Diabetes Care
American Diabetes Association

Health Expenditures Decline After Bariatric Surgery for Patients With Type 2 Diabetes

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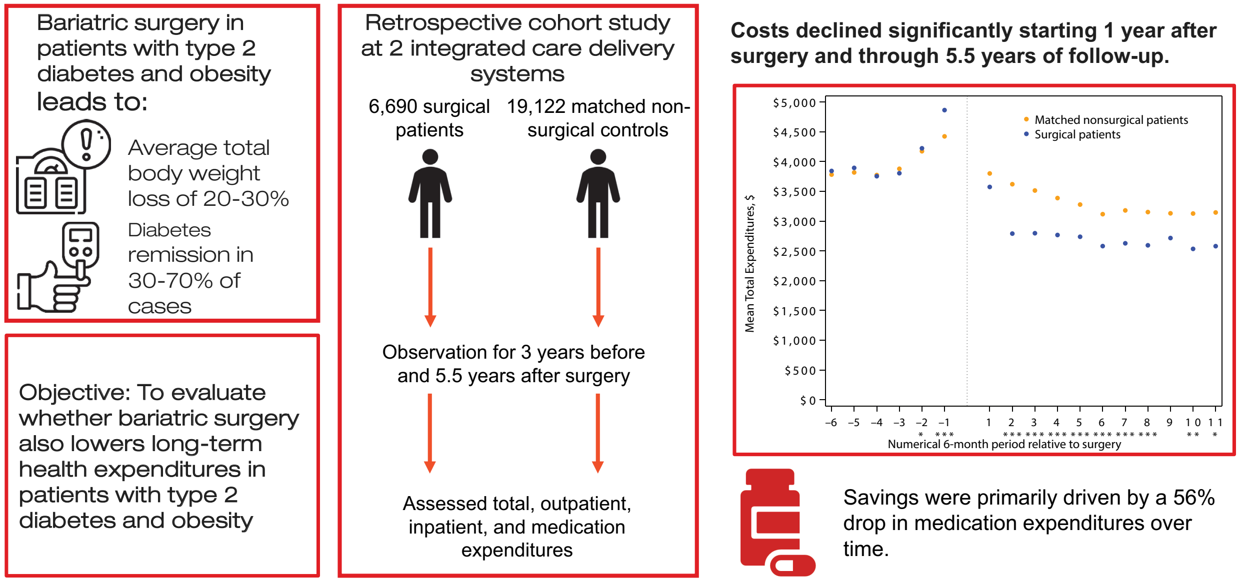
Diabetes Care 2025;48(9):1502–1511 | https://doi.org/10.2337/dc25-0254



ARTICLE HIGHLIGHTS

- **Why did we undertake this study?**
  The U.S. spends hundreds of billions of dollars on obesity and diabetes care annually. Bariatric surgery induces significant weight loss and type 2 diabetes remission, but no studies have evaluated whether surgery could also lower long-term health expenditures in this population.
- **What is the specific question we wanted to answer?**
  We compared health expenditures for 6,690 patients with obesity and type 2 diabetes who underwent bariatric surgery versus 19,122 matched nonsurgical patients.
- **What did we find?**
  Expenditures for patients undergoing bariatric surgery dropped significantly over 5.5 years of follow-up and were consistently lower than expenditures for nonsurgical patients.
- **What are the implications of our findings?**
  Bariatric surgery improves health among patients with type 2 diabetes and may lead to substantial cost savings.

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ORIGINAL ARTICLE

OBJECTIVE

Bariatric surgery lowers the risk of developing microvascular and macrovascular complications of type 2 diabetes, but it is unclear whether it also lowers long-term health expenditures in this population.

RESEARCH DESIGN AND METHODS

In a retrospective cohort study of 6,690 patients with obesity and type 2 diabetes who underwent bariatric surgery in 2012–2019 and 19,122 matched nonsurgical patients, we compared total, outpatient, inpatient, and medication expenditures 3 years presurgery and 5.5 years postsurgery, using generalized estimating equations. Expenditures were estimated in 6-month intervals.

RESULTS

Surgical and nonsurgical cohorts were well-matched, with 73% female, average BMI 44 kg/m^2, mean age 50 years, and 32% on insulin. Estimated total expenditures were similar between surgical and nonsurgical patients up to 1 year presurgery. Total expenditures were significantly lower for surgical patients starting 1 year postsurgery and up to 5.5 years postsurgery compared with control patients ($566 lower per 6-month interval at 5.5 years; 95% CI −$807, −$316). Expenditure differences were largely attributable to a 56% drop in medication expenditures for surgical patients, from $2,204 in the 6 months presurgery to $969 per 6-month interval at 5.5 years postsurgery. Surgical patients had a higher probability of inpatient admission throughout the postsurgical period (4.0–6.5% vs. 2.4–3.1% per 6-month interval).

CONCLUSIONS

Patients with type 2 diabetes undergoing bariatric surgery have significantly lower total postsurgical expenditures than matched control patients, primarily because of substantial reductions in pharmacy expenditures. The long-term cost savings associated with bariatric surgery are likely to increase further, given the rapidly escalating costs of diabetes pharmacotherapy.

Nearly 90% of patients with type 2 diabetes suffer from overweight or obesity (1). Patients with type 2 diabetes and obesity have higher rates of cardiovascular disease, sleep apnea, and mortality compared with those without obesity (2). The American Diabetes Association recommends weight management intervention to prevent the development and progression of comorbidities (3), either via lifestyle intervention, antiobesity medications (e.g., glucagon-like peptide 1 receptor agonists [GLP-1RA]), or bariatric surgery. Lifestyle intervention rarely leads to enough

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Received 31 January 2025 and accepted 7 May 2025

This article contains supplementary material online at https://doi.org/10.2337/figshare.29042288.

