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ARTICLE

Bariatric Surgery

Insurance status differences in weight loss and regain over 5 years following bariatric surgery

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Abstract

Background The effectiveness of bariatric surgery among Medicaid beneficiaries, a population with a disproportionately high burden of obesity, remains unclear. We sought to determine if weight loss and regain following bariatric surgery differed in Medicaid patients compared to commercial insurance.

Subjects/methods Data from the Longitudinal Assessment of Bariatric Surgery, a ten-site observational cohort of adults undergoing bariatric surgery (2006–2009) were examined for patients who underwent Roux-en-Y Gastric Bypass (RYGB), Laparoscopic Adjustable Band (LAGB), or Sleeve Gastrectomy (SG). Using piecewise spline linear mixed-effect models, weight change over 5 years was modeled as a function of insurance type (Medicaid, $N = 190$; commercially insured, $N = 1448$), time, procedure type, and sociodemographic characteristics; additionally, interactions between all time, insurance, and procedure type indicators allowed time- and procedure-specific associations with insurance type. For each time-spline, mean (kg) difference in weight change in commercially insured versus Medicaid patients was calculated.

Results Medicaid patients had higher mean weight at baseline (138.3 kg vs. 131.2 kg). From 0 to 1 year post-operatively, Medicaid patients lost similar amounts of weight to commercial patients following all procedure types (mean weight Δ difference [95% CI]: RYGB: −0.9 [−3.2, 1.4]; LAGB: −1.5 [−6.7, 3.8]; SG: 5.1 [−4.0, 14.2]). From 1 to 3 years post-operatively Medicaid and commercial patients continued to experience minimal weight loss or began to slowly regain weight (mean weight Δ difference [95% CI]: RYGB: 0.9 [0.0, 2.0]; LAGB: −2.1 [−4.2, 0.1]; SG: 0.7 [−3.0, 4.3]). From 3 to 5 years post-operatively, the rate of regain tended to be faster among commercial patients compared to Medicaid patients (mean weight Δ difference [95% CI]: RYGB: 1.1 [0.1, 2.0]; LAGB: 1.5 [−0.5, 3.5]; SG: 1.0 [−2.5, 4.5]).

Conclusions Although Medicaid patients had a higher baseline weight, they achieved similar amounts of weight loss and tended to regain weight at a slower rate than commercial patients.

Introduction

In the United States (U.S.), obesity and its cardiometabolic sequelae are among the leading causes of preventable disease and death [1]. In the general population, bariatric surgery is well documented as the most effective treatment for severe obesity (class II and III) that facilitates important sustained weight loss [2–5]. However, the need to

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characterize patient subgroups who are most likely to benefit from bariatric surgery has been highlighted in the recent obesity treatment guidelines developed by The American College of Cardiology, the American Heart Association, and The Obesity Society [6].

The evidence regarding the effectiveness of bariatric surgery among Medicaid beneficiaries—a low-income population with a disproportionately high burden of obesity—is scant. In recent years, Medicaid eligibility and surgery eligibility have expanded, yet the long-term durability of surgically induced weight loss among Medicaid recipients remains unknown. Seven observational studies have examined weight loss following bariatric surgery among Medicaid beneficiaries. In all but one study, Medicaid patients had a higher baseline weight. Despite these differences, four studies reported similar weight loss outcomes between the groups at follow-up [7–10], while three reported inferior weight loss outcomes among Medicaid patients [11–13]. However, results from these studies are limited by small sample sizes ($n < 500$) [7, 10, 12, 13], short follow-up (< 2 years) [7–10, 13], substantial attrition [7–10], and focus on a single surgeon or center [7, 9, 10, 12, 13]. Importantly, these studies did not examine the variable weight loss and regain that may occur beyond 2 years post-operatively and, as a result, may overestimate the procedure's effectiveness among the subgroups. Investigation of long-term weight loss and regain patterns among Medicaid patients remains a critical step in informing appropriate obesity treatment guidelines for low-income patient populations with severe obesity. Notably, the amount of weight loss and regain following bariatric surgery is central to a patient's ability to achieve and maintain remission of associated comorbidities, like diabetes [14].

To investigate long-term weight loss and regain patterns following bariatric surgery, we compared 5-year weight change between Medicaid beneficiaries and commercially insured patients. We utilize data from the Longitudinal Assessment of Bariatric Surgery (LABS) [15], a large, multi-site, observational cohort with levels of follow-up greater than 85%. We hypothesized that Medicaid patient's experience a similar magnitude of weight loss but earlier onset of and greater weight regain.

Methods

Study population

Between March 2006 and April 2009, 2458 individuals 18 years and older undergoing bariatric procedures were enrolled in the LABS study, a prospective observational cohort study designed to assess the risks and benefits of bariatric surgery. Upon enrollment, LABS participants underwent first-time bariatric procedures with a surgeon participating in the LABS consortium at one of 10 hospitals at six clinical centers in the US, as previously described [15]. The institutional review boards at each center approved the protocol and consent forms; IRB exemption was obtained from Oregon Health & Science University for this analysis of existing data. LABS is registered at ClinicalTrials.gov (NCT00465829).

