JAMA Surgery | Review

Comparative Effectiveness and Safety of Bariatric Procedures in Medicare-Eligible Patients
A Systematic Review

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Invited Commentary

Supplemental content

IMPORTANCE The prevalence of obesity in patients older than 65 years is increasing. A substantial number of beneficiaries covered by Medicare meet eligibility criteria for bariatric procedures.

OBJECTIVE To assess the comparative effectiveness and safety of bariatric procedures in the Medicare-eligible population.

EVIDENCE REVIEW This systematic review was conducted according to the PRISMA guidelines. Articles were identified through searches of PubMed, Embase, CINAHL, PsycINFO, Cochrane Central Trials Registry, Cochrane Database of Systematic Reviews, and scientific information packages from manufacturers, ClinicalTrials.gov, World Health Organization International Clinical Trials Registry Platform, and US Food and Drug Administration drugs and devices portals from January 1, 2000, to June 31, 2017. Randomized and nonrandomized comparative studies that evaluated bariatric procedures in the Medicare-eligible population were eligible. Six researchers extracted data on design, interventions, outcomes, and study quality. Findings were synthesized qualitatively; a planned meta-analysis was not undertaken owing to clinical heterogeneity.

FINDINGS A total of 11 455 citations were screened for eligibility. Of those, 16 met the eligibility criteria. Compared with no surgery or conventional weight-loss treatment, bariatric surgery results in greater weight loss. Overall mortality after 30 days is lower among bariatric patients (hazard ratio, HR, 0.50; 95% CI, 0.31-0.79, in the study with the longest follow-up of 5.9 years), although, based on 1 study, mortality within 30 days of surgery was higher than in nonsurgically treated controls (1.55% vs 0.53%; $P < .001$). Bariatric surgery is associated with lower risk of cardiovascular disease (HR, 0.59; 95% CI, 0.44-0.79 in the largest study comparison) and with improvements in respiratory, musculoskeletal, metabolic, and renal outcomes (increase in estimated glomerular filtration rate, 9.84; 95% CI, 8.05-11.62 mL/min/1.73m^2). Compared with sleeve gastrectomy (SG) and adjustable gastric banding (AGB), Roux-en-Y gastric bypass (RYGB) appears to be associated with greater weight loss (percent excess weight loss, 23.8% [95% CI, 16.2%-31.4%] at the longest follow-up of 4 years) but the 3 procedures have similar associations with most non–weight loss outcomes. Overall postoperative complications are not statistically significantly different between RYGB and SG, although major and/or serious complications are more common after RYGB. However, these associations are susceptible to at least moderate risk of confounding, selection, or measurement biases.

CONCLUSIONS AND RELEVANCE In the Medicare population, there is low to moderate strength of evidence that bariatric surgery as a weight loss treatment improves non–weight loss outcomes. Well-designed comparative studies are needed to credibly determine the treatment effects for bariatric procedures in this patient population.

JAMA Surg. doi:10.1001/jamasurg.2018.3326
Published online September 5, 2018.

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Many individuals in the United States who are eligible for Medicare meet criteria for bariatric surgery, but the use of surgical and endoscopic procedures for weight loss remains low in this group of patients.[1,2] Based on the 2012 National Health and Nutrition Examination Survey,[3] 35% of people 60 years and older had a body mass index (BMI) (calculated as weight in kilograms divided by height in meters squared) greater than or equal to 30, 14% had a BMI greater than or equal to 35, and 6% had a BMI greater than or equal to 40. Obesity and its associated comorbidities (eg, diabetes, hypertension) are leading causes of disability and renal disease, which determine Medicare eligibility regardless of age.

Surgical and endoscopic bariatric procedures have become the preferred therapy for persons with severe obesity refractory to medical treatment and lifestyle modifications.[4] Previous evidence suggests that bariatric therapy is safe and effective and appears to be associated with reductions in morbidities.[5-7] However, these results are not directly applicable to Medicare patients because, to our knowledge, few, if any, studies have focused exclusively on adults older than 65 years. Synthesizing the evidence that is directly applicable to Medicare-eligible patients can better inform both clinical and policy decision making.

To address the needs for evidence regarding the effectiveness and safety of bariatric procedures specific to the Medicare-eligible population, we conducted a systematic literature review to summarize and appraise the current evidence.

Key Points

Question What is the effectiveness and safety of bariatric surgery procedures in the Medicare-eligible population?

Findings In this systematic review of 16 nonrandomized comparative studies, bariatric procedures and their association with weight loss, postoperative complications, mortality, metabolic, cardiovascular, respiratory, orthopedic, and renal outcomes, and medication use were assessed. Bariatric surgery overall, and in particular Roux-en-Y gastric bypass, sleeve gastrectomy, and adjustable gastric banding, appear to be associated with improvements in weight loss outcomes beyond 1 year after surgery.

Meaning In the Medicare population, low to moderate strength of evidence exists regarding bariatric surgery as a weight loss treatment and its association with non–weight loss outcomes.

Methods

Scope of the Review

This systematic review was designed to complement a technology assessment for the Agency for Healthcare Research and Quality and the Centers for Medicare & Medicaid Services (CMS),[8] and it was requested by CMS to understand the current state of evidence for bariatric procedures in the Medicare population. The protocol is registered at PROSPERO (CRD42017065285).

Data Sources and Searches

We performed literature searches of the PubMed, Embase, CINAHL, PsycINFO, Cochrane Central Trials Registry, and Cochrane Database of Systematic Reviews databases from January 1, 2010, to June 31, 2017. Search terms are given in the eAppendix in the Supplement. We searched the reference lists of published clinical practice guidelines, narrative and systematic reviews, and scientific information packages from manufacturers or other stakeholders. We searched ClinicalTrials.gov, the World Health Organization International Clinical Trials Registry Platform, and the US Food and Drug Administration drugs and devices portals (eAppendix in the Supplement).

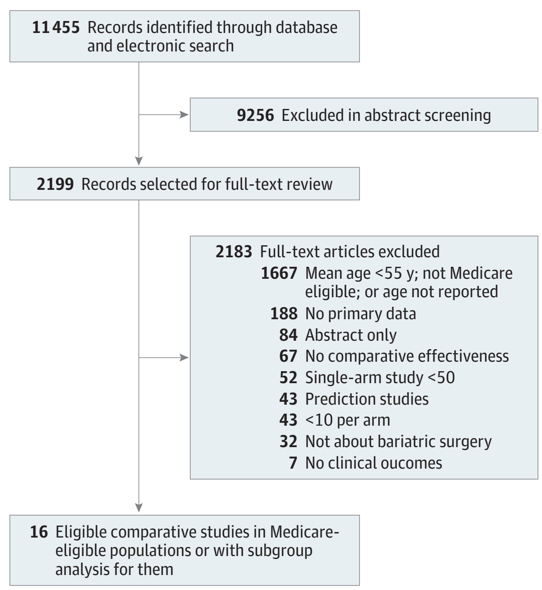
Study Selection

Eligibility criteria are shown in detail in the eAppendix of the Supplement. Because the interest is in Medicare-eligible individuals, eligible studies were those whose population resembled people who meet Medicare coverage criteria, ie, people aged 65 years or older, or people younger than 65 who are disabled or have end-stage renal disease. Because studies conducted exclusively in adults aged 65 years and older are uncommon,[9] eligible for inclusion were studies with a mean and/or median age of 55 years or older.[10] We also included studies in disabled patients, and studies in patients with end-stage renal disease. If the total study population did not meet these criteria, we identified subset analyses in these groups. We included studies on any surgical (open or laparoscopic) or endoscopic procedure.

We included studies on any clinical outcomes, which were classified into weight-related outcomes, non–weight-related outcomes, and adverse events or complications (occurring within 90 days after surgery unless if otherwise specified in the eligible studies). We focused on studies published after 2000.

Both randomized and nonrandomized comparative studies were eligible. Because our aim was to minimize the role of confounding, we required that nonrandomized comparative studies (NRCS) have achieved minimal balance in confounders between compared groups either by design or through statistical modeling.[11,12]

Figure. Literature Flow Diagram



Flow diagram depicting the number of studies meeting eligibility criteria and the reasons for exclusion.