See accompanying article, p. 1478.

weight reduction to induce durable diabetes remission (1). GLP-1RA are consistently less effective at inducing total body weight loss in patients with type 2 diabetes compared with patients without diabetes, and their impact on diabetes remission is as yet unknown (4). Bariatric surgery, in contrast to other interventions, induces durable total body weight loss of 20–30% among people with type 2 diabetes (1,5), diabetes remission for 30–70% of patients even before appreciable weight loss (6–9), reduced risk of microvascular and macrovascular complications (5), and improved survival (5). These findings are consistent across bariatric surgery types, including Roux-en-Y gastric bypass (RYGB) and sleeve gastrectomy (SG), with the diabetes-related health benefits of RYGB generally considered to be greater than those of SG (1,9).

Rising obesity rates have significantly increased diabetes-related spending; in 2017, the U.S. spent an estimated \$237 billion on diabetes care (10). While bariatric surgery is an effective treatment of obesity, its direct cost in the U.S. is high, ranging from \$15,200 for SG to \$16,300 for RYGB (excluding pre- and postsurgical visits) (11). This high cost has led commercial and public payors to limit coverage. There may be value in prioritizing coverage for those patients who are most likely to benefit clinically and save costs in the long term. Among the general population of patients with obesity, observational studies and randomized trials have found that bariatric surgery does not lead to long-term cost savings (11–14), although one observational study did find a promising return on investment for patients with class 3 obesity (BMI >40 kg/m^2) (15). Among patients with type 2 diabetes, bariatric surgery has been shown to lead to lower pharmacy expenditures for diabetes and other diseases (4,11,13,16–19), but the impact on total health expenditures in the U.S. is unclear.

To date, no studies have evaluated long-term (>5 years) total expenditures following bariatric surgery versus usual medical care in a real-world cohort of patients with type 2 diabetes in the U.S. To address this gap and provide the evidence base needed for payors to make coverage prioritization decisions, we compare health expenditures over a 5.5-year follow-up period for patients with obesity class 2 and above (BMI >35 kg/m^2) and type 2 diabetes who did or did not undergo bariatric surgery via RYGB or SG.

RESEARCH DESIGN AND METHODS

Study Design and Population

In this target trial emulation study (20), we compared long-term expenditures among retrospective cohorts of patients with obesity class 2 or higher and type 2 diabetes who underwent bariatric surgery between 1 January 2012 and 31 December 2019 versus a matched cohort of patients who did not undergo bariatric surgery. Patients received care at two large, nonprofit integrated care delivery systems in the western and northwestern U.S. The target trial being emulated (Supplementary Table 1) is a pragmatic, two-stage nested design in which patients are first pseudorandomized to surgery or not (at the day of surgery). Patients receiving surgery are then pseudorandomized to RYGB or SG.

Patients were defined as having diabetes if they had hemoglobin A_{1c} (HbA_{1c}) $\geq$6.5% at the most recent measure prior to the index date, or if they had two or more fills for a diabetes medication separated by $\geq$30 days in the 12 months prior to the index date. Diabetes medications included metformin, sulfonylureas, thiazolidinediones, dipeptidyl peptidase 4 inhibitor (DPP-4i), sodium–glucose cotransporter 2 inhibitors (SGLT2i), GLP-1RA, and insulin. Since metformin could be prescribed for other conditions (e.g., prediabetes and polycystic ovarian syndrome), patients taking metformin were also required to have one or more diabetes diagnosis codes in the 12 months prior to the index date. At the time of the observation period, SGLT2i was only approved for use in diabetes. Patients with type 1 diabetes were excluded. After all exclusions (Supplementary Fig. 1), the final surgical cohort included 6,690 patients with BMI $\geq$35 kg/m^2.

We identified 1,269,362 potential nonsurgical matches from the electronic health record, based on meeting the same inclusion and exclusion criteria as surgical patients (Supplementary Fig. 1), including type 2 diabetes as defined above and BMI $\geq$35 kg/m^2 between 1 July 2011 and 30 June 2020 (21,22). We used sequential stratification matching (22) to make the cohorts comparable, because this method allows for matching in longitudinal studies where comparators have multiple potential index dates and evolving comorbidity incidence (Supplementary Methods). Nonsurgical patients were matched to each surgical patient based on region, sex, age, race, insulin use (yes/no), micro- or macrovascular diabetes complications, BMI, insurance type (commercial, Medicare, Medicaid, other), number of comorbid conditions from the Gagne score (23), and health care usage in the 7–12 months prior to the index date (24). As in prior work (13), up to three matches for each surgical patient were selected based on minimizing a distance function including continuous covariates (25).

Nonsurgical patients could be matched to multiple surgical patients, so there were 14,944 individuals in the final nonsurgical cohort, representing 19,122 matches. Some matched nonsurgical patients may have later undergone bariatric surgery themselves. These patients contributed "untreated" person-time until 6 months prior to their surgery date, when they were then censored. We used the Kaplan-Meier method to estimate cohort loss due to disenrollment or death. Patients were administratively censored at the end of the study period (31 December 2020).

Health Expenditures

We compared outpatient, inpatient, medication, and total expenditures between the surgical and nonsurgical cohorts 3 years prior to enrollment in the cohort and for up to 5.5 years after. For surgical patients, the postsurgical period began the day after discharge from the index admission. For nonsurgical patients, the postindex period began the day after the BMI measurement used in matching, which had to fall within 6 months of the matched surgical patient's index admission. Expenditures were calculated in 6-month intervals. To determine outpatient expenditures, we multiplied usage of each health care type (emergency department visits, outpatient visits, laboratory, radiology, skilled nursing facility, hospice, and home health) by the unit cost of each health care type (Supplementary Methods). To determine inpatient expenditures, we used Medicare reimbursement rates for diagnostic related groups.

Patients were censored after death. If a patient was enrolled in the integrated health system for only part of a 6-month interval for any reason aside from death (e.g., disenrollment from the health system), we prorated expenditures based on the number of days enrolled in that interval. If a patient had no observed health care usage during a 6-month interval, expenditures were set to $0, unless the patient was disenrolled from the integrated health system for the entire period, at which point costs were censored. Consistent with our prior work, the expenditures of the bariatric hospitalization itself were excluded from the model, because estimates were obtained using different sources and assumptions, and the limited variability in estimates across patients made it difficult to fit the models (19). We inflation-adjusted all expenditures to 2020 dollars using the Personal Consumption Expenditure Price Index (26).