Analytic sample

Of the 2458 LABS participants, we first excluded participants who were missing baseline health insurance information or reported self-paying for surgery ($N = 389$). Next, participants reporting Medicare only ($N = 210$), Tricare only ($N = 67$) or Other insurance ($N = 86$) were excluded. Participants undergoing Biliary Pancreatic Diversion with Duodenal Switch ($N = 16$) and Banded Bypass ($N = 26$) were uncommon in this cohort and thus excluded. Finally, participants with only a single weight measurement over the five post-operative time points were excluded from analyses ($N = 26$), leaving 1638 participants in the final analytic cohort (Fig. 1).

Data collection

LABS-certified trained personnel collected study data using standard protocols [16, 17]. Data collection consisted of blood and urine samples, physical measurements, self-assessment forms, surgeon and medical staff forms, and chart review procedures. Baseline weights and other clinical data were collected within 30 days before surgery. Annual follow-up assessments were conducted within 6 months of

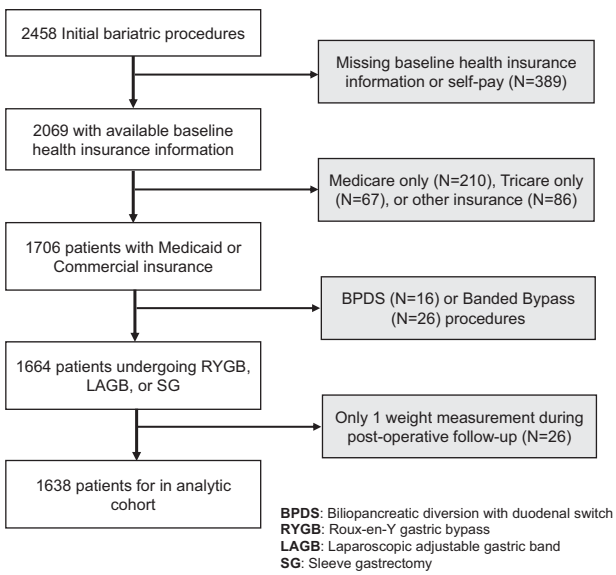

Fig. 1 Flow diagram, creation of analytic cohort

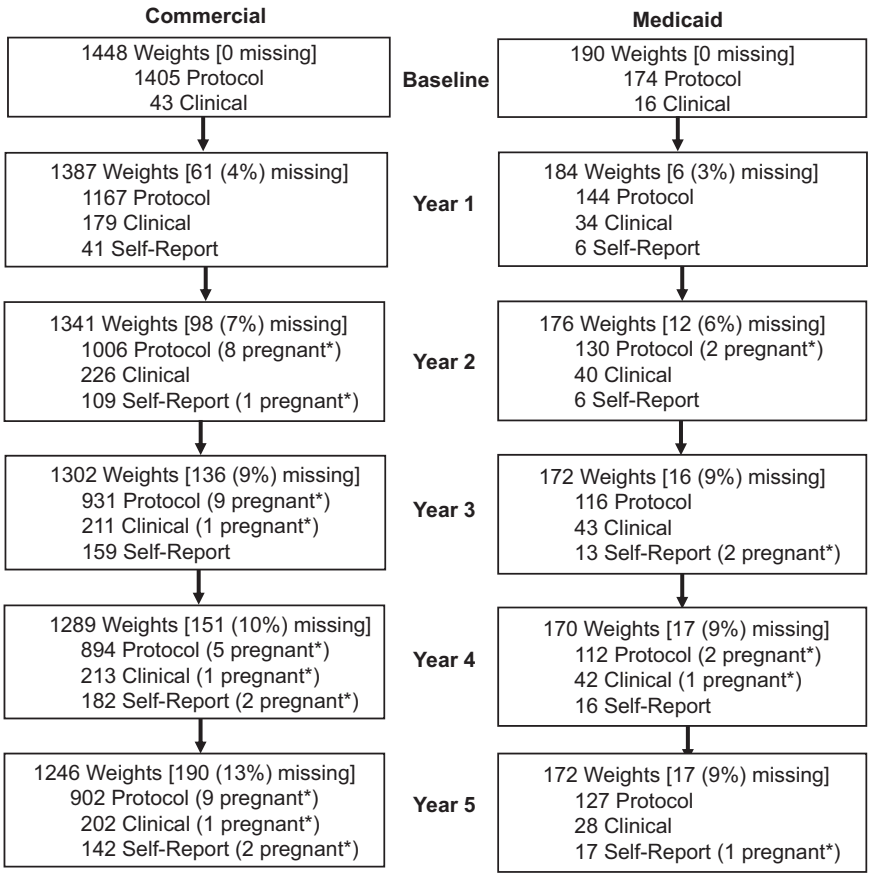

Fig. 2 Flow diagram, weight measurements and missing data over study visits
*Weights of women currently pregnant and those up to 6-months postpartum were excluded from analyses

surgery anniversary date for five consecutive years. Data were entered twice using a web-based data entry system developed, distributed, and maintained by the University of Pittsburgh LABS Data Coordinating Center.

