

Original Article

The effect of weight in the outcomes of meningioma patients

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Abstract

Background: Meningiomas are more prevalent in women and mostly benign in nature. Our aim was to evaluate the association of weight and outcomes of meningioma patients undergoing craniotomy.

Methods: A retrospective analysis of meningioma patients discharged postcraniotomy between 1998 and 2007 was conducted. Univariate and multivariate analysis evaluated in-hospital mortality, complications, length of stay (LOS), and cost.

Results: According to the nationwide inpatient sample (NIS) database, an estimated 72,257 adult meningioma patients underwent a craniotomy in US hospitals during the study period. Female and male weight loss rates were 0.7% and 1.2%, respectively; obesity rates were 5.2% and 3.7%. Males had higher rates of malignant tumors than females (6.2% vs. 3.5%, $P < 0.0001$), and malignant tumors were more common in patients with weight loss (6.4% vs. 4.3%, $P = 0.03$). Weight loss was associated with higher mortality in men (OR 6.66, $P < 0.0001$) and women (OR 3.92, $P = 0.04$) as well as higher rates of postoperative complications in both men (OR 6.13, $P < 0.0001$) and women (OR 8.37, $P < 0.0001$). Furthermore, patients suffering weight loss had longer LOS and higher overall hospital cost when compared with all patients. In contrast, obesity seemed to reduce mortality (OR 0.47, $P = 0.0006$) and complications (OR 0.8, $P = 0.0007$) among women.

Conclusions: In summary, weight loss seems to be the single most critical factor present in patients experiencing higher mortality, complications, hospital charges, and longer LOS. However, further studies aimed to assess the inter-relation of potential preexisting comorbidities and weight loss are needed to establish causation.

Key Words: Complications, craniotomy, hospitalization cost, length of stay, meningioma, mortality, obesity, weight loss

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INTRODUCTION

Meningiomas are the second most common primary neoplasm of the central nervous system and are

mostly (90%) of benign nature. Incidence is approximated at about 209 per 100,000 people in the United States,^[19] cases occur mainly in patients aged 40-70 and in women. Among middle-aged patients, there is a marked female

bias, with a female to male ratio of almost 3:1 in the brain and up to 6:1 in the spinal cord. Meningiomas rarely occur in children (1.5% of total cases). Clinical studies suggest that meningiomas may be influenced by estrogen and progesterone based on the observation of a positive association with breast cancer^[18] and tumor growth during pregnancy and menstruation.^[16] Molecular and immunohistochemical studies confirm that meningioma is a hormone-sensitive tumor, with approximately 70% of meningiomas expressing progesterone receptors and approximately 30% expressing estrogen receptors.^[4,12] Proliferation of human meningioma cell lines after exposure to estrogen and progesterone has also been reported.^[8]

Besides the implicated risk of gender for meningiomas, previous studies identified obesity as a potential comorbidity associated with increased risk of postoperative complications, particularly in men.^[2] While there have been several studies reporting adverse effects of obesity on postsurgical complications and mortality, most notably in males, no investigation into the effects of obesity on female obese meningioma patients or the effects of weight loss on meningioma outcome has been conducted. This study aims to determine the effect of weight (weight loss and obesity) in the outcomes of women and men following a craniotomy.

MATERIALS AND METHODS

Data source

Using the Nationwide Inpatient Sample (NIS) database, we analyze the outcomes of adult meningioma patients that underwent a craniotomy between 1998 and 2007. Data was obtained from the Healthcare Cost and Utilization Project of the Agency for Healthcare Research and Quality (HCUP). The NIS contains discharge data on 100% of discharges from a sample of hospitals that are selected for inclusion into the database using a stratified random sampling technique. This produces a representative 20% sub-sample of all United States nonfederal hospital discharges, so that conclusions drawn from the database can be confidently generalized to the entire United States medical community. Because the NIS contains data on all patients discharged from sampled hospitals during a given year regardless of age or payer status, it can be used to obtain an annual total volume of specified procedures at individual hospitals. This study was deemed as exempt from review by the Cedars-Sinai Institutional Review Board.

