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Acute Care Utilization and Costs Up to 4 Years After Index Sleeve Gastrectomy or Roux-en-Y Gastric Bypass

A National Claims-based Study

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Objective: To compare acute care utilization and costs following sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB).

Summary Background Data: Comparing postbariatric emergency department (ED) and inpatient care use patterns could assist with procedure choice and provide insights about complication risk.

Methods: We used a national insurance claims database to identify adults undergoing SG and RYGB between 2008 and 2016. Patients were matched on age, sex, calendar-time, diabetes, and baseline acute care use. We used adjusted Cox proportional hazards to compare acute care utilization and 2-part logistic regression models to compare annual associated costs (odds of any cost, and odds of high costs, defined as ≥80th percentile), between SG and RYGB, overall and within several clinical categories.

Results: The matched cohort included 4263 SG and 4520 RYGB patients. Up to 4 years after surgery, SG patients had slightly lower risk of ED visits [adjusted hazard ratio (aHR): 0.90; 95% confidence interval (CI): 0.85,0.96] and inpatient stays (aHR: 0.80; 95% CI: 0.73,0.88), especially for events associated with digestive-system diagnoses (ED aHR: 0.68; 95% CI: 0.62,0.75; inpatient aHR: 0.61; 95% CI: 0.53,0.72). SG patients also had lower odds of high ED and high total acute costs (eg, year-1 acute costs adjusted odds ratio (aOR) 0.77; 95% CI: 0.66,0.90) in early follow-up. However, observed cost differences decreased by years 3 and 4 (eg, year-4 acute care costs aOR 1.10; 95% CI: 0.92,1.31).

Conclusions: SG may have fewer complications requiring emergency care and hospitalization, especially as related to digestive system disease. However, any acute care cost advantages of SG may wane over time.

Keywords: acute care, gastric bypass, sleeve gastrectomy

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Despite the safety and efficacy of bariatric surgery, patients with severe obesity represent a high-morbidity population at increased risk of complications.1·2 Sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB) comprise >90% of bariatric procedures performed in the United States.[3] Several studies have demonstrated increased emergency department (ED)[4-8] and inpatient[3,4,8-15] utilization after these 2 surgeries, potentially more so for patients undergoing RYGB.[1,4-6,8-10,12-17] However, follow-up for many of these studies is limited to the first 30 days after surgery[4,9-14] and many have not directly compared SG and RYGB patients.[1,18-28] Data on reasons for postbariatric acute care use are also limited. In addition to surgical complications, patients may experience indirect sequelae of surgery such as exacerbation of mental illness.[29] Alternatively, some postbariatric acute care could represent desired consequences of weight loss, such as pregnancy or eligibility for joint replacement.[30,31]

The present analysis uses a nationwide insurance claims database to characterize ED and inpatient utilization and costs among matched patients with SG or RYGB, up to 4 years after their index procedures.

METHODS

Study Design and Data Source

This retrospective cohort study was conducted in Optum's deidentified Clinformatics Data Mart Database, which includes all medical and pharmacy claims, as well as enrollment and socioeconomic information, for members with commercial or Medicare Advantage plans from January 1, 2008 to June 30, 2017. The study was approved by the Harvard Pilgrim Institutional Review Board.