Statistical Analysis

We evaluated covariate balance at baseline between surgical and nonsurgical cohorts using standardized mean differences (SMDs) (27). After specification testing (28), we used generalized linear models via generalized estimating equations (GEEs) with log link and SD proportional to the mean to estimate total and outpatient medication expenditures, with an exchangeable covariance and empirical sandwich SEs. Specification testing for outpatient expenditures indicated a GEE model with a log link and variance proportional to the mean. Because the proportion of patients who were hospitalized in any given 6-month interval was low (2–6%), a marginalized two-part model (29) of inpatient expenditures did not converge, so we estimated the probability of inpatient usage using logistic regression fit with GEEs. We also described unadjusted inpatient expenditures for the overall cohort as well as the subset of admitted patients. We pooled patients undergoing RYGB and SG in regression analysis.

All models adjusted for procedure type (RYBG or SG; control patients were assigned the procedure type of the matched surgical patient), study site, insurance type, demographic characteristics, BMI, Gagne score, presence of several comorbidities, smoking status, and diabetes-specific covariates (Supplementary Methods). Models included an indicator for receiving surgery, indicators for each 6-month interval, and all interactions between them. Average expenditures and expenditure differences were calculated using model-estimated expenditures with bootstrapped 95% CIs. Statistical significance was determined from model results and set a priori at 0.05 for all analyses, which were conducted in SAS 9.4 (SAS Institute, Cary, NC).

This study was approved by Institutional Review Boards at each institution involved in the study. Informed consent was waived.

RESULTS

Patient Characteristics

Surgical (*n* = 6,690) and matched nonsurgical (*n* = 19,122) cohorts were similar at baseline in nearly all characteristics (Table 1). Mean age was 50 years, mean BMI was 44 kg/m^2, and mean Gagne comorbidity score was 0.9 for surgical patients and 1.4 for matched control patients (SMD 29.7%). Most surgical and matched nonsurgical patients were female (74%), had White race (35%) or Hispanic ethnicity (45%), and had commercial insurance (81%). Diagnosed steatotic liver disease (16.5% vs. 1.5%, SMD 54.4%) and depression (30.0% vs. 8.7%, SMD 55.7%) were more prevalent among surgical patients than nonsurgical matches, potentially owing to presurgical screening for these conditions. Mean HbA_{1c} at baseline was higher in nonsurgical patients (7.7% vs. 7.1%, SMD 48.4%). A third of patients in both groups (32%) used insulin at baseline. Type 2 diabetes duration was 5.2 years for surgical patients and 5.4 years for nonsurgical patients (SMD 5.0%). Only 2.0% of surgical patients and 1.2% of nonsurgical patients used GLP-1RA at baseline (SMD 6.8%).

The estimated proportions of patients with 5-year follow-up were 81% for surgical patients and 75% for nonsurgical patients (Supplementary Fig. 2).

Expenditures of Surgical and Nonsurgical Patients

Total Expenditures

Overall estimated total expenditures were similar between surgical and nonsurgical patients in the 13–36 months before the index date (Fig. 1), averaging approximately $3,700 to $3,800 per 6-month interval. Expenditures were significantly higher for the surgical cohort in the 6 months prior to surgery ($4,865 vs. $4,424 per 6-month interval; difference = $441; 95% CI $303, $585). Total expenditures then became significantly lower for the surgical cohort starting at 12 months after the index date (difference = −$830 at 13–18 months postsurgery; 95% CI −$984, −$670) and through 5.5 years of follow-up (difference = −$566 at 5–5.5 years postsurgery; 95% CI −807, −316).

Overall, average cumulative expenditures were $6,157 lower for surgical patients compared with nonsurgical control patients over the 5.5-year follow-up period. Compared with presurgical levels, estimated overall total expenditures for surgical patients declined by 28%, from $3,574 in the 6 months presurgery to $2,580 at 5–5.5 years postsurgery.

Outpatient Expenditures

Model-estimated outpatient expenditures were similar for surgical and matched nonsurgical patients in the 13–36 months before the index date (Fig. 2), ranging from $900 to $1,000 per 6-month interval. Outpatient expenditures were higher for patients in the surgical cohort compared with the nonsurgical cohort in the 7–12 months before surgery ($1,484 vs. $1,351; difference = $133; 95% CI $116, $151). Outpatient expenditures became slightly lower for the surgical cohort in the 7–12 months after surgery (difference = −$70; 95% CI −$94, −$43) and were similar between the two cohorts for the remaining 4.5 years.

Outpatient Medication Expenditures

Model-estimated medication expenditures were $100 to $250 lower per 6-month interval for the surgical cohort compared with the nonsurgical cohort throughout the 3-year period prior to the index date (Fig. 3). After the index date, medication expenditures in the surgical cohort dropped significantly and remained significantly lower compared with the nonsurgical cohort for the entire 5.5-year follow-up period. Overall, there was a 56% drop in medication expenditures for surgical patients, from $2,204 in the 6 months presurgery to $969 at 5–5.5 years postsurgery. At 5.5 years, estimated medication expenditures remained $698 lower per 6-month interval in the surgical cohort compared with the nonsurgical cohort (95% CI −$907, −$495).

Overall, average cumulative medication expenditures were $9,777 lower for surgical patients compared with nonsurgical patients over the entire 5.5-year follow-up period.