Study variables

Weight (outcome)

During in-person visits, weight was measured using a standard protocol ("protocol" weight) on a study-purchased standard scale (TanitaR Body Composition Analyzer, model TBF-310) [17]. If a protocol weight was not obtained, weight was measured by research or medical personnel on a non-study scale and is referred to as a "clinical weight". If neither a protocol nor clinical weight was available, a validated patient self-reported weight was used (ranging from 3 to 14% of weights across visits) (Fig. 2) [18]. Weight measurements of women who reported being currently pregnant and those up to 6-month postpartum at the time of weight measurement were excluded from analyses (47 person-time observations). Weight was analyzed as continuous weight in kilograms at each study time point; weight, as opposed to weight change, provides more precise statistical estimates and enables comparison of weight at baseline. We additionally examined weight change as a percent of weight at baseline to provide results comparable to most other bariatric surgery literature; and continuous BMI (kg/m^2) to incorporate height and weight, and provide results in a measure commonly used by clinicians in patient discussions.

Insurance type

Self-reported insurance type was collected using a self-assessment form at the baseline study visit. Participants with available baseline insurance information were classified into two categories: (1) Medicaid with or without Medicare; and (2) Commercial insurance with or without Medicare. Participants reporting other insurance types were excluded from this analysis as they were heterogeneous in regards to their sociodemographic and clinical profile. Insurance classification at baseline was analyzed as a time constant variable; potential changes to insurance status over time were not incorporated given the desire to understand how the differences in baseline health status between groups influenced long-term outcomes.

Surgery type

Three primary weight-loss procedures were ascertained from surgeon reports at baseline: (1) Roux-en-Y Gastric

Bypass (RYGB); (2) Laparoscopic Adjustable Gastric Banding (LAGB); and (3) Sleeve Gastrectomy (SG). Participants whose initial bariatric surgery was subsequently revised or reversed ($n = 132$) remain classified with the baseline surgery type to represent the natural history of each participant's post-surgical course.

Covariates

Covariates included self-reported age at surgery, sex (male, female), and baseline smoking status (never, current/former). Comorbidities (diabetes, hypertension, ischemic heart disease, congestive heart failure, history of stroke, sleep apnea, pulmonary hypertension, asthma, history of deep vein thrombosis or pulmonary embolism, and venous edema with ulcerations) were determined using a combination of self-report, clinical assessment, and medical chart review and are all defined elsewhere [15]. An index of comorbidities was created as the number of comorbidities at baseline (range: 0–10) to provide a rough estimate of disease burden.

Statistical analysis

Descriptive statistics summarize baseline characteristics for each insurance category. Pearson's chi-square test for categorical variables and t-tests for continuous variables were used to assess statistical significance of differences in baseline characteristics between the payer groups. Data management was conducted using SAS version 9.4, descriptive analyses and mixed models were conducted using Stata version 13.

To compare the timing and magnitude of weight loss and regain over the 5-year post-operative period, we fit piecewise linear mixed-effects models via maximum likelihood estimation. Piecewise models allowed us to examine nonlinear weight change over time (Supplementary Fig. 1) by fitting linear slopes within each of three-time periods. Among the insurance and surgery subgroups, mixed-effect models enable direct comparison of (1) baseline weight and (2) the timing and magnitude of weight loss and regain during distinct post-operative time periods. Further, mixed-effect models account for correlations among repeated measurements taken on the same individual over time, and missing weight measurements at varying post-operative time points (missingness ranged from 4–13% across time points; Fig. 2); [19] with maximum likelihood estimation, all available follow-up data are optimally used, and, missing outcome data are ignorable under the assumption of missing at random [20].

Appendix A details our model fitting process in which we determined the number and placement of knots, the final detailed regression equation, and how group-specific estimates were obtained. The spline functions were included as fixed and random effects, to estimate overall mean trajectories at the population level, and individual trajectories at the subject-specific level. Baseline covariates (age, sex, smoking status, and comorbidity index) were included as fixed effects.

Sensitivity analyses

First, a similar model was fit that examined percent weight loss from baseline as the primary dependent variable. Continuous weight in kilograms was the primary measure because it yields the most accurate and precise statistical model [21] and allows for comparison of baseline weight; we conducted this sensitivity analysis to provide results that are comparable to most bariatric surgery research. Second, we also fit a similar model with BMI (kg/m^2) as the primary dependent variable. In addition to statistical precision, continuous weight was also chosen as the primary measure as it provides the most logical interpretation over time (weight loss in kilograms per year); we conducted this sensitivity analysis to take into account weight and height and to provide a second clinically relevant outcome. Third, we repeated the primary analyses after restriction of the analytic cohort to patients with no revision or reversal surgery reported during the 5-year post-operative period. The revision or reversal of the primary bariatric surgery may alter the magnitude and timing of post-operative weight loss and regain, thus potentially impacting the group results over time. Fourth, we restricted the Medicaid group excluding Medicaid–Medicare dual eligible patients and repeated the primary analyses. Medicaid bariatric surgery patients who also qualify for Medicare likely do so on the basis of permanent disability given the relatively young age distribution of the study population, thus representing a unique population.

Results

Description of the sample

At baseline, Medicaid patients were slightly younger than commercial patients (mean age: 43.6 vs. 45.2 years) and were more likely to be female (85.7% vs. 79.8%). The baseline comorbidity index was higher among Medicaid patients (mean score: 2.2 vs. 1.9). In summarizing the most common four comorbidities included in this score, the baseline prevalence of diabetes (39.3% vs. 31.4%) and asthma (36.8% vs. 24.1%) was higher among Medicaid patients compared to commercial patients; in contrast, the baseline prevalence of hypertension (68.3% vs. 67.2%) and sleep apnea (53.4% vs. 50.7%) was similar in both groups).