Inclusion and exclusion criteria for cases analyzed

Data was queried to include adult patients (≥ 18 years) with a primary diagnosis of meningioma (ICD-9-CM diagnosis codes 225.2, 192.1, 237.6), principal procedure

of craniotomy (ICD-9-CM procedure code 01.51). Principal diagnosis code is assumed as the condition primarily responsible for the patient's need for treatment as deemed by the admitting physician.^[10]

Patient and hospital characteristics

A patient's age, gender, race, median household income, primary insurance payer (e.g., medicare, medicaid, private), type of admission (e.g., emergency, urgent, elective), discharge disposition (e.g., routine, transfer, home health care, died), hospital type (teaching vs. nonteaching), in-hospital length of stay (LOS), and total charges were extracted from the NIS database. Race was categorized into Caucasian versus all other. Missing rates for race and admission source variables were 35% and 2%, respectively. An Elixhauser, *et al.*^[11] based comorbidity score (continuous variable) that summarizes up to 30 possible preexisting conditions such as hypertension, alcohol or drug abuse, liver disease, neurological disorder, to name a few, was calculated for each patient and adjusted for in the analyses. Weight loss (ICD-9-CM: 260-263.9, V851) and obesity (ICD-9-CM: 278.0) were defined according to comorbidities coded in the study of Elixhauser, *et al.*^[11]

Primary outcomes of interest

Mortality, postsurgical complications, in-hospital LOS, and total charges were evaluated. NIS captures mortality as a binary outcome (death or alive), LOS in days, and total charges (dollars) as continuous variables. Postoperative complications consistent with a craniotomy included the following: Postoperative fluid and electrolyte abnormalities (276.0-276.9), cerebrospinal fluid rhinorrhea (349.81), pulmonary (518.81-518.85, 997.3), stroke (253.5, 998.11, 997.02), cardiac (410, 997.1), thromboembolic complications including deep venous thrombosis and pulmonary embolism (415, 387, 415.11-415.19, 451.0-451.9, 453.0-453.9), postoperative neurologic including those due to infarction or hemorrhage (997.00-997.09), hematoma (998.1-998.13), and hydrocephalus or ventriculostomy (331.3-331.4).

Statistical analysis

Descriptive statistics and multivariate analysis adjusted for weight loss, obesity, and potentially confounding factors. Adjusted Odds ratio (OR), 95% confidence intervals (CI), and corresponding *P* values were reported in all relevant analyses. Estimations to the entire US population were performed using the SAS PROC SURVEY methodology. All analysis was conducted using SAS version 9.1 for Windows (SAS Institute Inc., Cary, NC).

RESULTS

General descriptors

A total of 72,257 meningioma patients underwent a craniotomy between 1998 and 2007 [Table 1]. Of these

Table 1: Characteristics of meningioma patients undergoing a craniotomy between 1998 and 2007

Patient characteristics	Female			Male		
	Total N=50,356	Weight loss N=348 (0.7%)	Obesity N=2621 (5.2%)	Total N=21,901	Weight loss N=265 (1.2%)	Obesity N=811 (3.7%)
Number of cases, N	50,356	348	2,621	21,901	265	811
LOS (median, days)	6.6	19.9	6.7	7.4	25	7
Total charges (median, \$)	\$53,601	\$121,404	\$55,502	60698	154591	64341
Died in hospital	1.3	10.4	0.8	2	21.9	0
Postsurgical complication	9	52.3	7.4	10.6	48.2	9.5
Age (median, years)	57.6	67.8	55.8	58.4	67.4	56.2
Race						
White	74.2	72.6	70	75.9	72	81.9
Black	10.7	12.4	16.1	10.1	12	10.6
Primary payer						
Medicare	34.1	62.1	29.9	38.3	69.2	30.8
Private insurance	52.3	27.9	53	47.8	18.9	53
Discharge disposition						
Home/self-care	68.1	14.1	66	64.8	9.2	66.6
Transfer	21.6	66.9	21.7	23.6	61.3	22.7
Admission source						
Emergency room	11.6	26.0	14.6	14.3	35	14.6
Routine	83.6	67.3	81	79.6	51	80
Teaching hospital	77.2	73.4	73	77.2	87.7	79.3
Comorbidity score						
0	41.5	0.0	0	42.1	0	0
1	31.8	30.6	19.5	32.8	29.7	19.5
2	18.6	37.1	37	17.3	29.4	37
3+	8.1	14.6	13.6	7.8	8.1	13.6

