Original Investigation

Association Between Bariatric Surgery and Long-term Survival

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IMPORTANCE Accumulating evidence suggests that bariatric surgery improves survival among patients with severe obesity, but research among veterans has shown no evidence of benefit.

OBJECTIVE To examine long-term survival in a large multisite cohort of patients who underwent bariatric surgery compared with matched control patients.

DESIGN, SETTING, AND PARTICIPANTS In a retrospective cohort study, we identified 2500 patients (74% men) who underwent bariatric surgery in Veterans Affairs (VA) bariatric centers from 2000-2011 and matched them to 7462 control patients using sequential stratification and an algorithm that included age, sex, geographic region, body mass index, diabetes, and Diagnostic Cost Group. Survival was compared across patients who underwent bariatric surgery and matched controls using Kaplan-Meier estimators and stratified, adjusted Cox regression analyses.

EXPOSURES Bariatric procedures, which included 74% gastric bypass, 15% sleeve gastrectomy, 10% adjustable gastric banding, and 1% other.

MAIN OUTCOMES AND MEASURES All-cause mortality through December 2013.

RESULTS Surgical patients (n = 2500) had a mean age of 52 years and a mean BMI of 47. Matched control patients (n = 7462) had a mean age of 53 years and a mean BMI of 46. At the end of the 14-year study period, there were a total of 263 deaths in the surgical group (mean follow-up, 6.9 years) and 1277 deaths in the matched control group (mean follow-up, 6.6 years). Kaplan-Meier estimated mortality rates were 2.4% at 1 year, 6.4% at 5 years, and 13.8% at 10 years for surgical patients; for matched control patients, 1.7% at 1 year, 10.4% at 5 years, and 23.9% at 10 years. Adjusted analysis showed no significant association between bariatric surgery and all-cause mortality in the first year of follow-up (adjusted hazard ratio [HR], 1.28 [95% CI, 0.98-1.68]), but significantly lower mortality after 1 to 5 years (HR, 0.45 [95% CI, 0.36-0.56]) and 5 to 14 years (HR, 0.47 [95% CI, 0.39-0.58]). The midterm (>1-5 years) and long-term (>5 years) relationships between surgery and survival were not significantly different across subgroups defined by diabetes diagnosis, sex, and period of surgery.

CONCLUSIONS AND RELEVANCE Among obese patients receiving care in the VA health system, those who underwent bariatric surgery compared with matched control patients who did not have surgery had lower all-cause mortality at 5 years and up to 10 years following the procedure. These results provide further evidence for the beneficial relationship between surgery and survival that has been demonstrated in younger, predominantly female populations.

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Bariatric surgery is associated with improved weight, obesity-related comorbidities, and quality of life among severely obese adults.[1-5] No long-term randomized clinical trials have been completed, but there is accumulating observational evidence that bariatric surgery is associated with better long-term survival than usual care.[6-8]

Bariatric surgery was associated with 29% lower all-cause mortality relative to a matched usual care control group (hazard ratio [HR], 0.71 [95% CI, 0.54-0.92]; *P* = .01) in 4047 patients followed for an average of 10.9 years in the prospective Swedish Obese Subjects (SOS) study.[6] A retrospective cohort study in Utah of 7925 patients receiving Roux-en-Y gastric bypass and 7925 matched controls with 7.1 years of follow-up suggested a 40% reduction in all-cause mortality (HR, 0.60 [95% CI, 0.45-0.67]; *P* < .001).[7] A large retrospective cohort study involving 66 109 obese patients from Washington state (3328 had bariatric surgery) reported 33% lower all-cause mortality at 15 years of follow-up (HR, 0.67 [95% CI, 0.54-0.85]).[8]

These studies examined lower-risk, predominantly female cohorts, but the long-term outcomes of bariatric patients with substantial comorbid disease are not known. A retrospective cohort study among veterans examined outcomes of 847 higher-risk, predominantly male patients who had surgery in 2000-2006 and 847 matched control patients and did not find that bariatric surgery was associated with lower mortality.[9] This finding differed from the existing literature at the time.[10]