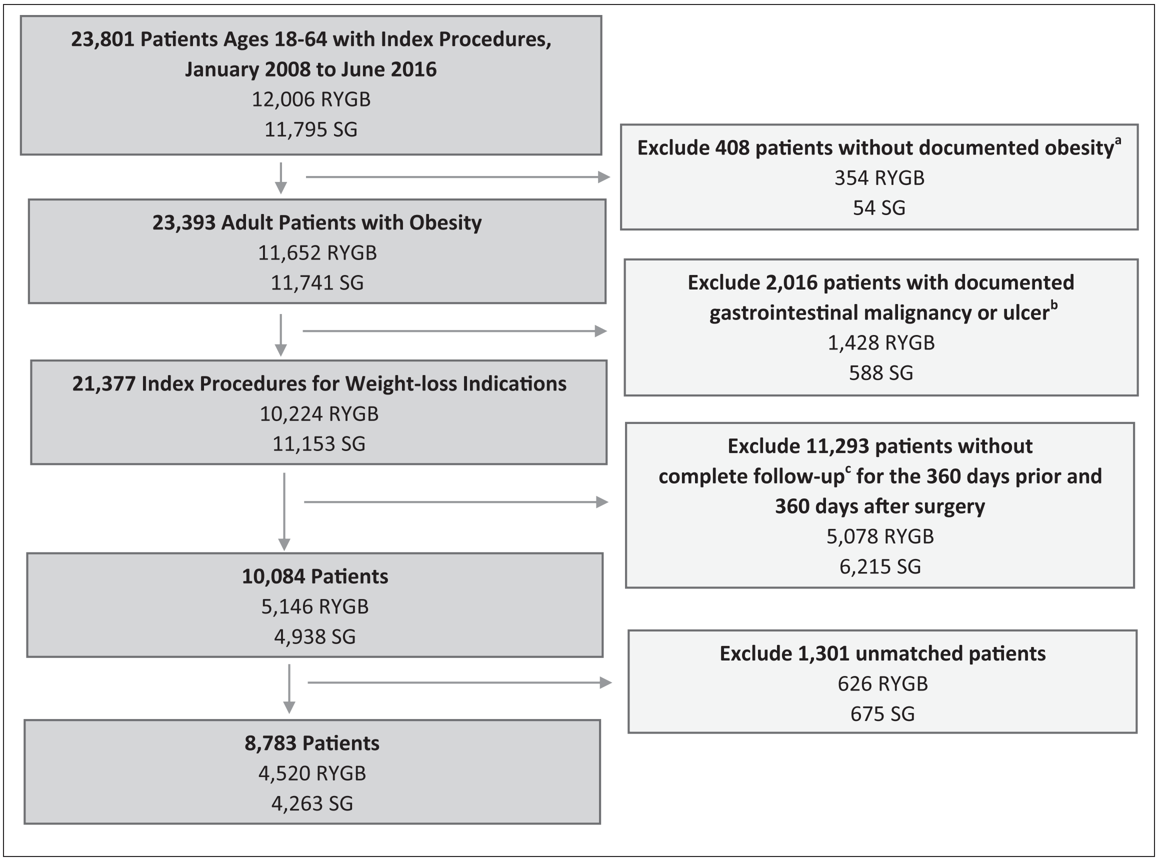

FIGURE 1. Flow diagram for cohort selection. It presents our inclusion/exclusion criteria and subsequent impact on sample size. RYGB indicates Roux-en-Y gastric bypass;SG, Sleeve gastrectomy. A, Based on the presence of either a specific BMI diagnosis $>30\,kg/m^2$ or a nonspecific morbid obesity diagnosis in the 390 days before surgery. B, Patients were excluded if they had a gastrointestinal malignancy diagnosis in the 720 days prior or a gastrointestinal ulcer diagnosis or procedure in the 30 days before their index surgery. C, Patients were censored when they turned 65, in the last month of our dataset (June 1, 2017), on the date of incident gastrointestinal malignancy or at insurance disenrollment (loss to follow-up).

Study Population

The study sample comprised adult bariatric patients (ages 18– 64 years) who underwent index laparoscopic SG or RYGB between January 1, 2008 and June 6, 2016 (Fig. 1). We identified patients' first bariatric surgery using previously-described procedure codes.[2,32] We restricted to surgeries likely performed for weight loss by excluding patients with prior revisional procedures, gastrointestinal malignancy or ulcer, or BMI < 30 kg/m.[2] Procedure codes for SG did not exist before 2010; all surgeries within this group, therefore, occurred after this date.

We required patients to have at least one year (360 days) of continuous insurance enrollment before and after surgery. A full baseline year was important since the 6 months immediately preceding that surgery displayed, predictably, low levels of ED and inpatient visits, not likely representative of patients' true baseline.

Outcome Measures

We assessed ED visits, hospitalizations, and associated annual acute care costs up to 4 years after SG or RYGB. ED visits and inpatient hospitalizations were identified in the medical claims and assigned a single primary diagnosis. We used discharge diagnoses for inpatient episodes since these reflect providers' final diagnostic assessment; the discharge diagnosis was the same as the admitting diagnosis for 97% of hospitalizations (data not shown). For ED visits, we prioritized diagnoses that were generated from face-to-face encounters with a provider. ED and inpatient visits were treated as 2 separate outcomes; a detailed algorithm can be found in Table A1, http://links.lww.com/SLA/D158 in the Supplement.

Annual acute care costs were measured in 2017 U.S. Dollars (USD) using the vendor's standardized cost variable, which eliminates pricing variability across calendar time (inflation) and region. We summed total acute care (inpatient and ED) costs for enrolled patients in the year before surgery (day –390 to –30) and within 1 year (day 14–360), 2 years (day 361–720), 3 years (day 721–1080), and 4 years (day 1081–1440) after surgery. Costs were winsorized (ie, capped) at the 95th percentile to reduce the impact of outliers.

To characterize common reasons for acute care use in our cohort, a clinician on the study team (K.H.L.) assigned each primary diagnosis into one of 11 clinical categories: "Digestive System," "Orthopedic/Musculoskeletal or Rheumatologic," "Skin/Subcutaneous tissue," "Neurologic," "Mental Illness" (including substance use), "Genitourinary System," "Cardiovascular

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(including cerebrovascular)," "Eyes, Ears/Nose/Throat (ENT) and Respiratory Tract," "Infectious/Parasitic Diseases," "Pregnancy," and "Miscellaneous" (comprising rare diagnoses, such as those related to hematologic, oncologic or metabolic disease, Table A2, http://links.lww.com/SLA/D157 in Supplement). Pregnancy-related episodes were assessed among women who were aged 18 to 49 on the date of surgery. Diagnosis codes were included in the infectious and parasitic diseases category if they specified an infectious agent (eg, streptococcal pneumonia), otherwise, they were classified by body system (eg, "bronchitis" as assigned to the "ENT and Respiratory Tract" category).

Covariates

Demographic measures included age, sex, and US region. We used validated measures to assign census-tract-level race[33–35] and poverty[33,36] and the Johns Hopkins ACG software[37] to measure presurgical morbidity and to flag cardiovascular disease, mental illness, and hypertension diagnoses in patients' baseline claims. The most recently coded presurgery BMI diagnosis was categorized as: "30–39.9"; "40–49.9"; "50–59.9"; ">60" kg/m^2, or "nonspecific obesity" when only a generic code (eg, ICD9 278.01 for morbid obesity) was available; this diagnosis-based approach has high validity compared to electronic health records.[38] Diabetes status was determined using diagnoses and insulin fills in the baseline year. Finally, because of secular trends in surgical technique and safety, surgeries were grouped by calendar period (2008–2011, 2012–2014, and 2015–2016).

Matching Strategy

We used Coarsened Exact Matching (CEM) to balance SG and RYGB groups within strata of measured characteristics, akin to stratified randomization in a trial.[39] We matched on variables likely to be associated with both procedure choice and acute care utilization: age group, sex, time period group, and diabetes, including a separate variable for insulin use to approximate more severe diabetes. Patients were also matched on whether they had (1) at least 1 ED but no inpatient, (2) at least 1 inpatient, or (3) no acute episodes in the year before surgery, and on categories of baseline acute care costs ("$0," "$1–500," "$500–999," and "≥$1,000" for ED and "$0," "$1–9999," "$10,000–24,999," and "≥$25,000" for inpatient).

Statistical Analysis

Measured characteristics were compared before and after matching using standardized differences, with values $< |0.2|$ used to deem groups well-balanced.[40]

We used CEM-weighted Kaplan Meier curves with 95% confidence intervals to estimate cumulative incidences of ED and inpatient use, overall and by clinical category, at 360 and 1440 days postsurgery. To provide additional detail about conditions common in postbariatric acute care, we described primary diagnoses associated with first events in each category. Patients without a qualifying event were censored at age 65, at the end of the data (June 1, 2017), or at insurance disenrollment (loss to follow-up). Cox proportional hazards models were used to compare the cumulative hazards of each outcome at 1440 days (4 years) after SG versus RYGB.