Table 1—Baseline characteristics of bariatric surgery patients and matched nonsurgical patients with diabetes

	Matched control patients	Surgical patients	SMD, %
N	19,122	6,690	
Year of surgery/index date, *n* (%)			8.6
2011–2012	3,188 (16.7)	985 (14.7)	
2013–2014	3,545 (18.5)	1,236 (18.5)	
2015–2016	4,916 (25.7)	1,674 (25.0)	
2017–2018	5,338 (27.9)	1,887 (28.2)	
2019	2,135 (11.2)	908 (13.6)	
Demographic characteristics			
Female, *n* (%)	14,035 (73.4)	4,909 (73.4)	0.0
Age, mean (SD), years	50.5 (10.4)	49.9 (10.5)	6.0
Age in years, categories, *n* (%)			5.1
21 to <45	5,968 (31.2)	2,244 (33.5)	
45 to <65	11,525 (60.3)	3,918 (58.6)	
≥65	1,629 (8.5)	528 (7.9)	
Race and ethnicity categories, *n* (%)			3.2
White	6,650 (34.8)	2,332 (34.9)	
Black	3,001 (15.7)	1,072 (16.0)	
Asian	375 (2.0)	148 (2.2)	
Hispanic	8,824 (46.1)	3,025 (45.2)	
Other or unknown	272 (1.4)	113 (1.7)	
Insurance type, *n* (%)			2.8
Commercial	15,681 (82.0)	5,426 (81.1)	
Medicare	1,738 (9.1)	615 (9.2)	
Medicaid	1,327 (6.9)	502 (7.5)	
Other or unknown	376 (2.0)	147 (2.2)	
Diabetes characteristics			
BMI, mean (SD), kg/m^2	43.0 (6.0)	43.8 (6.5)	11.9
BMI categories, *n* (%), kg/m^2			11.3
35 to <40	7,015 (36.7)	2,206 (33.0)	
40 to <50	9,611 (50.3)	3,399 (50.8)	
50 to <60	2,253 (11.8)	939 (14.0)	
≥60	243 (1.3)	146 (2.2)	
Complicated diabetes, *n* (%)[a]	8,755 (45.8)	3,097 (46.3)	1.0
Diabetes duration, mean (SD), years	5.4 (4.5)	5.2 (4.5)	5.0
Insulin use, *n* (%)	6,291 (32.9)	2,181 (32.6)	0.6
HbA_{1c}, mean (SD)	7.7 (1.5)	7.1 (1.0)	48.4
HbA_{1c} categories, *n* (%)			45.3
Missing	49 (0.3)	30 (0.4)	
<6.5%	3,057 (16.0)	1,775 (26.5)	
6.5 to <7%	4,610 (24.1)	1,966 (29.4)	
7 to <8%	5,149 (26.9)	1,910 (28.6)	
≥8%	6,257 (32.7)	1,009 (15.1)	
Advanced DiaRem score, mean (SD)[b]	9.1 (5.2)	8.2 (5.1)	17.4
Advanced DiaRem score categories, *n* (%)[b]			17.5
Missing	63 (0.3)	33 (0.5)	
0–2	1,487 (7.8)	726 (10.9)	
3–7	6,668 (34.9)	2,617 (39.1)	
8–12	5,515 (28.8)	1,779 (26.6)	
13–17	4,284 (22.4)	1,278 (19.1)	
18–21	1,105 (5.8)	257 (3.8)	
Diabetes medications, *n* (%)			
α-Glucosidase inhibitor	103 (0.5)	32 (0.5)	0.8
Amylinomimetic	—	—	0.1
Glinide	11 (0.1)	—	1.2
Metformin	13,233 (69.2)	4,677 (69.9)	1.5
Thiazolidinedione	762 (4.0)	253 (3.8)	1.1
DPP-4i	313 (1.6)	133 (2.0)	2.6
GLP-1RA	220 (1.2)	134 (2.0)	6.8
SGLT2i inhibitor	156 (0.8)	69 (1.0)	2.3
Sulfonylurea	7,755 (40.6)	2,373 (35.5)	10.5

Continued on p. 1506

Table 1—Continued

	Matched control patients	Surgical patients	SMD, %
Other clinical characteristics			
Gagne score, mean (SD)	1.4 (1.9)	0.9 (1.5)	29.7
Antihypertensive medication use, *n* (%)	12,828 (67.1)	4,129 (61.7)	11.2
Systolic blood pressure, mean mmHg (SD)[c]	131.3 (14.8)	130.3 (14.3)	6.5
Diastolic blood pressure, mean mmHg (SD)[c]	75.2 (10.7)	74.8 (10.2)	4.1
HDL cholesterol, mean mg/dL (SD)[c]	44.7 (10.6)	44.5 (10.3)	2.5
Total cholesterol, mean mg/dL (SD)[c]	168.3 (40.0)	166.3 (38.1)	5.1
Smoking status, *n* (%)			8.8
Missing[d]	—	—	
Current smoker	>3,963 (20.7)	>1,627 (24.3)	
Not a current smoker	15,149 (79.2)	5,053 (75.5)	
Comorbidities, *n* (%)			
Alcohol use disorder	186 (1.0)	71 (1.1)	0.9
Anemia	1,327 (6.9)	792 (11.8)	16.9
Arrhythmia	789 (4.1)	397 (5.9)	8.3
Congestive heart failure	469 (2.5)	262 (3.9)	8.3
Coagulopathy	126 (0.7)	39 (0.6)	1.0
Dementia[d]	12 (0.1)	—	2.4
Fluid and electrolyte disorders	904 (4.7)	332 (5.0)	1.1
Hemiplegia	49 (0.3)	12 (0.2)	1.6
HIV/AIDS[d]	—	—	1.9
Hypertension	13,723 (71.8)	4,453 (66.6)	11.3
Liver disease	1,342 (7.0)	905 (13.5)	21.6
Psychosis	2,131 (11.1)	894 (13.4)	6.8
Pulmonary circulation disorders	112 (0.6)	51 (0.8)	2.2
Pulmonary disease	3,345 (17.5)	1,298 (19.4)	4.9
Peripheral vascular disorder	883 (4.6)	308 (4.6)	0.1
Renal failure	1,524 (8.0)	773 (11.6)	12.1
Any tumor	34 (0.2)	50 (0.7)	8.4
Weight loss	37 (0.2)	16 (0.2)	1.0
Atrial fibrillation	131 (0.7)	148 (2.2)	12.8
Cirrhosis	43 (0.2)	81 (1.2)	11.7
Steatotic liver disease	289 (1.5)	1,107 (16.5)	54.4
Eating disorder	41 (0.2)	80 (1.2)	11.7
Gastroesophageal reflux disease	784 (4.1)	2,245 (33.6)	81.3
Depression	1,673 (8.7)	2,004 (30.0)	55.7
Myocardial infarction	165 (0.9)	181 (2.7)	14.0
Venous thromboembolism	47 (0.2)	45 (0.7)	6.3
Inferior vena cava filter	—	17 (0.3)	5.7
Risk of pulmonary embolism	175 (0.9)	329 (4.9)	24.0
Stroke, TIA, cerebrovascular disease	130 (0.7)	114 (1.7)	9.4
Hiatal hernia	33 (0.2)	1,010 (15.1)	58.6
Mental health severity, *n* (%)			31.4
No mental health diagnosis	14,240 (74.5)	4,009 (59.9)	
Mild-moderate diagnosis[e]	4,599 (24.1)	2,515 (37.6)	
Severe diagnosis[f]	283 (1.5)	166 (2.5)	
Baseline health care usage[g]			
Inpatient days, mean (SD)	0.0 (0.1)	0.0 (0.2)	4.3
Ambulatory care days, mean (SD)	9.6 (6.5)	11.6 (7.9)	28.2
Emergency department days, mean (SD)	0.1 (0.4)	0.2 (0.5)	5.3