Table 1. Characteristics of Eligible Nonrandomized Comparative Studies of Bariatric Procedures in the Medicare Population

Source and Intervention (No. of Participants)	Mean (SD)			Major Participant Characteristics, No., %			Outcomes
	Age, y	BMI	Weight, kg	Female	White	Type 2 Diabetes	
Ardestani et al, 2015[14]							
RYGB (3318)	53.1 (9.8)	47.9 (8.4)	ND	2220 (66.9)	2714 (81.8)	3318 (100)	Insulin cessation; remission of type 2 diabetes
LAGB (1907)	54.9 (10.7)	45.8 (7.2)	ND	1266 (66.4)	1552 (81.4)	1907 (100)	
Casillas et al, 2015[15]							
SG (252)	67.6 (ND)	42.5	ND	179 (71.0)	159 (63.1)	134 (53.1)	BMI; % WL; % EWL; mortality; postoperative complications
LRYGB (177)	67.5 (ND)	42.6 (ND)	ND	127 (72.0)	115 (64.9)	101 (57.0)	
Davidson et al, 2016[16]							
RYGB (605)	59.1 (3.3)	45.2 (7)	ND	461 (76.2)	ND	ND	All-cause mortality; CVD mortality; cancer mortality; other mortality
No surgery (605)	59 (3.4)	46.4 (6.3)	ND	461 (76.2)	ND	ND	
Hernigou et al, 2016[17,a]							
Bariatric surgery + THA (85)	71 (8)	42 (7.4)	ND	52 (60.7)	ND	ND	Hip dislocation
THA (215)	72 (9)	39.4 (5)	ND	126 (58.5)	ND	ND	
Imam et al, 2017[18]							
RYGB/SG (714)	58.1 (8.46)	44.3 (6.6)	ND	551 (77.2)	399 (55.9)	470 (65.8)	Absolute WL; kidney function
No surgery (714)	58.4 (8.9)	44 (7.16)	ND	543 (76.1)	404 (56.6)	487 (68.2)	
RYGB (234)	58.2 (8.19)	44.1 (6.68)	121.6 (23.2)	187 (79.9)	134 (57.3)	146 (62.4)	
SG (234)	58.7 (9.08)	43.7 (6.19)	120.3 (20.6)	186 (79.5)	140 (59.8)	146 (62.4)	
Irwin et al, 2013[19]							
Bariatric surgery (27)	56.9 (9.2)	50.2 (7.5)	ND	22 (81.5)	22 (81.5)	15 (55.6)	Warfarin dose
Cholecystectomy/ERCP (59)	60.5 (10.10)	31.1 (6.1)	ND	28 (47.5)	46 (78.0)	18 (30.5)	
Johnson et al, 2013[20]							
RYGB/AGB (349)	>55 (ND)	ND	ND	227 (65.0)	300 (86.0)	119 (34.0)	All-cause mortality; CVD mortality; non-CVD mortality
Orthopedic/GI surgery (903)	>55 (ND)	ND	ND	569 (63.0)	650 (72.0)	298 (32.8)	
Lee et al, 2016[21]							
RYGB (84)	54.1 (11.7)	42.8 (6.7)	130.3 (28.4)	30 (36.3)	56 (66.7)	ND	Absolute WL; BMI; % WL; % EWL; polypharmacy; glucose levels; Hb1Ac; total cholesterol, HDL cholesterol, and LDL cholesterol levels; triglyceride levels; SBP; DPB
SG (48)	55.5 (15.3)	42.8 (8.7)	130.5 (36.6)	11 (23.7)	28 (58.1)	ND	
LAGB (30)	57.4 (13)	41.9 (7.9)	132.3 (42.7)	5 (17.6)	18 (59.8)	ND	
Leonetti et al, 2012[22]							
LSG (30)	53 (8.1)	41.3 (6)	ND	21 (70.0)	ND	30 (100)	BMI; total cholesterol, HDL cholesterol, and LDL cholesterol levels; triglyceride levels; glucose; Hb1Ac; polypharmacy
Lifestyle/medical treatment (30)	56 (8.2)	39 (5.5)	ND	20 (67.0)	ND	30 (100)	
Martin et al, 2015[23]							
Bariatric + TKA/TKA alone (91)	58.1 (8)	37.2 (7)	ND	74 (81.3)	ND	34 (37.3)	Reoperation after TKA; revision after TKA; TKA complications; prosthetic joint infection
No surgery: low BMI (182)	58.7 (7)	37.2 (7)	ND	147 (80.7)	ND	35 (19.2)	
No surgery: high BMI (91)	57.4 (7)	51.2 (9)	ND	74 (81.3)	ND	27 (29.6)	
Perry et al, 2008[24,b]							
Bariatric surgery (11 903)	>65 y: 11% (ND)	ND	ND	9236 (77.6)	ND	5356 (44.9)	Survival; diabetes; sleep apnea; hypertension; hyperlipidemia; coronary artery disease
No surgery (11 903)	>65 y: 11% (ND)	ND	ND	9236 (77.6)	ND	5356 (44.9)	

(continued)

Data Extraction

Data were extracted in the Systematic Review Data Repository (https://srdr.ahrq.gov) and address population characteristics, including characteristics of presurgical and postsurgical workups, descriptions of patients, descriptions of the interventions, exposures, outcomes, and comparators analyzed, outcome definitions, effect modifiers, enrolled and analyzed sample sizes, study design features, funding source, and results.

Table 1. Characteristics of Eligible Nonrandomized Comparative Studies of Bariatric Procedures in the Medicare Population (continued)

Source and Intervention (No. of Participants)	Mean (SD)			Major Participant Characteristics, No., %			Outcomes
	Age, y	BMI	Weight, kg	Female	White	Type 2 Diabetes	
Persson et al, 2017[25,c]							
Bariatric surgery (2605)	>55 (ND)	ND	ND	ND	ND	ND	Heart failure; all-cause mortality
No surgery (6486)	>55 (ND)	ND	ND	ND	ND	ND	
Ritz et al, 2014[26,c]							
LAGB (50)	>55 (ND)	ND	ND	ND	ND	ND	% WL
RYGB (57)	>55 (ND)	ND	ND	ND	ND	ND	
SG (47)	>55 (ND)	ND	ND	ND	ND	ND	
Scott et al, 2013[27,d]							
Bariatric surgery (587)	50.5 (7.4)	ND	ND	487 (82.9)	474 (80.8)	33 (5.6)	Stroke; MI; all-cause mortality; any of the above
Orthopedic surgery (1352)	58.1 (9.3)	ND	ND	1029 (76.1)	909 (67.2)	541 (40.0)	
Gastrointestinal surgery (328)	53.7 (9.3)	ND	ND	257 (78.4)	228 (69.4)	141 (43.1)	
Spaniolas et al, 2014[28]							
RYGB (850)	>65 (ND)	ND	ND	592 (69.7)	ND	473 (55.6)	All-cause mortality; overall morbidity; serious morbidity
SG (155)	>65 (ND)	ND	ND	104 (66.9)	ND	67 (43.2)	
Valderas et al, 2009[29]							
RYGB (26)	58 (3.9)	29.5 (3.8)	ND	26 (100)	ND	ND	BMD; hyperparathyroidism; 25-hydroxyvitamin D
No surgery (26)	57.5 (4.7)	29.2 (4.1)	ND	26 (100)	ND	ND	

Abbreviations: AGB, adjustable gastric banding; BMD, bone mineral density; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CVD, cardiovascular disease; DPB, diastolic blood pressure; eGFR, estimated glomerular filtration rate; ERCP, endoscopic retrograde cholangiopancreatography; EWL, excess weight loss; HDL, high-density lipoprotein; LAGB, laparoscopic adjustable gastric banding; LDL, low-density lipoprotein; LRYGB, laparoscopic Roux-en-Y gastric bypass; LSG, laparoscopic sleeve gastrectomy; MI, myocardial infarction; ND, no data; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; SPB, systolic blood pressure; THA, total hip arthroplasty; TKA, total knee arthroplasty; WL, weight loss.