These findings deserved further examination for 2 reasons. First, the perioperative morbidity and mortality of bariatric surgery have progressively declined over time.[11] Second, we hypothesized that longer follow-up and a larger sample size of patients might yield findings similar to prior reports, given that it took 10 years to observe a significant relationship between bariatric surgery and survival in the SOS study.[6]

Methods

Study Design and Study Population

The institutional review board provided waiver of participant consent. This was a retrospective cohort study of Veterans Affairs (VA) patients receiving bariatric surgery and a matched cohort of VA patients who were severely obese. This study was approved by the Surgical Quality Data Use Group of the VA Office of Patient Care Services and the institutional review boards of the Durham, North Texas, and Pittsburgh VA medical centers, and the Group Health Research Institute.

Using high-quality VA Surgical Quality Improvement Program data collected by trained surgical clinical nurses using a standardized abstraction form,[12] we identified all veterans who underwent any bariatric surgical procedure in any VA medical center from January 1, 2000, through September 30, 2011 (eFigure 1 in the Supplement). Bariatric patients were excluded if their records were missing body mass index (BMI, calculated as weight in kilograms divided by height in meters squared) or they had a BMI lower than 35. Furthermore, patients were excluded if their records had no valid bariatric procedure code or if they had a baseline diagnosis considered a medical exclusion for surgery (ie, recent cancer, Crohn disease, end-stage renal disease, pregnancy, or ascites), a presurgical stay longer than 5 days, or no inpatient stay recorded at date of surgery.

To identify potential matches for the patients in the surgical cohort, we used sequential stratification matching[13] or "risk-set matching"[14,15] because eligibility for surgical treatment was dependent upon time-varying characteristics (eg, BMI). Sequential stratification enables matching of treated to untreated (control) patients in longitudinal studies in which control patients have multiple potential index dates (eg, any BMI ≥35 observed in the data) and changing comorbid health condition incidence and severity. These time-varying covariates affect both the likelihood of receiving surgery at any given time and the probability of death, so properly accounting for them in the matching procedure is important to minimize bias.

Following methods described previously,[13,15] we organized the data to resemble a sequential series of randomized trials, with n = 1 surgical patient for each of the trials. The trial "start date" was each patient's date of surgery. For each surgical patient, we created a group of potential matches composed of severely obese patients (627 547 potential matches) who had not yet undergone bariatric surgery but had characteristics considered the most relevant to surgical eligibility and long-term outcomes. The characteristics used in identifying potential matches included sex, diabetes diagnosis (yes/no), race (white/other/unknown race), VA region, BMI in categories (<40, ≥40-<50, ≥50) measured within 6 months prior to the surgery date, and age within 5 years of the surgical patient's age.

For each surgical patient, a Mahalanobis distance function was then used to identify the closest matches with respect to age, BMI, and Diagnostic Cost Group (DCG) score within the group of potential matches. The DCG score aggregates inpatient and outpatient diagnoses in the year prior to baseline. A patient with a DCG score of 1.0 has health expenditures that are equal to those of the average Medicare patient; a score higher than 1.0 implies above-average expected expenditures; and a score lower than 1.0 implies below-average expected expenditures. In prior research, DCG scores were highly predictive of mortality[16] and expenditures[17] in bariatric surgery.

Up to 3 matches were selected for each surgical patient based on the smallest caliper[18] that preserved covariate balance while minimizing the loss of surgical patients due to a lack of comparable matches. Potential matches often had many BMI measurements over the study period, so each could match to more than 1 surgical patient. The matching process was not contingent upon future information, so control patients who underwent bariatric surgery at a later date could contribute person-time to the control group in models until they underwent bariatric surgery. We obtained surgical data only through September 30, 2011, so we were unable to censor any matched controls who potentially went on to have bariatric surgery after this date.