LOS: Length of stay

patients, 50,356 (70.0%) were female, with median age of 57.6 years. A total of 27,691 (74.2%) were Caucasian, 26,333 (52.3%) had private insurance, 34,260 (68.1%) were discharge home/self-care, and 41,410 (83.6%) were admitted routinely. Of the 21,901 (30.0%) males, 12,268 (75.9%) were Caucasian, 10,463 (47.8%) had private insurance, 14,181 (64.8%) were discharged home/self-care, 17,014 (79.6%) were routine admissions. Comorbidity score distribution was comparable among females and males. The rate of weight loss among females and males was 0.7% (N = 348) and 1.2% (N = 265), respectively. Females with weight loss compared with all females had significantly higher LOS (19.9 vs. 6.6 days), total charges (\$121,404 vs. \$53,601), mortality rate (10.4% vs. 1.3%), and complications (52.3% vs. 8.9%). The association of weight loss in the outcome of males was even more dramatic. LOS increased from 7.4 to 25.0 days, total charges from \$60,698 to \$154,591, mortality from 2.0% to 21.9%, and postoperative complications from 10.6% to 48.2%. Obesity in female and male obese patients seem to be associated with lower rates of mortality (Female: 0.8%, Male: 0%) and complications (Female: 7.4%, Male: 9.5%) when compared with the overall cohorts.

Weight loss and tumor characteristics

Overall, meningiomas in females were 95.9% benign, 3.5% malignant, and 0.6% of uncertain behavior [Table 2]. In men, 92.9% of tumors were benign, 6.2% were malignant, and 0.9% of uncertain behavior. Frequency distribution of tumor malignancy by gender was statistically significant ($P < 0.0001$). Among patients diagnosed with weight loss, 6.4% had malignant, 0.9% were uncertain and 92.7% were benign tumors ($P = 0.03$). In comparison, those not coded with weight loss had higher rate of benign meningiomas (95.0%) followed by malignant meningioma (4.3%) and meningioma of uncertain behavior (0.7%). Even higher rates of patients with benign tumors were observed among those diagnosed with obesity compared with nonobesity (96.6% vs. 94.2%, $P < 0.0001$).

Weight loss and complications

In a sub-analysis of weight loss and obesity, we found that weight status was associated with increased rates of certain complications, yet decreased rates of others [Table 3]. Postoperative infections increased from 0.2% to 15.0% and 0.6 to 14.2% in females and males with weight

loss, respectively. Less pronounced increments in pulmonary (2.2-4.9%), cardiac (1.0-3.7%), stroke (3.6-5.1%), and thromboembolic (1.5-3.0%) were observed among females with weight loss. Stroke (4.2-5.8%), mechanical ventilation (5.4-8.3%), and thromboembolic (2.1-6.3%) increments were also observed in men with weight loss. Rates in pack cell transfusion (7.2-2.3%) and postoperative fluid and electrolyte abnormalities (9.1-3.4%) complications decreased with weight loss in females. Reductions in neurological (2.2-0%), pack cell transfusion (6.1-4.3%), and postoperative fluid and electrolyte abnormalities (9.8-6.0%) complications were observed in males as well. Mechanical ventilation, stroke, and cardiac complications were most commonly associated with the highest rates of mortality [Table 3].