We used a 2-part model approach, employing logistic regression to compare the odds of having (1) any cost in a year and (2) "high annual acute care costs, for SG vs RYGB. We did not perform linear modeling of acute care costs, since a majority of patients did not experience ED or hospitalization events; linear estimation would therefore have been skewed by a high proportion of zero costs.

It is frequently cited that the top 20% of patients account for 80% of medical costs.[41] We, therefore, defined members as having a "high-cost year" for a particular category (eg, ED visits, inpatient visits) if they exceeded the 80th cost percentile, relative to all adults in our dataset. Because secular trends in billing and available services could lead to changing cost distributions, we identified the "high cost" cutoffs based on adult members with nonzero costs and complete enrollment in 2012 (our study mid-point). The final cutoffs were: $9000 for total acute care, $700 for ED, and $30,000 for inpatient costs (Table A3, http://links.lww.com/SLA/D158 in Supplement). These values aligned with published data.[42,43]

Sensitivity Analyses

Our study approach optimized internal validity by matching SG and RYGB patients within calendar-year time periods (2008–2011, 2012–2014, 2014–2016), which could have reduced generalizability due to down-weighting of more recent SG and up-weighting of earlier SG procedures. To explore whether surgeries performed in earlier years differed systematically from later procedures, we repeated our analyses stratified by time period. We restricted to the first year after surgery, when all members had complete follow-up.

All models used the matching weights and adjusted for US region, which remained imbalanced postmatch.[40] The main exposure of surgical type met the proportional hazards assumption in the overall ED and inpatient Cox models (data not shown). We considered $P < 0.05$ statistically significant.

RESULTS

Study Population

The matched cohort included 4263 SG and 4520 RYGB patients; 78.2% were female, the mean (std) age was 45.2 (9.2) years, 62.8% of patients had documented presurgery BMIs over 40 kg/m^2, and 67.9% of surgeries were performed before 2012. SG patients were more likely to reside in Southern states, while RYGB was more common in the West and Midwest (standardized difference 0.24, Table 1). After 2012, SG was more common than RYGB; however, after matching within 3-year periods (2008–2011, 2012–2014, 2015–2017), there was no significant calendar difference between the matched groups (Table 1). The percentage of patients remaining at 720, 1080, and 1440 days were: 76.3%, 51.3%, and 35.3% of the SG group and 71.6%, 49.0%, and 34.5% of the RYGB group. We did not observe any substantial differences between patients enrolled at each of these time points, other than year of surgery. Despite attrition, the groups remained balanced on measured characteristics in each follow-up year (Tables A4, http://links.lww.com/SLA/D158 and A5, http://links.lww.com/SLA/D158 in Supplement).

Emergency Department Use

ED visits were common, with similar estimated cumulative incidences of 56.3% [95% confidence interval (CI): 54.3, 58.3] and 57.5% (95% CI: 55.7, 59.4) among SG and RYGB patients, respectively, by 1440 days (Table A6, http://links.lww.com/SLA/D158 in Supplement). Our finding of slightly lower cumulative ED use for SG (aHR: 0.90; 95% CI: 0.85, 0.96; Fig. 3) seemed to be driven by early postoperative differences (Fig. 2). In the 360 days after surgery, the most common diagnoses for first ED visits among SG patients were abdominal pain (14.5%), endocrine/metabolic diagnoses (5.9%), skin wounds

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Table 1Presurgery Characteristics of Matched and Unmatched Cohorts of Patients With Index SG and RYGB

	Before Matching, No. (%)			After Matching,* No. (%)		
Variable‡	*RYGB (N = 5146)*	*SG (N = 4938)*	*Standardized Difference*†	*RYGB (N = 4520)*	*SG (N = 4263)*	*Standardized Difference*†
Year of Surgery			1.2			0.00
2008–2011	3543 (68.9%)	920 (18.6%)		3071 (67.9%)	2896 (67.9%)	
2012–2014	1330 (25.9%)	2438 (49.4%)		1198 (26.5%)	1130 (26.5%)	
2015–2017	271 (5.3%)	1580 (32%)		251 (5.6%)	237 (5.6%)	
Age ≥ 40 yr	3517 (68.3%)	3374 (68.5%)	0.07	3139 (69.5%)	2960 (69.5%)	0.00
Female sex	3959 (76.9%)	3717 (75.3%)	−0.04	3533 (78.2%)	3332 (78.2%)	0.00
White Neighborhood,§ ≥ 75%	2791 (54.2%)	2567 (52%)	−0.05	2428 (53.7%)	2248 (52.7%)	–0.02
Neighborhood Poverty‖			0.06			0.14
Less poor (< 10%)	2363 (45.9%)	2427 (49.1%)		2083 (46.1%)	1981 (46.5%)	
More poor (≥10%)	2762 (53.7%)	2495 (50.5%)		2419 (53.5%)	2274 (53.3%)	
Missing	21 (0.4%)	16 (0.3%)		18 (0.4%)	8 (0.2%)	
region of United States			0.15			0.24
West	1065 (20.7%)	878 (17.8%)		968 (21.4%)	670 (15.7%)	
South	2413 (46.9%)	2551 (51.7%)		2120 (46.9%)	2483 (58.3%)	
Midwest	1182 (23.0%)	931 (18.9%)		1018 (22.5%)	707 (16.6%)	
Northeast	486 (9.4%)	578 (11.7%)		414 (9.2%)	402 (9.4%)	
BMI category¶			0.41			0.00
30–39.9	522 (10.1%)	801 (16.2%)		430 (9.5%)	406 (9.5%)	
40–49.9	2631 (51.1%)	2563 (51.9%)		2361 (52.2%)	2227 (52.2%)	
50–59.9	489 (9.5%)	760 (15.4%)		412 (9.1%)	389 (9.1%)	
≥60	99 (1.9%)	185 (3.7%)		67 (1.5%)	63 (1.5%)	
Nonspecific obesity	1405 (27.3%)	629 (12.7%)		1250 (27.7%)	1179 (27.7%)	
ACG Score ≥3	1464 (28.4%)	1445 (29.3%)	0.02	1131 (25.0%)	1080 (25.3%)	0.01
Type 2 Diabetes	2236 (43.5%)	1682 (34.1%)	−0.19	1852 (41.0%)	1747 (41.0%)	0.00
Insulin use	607 (11.8%)	310 (6.3%)	−0.19	394 (8.7%)	372 (8.7%)	0.00
Hypertension	2936 (57.1%)	2660 (53.9%)	−0.06	2501 (55.3%)	2446 (57.4%)	0.04
Cardiovascular Disease	560 (10.9%)	476 (9.6%)	−0.04	429 (9.5%)	364 (8.5%)	−0.03
Psychiatric Illness	1222 (23.7%)	1106 (22.4%)	−0.03	1022 (22.6%)	965 (22.6%)	0.00
Baseline Utilization *			0.08			0.00
≥1 inpatient episode	335 (6.5%)	297 (6.0%)		54 (1.2%)	51 (1.2%)	
≥1 ED episode but no inpatient	926 (18.0%)	1017 (20.6%)		693 (15.3%)	654 (15.3%)	
No inpatient or ED	3885 (75.5%)	3624 (73.4%)		3773 (83.5%)	3558 (83.5%)	
Baseline ED cost#			0.09			0.00
$0		4000 (77.7%)	3718 (75.3%)		3800 (84.1%)	3584 (84.1%)
$1–$499	588 (11.4%)	711 (14.4%)		435 (9.6%)	410 (9.6%)	
$500–$999	339 (6.6%)	342 (6.9%)		213 (4.7%)	201 (4.7%)	
≥$1000	219 (4.3%)	167 (3.4%)		72 (1.6%)	68 (1.6%)	
Baseline inpatient cost#			0.00			0.00
$0		4814 (93.5%)	4641 (94%)		4466 (98.8%)	4212 (98.8%)
$1–$9999	91 (1.8%)	94 (1.9%)		14 (0.3%)	13 (0.3%)	
$10,000–$24,999	150 (2.9%)	127 (2.6%)		31 (0.7%)	29 (0.7%)	
≥$25,000	91 (1.8%)	76 (1.5%)		9 (0.2%)	8 (0.2%)	