Mortality Outcome

The primary outcome was time until death from any cause. Death dates for all patients were obtained from 4 administrative data sets (Beneficiary Identification Records Locator Subsystem Death File, VA inpatient utilization files, Medicare Vital Status file, and the Social Security Administration's Death Master File).[19] Time until death was calculated from the surgical patient's day of surgery for both the patients and their corresponding matches until the death date or end of the observation period. The maximum possible survival time was 14 years (January 1, 2000-December 31, 2013).

Statistical Analysis

Covariate balance between the surgical patients and matched control patients was evaluated using standardized differences, which are insensitive to sample size.[20] Standardized differences less than 10% indicate reasonable covariate balance.[21] The association between bariatric surgery and all-cause mortality was examined in the matched cohorts using Kaplan-Meier estimators. All-cause mortality was then compared between surgical and matched control patients using a Cox model analysis adjusted for additional baseline covariates (specified below). The model was stratified by matched group, and a robust sandwich variance estimator[22] was used to account for the fact that the same individual could have been matched to multiple surgical patients. Inspection of log (−log[survival]) curves found that the proportional hazards assumption was violated, so follow-up time was split into 3 intervals: 1 year or less, more than 1 year to 5 years, and more than 5 years.[23]

We adjusted for several baseline covariates in these models, including age, BMI (continuous), DCG score, marital status (married/not married), free VA care due to disability (yes/no), and free VA care due to low income (yes/no). We also adjusted for the presence of comorbidities at baseline not used in sequential stratification matching, including hypertension, dyslipidemia, arthritis, depression, coronary artery disease, gastroesophageal reflux disease, asthma, fatty liver disease, posttraumatic stress disorder, alcohol abuse, substance abuse, and schizophrenia (identified using *International Classification of Diseases, Ninth Revision* [*ICD-9*] codes observed in the year prior to the surgical date).

We then conducted prespecified analyses of statistical effect modification by sex and diabetes diagnosis, because research suggests that survival benefits may differ by sex[24-28] and baseline diabetes status.[25-28] We conducted prespecified analyses to examine the relationship between surgery and mortality in 2 periods (2000-2005 and 2006-2011) to determine if mortality differed depending on when surgery occurred. Because the length of available follow-up time differed across these 2 periods, we modeled this interaction with follow-up intervals of 1 year or less, more than 1 year to 5 years, and more than 5 years to 8 years. For this analysis, patients in the 2000-2005 cohort were censored at December 31, 2007, and patients in the 2006-2011 cohort were censored at December 31, 2013, to provide comparable follow-up time with a maximum of 8 years for both cohorts.

We used the year 2006 as the basis for stratification because it was the midpoint of the study period, it was the year that the VA introduced a comprehensive weight management program (MOVE! Weight Management Program) that provided programmatic guidance on patient selection as well as preoperative management to all VA bariatric programs, and because the VA Bariatric Surgery Workgroup issued a comprehensive directive for pre- and postoperative patient care in the VA's bariatric centers in September 2005.[29,30] We also conducted post hoc statistical effect modification by super obesity (BMI <50 vs BMI ≥50) via interaction terms.

The a priori level of statistical significance was set at a 2-sided *P* of .05 for all analyses, which were performed using SAS (SAS Institute), version 9.2.

Results

Patient Characteristics in the Matched Cohorts

We identified 2752 patients who underwent any bariatric surgical procedure in VA bariatric centers from January 1, 2000, to September 30, 2011 (eFigure 1 in the Supplement). We excluded patients if their records were missing BMI data at time of surgery (n = 32) or had no valid bariatric surgery procedure code (n = 40), or if the patient never had a BMI above 35 (n = 15), preoperative medical exclusions (n = 120), a presurgical stay longer than 5 days (n = 24), or no inpatient stay record at date of surgery (n = 9). A total of 12 surgical patients were excluded because we were unable to find an appropriate matched control patient, resulting in a final surgical cohort of 2500 patients. After completing the matching process, the final control cohort included 7115 individual patients representing 7462 matches. Among these, 149 control patients (representing 161 matches) went on to have surgery, and their follow-up time as a matched control was censored at their date of surgery.