Multivariate analysis of outcomes

Female gender (OR 0.85, CI: 0.75-0.97, $P = 0.02$), higher hospital volume (OR 0.98, CI: 0.98-0.99, $P < 0.0001$) and obesity (OR 0.47, CI: 0.30-0.72, $P < 0.0001$) were associated with decreased risk of in-hospital mortality [Table 4]. Older age (OR 1.47, CI: 1.40-1.54, $P < 0.0001$), emergency room (ER) admission (OR 2.25, CI: 1.96-2.59, $P < 0.0001$), and tumor malignancy (OR 1.93, CI: 1.57-2.37) were significant and independent predictors of mortality. Patients with preexisting coagulopathy (OR 5.63, CI: 4.61-

6.86, $P < 0.0001$), peripheral vascular disease (OR 3.69, CI: 2.79-4.89, $P < 0.0001$), renal failure (OR 3.37, CI: 2.56-4.44, $P < 0.0001$), and chronic blood loss anemia (OR 3.15, CI: 1.94-5.12, $P < 0.0001$) were particularly at an increased risk of mortality. Weight loss in men (OR 6.66, CI: 4.72-9.41, $P < 0.0001$) and women (OR 3.92, CI: 2.78-5.53, $P = 0.04$) was significantly associated with mortality.

Older age and ER admission were significant predictors of postoperative complications in women and men [Table 5]. Caucasian women and men had a 16% and 15% reduction in the likelihood of a complication compared with all other patients, respectively. Coagulopathy (OR 4.24, CI: 3.56-5.06, $P < 0.0001$), paralysis (OR 2.98, CI: 2.72-3.26, $P < 0.0001$), and alcohol abuse (OR 1.82, CI: 1.18-2.84, $P = 0.007$) were the most likely comorbidities associated with the highest risk of complications in women. Weight loss was a significant and independent predictor of higher complications in women (OR 8.37, CI: 6.66-10.52, $P < 0.0001$) and men (OR 6.13, CI: 4.67-8.05, $P < 0.0001$). Obesity seem to be protective against complications in women (OR 0.80, CI: 0.68-0.94, $P = 0.007$).

Since length of hospital stay and cost are likely to be affected by a patient's survival status, these outcomes were analyzed while considering the survivors. Table 6 describes the LOS and cost analysis by gender; only predictors significant at the 0.05 level were included.

Age, race, admission source surgery delay, and number of procedures had a similar effect on LOS and cost independently of gender. Weight loss increased LOS by 2.3 and 3.2 days in women and men, respectively. Obesity reduced LOS in women by 0.3 days while having no effect in the LOS in men. Postoperative complications increased LOS in men more significantly than in women. For instance, thromboembolic, neurological, postoperative fluid complications, and pulmonary increased LOS in women by 3.6, 3.6, 1.6, and 1.3 days and in men by 4.3, 4.0, 2.5, and 2.4 days, respectively.

Table 2: Distribution of weight loss, obesity, gender by primary tumor type

	Weight loss status		Obesity status		Female	Male
	Yes	No	Yes	No		
Total cases	652	72,028	3,436	69,244	50,442	22,238
Tumor type						
Benign*	92.7%	95.0%	96.6%	94.9%	95.9%	92.9%
Malignant [§]	6.4%	4.3%	3.0%	4.4%	3.5%	6.2%
Uncertain [¶]	0.9%	0.7%	0.4%	0.7%	0.6%	0.9%
Chi-square P value		0.029		<0.0001		<0.0001