Table 1 Baseline characteristics of 1638 patients undergoing bariatric surgery

Characteristic	Overall (n = 1638)	Commercial (n = 1448)	Medicaid (n = 190)
Age [Mean (SD)]	45.1 (10.7)	**45.2 (10.7)**	**43.6 (11.0)**
Sex [n (%)]			
Male	316 (19.5)	**289 (20.2)**	**27 (14.3)**
Female	1305 (80.5)	**1143 (79.8)**	**162 (85.7)**
Smoking status [n (%)]			
Never smoker	948 (58.5)	**850 (59.4)**	**98 (51.9)**
Current/former smoker	673 (41.5)	**582 (40.6)**	**91 (48.2)**
Weight (kg) [Mean (SD)]	132.0 (25.6)	**131.2 (25.0)**	**138.3 (29.8)**
Comorbidity index [Mean (SD)]	1.9 (1.3)	**1.9 (1.3)**	**2.2 (1.4)**
Comorbidity prevalence [n (%)]			
Diabetes	524 (32.3)	**451 (31.4)**	**73 (39.3)**
Hypertension	1090 (67.3)	961 (67.2)	129 (68.3)
Sleep Apnea	835 (51.0)	734 (50.7)	102 (53.4)
Asthma	410 (25.5)	**343 (24.1)**	**67 (36.8)**
Procedure Type [n (%)]			
RYGB	1186 (73.2)	**1036 (72.4)**	**150 (79.4)**
LAGB	393 (24.2)	**366 (25.6)**	**27 (14.3)**
SG	42 (2.6)	**30 (2.1)**	**12 (6.4)**

Boldface indicates statistical significance ($p < 0.05$) for Commercial versus Medicaid, per t-test or χ^2-test for continuous or categorical variables, respectively

RYGB Roux-en-Y Gastric Bypass, *LAGB* laparoscopic adjustable gastric band, *SG* sleeve gastrectomy, *SD* standard deviation, *kg* kilogram

RYGB was the predominant surgery type in Medicaid (79.4%) and commercial (72.4%) patients. Less commonly Medicaid and commercial patients underwent LAGB (14.4% vs. 25.6%, respectively) and SG (6.4% vs. 2.1%, respectively). Selected characteristics of the analytic sample are reported in Table 1. Follow-up through 5 years was high: 90.5% for Medicaid patients and 87.0% for commercial patients (Fig. 2).

Five-year estimated weight change in patients undergoing RYGB, LAGB, and SG

At baseline, baseline weight was higher in Medicaid compared to commercially insured patients for RYBG and SG, but not LAGB (Table 2; Fig. 3). Baseline weight was the highest among the 12 Medicaid and 30 commercial patients undergoing SG (165.7 and 154.0 kg, respectively), and lower among the 150 Medicaid and 1037 commercial patients undergoing RYGB (137.6 and 132.3 kg), and the 28 Medicaid and 381 commercial patients undergoing LAGB (125.5 and 125.6 kg).

During the 0–1 year post-operative period, both insurance groups lost substantial but similar amounts of weight (kg). Medicaid and commercial patients undergoing SG lost the most weight (53.3 and 48.2 kg per year, respectively; weight Δ difference [95% CI]: 5.1 [−4.0, 14.2]), those undergoing RYGB lost similar amounts (45.1 and 46.0; weight Δ difference [95% CI]: −0.9 [−3.2, 1.4]), while those undergoing LAGB lost the considerably less (18.1 and 19.5; weight Δ difference [95% CI]: −1.5 [−6.7, 3.8]).

In the 1–3-year post-operative period, both insurance groups either continued to lose minimal amounts of weight or slowly regain weight, depending on the procedure type. For RYGB, Medicaid patients began to regain weight, but at a marginally slower rate than commercial patients (0.9 and 1.8 kg per year, respectively; weight Δ difference [95% CI]: 0.9 [0.0, 1.9]). For LAGB, Medicaid patients were regaining weight while commercial patients continued to lose weight (1.4 and -0.6 kg, respectively; weight Δ difference [95% CI]: −2.1 [−4.2, 0.1]). And for SG, Medicaid patients continued to lose weight at a slightly faster rate compared to commercial patients (−1.5 and −0.9 kg, respectively; weight Δ difference [95% CI]: 0.7 [−3.0, 4.3]).

Finally, in the 3–5-year post-operative period, the rate of regain was approximately 1 kg slower among Medicaid patients, compared to commercial patients for both RYGB (1.2 and 2.3, kg per year respectively; weight Δ difference [95% CI]: 1.1 [0.1, 2.0]) and SG (0.9 and 1.9; weight Δ difference [95% CI]: 1.0 [−2.5, 4.5]). For LAGB, Medicaid patients were relatively stable in loss/regain while commercial patients slowly regained weight (−0.3 and 1.2; weight Δ difference [95% CI]: (1.5 [−0.5, 3.5]).