The cohorts of surgical patients (n = 2500) and control patients (n = 7462) were similar in all observed characteristics on which they were matched and most other covariates on which they were not matched (**Table 1**). Surgical patients had a mean age of 52 years, a mean BMI of 47, and a mean DCG score of 0.89. Matched control patients had mean age of 53 years, a mean BMI of 46, and a mean DCG score of 0.82. The majority of surgical patients and matched controls were men (74%), were white (81%), and had diagnosed diabetes (55%).

Based on standardized differences higher than 10%, several comorbidities were more prevalent among surgical patients, including hypertension (80% for surgical patients vs 70% for matched control patients), dyslipidemia (61% for surgical patients vs 52% for matched control patients), arthritis (27% for surgical patients vs 15% for matched control patients), depression (44% for surgical patients vs 32% for matched control patients), gastroesophageal reflux disease (35% for surgical patients vs 19% for matched control patients), and fatty liver disease (6.6% for surgical patients vs 0.6% for matched control patients). Surgical patients were less likely to be diagnosed with schizophrenia (1.8% for surgical patients vs 4.9% for matched control patients) or alcohol abuse disorders (3.9% for surgical patients vs 6.2% for matched control patients). Of

Table 1. Baseline Characteristics of Bariatric Surgical Patients and Matched Control Patients

	No. (%)		
	Surgical Patients (n = 2500)	Matched Control Patients (n = 7462)	Standardized Differences, %[b]
Variables Included in Matching			
Men	1849 (74)	5542 (74)	0
Diagnosed diabetes	1367 (55)	4077 (55)	0
Race/ethnicity			
White	2033 (81)	6072 (81)	0
Other/unknown	467 (19)	1390 (19)	0
Age, mean (SD), y	52 (8.8)	53 (8.7)	−1.8
BMI at baseline, mean (SD)	47 (7.9)	46 (7.3)	6.9
Super obese (BMI >50), No. (%)	730 (29)	2130 (29)	0
DCG score			9.4
Mean (SD)	0.89 (0.76)	0.82 (0.70)	
Median (IQR)	0.69 (0.38 to 1.17)	0.63 (0.35 to 1.11)	
Geographic region (VISN)			
New England (VISN1)	18 (0.7)	54 (0.7)	0
Upstate New York (VISN2)	9 (0.4)	27 (0.4)	0
New York/ New Jersey (VISN3)	57 (2.3)	171 (2.3)	0
Pennsylvania (VISN4)	251 (10)	746 (10)	0
Capitol (VISN5)	15 (0.6)	43 (0.6)	0
Mid-Atlantic (VISN6)	45 (1.8)	135 (1.8)	0
Southeast (VISN7)	52 (2.1)	155 (2.1)	0
Sunshine (VISN8)	150 (6.0)	449 (6.0)	0
MidSouth (VISN9)	293 (12)	879 (12)	0
Ohio (VISN10)	78 (3.1)	228 (3.1)	0
Michigan, Illinois, and Indiana (VISN11)	9 (0.4)	27 (0.4)	0
Great Lakes (VISN12)	66 (2.6)	193 (2.6)	0
Heartland (VISN15)	36 (1.4)	108 (1.4)	0
South Central (VISN16)	154 (6.2)	462 (6.2)	0
Texas (VISN17)	285 (11)	852 (11)	0
Southwest (VISN18)	32 (1.3)	96 (1.3)	0
Rocky Mountain (VISN19)	18 (0.7)	54 (0.7)	0
Northwest (VISN20)	171 (6.8)	513 (6.9)	0
Sierra Pacific (VISN21)	324 (13)	963 (13)	0
Desert Pacific (VISN22)	330 (13)	987 (13)	0
Midwest (VISN23)	107 (4.3)	320 (4.3)	0
Variables Not Included in Matching			
Married	1337 (53)	3651 (49)	9.1
Required to pay VA co-pays	279 (11)	716 (10)	5.2
Exempt from VA co-pays			
Due to disability	1381 (55)	3872 (52)	6.7
Due to low income	650 (26)	2169 (29)	−6.8