*ICD-9-CM code 225.2, [§]192.1, [¶]uncertain behavior

Table 3: Weight loss and mortality rates by postoperative complication type

Complication type	Female rates			Obesity in patients with complication (All: 5.2%)	Male rates		
	Complication (All: 9.0%)	Weight-loss in patients with complication (All: 0.7%)			Complication (All: 10.6%)	Weight-loss in patients with complication (All: 1.2%)	Obesity in patients with complication (All: 3.7%)
Postoperative infections	0.2	15.0	0.0	0.6	14.2	3.6	
Stroke	3.6	5.1	3.3	4.2	5.8	3.1	
Pulmonary	2.2	4.9	3.9	3.9	4.9	2.3	
Mechanical ventilation	4.1	4.8	5.6	5.4	8.3	3.3	
Neurological	4.6	4.7	2.8	5.1	5.6	2.6	
Cardiac	1.0	3.7	6.6	1.2	1.7	6.1	
Postoperative fluid*	9.1	3.4	5.0	9.8	6.0	5.4	
Thromboembolic**	1.5	3.0	5.8	2.1	6.3	2.8	
Hematoma	1.6	2.3	4.7	2.2	0.0	3.1	

*And electrolyte abnormalities, **includes DVT and PE

Total charges were similar in women in men by age, race, admissions source, surgery delay, and number of procedures as observed in LOS [Table 6]. Patients with weight loss had increased hospital charges by \$13,343 and \$16,270 in women and men, respectively. Obesity reduced the total cost in women by \$1,329 while in men it did not have any effect. Postoperative complications in men implicated higher charges for the most part compared with women. Thromboembolic, neurological, postoperative fluid abnormalities, and pulmonary complications increased cost by \$19,339, \$18,477, \$8,662, and \$7,739 in women and by \$20,672, \$18,305, \$12,183, and \$12,682 in men.

Table 4: Adjusted odds ratio of risk of mortality, 95% confidence intervals and P values

Effect	OR	95% CI	P value
Female	0.85	0.8-1.0	0.0200
Age in decades	1.47	1.4-1.5	<0.0001
Admission source: ER	2.25	2.0-2.6	<0.0001
Hospital procedure count	0.98	0.9-1.0	<0.0001
Weight loss (men)	6.66	4.7-9.4	<0.0001
Weight loss (women)	3.92	2.8-9.4	0.0400
Obesity (women)	0.47	0.3-0.7	0.0006
Malignant meningioma	1.93	1.6-2.4	<0.0001
Comorbidities			
Chronic blood loss anemia	3.15	1.9-5.1	<0.0001
Coagulopathy	5.63	4.6-6.9	<0.0001
Peripheral vascular disease	3.69	2.8-4.9	<0.0001
Renal failure	3.37	2.6-4.4	<0.0001

*Diabetes was adjusted for and found to be not statistically significant

DISCUSSION

A total of 72,257 adult meningioma patients underwent craniotomy for resection of meningioma between 1998 and 2007; 70% were female and overall average age was 58 years. Women had shorter hospital stays and lower mortality than men. Higher rates of malignant tumors were found in patients with weight loss (6.4% vs. 3.0%). Weight loss alone was associated with a 9% increased rate of mortality in females and 20% increased rate in males.

In previous studies, comorbidities along with patient-level and tumor-specific characteristics have been found to be significantly associated with the outcomes of neurosurgical patients.^[5,13] According to our analysis, there were several comorbidities that appeared to have a robust effect on mortality and rate of complication. Tumor malignancy increased the odds of mortality by 93% (OR 1.93, $P < 0.0001$). Coagulopathy (OR 5.63, $P < 0.0001$), peripheral vascular disease (OR 3.69, $P < 0.0001$), renal failure (OR 3.37, $P < 0.0001$), and chronic blood loss anemia (OR 3.15, $P < 0.0001$) were among the top comorbidities associated with significantly higher mortality. Alcohol abuse (OR 1.83, $P = 0.0003$) and paralysis (OR 2.98, $P < 0.0001$) were significantly and independently associated with higher rates of complication. Our multivariate analyses showed that even after adjusting for these potential confounders, weight loss remained a strongly associated with mortality among men (OR 6.66, $P < 0.0001$) and women (OR 3.92, $P < 0.0001$).