TIA, transient ischemic attack. [a]Complicated diabetes was defined as ICD-9 codes 250.4–250.9 or ICD-10 codes E10.2–E10.8, E11.2–E11.8, E12.2–E12.8, E13.2–E13.8, and E14.2–E14.8 (38). [b]The advanced DiaRem score is a validated measure of the probability of diabetes remission after bariatric surgery (39). The score takes into account age, HbA_{1c}, diabetes duration, insulin use (yes/no), and number of other glucose-lowering agents prescribed. Patients with lower scores are more likely to achieve diabetes remission after bariatric surgery compared with people with higher scores. [c]Percent missing systolic BP = <1%, diastolic BP = <1%, HDL cholesterol = <1%, and total cholesterol = <1%. [d]Cells representing 1–10 patients are suppressed. [e]Mental health codes excluding dementia, suicidal ideation, remission codes, and conditions coded in the "Severe" diagnosis group. [f]Includes codes for the following conditions (excluding remission codes): psychotic disorder or symptoms, schizophrenia spectrum disorder, other nonschizophrenic psychotic disorders, and bipolar/manic disorder. [g]Inpatient admissions, ambulatory care visits, and emergency department visits were in the 7–12 months prior to index date.

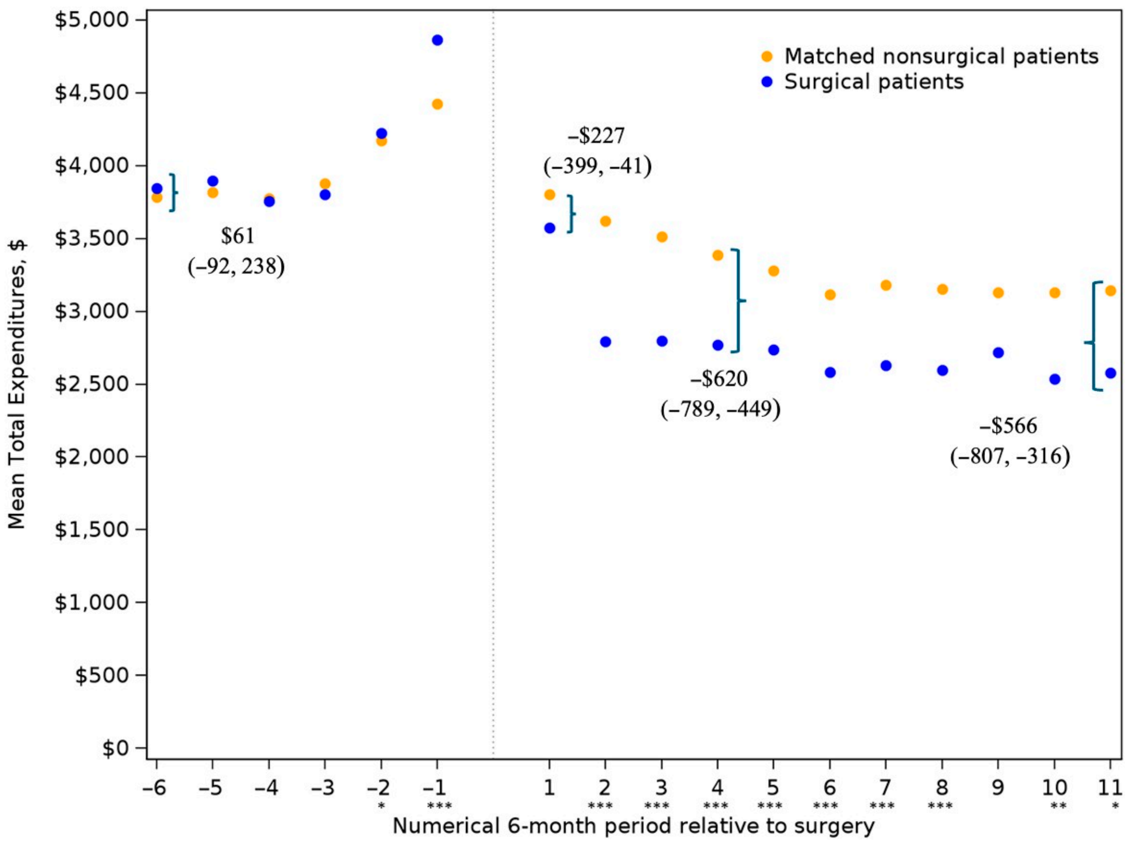

Figure 1—Total expenditures: model-estimated trends for surgical patients and nonsurgical matches with obesity and diabetes. **P* < 0.05, ***P* < 0.01, ****P* < 0.001. *P* values are obtained from model estimating the relative difference between surgical and matched nonsurgical patients adjusting for baseline characteristics. Numbers listed are estimated surgical vs. nonsurgical differences (95% CI). Model is adjusted for surgical procedure (nonsurgical patients were assigned the value of their matched surgical patient), study site, insurance type, sex, race, age, BMI, Gagne score, and presence or absence of several comorbidities, including alcohol use disorder, anemia, arrhythmia, congestive heart failure, coagulopathy, complicated diabetes, dementia, fluid and electrolyte disorders, hemiplegia, HIV/AIDS, hypertension, liver disease, psychosis, pulmonary circulation disorders, peripheral vascular disorder, renal failure, any tumor, weight loss, insulin use, antihypertensive medication use, atrial fibrillation, cirrhosis, depression, steatotic liver disease, eating disorder, gastroesophageal reflux disease, myocardial infarction, venous thromboembolism, risk of pulmonary embolism, inferior vena cava filter, stroke, hiatal hernia, smoking status, HbA_{1c}, and advanced DiaRem score.