[a] The unit of analysis was the hip, and the sample size refers to the number of hips.

[b] All patients were Medicare beneficiaries regardless of age.

[c] Subgroup analyses for patients older than 55 years were reported but baseline characteristics were not available for this group.

[d] In the bariatric arm, 51.2% were older than 50 to 59 years.

Strength of Evidence Assessment

We assessed the strength of evidence for each eligible outcome and comparison.[13] We assessed the number of studies, their study designs, the study limitations (ie, risk of bias and overall methodological quality), the directness of the evidence, the consistency of study results, the precision of effect estimates, the likelihood of reporting bias, and the overall findings across studies. We graded the strength of evidence as being either high, moderate, or low, or there being insufficient information to assess the strength of evidence.

Results

We screened 11 455 citations (**Figure**) for eligibility. Of those, 16 NRCS[14-29] met the eligibility criteria (**Table 1**; eTable 1 in the Supplement). All studies accounted for potential confounders but the variables and techniques varied substantially. The eligible studies recruited clinically heterogenous populations, used diverse definitions for the diagnosis of the outcomes of interest, and often combined multiple surgical procedures into a common intervention group. In addition, numerical data were often sparse across studies. As a result, combining the results of individual studies into summary estimates was not feasible.

Five studies reported weight loss outcomes and 15 reported adverse events and complications and other non–weight loss outcomes. One study[24] used claims data from Medicare-enrolled beneficiaries regardless of age. The remaining 15 studies reported on patients with a mean or median age of 55 years or older.

Weight Loss Outcomes

Five studies[15,18,21,22,26] assessed bariatric surgery and its associations with weight loss but only 4 studies[15,21,22,26] reported numerical data (**Table 2**). Although percent body weight loss is the preferred measure of weight loss, additional measures were used in the eligible studies including percent excess weight loss, absolute weight loss, and absolute BMI loss.

Two studies[18,22] compared any bariatric procedure with no surgery or to standard nonbariatric weight loss treatment. Based on the trajectories of body weight up to 3 years after surgery, weight loss is greater after bariatric surgery compared with no surgical controls in whom weight loss is negligible.[18] In patients with type 2 diabetes, bariatric surgery results in greater percent excess weight loss and BMI loss at 18 months compared with conventional treatment.[22]

Head-to-head comparisons between specific bariatric procedures were reported in 4 studies and included comparisons of Roux-en-Y gastric bypass (RYGB) vs sleeve gastrectomy (SG) (n = 3)[15,18,21]; RYGB vs laparoscopic adjustable gastric banding (LAGB) (n = 2)[21,26]; and SG vs LAGB (n = 2).[21,26] RYGB results in greater BMI loss, percent weight loss, and percent excess weight loss up to 4 years after surgery than SG and LAGB, and SG yields greater improvements in

Table 2. Bariatric Surgery and Weight Loss Outcomes in the Medicare Population

Source, Comparison, and Outcome	Time Point	Difference in Outcome Measured	*P* Value	Other Findings	Confounders (Methods to Adjust)
Casillas et al, 2015[15]					
LRYGB vs SG					
Mean BMI	1 y	−3.8 (−4.7 to−3.0)	ND	ND	Sex, race/ethnicity, year of procedure, BMI, diabetes, hypertension, Charlson comorbidity index (IPTW based on propensity score)
	2 y	−4.5 (−5.5 to−3.5)			
	3 y	−4.3 (−5.4 to−3.3)			
	4 y	−3.9 (−5.0 to−2.8)			
% WL	1 y	9.7 (7.7 to 11.7)	ND	ND	
	2 y	9.7 (7.3 to 12.0)			
	3 y	9.2 (6.5 to 11.9)			
	4 y	9.0 (6.1 to 11.9)			
% EWL	1 y	24.7 (19.2 to 30.2)	ND	ND	
	2 y	24.4 (18.3 to 30.5)			
	3 y	23.8 (16.8 to 30.8)			
	4 y	23.8 (16.2 to 31.4)			
Imam et al, 2017[18]					
RYGB/SG vs no surgery					
Absolute WL	3 mo	ND	ND	RYGB/SG: peak weight loss occurred 12.6 mo after surgery; no surgery: negligible weight loss	Age, race/ethnicity, hypertension, diabetes, body weight (propensity score matching and regression)
	1 y				
	2 y				
	3 y				
Lee et al, 2016[21]					
RYGB vs SG					
No. of kg lost	6 mo	10.5 (ND)	<.001	ND	Age, sex, race/ethnicity, body weight, BMI, glucose levels, Charlson comorbidity index (IPTW based on propensity score)
	1 y	16.3 (ND)			
BMI reduction	6 mo	3.3 (ND)	<.001		
	1 y	5.5 (ND)			
% WL	6 mo	7.5 (ND)	<.001		
	1 y	11.3 (ND)			
% EWL	6 mo	9.6 (ND)	<.001		
	1 y	14.7 (ND)			
RYGB vs LAGB					
No. of kg lost	6 mo	20 (ND)	<.001	ND	
	1 y	25.4			
BMI reduction	6 mo	6.7 (ND)	<.001		
	1 y	8.4 (ND)			
% WL	6 mo	15.7 (ND)	<.001		
	1 y	19.5 (ND)			
% EWL	6 mo	20.3 (ND)	<.001		
	1 y	25.3 (ND)			
SG vs LAGB					
No. of kg lost	6 mo	9.5 (ND)	<.001	ND	
	1 y	9.1 (ND)			
BMI reduction	6 mo	3.4 (ND)	<.001		
	1 y	2.9 (ND)			
% WL	6 mo	8.2 (ND)	<.001		
	1 y	8.2 (ND)			
% EWL	6 mo	10.7 (ND)	<.001		
	1 y	10.6 (ND)			

(continued)

Table 2. Bariatric Surgery and Weight Loss Outcomes in the Medicare Population (continued)

Source, Comparison, and Outcome	Time Point	Difference in Outcome Measured	*P* Value	Other Findings	Confounders (Methods to Adjust)
Leonetti et al, 2012[22]					
LSG vs lifestyle/medical treatment					
EWL, % of patients	18 mo	ND	<.001	ND	Age, sex, BMI, duration of diabetes, cholesterol levels (multiple regression)
BMI reduction	18 mo	ND	<.001		
Ritz et al, 2014[26]					
RYGB vs LAGB					
% WL	1 y	9.2 (ND)	ND	ND	Age, sex, BMI (multiple regression)
SG vs LAGB					
% WL	1 y				
		5.5 (ND)	ND	ND	

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); EWL, excess weight loss; HDL, high-density lipoprotein; IPTW, inverse probability of treatment weighting; LAGB, laparoscopic adjustable gastric banding; LSG, laparoscopic sleeve gastrectomy; ND, no data; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; WL, weight loss.