An important consideration regarding the observed risk of poor outcome in patients suffering weight loss may be explained by the fact that weight loss is associated with potentially confounding factors such as preexisting

Table 5: Adjusted odds ratio of risk of complications, 95% confidence intervals and P values

Effect	Complications odds ratio					
	Women			Men		
	OR	95% CI	P value	OR	95% CI	P value
Age in decades	1.14	1.1-1.2	<0.0001	1.10	1.1-1.1	<0.0001
Admission source: ER	1.43	1.3-1.6	<0.0001	1.31	1.2-1.5	<0.0001
Comorbidity score	0.95	0.9-1.0	0.0351	0.95	0.9-1.0	0.1600
Hospital procedure count	1.01	1.0-1.0	<0.0001	1.00	1.0-1.0	0.1600
Race (white vs. all other)	0.84	0.8-0.9	<0.0001	0.85	0.8-0.9	0.0005
Weight loss	8.37	6.7-10.5	<0.0001	6.13	4.7-8.1	<0.0001
Obesity	0.8	0.7-0.9	0.007	1.03	0.8-1.3	0.8100
Comorbidities						
Alcohol abuse	1.83	1.2-2.8	0.007	1.61	1.2-2.1	0.0003
Deficiency anemia	1.4	1.3-1.6	<0.0001	2.25	1.9-2.7	<0.0001
Chronic pulmonary disease	1.18	1.1-1.3	0.0048	1.22	1.0-1.4	0.0200
Coagulopathy	4.24	3.6-5.1	<0.0001	5.46	4.5-6.7	<0.0001
Diabetes	1.54	1.4-1.7	<0.0001	0.97	0.8-1.1	0.7400
Liver disease	1.65	1.0-2.6	0.0338	1.29	0.8-2.1	0.3100
Paralysis	2.98	2.7-3.3	<0.0001	2.38	2.1-2.7	<0.0001

Table 6: Effect of patient characteristics in LOS and hospital charges

Effect	Women		Men	
	Incremental LOS in days	Incremental hospital charges due to hospitalization	Incremental LOS in days	Incremental hospital charges due to hospitalization
Age in decades	0.29	\$1,431	0.32	\$1,446
Race (white vs. all other)	-0.51	-\$2682	-0.48	-\$2275
Admission source: ER	1.05	\$5,521	1.14	\$5,384
Days before first procedure	0.68	\$3,406	0.66	\$2,974
Number of procedures	0.46	\$2,462	0.58	\$2,752
Weight loss	2.33	\$13,343	3.17	\$16,270
Obesity	-0.26	-\$1329	-	-
Comorbidity score	0.13	\$662	0.12	\$565
Hospital procedure count	-0.01	-\$43	-0.01	-\$45
Complications				
Hematoma	1.52	\$7,732	2.29	\$10,431
Thromboembolic*	3.57	\$19,339	4.26	\$20,672
Neurological	3.64	\$18,477	4.02	\$18,305
Mechanical ventilation	1.56	\$8,600	1.38	\$6,836
Packed cell transfusion	0.34	\$1,777	0	\$0
Postoperative fluid**	1.6	\$8,662	2.51	\$12,183
Pulmonary	1.33	\$7,739	2.44	\$12,683
Stroke	0.72	\$3,805	0.82	\$3,931
Cardiac	0.8	\$4,076	0.98	\$4,483

*Includes DVT and PE, **and electrolyte abnormalities, LOS/hospital charges models had adjusted R² of 0.52 and 0.63, respectively, All effects were significant at P<0.05, Obesity did not have significant impact on LOS among men, Only patients who survived have been included in the analysis, *diabetes was adjusted for and found to be not statistically significant

conditions (as opposed to acting in causation of them), and it is rather these comorbidities ultimately affecting patient outcomes. To this end, our current study adjusted for comorbidities such as diabetes, hypertension, coagulopathy, renal failure, and others, however, further studies are needed to decipher the potential relationship of weight loss with these comorbidities as well as others. Further explanation includes the fact that the complications selected for analyses were not all-encompassing and influenced outcomes of our statistical models, or that weight loss stemmed from malnutrition in direct result of these complications.