Inpatient Admissions

The model-estimated probability of all-cause admission was 1.9 percentage points (pp) higher for surgical patients 3 years before the index date and 2.1 pp lower 6 months before the index date, compared with nonsurgical patients (2.1 pp [95% CI 1.6, 2.3] at 3 years presurgery vs. 4.2 pp [95% CI 3.9, 4.5] at 6 months presurgery) (Supplementary Fig. 3*A*). In the first 6-month interval after the index date, the estimated probability of admission was 3.7 pp higher for the surgical cohort compared with the nonsurgical cohort (6.3 pp [95% CI 5.7, 6.9] vs. 2.6 pp [95% CI 2.4, 2.8]). Surgical patients continued to have a higher probability of admission throughout the remaining 5.5 years of follow-up.

Mean unadjusted inpatient expenditures ranged from $231 to $845 per 6-month interval for surgical patients and $203 to $788 per 6-month interval for matched nonsurgical patients over the 3 years before surgery (Supplementary Fig. 3*B*). After the index date, inpatient expenditures were generally higher in the surgical cohort ($714 to $1,155 per 6-month interval) compared with the nonsurgical cohort ($574 to $962 per 6-month interval). Among the 2–6% of patients who were hospitalized in a given 6-month interval, there was little difference in inpatient expenditures between surgical and nonsurgical cohorts (Supplementary Fig. 4).

CONCLUSIONS

In this study of patients with obesity and type 2 diabetes who were eligible for bariatric surgery in 2012–2019, we estimated that total expenditures dropped 28% after surgery and remained lower than those of nonsurgical matched control patients throughout the 5.5-year postsurgical observation period. The observed postsurgical reduction in total expenditures of ∼$200 to $400 per 6-month period after surgery was primarily driven by a 56% reduction in medication expenditures from 6 months prior to 5.5 years after surgery. Inpatient expenditures after the index date were higher in the surgical cohort but did not completely offset the large savings in medication expenditures. Commercial prices are typically two to three times larger than the Medicare unit prices used here, so the cumulative cost reduction over the postsurgical period translates to an ∼$12,000 to $18,000 reduction in total expenditures for commercially insured patients undergoing bariatric surgery.