Table 3. Postoperative Complications of Bariatric Surgery in the Medicare Population

Source, Comparison, and Outcome	Time Point	Summary of Findings: Effect Estimate (95% CI)	Summary of Findings: *P* Value	Summary of Findings: Other Findings	Confounders (Methods to Adjust)
Perry et al, 2008[24]					
Any bariatric surgery vs no surgery					
Overall mortality	30 d	ND	ND	30-d Mortality rate in the surgical cohort vs the nonsurgical cohort was 1.27% vs 0.49% (*P* < .001) for Medicare beneficiaries younger than 65 y; and 1.55% vs 0.53% (*P* < .001) for patients aged 65 y and older	Age, sex, race/ethnicity, hypertension, dyslipidemia, diabetes, obstructive sleep apnea, cardiovascular disease, fatty liver disease, gallstones, venous stasis, cellulitis, deep vein thrombosis, pulmonary embolism, arthritis, GERD, stress incontinence, back pain, disk disease, No. of comorbid conditions, year of surgery (propensity score with IPTW)
Casillas et al, 2015[15]					
LRYGB vs SG					
Overall mortality	3 mo	ND	ND	Mortality rate was 1.7 per 100 patients in the LRYGB arm, but there were no deaths in the SG arm	Sex, race/ethnicity, year of procedure, BMI, diabetes, hypertension, Charlson comorbidity index (IPTW based on propensity score)
Overall mortality	1 y	ND	ND	Mortality rate was 2.8 per 100 patients in the LRYGB arm and 0.4 per 100 patients in the SG arm	
Overall complications	1 y	ND	<.001	Rates: 30.5% vs 15.9%	
Minor complications	30 d	ND	<.05	Rates: 6.8% vs 4.8%	
Minor complications	1 y[a]	ND	<.05	Rates: 6.2% vs 4.4%	
Major complications	30 d	ND	.02	Rates: 6.2% vs 2.3%	
Major complications	1 y[a]	ND	<.001	Rates: 5.6% vs 1.6%	
Length of stay	NA	IRR: 1.58 (1.39-1.81)	ND	ND	
Hospital readmission	30 d	OR: 1.90 (0.83-4.37)	ND	ND	
ED visits	30 d	OR: 1.42 (0.74-2.73)	ND	ND	
Spaniolas et al, 2014[28]					
RYGB vs SG					
Overall mortality	30 d	OR: 0.85 (0.1-7.41)	ND	ND	Duration of diabetes (multiple regression)
Overall complications	30 d	OR: 1.0 (0.55-1.82)	ND	ND	
Serious complications	30 d	OR: 1.10 (0.51-2.38)	ND	ND	

Abbreviations: ED, emergency department; GERD, gastroesophageal reflux disease; IRR, incidence rate ratio; IPTW, inverse probability of treatment weighting; LRYGB, laparoscopic Roux-en-Y gastric bypass; LSG, laparoscopic sleeve gastrectomy; NA, not applicable; ND, no data; OR, odds ratio; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

[a] Does not include complications within the first month.

Table 4. Bariatric Surgery and Health Outcomes in the Medicare Population

Source, Comparison, and Outcome	Time Point	Summary of Findings: Effect Estimate (95% CI)	*P* Value	Other Findings	Confounders (Methods to Adjust)
Davidson et al, 2016[16]					
RYGB vs no surgery					
All-cause mortality	5.9 y[a]	HR: 0.50 (0.31-0.79)	ND	ND	Age, sex, BMI, year of surgery (matching and multiple regression)
CVD mortality	5.9 y[a]	HR: 0.57 (0.28-1.15)	ND	ND	
Cancer mortality	5.9 y[a]	HR: 0.54 (0.21-1.35)	ND	ND	
Any-cause mortality (except externally caused deaths)	5.9 y[a]	HR: 0.46 (0.28-0.75)	ND	ND	
Mortality owing to externally caused deaths	5.9 y[a]	HR: 1.30 (0.25-6.86)	ND	ND	
Scott et al, 2013[27]					
Any bariatric surgery vs orthopedic surgery					
Overall survival	13.7 mo[a]	HR: 0.81 (0.60-1.10)	ND	ND	Age, sex, race/ethnicity, hypertension, dyslipidemia, diabetes, obstructive sleep apnea, cardiovascular disease, myocardial infarction (multiple regression)
MI-free survival	13.7 mo[a]	HR: 0.59 (0.44-0.79)	ND	ND	
Stroke-free survival	13.7 mo[a]	HR: 0.69 (0.40-1.30)	ND	ND	
Time to MI, stroke, or death	13.7 mo[a]	HR: 0.72 (0.58-0.89)	ND	ND	
Any bariatric surgery vs gastrointestinal surgery					
Overall survival	13.7 mo[a]	HR: 0.45 (0.33-0.60)	ND	ND	
MI-free survival	13.7 moa	HR: 0.49 (0.36-0.68)	ND	ND	
Stroke-free survival	13.7 mo[a]	HR: 0.49 (0.24-0.98)	ND	ND	
Time to MI, stroke, or death	13.7 mo[a]	HR: 0.48 (0.39-0.61)	ND	ND	

(continued)

weight loss outcomes than LAGB. In the longest follow-up of 4 years, percent excess weight loss was 23.8% (95% CI, 16.2%-31.4%) higher after RYGB than SG.

Postoperative Complications

Postoperative complications were reported in 3 studies,[15,24,28] all of which reported on surgery-related mortality (**Table 3**). One study found higher 30-day mortality rates in the bariatric surgery group compared with nonsurgically treated controls for Medicare beneficiaries both younger than 65 years (1.27% vs 0.49%; *P* < .001) and older than 65 years (1.55% vs 0.53%; *P* < .001).[24] Between-procedure comparisons indicate no differences in 30-day and 1-year mortality rates between RYGB and SG.[15,28] Similarly, there was no statistically significant difference in the rates of overall complications between the 2 procedures,[15,28] although major or serious complications were more common after laparoscopic RYGB than SG.[15]

Mortality

Five studies[16,20,24,25,27] examined the association between bariatric surgical procedures and mortality or survival 90 or more days after surgery (**Table 4**). All studies compared 1 or more surgeries with no bariatric surgery, except for 1 study[15] which compared laparoscopic RYGB with SG.

In 3 studies,[16,24,25] patients undergoing bariatric surgery had lower risk of overall mortality compared with nonsurgically treated controls. In the study with the longest follow-up (5.9 years),[16] the hazard ratio (HR) for all-cause mortality was 0.50 (95% CI, 0.31-0.79). A fourth study[27] in patients with a history of cardiovascular disease found lower overall mortality after bariatric surgery compared with elective gastrointestinal surgery; however, all-cause mortality did not differ between bariatric surgery and orthopedic[27] or either orthopedic or gastrointestinal[20] surgery.

Two studies[16,20] reported on cardiovascular mortality. Patients undergoing bariatric surgery have lower risk of cardiovascular mortality compared with either nonsurgically treated controls[16] or patients undergoing orthopedic or gastrointestinal surgery,[20] although the differences did not reach nominal statistical significance.

With regard to other causes of mortality, there was no statistically significant difference between bariatric surgery and control interventions,[16,20] except for mortality resulting from causes other than external unintentional injury unrelated to drugs, poisoning of undetermined intent, suicide, and other externally caused deaths.[16] Finally, as far as individual bariatric surgeries are concerned, 3-month and 1-year mortality rates are higher for laparoscopic RYGB than SG.[15]

Diabetes and Metabolic-Related Outcomes

Four studies[14,21,22,24] evaluated associations between bariatric surgery and diabetes and other metabolic-related outcomes (Table 4).

With regard to diabetes-related end points, 2 studies[22,24] compared bariatric surgery to no surgery[24] or to medical treatment and lifestyle modifications.[22] Diabetes rates at 1 year and 1.5 years after surgery are lower among patients undergoing bariatric surgery compared with nonsurgically treated controls,[24] while among patients with type 2 diabetes, laparoscopic sleeve gastrectomy (LSG) compared with medical treatment and lifestyle modifications improves the levels of hemoglobin A_{1c} (HbA_{1c}) for patients with over 10 years' duration of diabetes.[22] Another 2 studies[14,21] reported on direct comparisons for individual bariatric procedures. Among RYGB, SG, and LAGB, there were no statistically significant differences in the

Table 4. Bariatric Surgery and Health Outcomes in the Medicare Population (continued)