Table 1 presents demographic and clinical characteristics of patients with index SG and RYGB, before and after matching.
*We conducted coarsened exact matching (CEM) on age group, sex, calendar year group, baseline diabetes status, insulin use, utilization, and costs.
†Standardized differences are the difference in means between intervention and control divided by the SD of the difference in means. Lower absolute values indicate greater similarity, and values < 0.2 indicate minimal differences between groups.
‡Please refer to the methods section for complete descriptions of how we constructed baseline variables.
§White neighborhoods defined as census tracts where > 75% of residents were Non-Hispanic White.
‖Neighborhoods with more poverty were those where ≥10% of households were below the poverty line.
¶Body mass index based on most recent pre-surgery diagnosis.
#Categories based on 390 days before surgery, excluding the 30 days immediately before the index procedure.
ACG indicates Johns Hopkins Adjusted Clinical Groups System; BMI, Body Mass Index; ED, Emergency Department; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

(5.1%) and syncope (4.6%), and 5.9% of first-year visits were for nonspecific conditions (eg, unspecified injury, weakness, or fatigue). Among RYGB patients, the most common diagnoses were abdominal pain (22.8%), chest pain/angina (5.8%), skin wounds (5.4%), nausea/vomiting (4.3%), and nephrolithiasis (4.2%) (Table A7, http://links.lww.com/SLA/D158 in Supplement).

Among the ED subcategories, we observed the highest incidence for digestive-system-related visits (19.8% for SG and 26.4% for RYGB by 1440 days, Table A6, http://links.lww.com/SLA/D158 in Supplement). SG patients had lower 4-year cumulative hazards of digestive-system-related ED use (aHR: 0.68; 95% CI: 0.62,0.75, Fig. 3) compared to RYGB patients. Abdominal pain, nausea, or vomiting accounted for > 60% of ED visits in the first year. During year 4, gallbladder or biliary-tract-related diagnoses represented 12.5% to 14.0% of visits (Table A8, http://links.lww.com/SLA/ D158 in Supplement). We