Obesity has long been an accepted risk factor associated with poor outcomes in patients undergoing surgery. However, recent studies regarding the prognostic effect of obesity yielded mixed conclusions.^[6,9,13,14,15,20] While several studies have demonstrated increased risk of mortality in obese breast cancer patients,^[14,17] other studies denounce obesity as a risk factor in various surgeries (such as vascular, general elective, renal, and intraabdominal), and instead support the “obesity paradox.” This novel concept describes the apparent protective effect of mild obesity against postoperative complication and mortality.^[6,9,15,20]

Within the field of neurosurgery very few studies have investigated the role of obesity in patient outcomes. These previous studies have shown higher levels of

mortality and complication in both solely male obese and mixed male and female obese meningioma patient cohorts.^[2,3,21] Aghi, *et al.* demonstrated a disproportionate number of men with meningioma diagnosis and obesity; this cohort had poorer outcomes than normal weight patients. However, this study had several limitations possibly influencing the results. First, solely male patients were analyzed, to the exclusion of female, and a small cohort of 32 patients was investigated (47% of whom were obese) over the course of 4 years (2001-2005). Our study included 21,901 males (811 of whom were obese) as well as 50,356 females (2621 of whom were obese), for a total cohort of 72, 257. It is possible that severity of obesity is a critical component in predisposing patients for poorer outcomes and Aghi’s cohort of patients may have a higher body mass index (BMI) average than other comparison cohorts, potentially interfering with data on mortality and complications.^[2]

The strengths of this study lie in its ability to assess the effect of weight at a large scale, which permits critical gender-specific explorations. However, there are also several limitations in this study that should be considered in future explorations. Obesity as coded in the NIS database does not involve severity levels, which is likely to be essential in understanding the association of obesity in the outcomes of patients. Future studies of obesity should involve BMI as an improved measure of obesity. Given the obesity rates found in this study

and recently increasing rates of obesity in the US, it is very likely that NIS data underestimates obesity. Unlike obesity, however, weight loss as coded in the NIS seems to involve fewer limitations. Lastly, our study is limited in that it can only assess short-term outcomes such as mortality and complications, however, future studies should also involve long-term outcomes such as hospital readmissions, overall survival and postdischarge complications, to name a few.

In congruence with the previously cited studies, our data emphasizes weight loss rather than obesity seems to be associated with poor outcomes among meningioma patients undergoing a craniotomy. Potentially explaining this result is that weight loss may be considered a proxy for malnutrition, a condition resulting in poor homeostasis. Patients experiencing preoperative weight loss have less nutritional reserve than patients who are overweight or mildly obese.^[11] Because protein energy requirements increase after surgery, sufficient nutritional reserve is essential for adequate recovery.^[7]

Based on the results of our study, weight status appears to be associated with both mortality and postoperative morbidity. Our findings show that factors such as weight loss, admission source, and specific postoperative complications are critical in determining cost and resource utilization burden in the care of meningioma patients undergoing a craniotomy. Our results emphasize the need for systematic assessment of weight loss history and nutritional status in all meningioma patients under consideration for craniotomy, especially in the context of alternative, less invasive treatment options such as radiosurgery. Furthermore, although obesity has long been considered a significant surgical risk factor, the results of our study demonstrate that this may not necessarily be the case, as in our cohort no obese men experienced death and the odds of mortality was less in obese women. Future studies that are able to take into account the severity of obesity may shed more light on the complex relationship between obesity and postsurgical meningioma patient outcomes.

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