Sensitivity analyses

We performed four sensitivity analyses. First, we reran the foregoing analyses specifying percent weight loss from baseline as the primary dependent variable. The patterns of post-operative regain for the groups and surgery types were analogous to the primary analyses. In the 0–1-year time period, RYGB resulted in 32.5% loss (LAGB: 15.0%; SG: 31.5%) from baseline among Medicaid patients and 34.6% (LAGB: 15.7%; SG: 30.8%) among commercial patients (Supplementary Table 1; Supplementary Fig. 2). In the 3–5-year post-operative period, Medicaid patients maintained a similar percent weight loss than commercial patients following RYGB (28.9% vs. 28.5%, respectively) and SG (30.4% vs. 29.4%, respectively). While examining percent weight loss yields similar overall results, analysis of weight in kg enabled comparison of baseline differences between groups.

Second, we repeated the primary analyses after specifying BMI (kg/m^2) as the primary dependent variable; results were homologous to the results of the primary analyses

Table 2 Estimated mean weight loss/regain between insurance groups by surgery type

Estimated mean	Commercial	Medicaid	Difference (Comm - Med)
Roux-en-Y Gastric Bypass			
Baseline weight (kg)	132.3 (131.0, 133.6)	137.6 (134.1, 141.1)	**5.3 (1.6, 9.0)**
Weight Δ 0 y → 1 y	−46.0 (−46.8, −45.1)	−45.1 (−47.2, −42.9)	−0.9 (−3.2, 1.4)
Weight Δ 1 y → 3 y	1.8 (1.5, 2.1)	0.9 (0.0, 1.8)	0.9 (0.0, 1.9)
Weight Δ 3 y → 5 y	2.3 (2.0, 2.6)	1.2 (0.4, 2.1)	**1.1 (0.1, 2.0)**
Laparoscopic adjustable gastric band			
Baseline weight (kg)	125.6 (123.5, 127.8)	125.5 (117.5, 133.5)	−0.1 (−8.4, 8.1)
Weight Δ 0 y → 1 y	−19.5 (−20.9, −18.2)	−18.1 (−23.1, −13.0)	−1.5 (−6.7, 3.8)
Weight Δ 1 y → 3 y	−0.6 (−1.2, −0.1)	1.4 (−0.6, 3.5)	−2.1 (−4.2, 0.1)
Weight Δ 3 y → 5 y	1.2 (0.6, 1.7)	−0.3 (−2.2, 1.6)	1.5 (−0.5, 3.5)
Sleeve gastrectomy			
Baseline weight (kg)	154.0 (146.3, 161.6)	165.7 (153.6, 177.9)	11.8 (−2.6, 26.2)
Weight Δ 0 y → 1 y	−48.2 (−53.1, −43.4)	−53.3 (−61.0, −45.7)	5.1 (−4.0, 14.2)
Weight Δ 1 y → 3 y	−0.8 (−2.8, 1.1)	−1.5 (−4.6, 1.6)	0.7 (−3.0, 4.3)
Weight Δ 3 y → 5 y	1.9 (0.0, 3.8)	0.9 (−2.1, 3.8)	1.0 (−2.5, 4.5)

Boldface indicates a statistically significant difference ($p < 0.05$)

Δ change, *kg* kilograms, *y* year

(Supplementary Table 2; Supplementary Fig. 3). Medicaid patients had higher BMIs at baseline across all three surgery types and experienced similar response to surgery in the 0–1- and 1–3-year time period. In the 3–5-year post-operative period, Medicaid patients experienced slightly slower increases in BMI levels across surgery types.

Third, we removed any patients who reported undergoing a revision or reversal of their primary procedure and repeated the analyses. Few patients who underwent RYGB ($N = 6$) or SG ($N = 8$) underwent revisions or reversals of their primary surgery. The majority of revisions/reversals occurred in patients undergoing LAGB (Medicaid = 14; Commercial = 87). Upon removing these patients, the pattern of weight loss and regain among patients undergoing RYGB remain unchanged. For both insurance groups undergoing SG and LAGB, the magnitude of weight regain was slightly increased in the 3–5-year post-operative period. (Supplementary Table 3).

Fourth, we restricted the analytic cohort to include Medicaid patients only ($N = 124$), excluding any dual eligible Medicaid–Medicare patients ($N = 66$). The magnitude of the differences in baseline weight between Medicaid and commercial patients decreased (Supplementary Table 4). The post-operative weight loss and regain patterns were otherwise similar to the results of the primary analysis.

Discussion

In this study of weight loss and regain patterns following bariatric surgery, we provide new information on the long-term durability of surgery among Medicaid and commercially insured patients. For all three surgery types examined, Medicaid and commercially insured patients lost a substantial and similar amount of weight in the first post-operative year. During the 1–3-year post-operative period, both insurance groups began to experience minimal amounts of weight regain, with a slight increase in the rate of regain in the 3–5-year period. In contrast to our initial hypothesis, Medicaid patients, on average, exhibited a marginally slower rate of post-operative weight regain compared to commercially insured patients; this difference was more pronounced during the 3–5-year post-operative period.

Seven studies have examined weight loss following bariatric surgery between Medicaid and commercially insured patients, all within 2 years post-operatively [7–13]. Our findings are consistent with prior research in that Medicaid patients were heavier at baseline and lost a similar amount of weight in the first year. However, no other studies have compared Medicaid and commercially insured patients with respect to weight loss beyond 2 years post-operatively or, correspondingly, rate of weight regain over time. Notably, our results demonstrate that modest levels of regain tend to occur after the first post-operative year and then may escalate at 3 years post-operatively; studies with short-term follow-up may consequently overestimate long-term treatment effects.

