5] In a review of the California inpatient database, Kalanithi et al found that average costs of patients undergoing spinal fusion were significantly higher in morbidly obese patients ($108,604 versus $84,861).[3] Similarly, Shamji et al reported a nearly linear increase in costs in normal, obese, and morbidly obese individuals undergoing thoracolumbar fusions. Somewhat contradictory, Walid et al described that BMI was not a significant determinant of hospital cost for anterior cervical decompressions and fusions, lumbar decompression and fusion, and lumbar microdiskectomy on univariate analysis. This retrospective study of 787 randomly selected patients did describe an interaction between increasing age and BMI to be significant; however, the researchers acknowledged the increased cost of spinal surgery in relation to age and especially BMI as small.[23] The cost differential reported in our study is able to elicit a difference between the total cost of nonfusion procedures with univariate and multivariate analysis. Although not as large as the difference seen in the fusion analysis of Kalanithi et al, this difference is not trivial and points to another facet increasing the burden of degenerative spine disease on obese individuals. Despite controlling for the extent of degenerative disease by evaluating for bilateral decompressive laminectomies and the number of operative levels, there are still many unexplained variables factoring into the increased costs. Walid et al previously looked at the effect of obesity and other comorbidities (i.e., chronic obstructive pulmonary disease, diabetes, etc.) on overall costs and found additive increases with cost and comorbid conditions.[23,24] Therefore, a greater prevalence of comorbid conditions, as seen in our obese cohort, could be driving the residual difference demonstrated on multivariate analysis.

A cumulative analysis of cost utilizing the overall difference between obese and nonobese individuals reported by this study demonstrates an impressive difference on a yearly basis. A net increase of $332,928 is attributable to obesity for the 483 procedures (279 nonobese; 204 obese) completed in 2011, the final full year of this study. This evaluation of cost is strengthened by standardized practices of a single institution and provides a clearer representation of the true differences in cost between these populations. This result suggest that the standard per capita compensation for all individuals does not effectively address these differences and for obese individuals who are more prone to complication, there is a valid criticism that reimbursement tied to outcomes may prove suboptimal.[25]

Efficacy versus Morbidity

Despite a growing body of evidence that obesity may increase perioperative morbidity, resource utilization, and costs, the current literature would suggest that obese patients also significantly benefit after open and minimally invasive spine surgery.[15,17–19,26,27] The degree of benefit relative to nonobese patients is debatable. Several studies have shown that the benefit is less in obese individuals,[28–30] whereas no difference in improvement was found by Andreshak et al and Djurasovic et al.[17,26] Similarly, minimally invasive approaches are more commonly advocated in obese patients, as studies have shown higher complication rates after diskectomy,[31] posterior lumbar interbody fusion,[27] thoracolumbar fusions,[32] and deformity surgery.[33] Shamji found that degree of obesity (morbidly obese, but not obese) correlated with perioperative morbidity in patients undergoing thoracolumbar fusion.[4] Similarly, Kalanithi et al revealed higher in-hospital complication rates (13.6% versus 6.9%) and higher mortality (0.41 versus 0.13) in obese patients, which was most pronounced in the patients undergoing anterior cervical and posterior lumbar fusions.[3] We demonstrate in the present study significant differences in ASA class distribution among obese and nonobese individuals, indicating that the obese patients are more likely to have severe systemic diseases, like complicated diabetes. Thus, we speculate that a higher prevalence of existing comorbidities of obese patients prior to surgery may contribute to higher complication rates. Indeed, the presence of multiple comorbidities has been cited as a risk factor for complications following spine surgery.[34–36] Further studies are therefore warranted to determine the long-term benefits of elective spine surgery in obese patients compared with nonobese patients.

Limitations

Although the availability of a searchable database allowed for accurate compilation of patient data, this was a retrospective study, and as such was limited to the information available in patient records. Similarly, the results reported here are the outcomes of a single institution study, and so may be affected by the patient demographics.

Conclusion

In summary, our results affirm increased utilization of resources in obese patients undergoing elective decompression for degenerative disease. Although significant variability exists in the scant literature available on this subject, we demonstrate here that obesity likely increases pre- and perioperative morbidity, resource utilization, and costs as a function of the extent of the surgery and approach. As long-term outcomes studies do suggest that obese patients substantially benefit from surgery, future studies should be aimed at methods of mitigating perioperative morbidity and costs in this population.

Disclosures
Ryan F. Planchard, none
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