Source, Comparison, and Outcome	Time Point	Summary of Findings: Effect Estimate (95% CI)	Summary of Findings: P Value	Summary of Findings: Other Findings	Confounders (Methods to Adjust)
Perry et al, 2008[24]					
Any bariatric surgery vs no surgery					
Overall mortality	2 y	ND	ND	2-y Mortality rate in the surgical cohort vs the nonsurgical cohort was 4.5% vs 8.6% (P < .001) for Medicare beneficiaries younger than 65 y; and 8.0% vs 12.2% (P < .001) for patients aged >65 y	Age, sex, race/ethnicity, hypertension, dyslipidemia, diabetes, obstructive sleep apnea, cardiovascular disease, fatty liver disease, gallstones, venous stasis, cellulitis, deep vein thrombosis, pulmonary embolism, arthritis, GERD, stress incontinence, back pain, disk disease, No. of comorbid conditions, year of surgery (propensity score with IPTW)
Type 2 diabetes	6 mo	ND	.08	Overall: 46.5% vs 47.8%	
			.05	Age <65 y: 45.6% vs 47.1%	
			.83	Age >65 y: 54.1% vs 53.6%	
	1 y	ND	<.001	Overall: 42.4% vs 48.4%	
			<.001	Age <65 y: 41.5% vs 47.7%	
			.21	Age >65 y: 50.6% vs 53.8%	
	1.5 y	ND	<.001	Overall: 39.1% vs 49.5%	
			<.001	Age <65 y: 38.2% vs 48.9%	
			.02	Age >65 y: 46.6% vs 53.9%	
Sleep apnea	6 mo	ND	<.001	Overall: 36.3% vs 28.3%	
			<.001	<65 y: 36.7% vs 28.9%	
			<.001	>65 y: 33.0% vs 23.0%	
	1 y	ND	.19	Overall: 29.9% vs 28.9%	
			.30	<65 y: 30.4% vs 29.6%	
			.22	>65 y: 25.7% vs 22.9%	
	1.5 y	ND	.002	Overall: 26.1% vs 29.0%	
			.004	<65 y: 26.8% vs 29.6%	
			.21	>65 y: 19.5% vs 22.9%	
Hypertension	6 mo	ND	.84	Overall: 62.0% vs 61.9%	
			.80	Age <65 y: 60.0% vs 60.2%	
			.15	Age >65 y: 78.0% vs 75.4%	
	1 y	ND	<.001	Overall: 53.2% vs 62.4%	
			<.001	Age <65 y: 51.4% vs 60.9%	
			<.001	Age >65 y: 67.9% vs 75.9%	
	1.5 y	ND	<.001	Overall: 50.0% vs 63.4%	
			<.001	Age <65 y: 48.1% vs 61.8%	
			<.001	Age >65 y: 66.4% vs 76.7%	
Hyperlipidemia	6 mo	ND	<.001	Overall: 35.8% vs 39.8%	
			<.001	Age <65 y: 33.7% vs 38.2%	
			.87	Age >65 y: 52.8% vs 53.2%	
	1 y	ND	<.001	Overall: 32.9% vs 40.5%	
			<.001	Age <65 y: 31.0% vs 38.9%	
			.03	Age >65 y: 48.2% vs 53.9%	
	1.5 y	ND	<.001	Overall: 29.2% vs 41.5%	
			<.001	Age <65 y: 27.3% vs 40.1%	
			.01	Age >65 y: 45.6% vs 54.5%	
Coronary artery disease	6 mo	ND	<.001	Overall: 9.6% vs 13.6%	
			<.001	<65 y: 8.5% vs 12.3%	
			.01	>65 y: 19.1% vs 23.8%	
	1 y	ND	<.001	Overall: 9.0% vs 13.7%	
			<.001	<65 y: 7.9% vs 12.4%	
			<.001	>65 y: 17.4% vs 24.7%	
	1.5 y	ND	<.001	Overall: 9.7% vs 14.2%	
			<.001	<65 y: 8.6% vs 12.8%	
			.03	>65 y: 19.5% vs 25.5%	

(continued)

Table 4. Bariatric Surgery and Health Outcomes in the Medicare Population (continued)

Source, Comparison, and Outcome	Time Point	Summary of Findings: Effect Estimate (95% CI)	P Value	Other Findings	Confounders (Methods to Adjust)
Persson et al, 2017[25]					
VBG, RYGB, or duodenal bypass vs no surgery					
All-cause mortality	3.7 y[a]	HR: 0.72 (0.56-0.93)	ND	ND	Age, sex, race/ethnicity, hypertension, diabetes, cardiovascular disease (multiple regression)
Heart failure	3.7 y[a]	HR: 0.35 (0.25-0.49)	ND	ND	
Johnson et al, 2013[20]					
RYGB or AGB vs orthopedic or GI surgery					
All-cause mortality	35.2 mo[a]	HR: 0.68 (0.38-1.23)	ND	ND	Age, sex, race/ethnicity, hypertension, dyslipidemia, diabetes, obstructive sleep apnea, smoking, ischemic myocardial infarction, cardiovascular disease (multiple regression)
CVD mortality	35.2 mo[a]	HR: 0.83 (0.36-1.93)	ND	ND	
Non-CVD mortality	35.2 mo[a]	HR: 0.60 (0.26-1.39)	ND	ND	
Ardestani et al, 2015[14]					
RYGB vs LAGB					
Type 2 diabetes remission	1 mo	ND	.02	Remission rates: 14.4% vs 7%	Age, sex, BMI, % WL (matching)
	3 mo	ND	.001	Remission rates: 28% vs 12.9%	
	6 mo	ND	.01	Remission rates: 30.7% vs 19.3%	
	12 mo	ND	.01	Remission rates: 35.7% vs 24.4%	
Insulin cessation	3 mo	ND	.03	Cessation rates: 37.1% vs 26.3%	

(continued)

levels of HbA_{1c} up to 1 year after surgery.[21] However, among patients with type 2 diabetes, RYGB achieves higher rates of insulin cessation and results in higher rates of clinical remission of type 2 diabetes up to 1 year after surgery.[14]

Three studies[21,22,24] reported on the associations between bariatric surgery and lipids. Obese patients undergoing bariatric surgery have improved lipidemic profile at 6 months, 1 year, and 2 years after surgery, although these improvements do not manifest in the first 6 months for Medicare patients older than 65 years.[24] However, among patients with type 2 diabetes, bariatric surgery with LSG compared with medical treatment and lifestyle modifications results in improvements in low-density lipoprotein (LDL) cholesterol and triglyceride levels but not to other markers of metabolism at 18 months after surgery.[22] With regard to individual procedures, total and LDL cholesterol levels are lower after RYGB compared with SG at 6 and 12 months after surgery, while high-density lipoprotein (HDL) cholesterol levels are higher only at 6 months but they are not different thereafter[21]; in addition, there is no difference between RYGB and SG with regard to triglyceride levels. Similarly, total cholesterol levels are lower after LAGB compared with SG at 6 and 12 months after surgery, but the 2 procedures are not different with regard to their associations with levels of LDL cholesterol, HDL cholesterol, and triglycerides.[21]

Cardiovascular Outcomes

Five studies[21,22,24,25,27] reported on cardiovascular outcomes (Table 4). Patients undergoing bariatric surgery have lower risk of myocardial infarction compared with patients undergoing elective gastrointestinal or orthopedic surgery (HR, 0.59; 95% CI, 0.44-0.79).[27] Similarly, rates of coronary artery disease at 6 months, 1 year, and 2 years after surgery are lower among surgically treated patients compared with nonsurgically treated controls.[24] The association of bariatric surgery with stroke was examined in a single study,[27] which found lower risk among bariatric patients compared with patients undergoing gastrointestinal surgery, but there was no statistically significant difference compared with patients undergoing orthopedic surgery. Additionally, bariatric surgery is associated with lower risk of either myocardial infarction, stroke, or death.[27]

Three studies[21,22,24] reported on the association between bariatric surgery and blood pressure. In patients with type 2 diabetes, no evidence supported an association between bariatric surgery and hypertension compared with conventional weight loss treatment.[22] However, surgically treated patients with obesity have lower rates of hypertension at 1 year and 1.5 years after surgery compared with nonsurgically treated controls.[24] With regard to the comparison of individual bariatric procedures, there was no difference in systolic or diastolic blood pressure among RYGB, SG, and LAGB at 6 and 12 months after surgery, although RYGB appears to be more effective than LAGB in reducing systolic blood pressure at 12 months.[21]

Finally, the association between bariatric surgery and heart failure was examined in 1 study.[25] That study showed that surgically treated patients had lower risk of heart failure compared no surgically treated controls.