Baseline differences

Our study findings corroborate the existing body of evidence in that, at baseline, Medicaid patients present with more severe obesity and comorbid disease, which despite

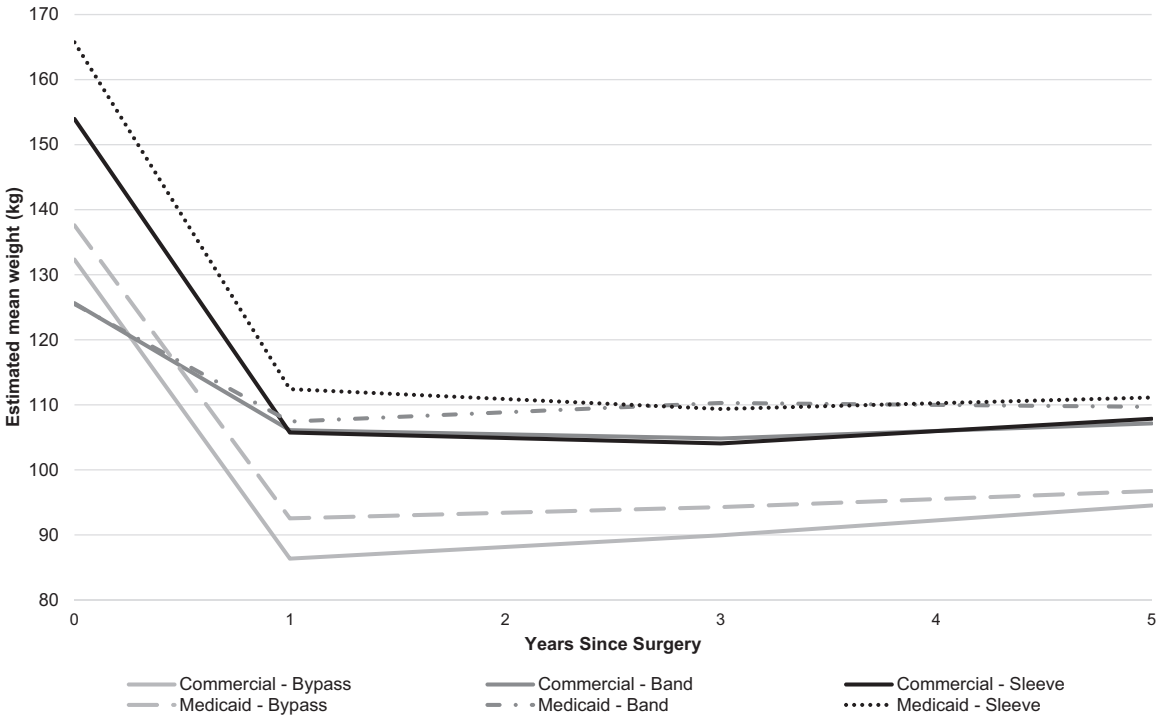

Fig. 3 Estimated weight (kg) over time by insurance type and surgical procedure type

similar surgical response, persists post-operatively. Although we observed that initial weight loss was similar and long-term patterns of regain were slightly superior among Medicaid beneficiaries, Medicaid patients remained heavier at all follow-up time points. A few studies have reported similar differences between the insurance groups at follow-up time points [7, 11–13]. The methods utilized in this study illustrate that those differences are likely attributable to the differences present at baseline, and not the response to surgical intervention.

Several factors likely contribute to these differences, including the strong association between poverty, poor health, and disability, cost prohibitive primary-care health maintenance, delayed diagnosis, and limited access to specialty providers. Hayes et al reported Medicaid patients had a 1.5-month longer interval between initial consultation and surgery compared to the commercially insured; [9] similarly, among insurer groups, Medicaid patients comprise the largest proportion of bariatric surgery eligible patients, who undergo surgery the least often [22, 23]. The contribution of poverty to poor baseline health may be partially modifiable by reducing cost- and provider-related barriers among Medicaid patients, in turn lessening the persistent disparities in post-operative health.

Period-specific differences

Our analysis differed from previously published research examining insurer sub-group differences by examining period-specific weight loss and regain through 5 years post-operatively. Although Medicaid patients presented with a greater burden of baseline disease, they experienced similar amounts of weight loss in the first post-operative year and very minimal weight regain through 5 years post-operatively. Medicaid patients, on average, only regained 1 kg per year over both the 1–3- and 3–5-year period. On the other hand, Commercial patients regained nearly 2 kg per year in the 1–3- and 3–5-year post-operative periods. Although this is not a large clinical difference, it suggests that for patients with severe baseline disease and limited resources, bariatric surgery is a successful and potentially life-saving treatment.

These findings were relatively consistent when we removed patients who either underwent a revision/reversal of their primary bariatric procedure or were dual eligible Medicaid–Medicare. Revisions/reversals were most common in the LAGB group and a slight increase in the magnitude of weight regain in the 3–5-year period was observed. These results suggest that the exclusion of revisions and reversals, when they occur in a large proportion of the study population, may lead to the overestimation of weight regain in the long term. When dual eligible patients were removed, the magnitude in difference in baseline weight lessened between the insurer groups, suggesting the inclusion of dual eligible patients may be important to inform pre-operative care and surgery selection but are potentially less important in informing loss and regain over time.