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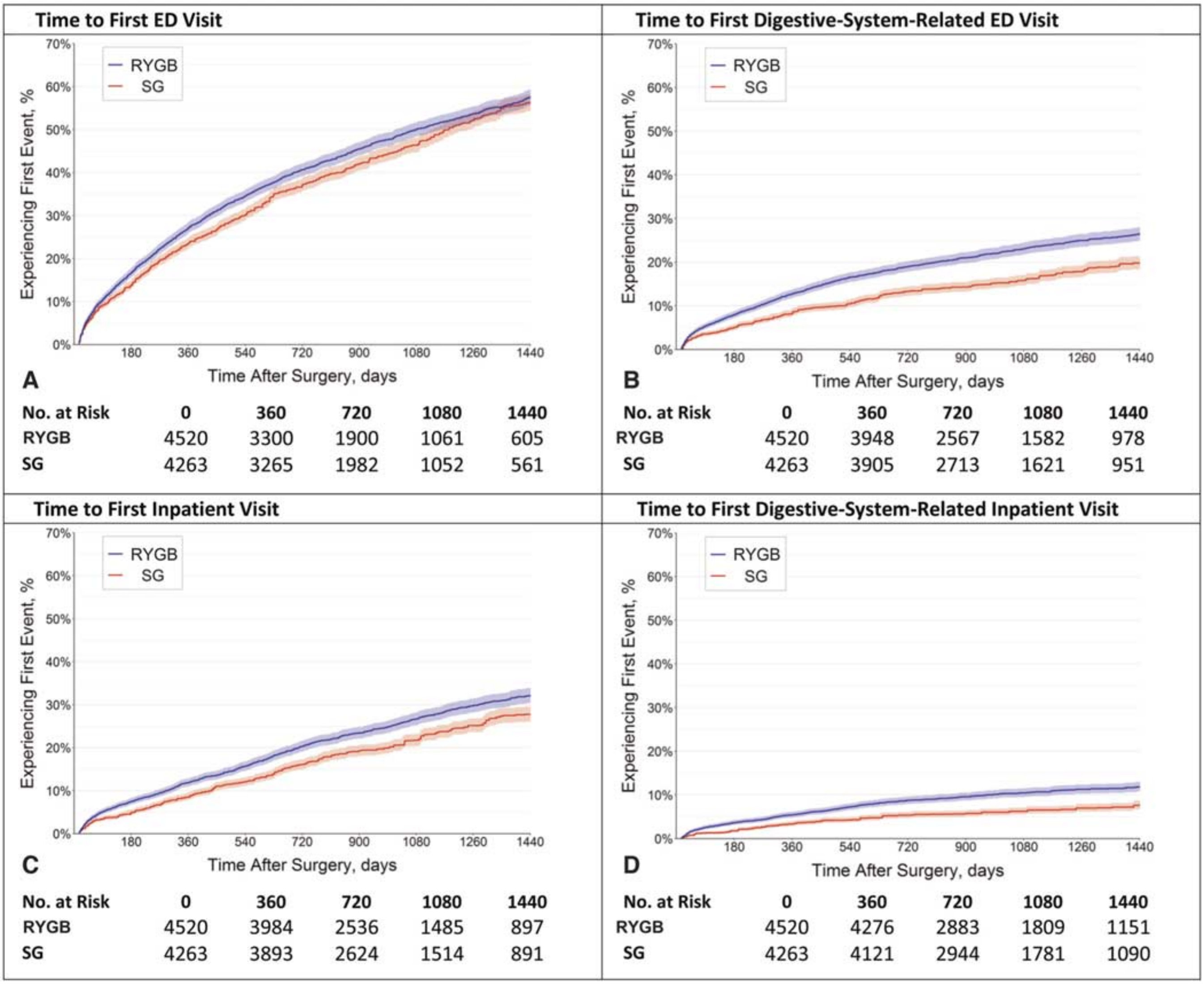

FIGURE 2. Time to first overall or digestive-system-related ED or inpatient visit among matched cohorts of patients with index SG and RYGB, up to 4 years after surgery. Figure 2 presents Kaplan Meier curves for time-to-first Emergency Department or inpatient visit among matched cohorts of patients with index RYGB or SG up to 4 years after surgery, overall and for digestive-system-related complaints. ED indicates Emergency Department; RYGB, Roux-en-Y gastric bypass; SG, Sleeve gastrectomy. Numbers at risk are CEM-weighted and represent patients who remained enrolled and at risk at each time point. Shaded areas represent 95% CIs. Because many of the procedures took place in the later years of the data, some proportions of the RYGB and SG groups lack complete follow-up because of insufficient time between the date of surgery and the end of the data set. To represent completeness of follow-up accounting for this fact, Table A4 in the Supplement lists counts and percentage enrolled relative to those eligible for complete follow-up at all relevant time points. A, Category includes any Emergency Department visit at least 14 days after the index procedure; see algorithm in Table A1 of the Supplement. B, Category includes any Emergency Department visit with a primary diagnosis for a digestive system complaint, based on the episode's most expensive claim (Table A2 for component diagnoses). C, Category includes any inpatient visit at least 14 days after the index procedure (Table A1 for algorithm);D, Category includes any inpatient visit with a primary diagnosis for a digestive system complaint, based on the most commonly coded condition on the first and second days (Table A2 for component diagnoses).

also observed lower hazards of mental-illness-related ED visits among SG patients (aHR: 0.65; 95% CI: 0.48, 0.89), although absolute incidence of this outcome was low (2.6% for SG and 3.5% for RYGB by 1440 days, Table A6, http:// links.lww.com/SLA/D158 in Supplement). Between-surgery differences in hazards of ED use did not reach statistical significance for the other clinical categories (Fig. 3; Figure A4–A12, http://links. lww.com/SLA/D156).

Inpatient Care Use

By 1440 days after surgery, 27.7% (95% CI: 26,29.5) of SG and 32.1% (95% CI: 30.4,33.9) of RYGB patients had

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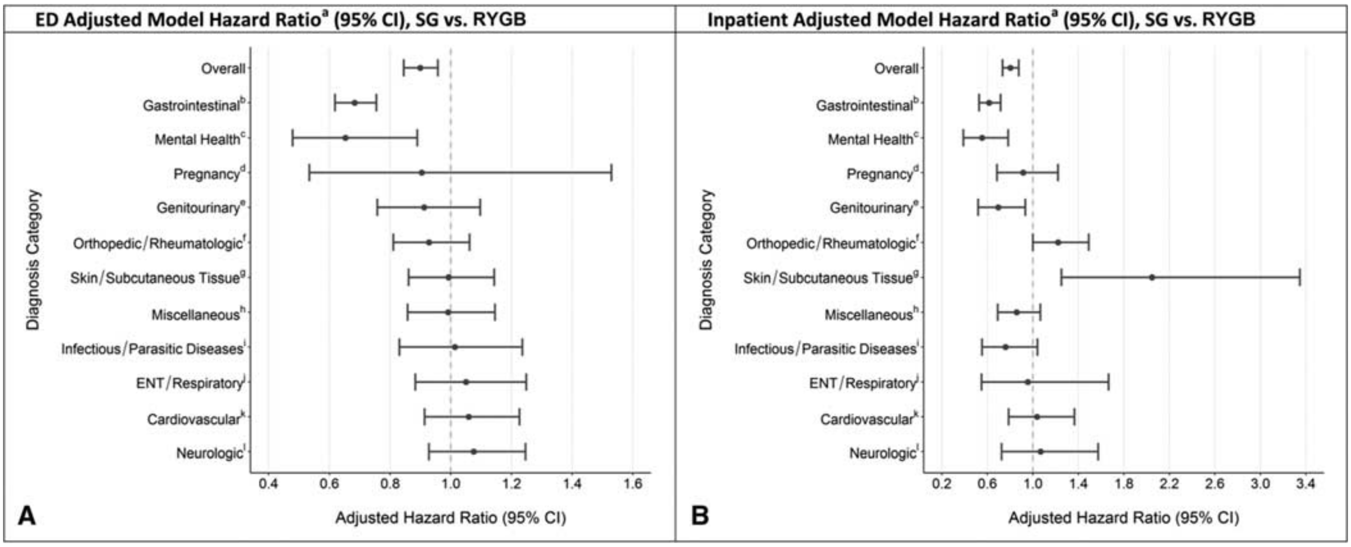