Respiratory Outcomes

Only 1 study[24] reported on the associations between bariatric surgery and respiratory outcomes. Among all Medicare beneficiaries, there was evidence of improvement in sleep apnea at 6 months and 18 months after surgery compared with nonsurgically treated controls (Table 4). Results were similar for Medicare

Table 4. Bariatric Surgery and Health Outcomes in the Medicare Population (continued)

Source, Comparison, and Outcome	Time Point	Summary of Findings: Effect Estimate (95% CI)	*P* Value	Other Findings	Confounders (Methods to Adjust)
Lee et al, 2016[21]					
RYGB vs SG					
Reduction in No. of medications	6 mo	1.1 (ND)	.01	ND	Age, sex, race/ethnicity, body weight, BMI, glucose levels, Charlson comorbidity index (IPTW based on propensity score)
	12 mo	1.4 (ND)	.001	ND	
Glucose levels, mg/dL	6 mo	1.1 (ND)	.80	ND	
	12 mo	−7.3 (ND)	.08	ND	
HbA_{1c} levels	6 mo	−0.1 (ND)	.46	ND	
	12 mo	−0.1 (ND)	.73	ND	
Total cholesterol level, mg/dL	6 mo	−21.6 (ND)	.003	ND	
	12 mo	−27. (ND)1	.002	ND	
LDL cholesterol level, mg/dL	6 mo	−14.7 (ND)	.03	ND	
	12 mo	−26.1 (ND)	<.001	ND	
HDL cholesterol level, mg/dL	6 mo	−5.1 (ND)	.02	ND	
	12 mo	−2.3 (ND)	.49	ND	
Triglyceride level, mg/dL	6 mo	1.7 (ND)	.90	ND	
	12 mo	−2.8 (ND)	.81	ND	
Systolic blood pressure, mm Hg	6 mo	−3.7 (ND)	.45	ND	
	12 mo	−7.2 (ND)	.12	ND	
Diastolic blood pressure, mm Hg	6 mo	−1.5 (ND)	.59	ND	
	12 mo	−3.9 (ND)	.13	ND	
RYGB vs LAGB					
Reduction in No. of medications	6 mo	1.5 (ND)	<.001	ND	
	12 mo	2.1 (ND)	<.001	ND	
Glucose level, mg/dL	6 mo	−4.9 (ND)	.49	ND	
	12 mo	−8.3 (ND)	.18	ND	
HbA_{1c} level	6 mo	−0.1 (ND)	.80	ND	
	12 mo	−0.2 (ND)	.28	ND	
Total cholesterol level, mg/dL	6 mo	−0.7 (ND)	.92	ND	
	12 mo	−6.7 (ND)	.34	ND	
LDL cholesterol level, mg/dL	6 mo	0.3 (ND)	.96	ND	
	12 mo	−9.3 (ND)	.14	ND	
HDL cholesterol level, mg/dL	6 mo	−1.1 (ND)	.76	ND	
	12 mo	2.2 (ND)	.54	ND	
Triglyceride level, mg/dL	6 mo	5 (ND)	.70	ND	
	12 mo	−9.4 (ND)	.60	ND	
Systolic blood pressure, mm Hg	6 mo	1.1 (ND)	.80	ND	
	12 mo	−11.5 (ND)	.03	ND	
Diastolic blood pressure, mm Hg	6 mo	−0.9 (ND)	.76	ND	
	12 mo	−2 (ND)	.50	ND	
SG vs LAGB					
Reduction in No. of medications	6 mo	0.4 (ND)	.39	ND	
	12 mo	0.7 (ND)	.15	ND	
Glucose level, mg/dL	6 mo	−6 (ND)	.39	ND	
	12 mo	−1 (ND)	.89	ND	
HbA_{1c} levels	6 mo	0	.67	ND	
	12 mo	−0.1 (ND)	.56	ND	
Total cholesterol level, mg/dL	6 mo	20.9 (ND)	.01	ND	
	12 mo	20.4 (ND)	.03	ND	
LDL cholesterol level, mg/dL	6 mo	15 (ND)	.05	ND	
	12 mo	16.8 (ND)	.05	ND	
HDL cholesterol, mg/dL	6 mo	4 (ND)	.30	ND	
	12 mo	4.5 (ND)	.30	ND	
Triglyceride level, mg/dL	6 mo	3.3 (ND)	.82	ND	
	12 mo	−6.6 (ND)	.70	ND	
Systolic blood pressure, mm Hg	6 mo	4.8 (ND)	.40	ND	
	12 mo	−4.3 (ND)	.48	ND	
Diastolic blood pressure, mm Hg	6 mo	0.6 (ND)	.85	ND	
	12 mo	1.9 (ND)	.54	ND	

(continued)

Table 4. Bariatric Surgery and Health Outcomes in the Medicare Population (continued)

Source, Comparison, and Outcome	Time Point	Summary of Findings: Effect Estimate (95% CI)	P Value	Other Findings	Confounders (Methods to Adjust)
Leonetti et al, 2012[22]					
LSG vs lifestyle/medical treatment					
Polypharmacy/drug use	18 mo	ND	ND	LSG: mean No. of antihypertensive drugs decreased from 1.5 to 0.83 pills; mean No. of hypolipemic drugs decreased from 0.4 to 0.2; lifestyle/medical treatment: mean No. of antihypertensive drugs increased from 1.53 to 1.78 pills; mean No. of hypolipemic drugs increased from 0.53 to 0.83 pills	Age, sex, BMI, duration of diabetes, cholesterol levels (multiple regression)
HbA_{1c}	18 mo	ND	<.001	Duration of diabetes >10 y: 2.9 percentage point reduction in LSG vs 0.31 percentage point reduction in control	
			>.05	Duration of diabetes <10 y: 1.23 percentage point reduction in LSG vs 1.24 percentage point disease, or other reduction in control	
Total cholesterol level	18 mo	ND	>.05	6-mg/dL Reduction in LSG vs −14.4-mg/dL reduction in control	
HDL cholesterol level	18 mo	ND	<.01	10.8-mg/dL Increase in LSG vs 1.3-mg/dL increase in control	
LDL cholesterol level	18 mo	ND	>.05	3.6-mg/dl Decrease in LSG vs 7.0-mg/dL decrease in control	
Triglyceride level	18 mo	ND	.011	63.5-mg/dL Reduction in LSG vs 30.3-mg/dL reduction in control	
Glucose level	18 mo	ND	ND	Duration of diabetes >10 y: 116.2-mg/dL reduction in LSG vs 36.1-mg/dL reduction in control (*P* = .05); duration of diabetes <10 y: 45-mg/dL reduction in LSG vs 30.4-mg/dL reduction in control (*P* > .05)	
Valderas et al, 2009[29]					
RYGB vs no surgery					
BMD	3.5 y[a]	ND	<.05	No difference in femoral and lumbar BMD between groups	Age, BMI (matching)
25-Hydroxyvitamin D		ND	<.05	No difference in 25-hydroxyvitamin D between groups	
Hyperparathyroidism/PTH levels		ND	.02	Higher PTH levels in RYGB (mean: 68.3) than in nonsurgically treated controls (mean: 49.4)	
Martin et al, 2015[23]					
Bariatric surgery vs no surgery in patients with high BMI					
Reoperation	3.9 y[a]	HR: 2.5 (1.2-6.2)	ND	ND	BMI (multiple regression)
Revision	3.9 y[a]	HR: 1.39 (0.4-4.7)	ND	ND	
Complications	3.9 y[a]	HR: 0.79 (0.4-1.3)	ND	ND	
Periprosthetic joint infection	3.9 y[a]	HR: 1.98 (0.4-14.3)	ND	ND	
Bariatric surgery vs no surgery in patients with low BMI					
Reoperation	3.9 y[a]	HR: 2.4 (1.2-3.3)	ND	ND	
Revision	3.9 y[a]	HR: 2.2 (1.1-6.5)	ND	ND	
Complications	3.9 y[a]	HR: 0.9 (0.5-1.9)	ND	ND	
Periprosthetic joint infection	3.9 y[a]	HR: 2.6 (0.8-13.4)	ND	ND	

(continued)