Despite potential post-operative financial limitations and barriers, Medicaid patients are as successful as commercially insured patients following bariatric surgery. The mechanisms underlying these findings can only be hypothesized, but could occur, at the individual, provider, or community level. Individual level factors could include the general younger age distribution of Medicaid patients or an increased level of motivation due to the longer pre-operative wait times. At the provider level, it is possible that simply gaining and maintaining access to a specialty provider may be associated with improved outcomes. Finally, at the community level, factors like level or quality of social support may contribute to the successful outcomes.

Future directions

To date, no bariatric surgery-specific clinical guidelines exist that help guide surgeons to the best procedure type for a given patient; commonly, the selected procedure is largely a result of surgeon or patient preference. Future research comparing distinct patient subgroups and their outcomes following varied bariatric surgery procedure types and outcomes will help inform an evidence base to guide clinical decision making and further improve long-term patient outcomes.

Also, while SG is a relatively new procedure, it is now the most commonly performed procedure in the U.S. (53.8% of all procedures) [24]. The small number of patients in this cohort undergoing SG, likely a function of the time interval of patient recruitment, limits the ability to draw strong conclusions. Studies with larger samples of patients undergoing SG are essential to further elucidate our findings and better understand the long-term durability of this procedure type among patient subgroups.

More evidence is also needed on the post-operative period extending beyond 5 years post-operatively. No current studies have examined weight loss between insurance or other important patient subgroups in this post-operative period. The apparent upward trend of our 5-year results suggest the rate of weight regain may continue to increase for both insurance groups and surgery types. It is possible that the increased magnitude in regain could be mitigated by the development of time- and group-specific post-operative interventions.

Finally, the further exploration of post-operative predictors of successful long-term outcomes (e.g., physical activity, patient–provider relationship) remains an important area of ongoing research. Although we hypothesize several reasons why the Medicaid sub-group experienced slightly superior weight regain over time, the post-operative mechanisms through which these outcomes function remain unclear. Attributes beyond individual level, like provider and contextual characteristics, should be explored as potentially important predictors.

Clinical and public health implications

These findings suggest that baseline levels of disease are critical to long-term surgical success. For most patient groups, the clinical and administrative pathway to receiving authorization for bariatric surgery is extensive, including identifying and scheduling with specialty providers, myriad of paperwork, and clinical milestones with numerous providers (e.g., dieticians, psychiatrists/psychologists, surgeons). Medicaid beneficiaries face additional barriers to authorization, including the limited number of clinics and clinicians accepting publicly funded patients, the additional pre-operative qualifications required by the state (e.g., requiring type II diabetes), or exclusion of bariatric surgery by the state Medicaid plan. Increasing access to bariatric surgery among Medicaid beneficiaries by universally aligning pre-operative qualifications with the national guidelines and providing consistent state-level coverage may mitigate the disease severity differences that persist post-operatively and help to alleviate the disproportionate burden of obesity carried by this population. Finally, given the increased disease severity prevalent at younger ages among Medicaid beneficiaries, targeted upstream obesity prevention efforts among this sub-population remain a critical area of public health importance.

Strengths and limitations

There were several limitations to this study. First, a relatively small number of bariatric surgery patients in this cohort were covered by Medicaid, although the proportion was similar to national estimates. Further, the small number of patients undergoing SG and LAGB limit the precision of the generated estimates. However, this study is one of the largest samples with 5 years of follow-up to examine weight loss outcomes among Medicaid patients. Second, it is possible that results may under estimate the amount of weight regain due to loss to follow-up, as drop-out from weight loss trials is associated with weight regain [25]. LABS placed a strong emphasis on maximizing retention over time, high levels of weight ascertainment minimized the possibility of this bias.

The primary strength of this study is the availability of long-term follow-up data with high levels of retention, enabling investigation of differences in weight regain between insurance groups. Outcome measures were prospectively collected via a standardized research protocol with objective measurement procedures conducted by trained evaluators. Additionally, our study results provide a high level of generalizability as LABS is a multicenter

geographically diverse cohort with long-term follow-up. Finally, our study provides one of the largest sample sizes to date, filling a gap from prior studies.