Our finding that medication expenditures dropped significantly for surgical

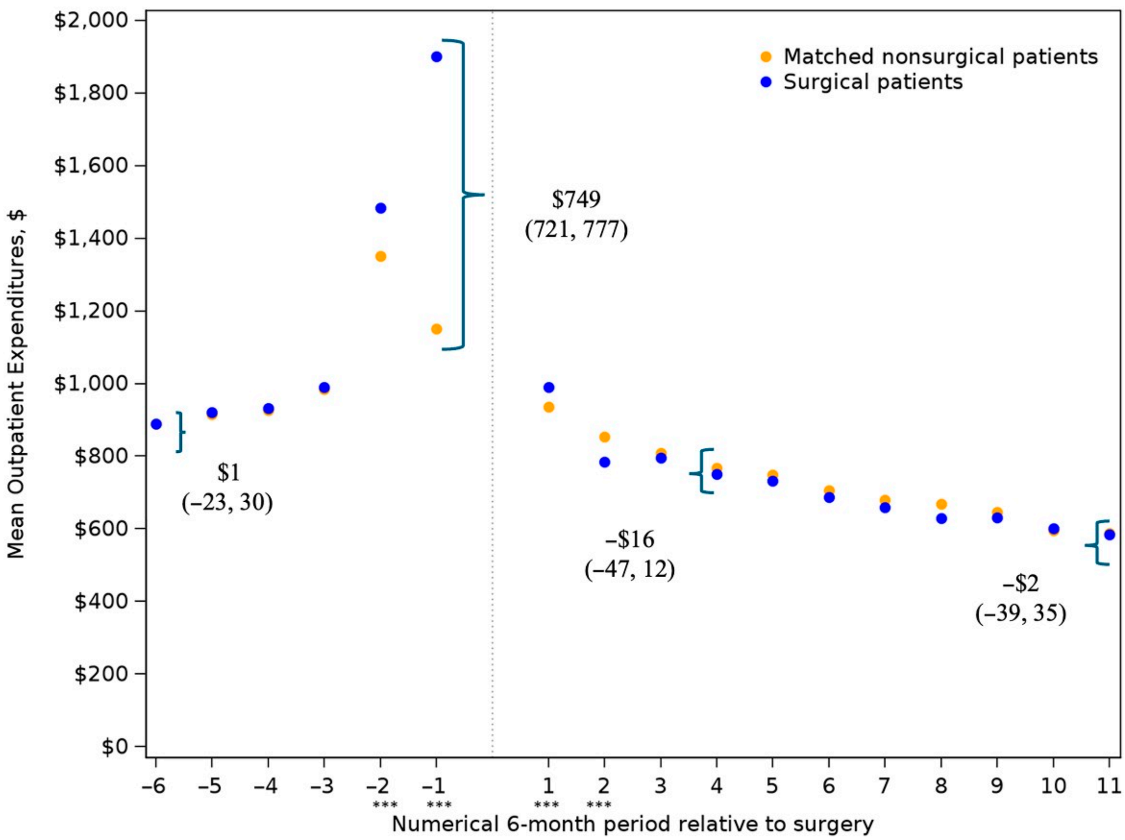

Figure 2—Outpatient expenditures: model-estimated trends for surgical patients and nonsurgical matches with obesity and diabetes. ****P* < 0.001. *P* values are obtained from model estimating the relative difference between surgical and matched nonsurgical patients adjusting for baseline characteristics. Numbers listed are estimated surgical vs. nonsurgical differences (95% CI). Model is adjusted for surgical procedure (nonsurgical patients were assigned the value of their matched surgical patient), study site, insurance type, sex, race, age, BMI, Gagne score, and presence or absence of several comorbidities, including alcohol use disorder, anemia, arrhythmia, congestive heart failure, coagulopathy, complicated diabetes, dementia, fluid and electrolyte disorders, hemiplegia, HIV/AIDS, hypertension, liver disease, psychosis, pulmonary circulation disorders, peripheral vascular disorder, renal failure, any tumor, weight loss, insulin use, antihypertensive medication use, atrial fibrillation, cirrhosis, depression, steatotic liver disease, eating disorder, gastroesophageal reflux disease, myocardial infarction, venous thromboembolism, risk of pulmonary embolism, inferior vena cava filter, stroke, hiatal hernia, smoking status, HbA_{1c}, and advanced DiaRem score.

patients with type 2 diabetes is consistent with several prior studies (13,16,17,30), including an analysis of 15-year expenditures in the subset of patients with type 2 diabetes from the Swedish Obesity Subjects (SOS) study (18). The similarity in outpatient expenditures between surgical and nonsurgical patients over time is also consistent with SOS and other studies. Unlike SOS, we also found that total expenditures were lower for surgical patients compared with matched nonsurgical patients over the entire 5.5-year follow-up period. This discrepancy may be due to the advent of newer and more expensive chronic disease medications (including diabetes medications) since the SOS and other studies were completed. Additionally, the prices of medications in the U.S. are considerably higher than in European countries (31), so any medication discontinuation in a U.S. context is likely to have a larger effect on expenditures. Future research should decompose the medication expenditures of patients undergoing versus not undergoing bariatric surgery to determine whether diabetes medication discontinuations are driving medication expenditure reductions.

These findings also suggest that patients with type 2 diabetes undergoing bariatric surgery have a more favorable cost profile than the general population of patients undergoing bariatric surgery, whose total expenditures have previously been shown to be similar to those of matched control patients over the long term (11,13,18). Bariatric surgery is known to lead to short- and long-term type 2 diabetes remission (6,7,32) and to reduce the risk of microvascular and macrovascular complications (5), so the reduced costs may be due to a reduced need for care related to those conditions. Additionally, patients with type 2 diabetes have higher presurgical expenditures than patients without type 2 diabetes and thus have greater room for cost reduction (18). For example, 33% of patients in our study were taking insulin, which cost an average of $6,000/year at the time of the observation period (33).

It is important to note that GLP-1RA and SGLT2i use was low (<2.0% use at baseline) during this study period. The American Diabetes Association now recommends initiating treatment with GLP-1RA or SGLT2i for patients with type 2 diabetes who have cardiac complications, renal complications, or obesity (34). As use of these expensive medications continues its dramatic rise, their postsurgical discontinuation, when clinically appropriate, may further increase the long-term cost savings associated with bariatric