Table 4. Bariatric Surgery and Health Outcomes in the Medicare Population (continued)

Source, Comparison, and Outcome	Time Point	Summary of Findings: Effect Estimate (95% CI)	*P* Value	Other Findings	Confounders (Methods to Adjust)
Irwin et al, 2013[19]					
Bariatric surgery vs cholecystectomy/ERCP					
Weekly warfarin dose, mg	6 mo	ND	<.01	The bariatric surgery group had statistically significant greater decreases in the weekly warfarin doses compared with the control group	Age, year of surgery, INR (multiple regression)
Imam et al, 2017[18]					
RYGB or SG vs no surgery					
eGFR, mL/min/1.73 m^2	3 mo	12.58 (10.46-14.7)	ND	ND	Age, race/ethnicity, hypertension, diabetes, body weight (propensity score matching and regression)
	6 mo	13.29 (11.84-14.74)	ND	ND	
	1 y	12.27 (10.87-13.67	ND	ND	
	2 y	12.66 (11.15-14.17)	ND	ND	
	3 y	9.84 (8.05-11.62)	ND	ND	
RYGB vs SG					
eGFR, mL/min/1.73 m^2	3 mo	4.22 (0.49-7.95)	ND	ND	
	6 mo	4.75 (2.21-7.29	ND	ND	
	1 y	5.03 (2.53-7.54)	ND	ND	
	2 y	7.52 (4.84-10.2)	ND	ND	
	3 y	6.6 (3.42-9.78)	ND	ND	
Hernigou et al, 2016[17]					
Bariatric surgery+THA vs THA					
Hip dislocation	1 y	OR: 2.31 (0.99-5.38)	ND	ND	Not reported

Abbreviations: AGB, adjustable gastric banding; BMD, bone mineral density; BMI, body mass index; CVD, cardiovascular disease; DPB, diastolic blood pressure; eGFR, estimated glomerular filtration rate; ERCP, endoscopic retrograde cholangiopancreatography; EWL, excess weight loss; GERD, gastroesophageal reflux disease; GI, gastrointestinal; HbA_{1c}, hemoglobin A_{1c}; HDL, high-density lipoprotein; HR, hazard ratio; INR, international normalized ratio; IPTW, inverse probability of treatment weighting; LAGB, laparoscopic adjustable gastric banding; LDL, low-density lipoprotein; LRYGB, laparoscopic Roux-en-Y gastric bypass; LSG, laparoscopic sleeve gastrectomy; MI, myocardial infraction; ND, no data; OR, odds ratio; PTH, parathyroid hormone; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; SPB, systolic blood pressure; THA, total hip arthroplasty; TKA, total knee arthroplasty; VBG, vertical banded gastroplasty; WL, weight loss.

SI conversion factors: To convert cholesterol to millimoles per liter, multiply by 0.0259; HDL cholesterol to millimoles per liter, multiply by 0.0259; LDL cholesterol to millimoles per liter, multiply by 0.0259; triglycerides to millimoles per liter, multiply by 0.0113; glucose to millimoles per liter, multiply by 0.0555.

[a] Median follow-up in the bariatric surgery group.

beneficiaries younger than 65 years but not for patients aged 65 years or older in whom sleep apnea rates were lower at 6 months after surgery but not at 1 year and 18 months (Table 4).

Orthopedic and Musculoskeletal Outcomes

Three studies[17,23,29] examined the associations between bariatric surgery and orthopedic and musculoskeletal outcomes (Table 4). In postmenopausal women who undergo bariatric surgery, there is increased risk of hyperparathyroidism and higher bone reabsorption but no change in bone mineral density compared with nonsurgically treated controls.[29] Two additional studies[17,23] reported on outcomes after total knee and hip arthroplasty in patients who had undergone bariatric surgery before the orthopedic procedures compared with patients who did not received bariatric surgery. Patients undergoing bariatric surgery before total knee arthroplasty are more likely to need reoperation and revision for total knee arhroplasty,[23] although there is no association with complications or periprosthetic joint infection.[23] Similarly, bariatric surgery prior to total hip arthroplasty does not reduce the risk of hip dislocation.[17]

Renal Function

One study[18] reported on bariatric surgery and renal function. In patients with stage 3 or 4 chronic kidney disease, bariatric surgery patients who underwent either RYGB or SG had a higher estimated glomerular filtration rate (eGFR) than nonsurgically treated controls at up to 3 years after surgery (standardized mean difference, 9.84 mL/min/1.73m^2; 95% CI, 8.05-11.62 mL/min/1.73m^2) (Table 4). Between the 2 procedures, RYGB achieved higher levels of eGFR than SG (standardized mean difference at 3 years, 6.6; 95% CI, 3.42-9.78) (Table 4).

Polypharmacy and Drug Use

Polypharmacy and drug use after bariatric surgery were reported in 3 studies[19,21,22] (Table 4). One study[21] compared the associations between RYGB, SG, and LAGB and the number of medications. At 6 and 12 months after surgery, patients undergoing RYGB had a greater reduction in the number of medications compared with patients undergoing SG or LAGB, while the associations between SG and LAGB did not differ. Patients with type 2 diabetes who undergo LSG may have lower use of their hypolipemic and antihypertensive drugs at 18 months after surgery compared with patients who receive medical treatment and lifestyle modifications for weight loss.[22] Finally, a third study[19] compared postsurgical differences in warfarin doses between patients receiving RYGB or gastric banding and a control group of patients undergoing cholecystectomy or endoscopic retrograde cholangiopancreatography. The decrease in weekly warfarin dose was significantly lower in bariatric patients, who also achieved lower percentage time in therapeutic INR range and experienced less bleeding during the 180-day postsurgical period.

Strength of the Evidence

There is low to moderate strength of evidence regarding the comparative effectiveness and safety associations of bariatric surgery in the Medicare-eligible population (eTables 2-4 in the Supplement). The evidence base consists of NRCS, only a few of which allow for credible estimation of causal treatment effects. In addition, we cannot exclude the possibility that unmeasured confounding may produce inaccurate estimates of their associations.

Discussion

We identified 16 NRCS assessing associations of bariatric surgery procedures in obese patients with characteristics of Medicare beneficiaries. The most commonly studied surgeries are RYGB, SG, and AGB. Most studies have relatively small sample sizes and very few studies have been exclusively performed in patients with type 2 diabetes, cardiovascular disease, or other major obesity-related diseases. In addition to weight loss outcomes, commonly assessed are cardiovascular and metabolic outcomes, mortality, and postoperative complications. For both weight loss and non–weight loss outcomes, the strength of the evidence for causal effects of bariatric surgical procedures in the Medicare-eligible population is low to moderate. Notwithstanding these limitations, bariatric surgery may be associated with sustainable weight loss and with improvements in metabolic, cardiovascular, renal, and musculoskeletal outcomes. Compared with SG and AGB, RYGB appears to be associated with greater weight loss but the 3 procedures have similar associations with most non–weight loss outcomes.

Certain outcomes of primary relevance to the Medicare population have not been extensively studied. These outcomes include health-related quality of life, hospital readmission after surgery, admission to skilled nursing facilities, and ability to return to work. Many studies have assessed the associations between bariatric procedures in intermediate end points and surrogate markers (eg, lipid levels, HbA_{1c} values) but limited evidence exists for hard outcomes, such as type 2 diabetes remission or cardiovascular disease. Even for clinically important outcomes, there is substantial clinical heterogeneity in the evidence base resulting from the use of multiple time points at which an outcome is measured, the combination of multiple procedures into a single arm, and the diagnostic criteria used for certain conditions.