FIGURE 3. Adjusted Hazard of acute care utilization up to 4 years after surgery among matched Cohorts of patients with index SG and RYGB. Figure 3 compares the adjusted cumulative hazard of emergency department (A) or inpatient (B) utilization among matched cohorts of patients with index RYGB and SG up to 4 years after surgery, overall and by diagnosis category. ED indicates Emergency Department; ENT, ears, nose, and throat; RYGB, Roux-en-Y gastric bypass; SG, Sleeve gastrectomy. A, Cox models weighted for matching variables and adjusted for US region. B, Includes abdominal, pancreatic, and gastrointestinal conditions (eg, abdominal pain, nausea/vomiting) C, Includes drug or alcohol withdrawal, dependence or abuse, and mental illness (eg, major depression, bipolar disorder). D, Includes conditions of pregnancy (eg, pre-eclampsia), pregnancy-related events other than miscarriage (eg, twin liveborn infant birth, normal spontaneous vaginal delivery), and diagnoses related to the immediate post-partum period (eg, maternal care for scar prevention after a C-section) among matched women who were 18 to 49 years old at index surgery. E, Includes kidney conditions, as well as gynecologic and male GU complaints. Threatened or completed spontaneous abortions were also included. F, Includes orthopedic conditions (eg, fractures, arthritis) and rheumatologic conditions such as lupus. G, Includes conditions such as lacerations, contusions, burns, or rashes. H, Includes rare diagnoses not elsewhere classified. I, Includes diagnoses that specified an infection or infectious agent (eg, urinary tract infection, streptococcal pharyngitis). J, Includes ophthalmic or ENT diagnoses (eg, glaucoma, sinusitis) and respiratory complaints (eg, asthma, cough). K, Includes acute and chronic cerebrovascular or cardiovascular diseases (eg, hypertension, acute coronary syndromes, ischemic stroke and congestive heart failure). L, Includes neurological conditions (eg, head trauma including concussion, subdural or subarachnoid bleeding).

experienced ≥1 hospitalization (Table A6, http://links.lww.com/SLA/D158 in Supplement). The cumulative hazard of inpatient use was lower after SG (aHR: 0.8; 95% CI: 0.73,0.88, Fig. 3). Gastrointestinal, biliary, and endocrine or metabolic reasons for hospitalization were common in both groups during the first year. During year 4, reasons for hospitalization shifted slightly - almost 1 in 5 episodes were for arthritis or degenerative joint disease, or pregnancy-related conditions (Table A9, http://links.lww.com/SLA/D158 in Supplement).

Like the ED analyses, patients with SG had a lower 4-year hazard of digestive-system-related hospitalization (aHR: 0.61; 95% CI: 0.53,0.72, Fig. 3), with cumulative incidence of 7.6% (95% CI: 6.7,8.6) versus 11.8% (95% CI: 10.7,13.0) among those with RYGB (Table A6, http://links.lww.com/SLA/D158 in Supplement). In the fourth year after surgery, 12 of the 20 (61.4%) digestive-system-related episodes in the SG group were for gallbladder disease, compared to 6 out of 20 episodes (26.1%) in the RYGB group (Table A10, http://links.lww.com/SLA/D158 in Supplement).

SG was associated with lower hazards of mental health (aHR: 0.55, 95% CI: 0.39,0.78) and genitourinary system (aHR: 0.70; 95% CI: 0.52,0.93) hospitalizations compared to RYGB, but higher skin/subcutaneous-tissue related hospitalizations (aHR: 2.05; 95% CI: 1.25,3.35, Fig. 3). In both groups, over two thirds of skin-related admissions had a primary diagnosis for cellulitis (Table A10, http://links.lww.com/SLA/D158 in Supplement). Between-group differences in hospitalizations were nonsignificant for the other categories (Fig. 3; Figure A4–A12, http://links.lww.com/SLA/D156).

Acute Care Costs

In the first postbariatric year (days 14–360), SG patients had 20% to 30% lower odds of accruing any ED, inpatient, or total acute care costs (Fig. 4) compared with RYGB patients. SG patients were also less likely to have high (> 80th percentile) year-1 acute care costs (aOR: 0.77; 95% CI: 0.66,0.90), mainly driven by ED care (high-ED cost aOR: 0.74; 95% CI: 0.63,0.86). Odds of high year-1 inpatient costs did not differ between groups (aOR: 0.89; 95% CI: 0.70,1.14, Fig. 4).

The early observed acute care cost differences favoring SG waned over follow-up. The adjusted odds ratios for any acute care cost and for ED costs were nonsignificant during year 3. No significant differences were observed in year 4, except for SG having greater odds of high annual ED costs (aOR: 1.93;95%CI: 1.36,2.73); however, only 55 RYGB and 92 SG patients met this year-4 high-cost cutoff.