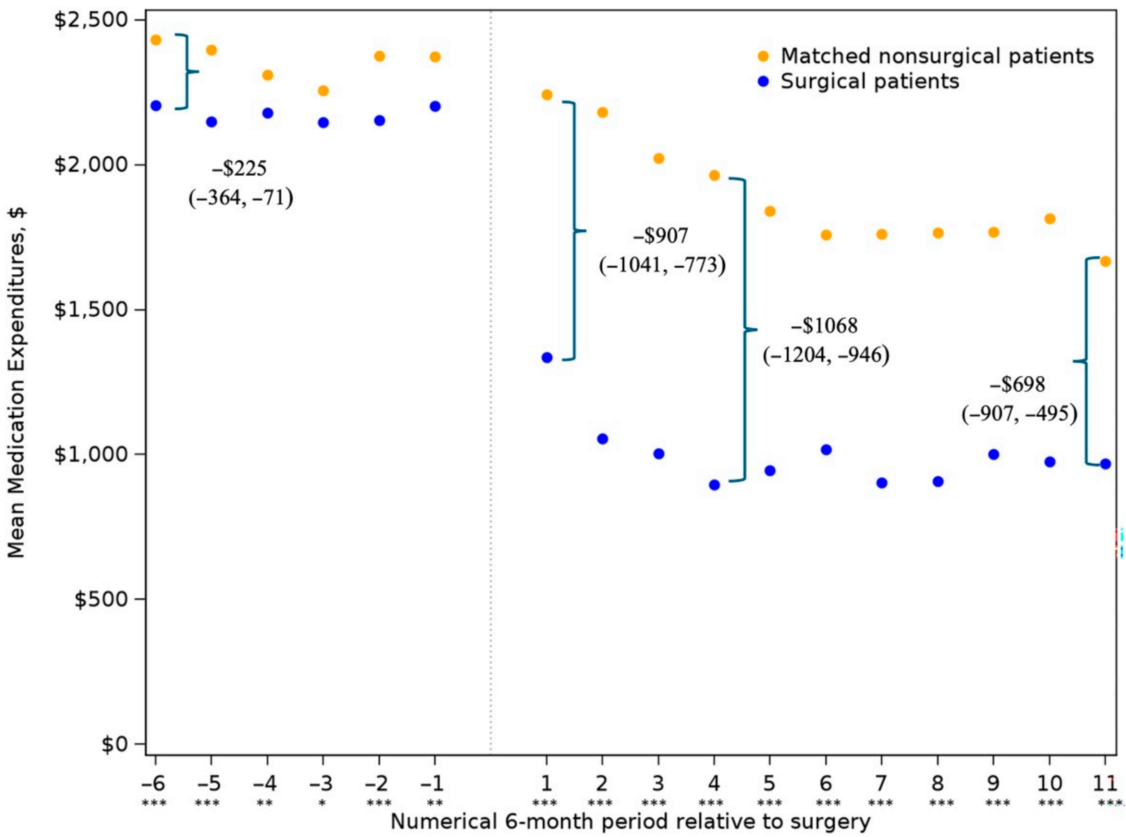

Figure 3—Outpatient medication expenditures: model-estimated trends for surgical patients and nonsurgical matches with obesity and diabetes. $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$. *P* values are obtained from model estimating the relative difference between surgical and matched nonsurgical patients adjusting for baseline characteristics. Numbers listed are estimated surgical vs. nonsurgical differences (95% CI). Model is adjusted for surgical procedure (nonsurgical patients were assigned the value of their matched surgical patient), study site, insurance type, sex, race, age, BMI, Gagne score, and presence or absence of several comorbidities, including alcohol use disorder, anemia, arrhythmia, congestive heart failure, coagulopathy, complicated diabetes, dementia, fluid and electrolyte disorders, hemiplegia, HIV/AIDS, hypertension, liver disease, psychosis, pulmonary circulation disorders, peripheral vascular disorder, renal failure, any tumor, weight loss, insulin use, antihypertensive medication use, atrial fibrillation, cirrhosis, depression, steatotic liver disease, eating disorder, gastroesophageal reflux disease, myocardial infarction, venous thromboembolism, risk of pulmonary embolism, inferior vena cava filter, stroke, hiatal hernia, smoking status, HbA_{1c}, and advanced DiaRem score.

surgery. Future research should evaluate the economic impact of bariatric surgery in the most recent era of increasing GLP-1RA and SGLT2i use. Additionally, some payors may consider covering only GLP-1RA or bariatric surgery for weight loss, but not both. Therefore, long-term studies should compare the economic impact of one-time bariatric surgery versus chronic use of GLP-1RA for obesity among patients with type 2 diabetes.

The economic impact of bariatric surgery is critical to establish given that broader coverage could cost billions. In the U.S., only 1% of patients with obesity who meet criteria for bariatric surgery receive it. Limited coverage for bariatric surgery by commercial insurers may be in part due to uncertainty about which eligible patients provide the greatest potential return on investment. Our findings suggest a positive return on investment in the long term for patients who have both obesity and type 2 diabetes. A prior study found that postsurgical reductions in expenditures in this population are similar for RYGB and SG (19). Given that an estimated 29 million adults have diabetes, commercial payors may want to actively encourage consideration of bariatric surgery for patients with obesity and type 2 diabetes, who have the greatest likelihood of cost savings. Further research should explore whether any subgroups of patients with type 2 diabetes derive greater clinical and financial benefits from bariatric surgery.

Several limitations must be acknowledged. First, our analyses may be subject to unobserved confounding because patients were not randomized. While we attempted to create comparable cohorts via matching and adjusting for residual imbalances in regression models, confounding by indication could have remained (e.g., patients may have had unobservable reasons for deciding to undergo surgery vs. not to undergo surgery). Second, this study only included data on presurgical and postsurgical health care usage, but not the cost of the bariatric surgery itself. Nor did we consider social costs such as employment status and absenteeism. Additionally, we were unable to compare surgical versus nonsurgical inpatient expenditures, because the two-part regression models did not converge (19,29). Third, the mean BMI in our cohort (44 kg/m^2) was higher than the indication for bariatric surgery in many countries (35 kg/m^2), although this average BMI is consistent with prior cohorts of patients with type 2 diabetes undergoing bariatric surgery (5–9,35). Fourth, we lacked information on out-of-pocket health care costs, which can vary widely and act as barriers to bariatric surgery as well as other aspects of health care usage evaluated in this study (36,37). Fifth, we only included commercially insured patients from two integrated health systems. While health plan members are similar to area populations, our findings may not generalize beyond this population. Finally, we conservatively used Medicare unit prices, which are typically two to three times lower than commercial insurance prices. We used Medicare prices to increase the generalizability of our results across payors, as different commercial payors have different approaches to cost accounting.

Conclusion

This analysis suggests that the significant health benefits associated with bariatric surgery that were identified in prior studies are also associated with lower total postsurgical expenditures for patients with type 2 diabetes, because of, in large part, significant reductions in medication expenditures. Given the lack of universal insurance coverage of bariatric surgery in the U.S., future work is needed to determine whether there are subgroups of patients with type 2 diabetes who are most likely to benefit clinically and economically from bariatric surgery.

Funding. This research was funded by the National Institute of Diabetes and Digestive and Kidney Diseases (R01 DK125380). M.L.M. was also supported by a Research Career Scientist award from the Department of Veterans Affairs (RCS 10-391). C.E.S. is a Health and Aging Policy Fellow and American Political Science Association Fellow and is supported by the John A. Hartford Foundation. R.M.K. is a National Clinician Scholar in the Duke Clinical and Translational Science Institute (CTSI). Through R.M.K.'s affiliation, the project described herein was supported by the Duke CTSI.

The content is solely the responsibility of the authors and does not necessarily represent the official views of the Duke CTSI.

National Institute of Diabetes and Digestive and Kidney Diseases had no role in the design, conduct, collection, management, analysis, or interpretation of the data, or in the preparation, review, or approval of the manuscript.

The opinions expressed are those of the authors and not necessarily those of the Department of Veterans Affairs, Duke University, Kaiser Permanente Southern California, or Kaiser Permanente Washington Health Research Institute.

Duality of Interest. D.E.A. presented preliminary results of this analysis at the American Society of Metabolic and Bariatric Surgery annual meeting on 28 June 2023, for which he received a travel reimbursement. D.E.A. reports other grants related to bariatric surgery from National Institutes of Health and Patient-Centered Outcomes Research Institute. No other potential conflicts of interest relevant to this article were reported.

Author Contributions. All authors were involved in the conception, design, and conduct of the study. L.Z. and V.A.S. conducted the analysis. All authors participated in the interpretation of results. C.E.S. wrote the first draft of the manuscript. All authors edited, reviewed, and approved the final version of the manuscript. L.Z. and V.A.S. are the guarantors of this work and, as such, had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Handling Editors. The journal editor responsible for overseeing the review of the manuscript was John B. Buse.

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