(continued)

Table 1. Baseline Characteristics of Bariatric Surgical Patients and Matched Control Patients (continued)

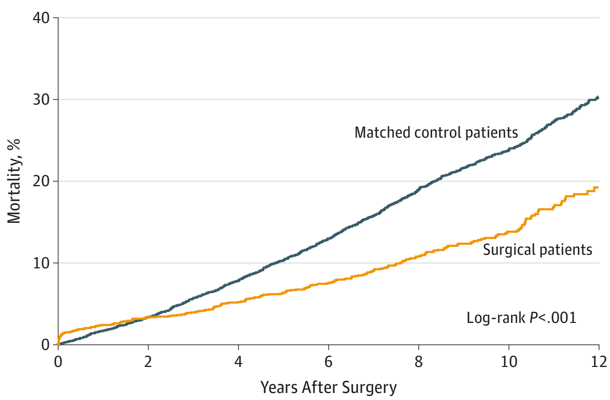
	No. (%)		
	Surgical Patients (n = 2500)	Matched Control Patients (n = 7462)	Standardized Differences, %[b]
Diagnoses[a]			
Hypertension	2012 (80)	5201 (70)	24
Dyslipidemia	1514 (61)	3905 (52)	17
Arthritis	685 (27)	1116 (15)	33
Depression	1103 (44)	2411 (32)	25
Coronary artery disease	494 (20)	1380 (18)	3.2
GERD	871 (35)	1429 (19)	38
Asthma	291 (12)	713 (10)	6.9
Fatty liver disease	164 (6.6)	43 (0.6)	43
PTSD	451 (18)	1198 (16)	5.3
Alcohol abuse	97 (3.9)	462 (6.2)	−10
Substance abuse	87 (3.5)	316 (4.2)	−3.8
Schizophrenia	44 (1.8)	365 (4.9)	−16
Surgical procedure type			
Adjustable gastric banding	249 (10)		
Biliopancreatic diversion	18 (0.7)		
Roux-en-Y gastric bypass			
Laparoscopic	525 (21)		
Open	1319 (53)		
Sleeve gastrectomy	381 (15)		
Vertical banded gastroplasty	8 (0.3)		

Abbreviations: BMI, body mass index; DCG, Diagnostic Cost Group; GERD, gastrointestinal reflux disease; IQR, interquartile range; PCOS, polycystic ovarian syndrome; PTSD, posttraumatic stress disorder; VA, Veterans Affairs; VISN, Veterans Integrated Service Network.

[a] All diagnoses were identified from inpatient and outpatient visit records using *International Classification of Diseases, Ninth Revision* codes.

[b] Standardized differences compare each covariate's mean or proportion between the surgical cases and matches in units of the pooled standard deviation; the difference is then multiplied by 100.[20]

Figure. Kaplan-Meier Estimated Mortality Curves for Surgical Patients and Matched Control Patients



No. at risk	0	2	4	6	8	10	12
Matched control patients	7462	7114	5306	3878	2641	1407	472
Surgical patients	2500	2416	1868	1412	1004	552	185

Entire cohort includes 2500 surgical patients and 7462 matched control patients; follow-up was censored at December 31, 2013. Estimated mortality rates were 2.4% at 1 year, 6.4% at 5 years, and 13.8% at 10 years for surgical patients; for matched control patients, 1.7% at 1 year, 10.4% at 5 years, and 23.9% at 10 years.

bariatric patients, 74% had Roux-en-Y gastric bypass, 15% had sleeve gastrectomy, 10% had adjustable gastric banding, and 1% had another procedure.

Association Between Bariatric Surgery and Mortality in Matched Cohorts

At the end of the 14-year study period, there were a total of 263 deaths in the surgical group (n = 2500; mean follow-up, 6.9 years) and 1277 deaths in the matched control group (n = 7462; mean follow-up, 6.6 years). Kaplan-Meier estimated mortality rates were 2.4% at 1 year, 6.4% at 5 years, and 13.8% at 10 years for surgical patients; for matched controls, estimated mortality rates were 1.7% at 1 year, 10.4% at 5 years, and 23.9% at 10 years (**Figure**).