Evidence syntheses of comparative studies specific to the Medicare population are lacking. A systematic review[10] from 2015 reported on effectiveness and safety outcomes based on presurgery vs postsurgery changes in primary studies without a control group. Such studies may provide insights into changes in outcomes after surgery is the lack of a control group does not allow for inferences of causal treatment effects.[30] Comparative evidence is valuable when specific procedures are of interest, such as when patients and clinicians engage in decision making regarding which of various procedures is appropriate or when insurers and payers make coverage determinations about specific procedures. These decisions require that the evidence be sufficient for estimating causal effects, something that is not feasible with before-and-after study designs. Our findings build on recent descriptive evidence for certain bariatric procedures, and especially gastric banding rates of revisional surgery, which are particularly high in the Medicare population reflecting either failure to achieve weight loss or increased complication rates.[31]

To our knowledge, our systematic review is the first to specifically assess the comparative effectiveness and safety of bariatric surgery in the Medicare-eligible population. We identified a small number of NRCS, most of which were deemed to have at least moderate risk of confounding, selection, or measurement biases, because confounders and other prognostic factors were not accounted for. The number of confounders across the studies varied substantially, thus not allowing a clinically meaningful statistical synthesis of treatment effects. Few studies, primarily those using administrative data, accounted for a large number of confounders and are likely to sufficiently balance important differences between intervention groups. Nevertheless, many studies reported on the use of a limited number of confounders, which are unlikely to result in unbiased estimates of treatment effects. Therefore, in the absence of randomized trials in the Medicare population, we graded the available evidence as being of low to moderate strength. These conclusions are in accordance with previous statements from the American College of Cardiology, the American Heart Association, and the Obesity Society[32] regarding long-term cardiovascular outcomes.

Well-conducted and well-executed randomized trials are the standard for estimating causal treatment effects. However, conducting randomized trials in the elderly may be superfluous, challenging, or even impractical. For questions with little or no clinical equipoise, such as comparing bariatric surgery with nonsurgical interventions for weight outcomes, randomized trials would arguably be unnecessary. For comparisons between alternative surgical interventions, however, where the differences in the outcomes are expected to be at most modest, randomized trials may be desirable but challenging to conduct, if only in terms of enrolling enough patients to attain the statistical power to meet the trial's inferential goals. If treatment effects are modest to small, or if substantial patient-level heterogeneity is expected, a trial may have to enroll several hundreds or even thousands of patients. Trials with restrictive eligibility criteria in terms of comorbidities would have to screen a large number of patients to identify eligible individuals because multimorbidity is prevalent in the elderly. Conversely, pragmatic trials with lenient eligibility criteria may need large sample sizes to attain enough power to explore patient-level heterogeneity. It is unclear whether older persons are more or less likely to give consent to be enrolled in a trial compared with younger patients. At any rate, the need for specific randomized trials can be formally addressed using future research prioritization methods, including value-of-information analyses.[33,34]

Patients and clinicians who consider bariatric surgery may still utilize evidence from younger patients to inform clinical judgments and treatment decision making at the individual level.[35] For relatively healthier older adults, results of trials in younger patients may be applicable, albeit not directly. Among younger patients, bariatric surgery overall as well as certain procedures appear both effective for weight loss and reducing the risk of other non–weight loss outcomes and safe.[5-7,36] However, evidence from studies in younger populations is probably not directly generalizable to the broader group of Medicare-eligible patients because Medicare beneficiaries tend to have more and more severe comorbid conditions and are more often frail compared with the non–Medicare-eligible population. Age itself has a strong predictive association with patients' ability to lose weight after surgery with younger patients being able to lose more weight than older ones.[37] Even among younger patients, evidence from non–Medicare-eligible individuals with obesity may not be directly applicable to Medicare beneficiaries as the latter may have disability or end-stage renal disease, and, thus, a different clinical profile and perhaps different prognosis.

Limitations

Our findings must be qualified given the following limitations. First, owing to clinical heterogeneity in interventions, outcomes, and populations, we did not perform a statistical synthesis of study results. Further, the included studies controlled for different sets of cofounders, and thus estimate different conditional effects. Second, we only included studies published after 2000 because many older procedures may not be used in contemporary surgical practice. We believe that this time cut-off is unlikely to have a major impact on our conclusions. Most of the eligible studies were published after 2010, and it is thus unlikely that searching for studies published before 2000 would have yielded a large number of eligible studies that also had systematically different results from the ones we found. Third, the results we report are obtained from nonrandomized studies and may be more susceptible to selection, confounding, and information biases compared with estimates from randomized trials, were any such studies available.

Conclusions

Limited evidence exists about the comparative effectiveness of bariatric procedures in the Medicare population. Carefully designed and analyzed studies of routinely collected health data in large databases and registries using statistical methods to control for confounding may help provide relatively unbiased estimates of treatment effects.

ARTICLE INFORMATION

Accepted for Publication: June 10, 2018.

Published Online: September 5, 2018. doi:10.1001/jamasurg.2018.3326

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Author Contributions: Drs Panagiotou and Trikalinos had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Panagiotou, Trikalinos.
Acquisition, analysis, or interpretation of data: All authors.
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Statistical analysis: Panagiotou, Markozannes, Kowalski, Trikalinos.
Obtained funding: Bond, Ryder, Trikalinos.
Administrative, technical, or material support: Markozannes, Adam, Kowalski, Gazula, Di, Trikalinos.
Supervision: Panagiotou, Trikalinos.
Other - Literature search and screening; data extraction: Adam.

Conflict of Interest Disclosures: None reported.

Funding/Support: Funding was provided from the Agency for Healthcare Research and Quality, US Department of Health and Human Services Contract HHSA290201500002I-HHSA29032009T.

Role of the Funder/Sponsor: Lionel Bañez, MD, and Elise Berliner, PhD, from the Agency for Healthcare Research and Quality (AHRQ) and Jyme Schafer, MD, from the Centers for Medicare & Medicaid Services (CMS) served as contracting officers' representatives and provided technical assistance during the conduct of the evidence report and comments on draft versions of the evidence report. They participated in the topic refinement to ensure that the determination of study eligibility criteria was informative for CMS. Investigators worked with AHRQ staff to develop the scope, analytic framework, and key questions for this review. AHRQ had no role in study selection, quality assessment, or synthesis. AHRQ staff provided project oversight, reviewed the report to ensure that the analysis met methodological standards, and distributed the draft for peer review. Otherwise, AHRQ had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review, or approval of the manuscript findings.

Disclaimer: The findings, conclusions, and opinions in this article are those of the authors, who are responsible for its content, and do not necessarily represent the views of the Agency for Healthcare Research and Quality (AHRQ) and the Centers for Medicare and Medicaid Services (CMS). No statement in this article should be construed as an official position of the AHRQ, CMS or the U.S. Department of Health and Human Services (HHS).

Meeting Presentation: The technology assessment portion of this paper was presented at the Medicare Evidence Development & Coverage Advisory Committee Meeting; August 30, 2017; Baltimore, Maryland.

Additional Contributions: We gratefully acknowledge Aevan McLaughlin, MD (Department of Surgery, Brown University Warren Alpert Medical School) (no compensation was received), and Ms Erin Twomey-Wilson, MSc (Brown University Evidence-based Practice Center) (no compensation was received outside of her normal salary), for their contributions to this project and deeply appreciate their considerable support for and commitment to this work. We also acknowledge the contributions of the Key Informants at the early stage of topic refinement: Maureen T. Quigley, APRN, MS (Dartmouth Hitchcock Medical Center, Lebanon, New Hampshire), Aurora D. Pryor, MD (Stony Brook University School of Medicine, Stony Brook, New York), Samuel Klein, MD (Washington University School of Medicine in St Louis, St Louis, Missouri), Philip R. Schauer, MD, FACS (Cleveland Clinic, Cleveland, Ohio), and Rachel Batterham, MBBS, MRCP, PhD (University College London, London, United Kingdom). A draft version of the full Technology Assessment underwent external peer review from 4 content experts: Joe Nadglowski (Obesity Action Coalition, Tampa, Florida), Bruce M. Wolfe, MD (Oregon Health Sciences University,

School of Medicine, Portland), Maureen T. Quigley, APRN, MS (Dartmouth Hitchcock Medical Center, Lebanon, New Hampshire), and Michael Larsen, MD (Virginia Mason Hospital & Seattle Medical Center, Seattle, Washington).

Additional Information: Comments from reviewers were presented to CMS during its deliberation of the evidence and were considered in preparing the final evidence review.

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