Conclusions

Both Medicaid and commercial patients enrolled in a nationally representative longitudinal cohort undergoing bariatric surgery, lost and maintained a substantial amount of weight through 5 years post-operatively. We observed that Medicaid patients undergoing RYGB, LAGB, and SG regained weight at a similar or slightly slower rate over the 5-year post-operative period compared to commercially insured patients. We also observed that Medicaid patients had more severe levels of obesity at baseline and this persisted through post-operative time points even with the slower rate of regain. These results provide important evidence for the beneficial association between surgery and long-term weight loss among Medicaid patients.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. CDC. Adult Obesity Causes & Consequences 2016. https://www.cdc.gov/obesity/adult/causes.html.
2. Stunkard AJ, Stinnett JL, Smoller JW. Psychological and social aspects of the surgical treatment of obesity. Am J Psychiatry. 1986;143:417–29.
3. Velcu LM, Adolphine R, Mourelo R, Cottam DR, Angus LD. Weight loss, quality of life and employment status after Roux-en-Y gastric bypass: 5-year analysis. Surg Obes Relat Dis. 2005;1:413–6. discussion 7
4. Courcoulas AP, Christian NJ, Belle SH, Berk PD, Flum DR, Garcia L, et al. Weight change and health outcomes at 3 years after bariatric surgery among individuals with severe obesity. JAMA. 2013;310:2416–25.
5. Courcoulas AP, Yanovski SZ, Bonds D, Eggerman TL, Horlick M, Staten MA, et al. Long-term outcomes of bariatric surgery: a National Institutes of Health symposium. JAMA Surg. 2014;149:1323–9.
6. Jensen MD, Ryan DH, Apovian CM, Ard JD, Comuzzie AG, Donato KA, et al. 2013 AHA/ACC/TOS guideline for the management of overweight and obesity in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. J Am Coll Cardiol. 2014;63(25 Pt B):2985–3023.
7. Alexander JW, Goodman HR, Hawver LRM, James L. The impact of medicaid status on outcome after gastric bypass. Obes Surg. 2008;18:1241–5.
8. Gomez JP, Davis MA, Slotman GJ. In the superobese, weight loss and resolution of obesity comorbidities after biliopancreatic bypass and/or duodenal switch vary according to health insurance carrier: Medicaid vs Medicare vs Private insurance vs Self-Pay in 1681 Bariatric Outcomes Longitudinal Database patients. Am J Surg. 2016;211:519–24.
9. Hayes S, Napolitano MA, Lent MR, Wood GC, Gerhard GS, Irving BA, et al. The effect of insurance status on pre- and post-operative bariatric surgery outcomes. Obes Surg. 2015;25:191–4.
10. Jensen-Otsu E, Ward EK, Mitchell B, Schoen JA, Rothchild K, Mitchell NS, et al. The effect of Medicaid status on weight loss, hospital length of stay, and 30-day readmission after laparoscopic Roux-en-Y gastric bypass surgery. Obes Surg. 2015;25:295–301.
11. Chen EY, Fox BT, Suzo A, Greenberg JA, Campos GM, Garren MJ, et al. One-year surgical outcomes and costs for medicaid versus non-medicaid patients undergoing laparoscopic Roux-en-Y Gastric Bypass: a single-center study. Surg Laparosc Endosc Percutan Tech. 2016;26:38–43.
12. Funk LM, Suzo A, Mikami DJ, Needleman BJ. Two-year outcomes for medicaid patients undergoing laparoscopic Roux-en-Y gastric bypass: a case-control study. Obes Surg. 2014;24:1679–85.
13. Melton GB, Steele KE, Schweitzer MA, Lidor AO, Magnuson TH. Suboptimal weight loss after gastric bypass surgery: correlation of demographics, comorbidities, and insurance status with outcomes. J Gastrointest Surg. 2008;12:250–5.
14. Purnell JQ, Selzer F, Wahed AS, Pender J, Pories W, Pomp A, et al. Type 2 diabetes remission rates after laparoscopic gastric bypass and gastric banding: results of the Longitudinal Assessment of Bariatric Surgery study. Diabetes Care. 2016;39:1101–7.
15. Belle SH, Berk PD, Chapman WH, Christian NJ, Courcoulas AP, Dakin GF, et al. Baseline characteristics of participants in the Longitudinal Assessment of Bariatric Surgery-2 (LABS-2) study. Surg Obes Relat Dis. 2013;9:926–35.
16. Belle S, Consortium L. The NIDDK Bariatric Surgery Clinical Research Consortium (LABS). Surg Obes Relat Dis. 2005;1:145–7.
17. Belle SH, Berk PD, Courcoulas AP, Flum DR, Miles CW, Mitchell JE, et al. Safety and efficacy of bariatric surgery: Longitudinal Assessment of Bariatric Surgery. Surg Obes Relat Dis. 2007;3:116–26.
18. Christian NJ, King WC, Yanovski SZ, Courcoulas AP, Belle SH. Validity of self-reported weights following bariatric surgery. JAMA. 2013;310:2454–6.
19. Fitzmaurice GM, Laird NM, Ware JH. Applied longitudinal analysis. 2nd ed. Hoboken, NJ: Wiley; 2011. **xxv**, 701pp.
20. Ibrahim JG, Molenberghs G. Missing data methods in longitudinal studies: a review. Test (Madr). 2009;18:1–43.

21. Dallal RM, Quebbemann BB, Hunt LH, Braitman LE. Analysis of weight loss after bariatric surgery using mixed-effects linear modeling. Obes Surg. 2009;19:732–7.
22. Livingston EH, Ko CY. Socioeconomic characteristics of the population eligible for obesity surgery. Surgery. 2004;135:288–96.
23. Martin M, Beekley A, Kjorstad R, Sebesta J. Socioeconomic disparities in eligibility and access to bariatric surgery: a national population-based analysis. Surg Obes Relat Dis. 2010;6:8–15.
24. Ponce J, DeMaria EJ, Nguyen NT, Hutter M, Sudan R, Morton JM. American Society for Metabolic and Bariatric Surgery estimation of bariatric surgery procedures in 2015 and surgeon workforce in the United States. Surg Obes Relat Dis. 2016;12:1637–9.
25. Puzziferri N, Roshek TB 3rd, Mayo HG, Gallagher R, Belle SH, Livingston EH. Long-term follow-up after bariatric surgery: a systematic review. JAMA. 2014;312:934–42.