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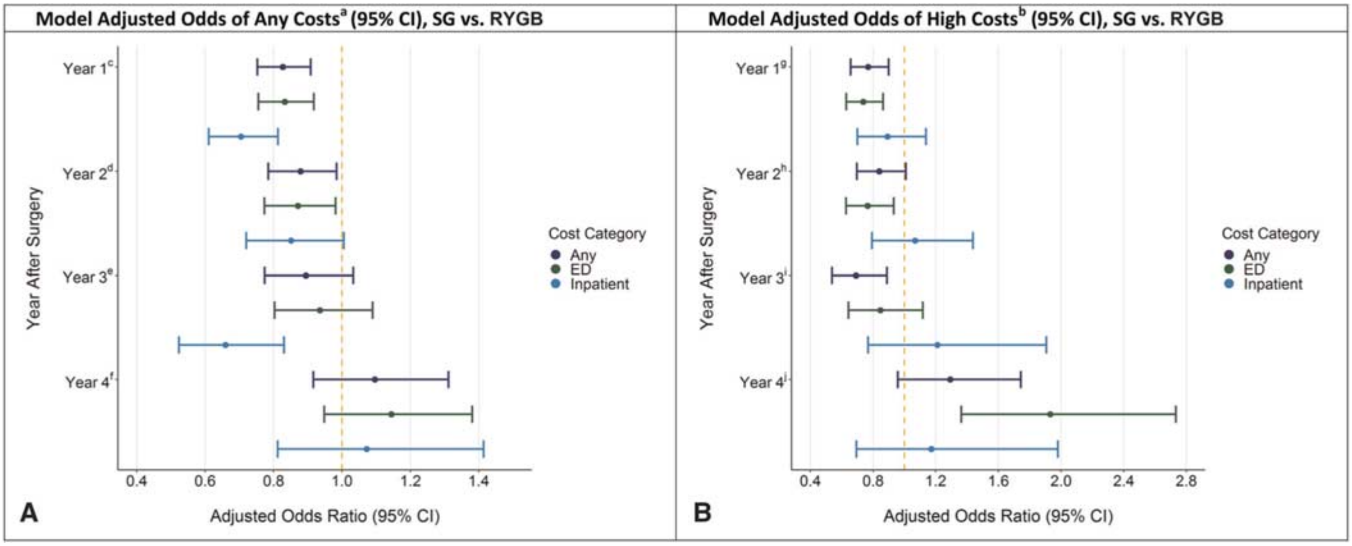

FIGURE 4. Adjusted odds of any or high acute care costs up to 4 years after surgery among matched cohorts of patients with index SG and RYGB. Figure 4 compares the adjusted odds of any (A) or high (B) emergency department, inpatient, or total acute costs up to 4 years after surgery among matched cohorts of patients with index RYGB and SG. ED indicates Emergency Department;RYGB, Roux-en-Y gastric bypass; SG, Sleeve gastrectomy. A, Patients were defined as having any costs if the annual sum of their billed standardized costs was >0 USD. Logistic regression models were weighted by matching variables and adjusted for US region. B, Patients were defined as having high costs if the annual sum of their billed standardized costs exceeded the 80th percentile value for adult patients enrolled for the entirety of 2012 (9000 USD for acute costs, 700 USD for ED costs, and 30,000 USD for inpatient costs; Table A3 in Supplement). Logistic regression models were weighted by matching variables and adjusted for US region. C, Year 1 is defined as 14 to 360 days after surgery. About 1349/4520 enrolled RYGB patients had any acute care cost, with a median (IQR) cost of 827 (354,12397) USD. 1111/4263 enrolled SG patients had any cost, with a median (IQR) cost of 521 (352,10685) USD. D, Year 2 defined as 361 to 720 days after surgery. 855/3149 enrolled RYGB patients had any acute care cost, with a median (IQR) cost of 816 (352,13189) USD. 778/3118 enrolled SG patients had any cost, with a median (IQR) cost of 701 (352,11266) USD. E, Year 3 is defined as 721 to 1080 days after surgery. About 529/2006 enrolled RYGB patients had any acute care cost, with a median (IQR) cost of 703 (352,11907) USD. 466/1922 enrolled SG patients had any cost, with a median (IQR) cost of 456 (299,8734) USD. F, Year 4 defined as 1081 to 1440 days after surgery. About 331/1288 enrolled RYGB patients had any acute care cost, with a median (IQR) cost of 517 (299,9589) USD. About 331/1189 enrolled SG patients had any cost, with a median (IQR) cost of 740 (299,11216) USD. G, In year 1, 400/4520 enrolled RYGB patients and 299/4263 enrolled SG patients had high acute care costs. H, In year 2, 269/3149 enrolled RYGB patients and 228/3118 enrolled SG patients had high acute care costs. I, In year 3,164/2006 enrolled RYGB patients and 111/1922 enrolled SG patients had high acute care costs. J, In year 4, 87/1288 enrolled RYGB patients and 101/1189 enrolled SG patients had high acute care costs.

Sensitivity Analysis Stratified by Time Period

Our matching approach upweighted earlier procedures, especially among the SG group (67.9% of SG vs 18.6% were before 2012 in matched vs unmatched cohort, Table 1). In sensitivity analyses stratifield by calendar year group of surgery, matched patients in each time period had similar 360-day ED use (eg, 360-day incidence among RYGB patients of 26.5% in 2008–2011 vs 29.9% in 20152016, Figure A1, http://links.lww.com/SLA/D156 and Table A11, http://links.lww.com/SLA/D158 in Supplement). However, postoperative hospitalization became less common in later years (eg, 360-day incidence among SG patients of 9.2% in 2008–2011 vs 5.2% in 2015–2016, Figure A2, http://links.lww.com/SLA/D156 and Table A11, http://links.lww.com/SLA/D158 in Supplement).

Between-surgical-type differences in year 1 utilization and associated costs were consistent across the first 2 time periods (eg, adjusted odds ratios comparing any acute costs of 0.86; 95% CI 0.77,0.96 for 2008–2011, vs 0.79; 95% CI 0.66,0.95 for 2012–2014). We observed a slightly greater advantage of SG versus RYGB in 2015–2016 (eg, any acute costs aOR of 0.66; 95% CI 0.44,0.99); however, the absolute numbers of individuals in this time period were few (Table A12, http://links.lww.com/SLA/D158 in Supplement).

DISCUSSION

In this nationwide cohort study, SG patients experienced lower early postoperative acute care utilization than matched RYGB patients, and generally had lower ED and inpatient costs (Figs. 3 and 4), over 4 follow-up years, driven primarily by early differences in gastrointestinal problems (Fig. 2). Although SG patients were slightly less likely to have ED visits and hospitalizations, such episodes were very common after both operations, and seemed to be often related to potentially-preventable side effects of surgery. Importantly, between-surgery differences in acute care use waned over follow-up, which could indicate that relative safety benefits of SG are short-lived when balanced against potential greater long-term effectiveness of RYGB. Our findings build on those from prior studies by following patients longer, examining costs, and analyzing clinically relevant subcategories of acute care use.