In multivariable-adjusted Cox regression (**Table 2**), bariatric surgery was not associated with all-cause mortality in the first year of follow-up (HR, 1.28 [95% CI, 0.98-1.68]), but was associated with lower mortality after 1 to 5 years (HR, 0.45

Table 2. Number at Risk, Number Who Died, and Number Censored by Time Interval With Hazard Ratios for the Association Between Bariatric Surgery and Survival[a]

Time Interval[b]	Surgical Patients (n = 2500)[c] No. at Risk	No. Died	No. Censored	Matched Control Patients (n = 7462)[c] No. at Risk	No. Died	No. Censored	Hazard Ratio (95% CI)	*P* Value
Baseline to 1 y	2500	61	0	7462	129	67	1.28 (0.98-1.68)	.07
>1 to 5 y	2439	86	696	7266	554	2088	0.45 (0.36-0.56)	<.001
>5 to 14 y	1657	116	1541	4624	594	4030	0.47 (0.39-0.58)	<.001

[a] Covariates included in the multivariable-adjusted Cox regression model (fit using SAS PROC PHREG with the COVS[AGGREGATE]) were age, body mass index (continuous), Diagnostic Cost Group score, marital status, free Veterans Affairs care due to disability, free Veterans Affairs care due to low income, and baseline comorbidities (hypertension, dyslipidemia, arthritis, depression, coronary artery disease, gastrointestinal reflux disease, fatty liver disease, asthma, posttraumatic stress disorder, alcohol abuse, substance abuse, schizophrenia).

[b] Sample sizes presented within the table represent number of patients at risk at the beginning of each time interval, and number died and censored represent the number experiencing these events within each interval. Time period of study ranges from January 1, 2000, to December 31, 2013.

[c] Surgical patients were censored at the end of study, and matches were censored either at the end of study or at the date of their bariatric surgery if they later received such surgery.

[95% CI, 0.36-0.56]) and 5 or more years of follow-up (HR, 0.47 [95% CI, 0.39-0.58]). Results were robust to number of matches and the type of distance function for matching.

Statistical Effect Modification by Sex, Diabetes Status, Period of Surgery, and Super Obesity

Unadjusted Kaplan-Meier curves indicated that bariatric surgery was associated with lower mortality in both periods, 2000-2005 and 2006-2011 (eFigure 2 in the Supplement); however, in the multivariable-adjusted Cox model (**Table 3**) the association between bariatric surgery and mortality differed by period of surgery only in the first year of follow-up (*P* = .03). Veterans who underwent bariatric surgery in the 2000-2005 period had a greater risk of death than matched controls in their first year of follow-up (HR, 1.66 [95% CI, 1.19-2.33]), but there was no association (HR, 0.88 [95% CI, 0.53-1.43]) between bariatric surgery and mortality for patients in the 2006-2011 period in their first year of follow-up. The period by treatment interactions were not significant in either the 1- to 5-year follow-up interval or the more than 5- to 8-year follow-up interval.

Unadjusted Kaplan-Meier curves suggested that surgery was associated with lower mortality for patients with diabetes compared with those without diabetes (eFigure 3 in the Supplement) and for men compared with women (eFigure 4 in the Supplement). However, these interactions were not statistically significant in multivariable-adjusted Cox models (Table 3).

Unadjusted Kaplan-Meier curves suggested that surgery was associated with lower long-term mortality for both super obese (BMI ≥50) patients and less obese (BMI <50) patients (eFigure 5 in the Supplement), and the interactions between super obesity and treatment were not statistically significant in multivariable-adjusted Cox models (Table 3).

Discussion

Most observational evidence suggests that bariatric surgery is associated with improved survival among patients with severe obesity,[6-8] but previous research among veterans showed no significant relationship with survival.[9] This finding was contrary to the original hypothesis that severely obese veterans, often with multiple high-risk comorbid health conditions, would realize a survival benefit from bariatric surgery.[9] The unexpected result motivated us to re-examine these findings with 5 additional years of follow-up on the previously examined cohort and to expand the sample size with a more contemporary cohort (ie, 1653 additional surgical patients).