Our results are generally consistent with those of previous studies that found early (eg, 30 or 90 days) differences in acute

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care utilization favoring SG.[3–5,7–15,44] A recent long-term analysis found 5-year hospitalization rates of 32.7% and 38.3% among patients with SG and RYGB,[16] respectively, aligning closely with our 4-year estimates of 27.7% and 32.1% (Table A6, http://links.lww.com/ SLA/D158 in Supplement). The narrowing we observed between groups by year 4 is also consistent with a study of SG and RYGB procedures performed in New York state from 2009 to 2011.[17]

There are several important takeaways from our results that may help guide clinical practice. Firstly, gastrointestinal symptoms and conditions contributed substantially to early postbariatric acute care, especially after RYGB (Fig. 2). One potentially intervenable category of digestive-system acute care use is gallbladder disease (Tables A8, http://links.lww.com/SLA/D158 and A10, http://links.lww.com/SLA/D158 in Supplement). Postsurgical gallstones may be preventable with medicines such as ursodeoxycholic acid.[45] Simultaneous cholecystectomy may also reduce gallstone risk; however, an additional procedure at the time of bariatric surgery may also increase reoperation risk.[46] Future analyses should consider post-bariatric acute care use and complication risk in cost-effectiveness models for these treatments.

Secondly, despite similar baseline prevalence of mental illness (Table 1), patients with RYGB had more mental health-related acute care visits after surgery compared to SG (Fig. 3). A high proportion of these visits had primary diagnoses for major depressive or bipolar disorder, especially in the RYGB group. We also observed acute care visits for alcohol intoxication and drug use, although the absolute number of these events were too few to accurately assess between-surgical differences (Tables A8, http://links.lww.com/SLA/D158 and A10, http://links.lww.com/ SLA/D158 in Supplement). Previous studies suggest higher rates of acute care in postbariatric patients with mental illness,[47] and that RYGB may impact the pharmacoki-netics of psychiatric medicines.[48] Our findings underscore the need for better study of the underlying social or behavioral factors that may contribute to increased acute care use in bariatric patients with mental illness. Such data could help inform tailored post-surgical care for this population.

Thirdly, our results underscore that inpatient care is not always synonymous with bad patient outcomes. For example, some portion of the acute care utilization (and cost) in this study may represent total joint replacements or pregnancies among patients who pursued bariatric surgery with these goals in mind.[30,31] In our sample, approximately 6% to 7% of reproductive-age women had been hospitalized for a pregnancy-related condition by 4 years (Table A6, http://links.lww.com/ SLA/D158 in Supplement). Few had evidence of pregnancy before 1 year postsurgery, consistent with current clinical guidance[30] (Figure A3 in Supplement, http://links.lww.com/SLA/ D156). Furthermore, many orthopedic hospitalizationswere for arthritis or degenerative joint disease, implying possible joint replacements (Table A10, http://links.lww.com/SLA/ D158 in Supplement).

Fourthly, in this study, we observed overall acute care cost advantages of SG compared to RYGB, but only in the first 1 to 2 years after surgery. These results are consistent with our overall finding that RYGB patients had a greater incidence of ED and inpatient visits in the first 2 years after surgery, especially for GI complaints (Fig. 2). These data suggest that RYGB may be associated with greater perioperative complication risk (and therefore, more directly-related costs). Short follow-up times precluded an analysis of costs beyond 4 years in this dataset. Additionally, this study was restricted to payer, rather than patient-facing, costs. Future analyses should compare out-of-pocket costs before and after RYGB versus SG, since these data would be especially meaningful to patients.

Lastly, many of the clinical categories we examined (eg, diseases of the cardiovascular, ears, eyes, and respiratory systems) had nearly identical postsurgical trajectories for SG and RYGB (Table A6, http://links.lww.com/SLA/D158 in Supplement). This finding is reassuring, since we would not expect an early differential effect of bariatric surgical type on these outcomes. There were also several clinical categories for which the primary diagnoses suggested typical acute care use, rather than complications of bariatric surgery. For example, over half of skin/subcutaneous tissue-related ED visits seemed to be for everyday skin wounds (eg, lacerations, contusions, pressure ulcers). The incidence of hospitalization for severe cardiovascular and neurologic events (eg, stroke, myocardial infarction, brain trauma) was low in both groups. Importantly, the lower hazard of acute events observed after SG should not be used as a basis to triage all bariatric surgery candidates to this procedure. Although it carries additional complication risk,[33,45] RYGB is also associated with better weight loss and diabetes remission.[32,49] Future studies should assess whether these advantages translate to decreased outpatient and pharmacy utilization and costs.

This study had several limitations. The observational nature of the study places findings at risk of unmeasured confounding. We matched study cohorts to optimize internal validity, but this approach upweighted early SG procedures, potentially decreasing generalizability to present-day patients. Differences between groups did not change substantially when we stratified by calendar period (Tables A11, http://links.lww.com/SLA/D158 and A12, http://links.lww.com/SLA/D158 in Supplement). However, 360-day hospitali-zation rates decreased over the study period (Figure A2 in Supplement, http://links.lww.com/SLA/D156); future analyses may therefore conclude larger postoperative advantages for SG. Although our use of commercial claims enabled us accurately to measure acute care costs, an inherent limitation of these data is that many patients had short enrollment lengths. Our results also may not generalize to publicly-insured populations, who may have higher risk of acute care postsurgery.[8] Finally, we did not model exact costs, given the high proportion of zeros and long right tails in our data. A different modeling approach would be necessary to perform a true cost-effectiveness analysis of acute care after these 2 procedures.

CONCLUSIONS

Compared to RYGB patients, those undergoing SG seem to have somewhat lower risk of ED and inpatient use, and lower odds of acute care costs in the first few years after surgery, particularly as related to gastrointestinal problems. Although these findings align well with prior research positioning SG as a lower-morbidity procedure, it will be important to understand the durability of these differences, which seemed to wane over time. Clinical changes such as greater weight regain or diabetes relapse after SG may portend better long-term outcomes for RYGB than are reflected here.

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