In these updated analyses, bariatric surgery was associated with a statistically significant reduction in all-cause mortality (HR, 0.47) relative to usual care after 5 years to 14 years of follow-up. This finding was consistent with several observational studies that examined lower-risk, predominantly female cohorts.[6-8] Notably, analyses suggested an association between bariatric surgery and greater risk of mortality in the first year of follow-up, although this was not statistically significant (HR, 1.28 [95% CI, 0.98-1.68]; *P* = .07).

In this study, we explored whether the association between bariatric surgery and mortality differed by period. Despite changes in patient selection and bariatric procedure types and increased use of laparoscopic procedures that have lowered operative and early postoperative risks over time,[11] we found similar associations with mortality in patients undergoing bariatric surgery in 2000-2005 and 2006-2011 after follow-up intervals of 1 year to 5 years and more than 5 years to 8 years. There was a significant (*P* = .03) interaction between period of surgery and mortality in the first year of follow-up, suggesting that earlier bariatric cases had a greater risk of operative and early postoperative mortality than more recent bariatric cases.

We also found no significant difference in the association of bariatric surgery on mortality across groups defined by sex, diabetes diagnosis, and super obesity; however, future studies with larger samples and longer-term follow-up should seek to confirm these findings. Despite the nonsignificant interaction indicating a constant relative risk, it is possible that a greater absolute number of deaths are avoided among some subgroups that are at higher risk of death (eg, patients with diabetes). It is also possible that significant differences by sex and diabetes status will be observed with even longer follow-up of the cohort if the mortality curves continue to diverge

Table 3. Hazard Ratios for Risk of Death After Bariatric Surgery From Adjusted Cox Regression Models With Interactions by Diabetes, Sex, Period of Surgery, and Super Obesity[a]

	Surgical Patients			Matched Control Patients				Surgical Patients			Matched Control Patients				
	No. at Risk	No. Died	No. Censored	No. at Risk	No. Died	No. Censored	Hazard Ratio (95% CI)	No. at Risk	No. Died	No. Censored	No. at Risk	No. Died	No. Censored	Hazard Ratio (95% CI)	*P* Value
Period of Surgery				2000-2005							2006-2011				
Baseline to 1 y	1159	46	0	3452	73	53	1.66 (1.19-2.33)	1341	15	0	4010	56	14	0.88 (0.53-1.43)	.03
>1 to 5 y	1113	41	681	3326	240	1973	0.50 (0.36-0.69)	1326	27	696	3940	234	2030	0.37 (0.25-0.54)	.22
>5 to 8 y[b]	391	8	383	1113	55	1058	0.44 (0.22-0.89)	603	12	591	1676	68	1608	0.53 (0.30-0.95)	.68
Diabetes				Yes							No				
Baseline to 1 y	1367	38	0	4077	92	30	1.18 (0.85-1.63)	1133	23	0	3385	37	37	1.54 (0.96-2.48)	.36
>1 to 5 y	1329	57	408	3955	376	1210	0.45 (0.34-0.59)	1110	29	288	3311	178	878	0.44 (0.30-0.64)	.91
>5 to 14 y	864	67	797	2369	393	1976	0.41 (0.32-0.53)	793	49	744	2255	201	2054	0.60 (0.44-0.81)	.05
Sex				Men							Women				
Baseline to 1 y	1849	55	0	5542	116	40	1.32 (0.99-1.76)	651	6	0	1920	13	27	0.98 (0.46-2.13)	.48
>1 to 5 y	1794	72	529	5386	501	1578	0.42 (0.33-0.53)	645	14	167	1880	53	510	0.72 (0.41-1.26)	.07
>5 to 14 y	1193	102	1091	3307	532	2775	0.46 (0.37-0.56)	464	14	450	1317	62	1255	0.64 (0.38-1.07)	.24
Super Obesity				Yes							No				
Baseline to 1 y	730	36	0	2130	59	42	1.57 (1.08-2.26)	1770	25	0	5332	70	25	1.13 (0.76-1.68)	.23
>1 to 5 y	694	38	99	2029	232	300	0.46 (0.33-0.64)	1745	48	597	5237	322	1788	0.47 (0.35-0.62)	.96
>5 to 14 y	557	53	504	1497	262	1235	0.45 (0.34-0.60)	1100	63	1037	3127	332	2795	0.54 (0.41-0.69)	.37

[a] Sample sizes presented within the Table represent the number of patients at risk at the beginning of each time interval, and number died and censored represent the number experiencing these events within each interval. Covariates included in adjusted analysis were age, body mass index (continuous), Diagnostic Cost Group score, marital status, free Veterans Affairs (VA) care due to disability, free VA care due to low income, and baseline comorbidities not included in sequential stratification match (hypertension, dyslipidemia, arthritis, depression, coronary artery disease, gastrointestinal reflux disease, fatty liver disease, asthma, posttraumatic stress disorder, alcohol abuse, substance abuse, schizophrenia). *P* values represent each interaction between bariatric surgery and the stratification variable.

[b] Follow-up was censored at December 31, 2007, in the 2000-2005 cohort to make maximum follow-up time equivalent to the 2006-2011 cohort, and enable period by treatment interaction terms.

(eFigure 3 and eFigure 4 in the Supplement). More research is needed to identify patient subgroups that receive the greatest survival benefit from bariatric surgery.

This study has several limitations that must be acknowledged. These analyses cannot address unobserved confounding that may persist after matching because this was a retrospective, nonrandomized study design, and not a randomized trial.[31] Due to the observational design, the estimated HRs represent associations and not necessarily the causal effect of bariatric surgery on survival. In this study, comorbid health conditions were identified using *ICD-9* diagnosis codes, which can be inaccurate and do not account for severity. Given sample size and statistical constraints related to the number of variables that could be accommodated in the matching process, we could not match on every available characteristic. This left some imbalances in other variables (Table 1; standardized differences greater than 10%) that were not part of our matching algorithm. Notably, these imbalances favored more comorbidity in the surgery group, which would generally be expected to bias the study against a survival benefit of surgery. We were unable to assess surgeon or institutional volume because most VA surgeons are affiliated with university hospitals and operate in both settings. Thus, any estimate of surgical volume that reflects only the VA bariatric cases is an underestimate. In addition, a minority of surgical cases (1%) were missing preoperative BMI data in the national databases and we did not have resources to conduct chart reviews to attempt to locate those missing measures; these small numbers are unlikely to affect our results.

Gaining a better understanding of the long-term outcomes of bariatric surgery is a priority for the National Institutes of Health.[32,33] Recent estimates indicate that more than 15% of the US adult population has a BMI of 35 or higher, and more than 6% is severely obese (BMI ≥40).[34] Compared with normal weight adults, those with a BMI of 35 or higher experience significantly greater all-cause mortality.[35] Yet, recent guidelines on the management of obesity have noted there is currently an outstanding need for evidence about the effects of behavioral, pharmacological, and surgical obesity treatments on long-term survival.[36,37] Our current study contributes to an increasing body of observational evidence that bariatric surgery is associated with better long-term survival than usual care.[6-8] Only randomized clinical trials could provide more definitive evidence that bariatric surgery improves survival, but large-scale bariatric randomized controlled trials are extremely challenging to conduct, often have limited generalizability, and may be prohibitively expensive.[32,33,38] As a result, clinicians and patients have to rely on the available observational research to make informed decisions about the potential effect of bariatric surgery on survival.[5]

Conclusions

Among obese patients receiving care in the VA health system, those who underwent bariatric surgery, compared with matched control patients who did not have surgery, had lower all-cause mortality at 5 years and up to 10 years following the procedure. These results provide further evidence for the beneficial relationship between surgery and survival that has been demonstrated in younger, predominantly female populations.[6-8]

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