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BRIEF COMMUNICATION

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Bariatric Surgery

Use of primary bariatric surgery among patients with obesity and diabetes. Insights from the Diabetes Collaborative Registry

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Despite its cardiometabolic benefits, bariatric surgery has historically been underused in patients with obesity and diabetes, but contemporary data are lacking. Among 1,520,182 patients evaluated from 2013 to 2019 within a multicenter, longitudinal, US registry of outpatients with diabetes, we found that 462,033 (30%) met eligibility for bariatric surgery. After a median follow-up of 854 days, 6310/384,859 patients (1.6%) underwent primary bariatric surgery, with a slight increase over time (0.38% per year [2013] to 0.68% per year [2018]). Patients who underwent bariatric surgery were more likely to be female (63% vs. 56%), white (87% vs. 82%), have higher body mass indices (42.1 ± 6.9 vs. 40.6 ± 5.9 kg/m^2), and depression (23% vs. 14%; $p < 0.001$ for all). Over a median (IQR) follow-up after surgery of 722 days (364–993), patients who underwent bariatric surgery had lost an average of 11.8 ± 18.5 kg (23% of excess body weight), 10.2% were on fewer glucose-lowering medications, and 8.4% were on fewer antihypertensives. Despite bariatric surgery being safer and more accessible over the past two decades, less than one in fifty eligible patients with diabetes receive this therapy.

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INTRODUCTION

In patients with diabetes and obesity, weight loss has the capacity to reduce cardiovascular risk through improvements in insulin sensitivity, glycemic control, blood pressure, and metabolic dyslipidemia [1–3], but can be challenging to achieve and maintain [4]. While pharmacologic weight loss strategies may be sufficient for some [5], bariatric surgery can be a useful option for many patients with diabetes and obesity [6], both for weight loss and improvement in glycemic control and cardiovascular risk factors [7–10]. Despite consistent evidence of metabolic benefit, however, bariatric surgery has historically been underused [11–13]. Multiple efforts over the past two decades have encouraged greater use, including increased availability of surgical weight loss centers, development of less invasive surgical techniques, educational efforts to both physicians and patients, and incorporation of bariatric surgery in guideline statements [14–16]. We used the Diabetes Collaborative Registry (DCR), a large US quality improvement registry of outpatients with diabetes seen in primary care, cardiology, and endocrinology clinics, to assess the contemporary use of bariatric surgery, to attempt to ascertain the extent to which these efforts have led to increased use of bariatric surgery. DCR is a longitudinal, clinical database with more detailed health data on patients followed over time, making it ideal for providing further insight into the real-world use and clinical impact of bariatric surgery.

METHODS

Beginning in 2014, DCR now includes 375 practices, 5035 clinicians, and >1.5 million unique patients across the US. Data are extracted from electronic health records through an automated system integration solution [17]. Eligibility for bariatric surgery was defined as no history of bariatric surgery, diabetes, and obesity (body mass index [BMI] ≥ 35 kg/m^2 or ≥32.5 kg/m^2 if Asian race) [18, 19]. We also performed a sensitivity analysis limited to patients with class III obesity (BMI ≥ 40 kg/m^2 or ≥37.5 kg/m^2 if Asian race). The earliest encounter in which a patient met eligibility criteria for bariatric surgery was considered the index visit. Patients were then followed through subsequent encounters to determine if bariatric surgery occurred, as documented in the electronic record as adjustable gastric banding, biliopancreatic diversion with duodenal switch, Roux-en-Y gastric bypass, vertical sleeve gastrectomy, or bariatric surgery (any).

Demographic and clinical characteristics at the index visit were compared between patients who did versus did not eventually undergo bariatric surgery using Student's *t*-tests for continuous variables and chi-square tests for categorical variables. Annual rate of bariatric surgery was calculated as the number of patients with bariatric surgery divided by the number of patients with an encounter in that year. For surgical patients

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followed at least 180 days after surgery, we examined changes in glycemic control, blood pressure, lipids, weight, excess BMI loss percentage (using an ideal BMI of 25 kg/m^2 [23 kg/m^2 if Asian race], and associated medications from the index to most recent visit. As follow-up in DCR is per clinical judgment and not standardized, a linear repeated measures model was used to estimate weight change over time for surgical patients, with estimates and 95% confidence intervals calculated at 180-day intervals. Because participation requires no data collection beyond routine clinical care and all data are de-identified, a waiver of written informed consent and authorization for this study was granted by Chesapeake Research Review Incorporated.

RESULTS

Among 1,544,163 patients with diabetes in DCR, 23,981 already had bariatric surgery, and 462,033 (30.4%) of the remaining patients met BMI eligibility for bariatric surgery. After excluding 77,174 patients with no follow-up visits, our analytic cohort included 384,859 patients (mean age 59.4 ± 12.9 years, 56.0% women, 82.1% White race). Mean BMI was 40.6 ± 6.0 kg/m^2 (41.1% class III obesity), mean HbA1c was 7.1 ± 1.6%, and 25.8% were treated with insulin. Hypertension was diagnosed in 77.1%, mean systolic blood pressure was 132.0 ± 16.9 mmHg, 46.4% were on two or more anti-hypertensive medications, mean LDL-cholesterol was 98.5 ± 33.1 mg/dL (50.4% on statin), and 26.6% had coronary artery disease.

Over a median follow-up of 854 days (IQR 483–1329), 6310 eligible patients (1.6%) with diabetes and obesity underwent bariatric surgery, with a median time from index visit to surgery of 507 days (237–868). The annual rate of bariatric surgery slightly increased over time, from 0.38% in 2013 to 0.68% in 2018 (Fig. 1). Annual rates were slightly higher in patients with class III obesity but remained <1% per year through 2018. Patients who underwent bariatric surgery (vs. who did not) were more likely to be younger (58.0 ± 12.5 years vs. 59.4 ± 12.9 years, $p < 0.001$), women (63.2% vs. 55.9%, $p < 0.001$), White race (87.4% vs. 82.0%, $p < 0.001$), have higher BMIs (42.1 ± 6.9 kg/m^2 vs. 40.6 ± 5.9 kg/m^2, $p < 0.001$) and to be treated with insulin (27.3% vs. 25.8%, $p < 0.001$), but HbA1c levels, LDL-cholesterol levels, and blood pressures were similar between groups. Patients treated with bariatric surgery had notably higher rates of depression compared with those who did not have surgery (22.6% vs. 14.1%, $p < 0.001$) (Table 1).

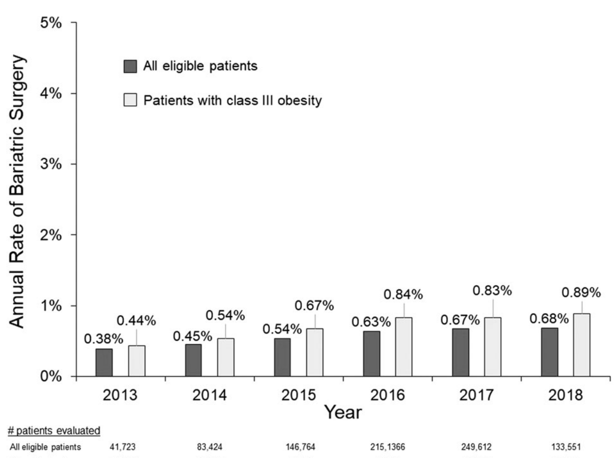

Fig. 1 Annual rate of bariatric surgery in patients with diabetes and obesity. Dark gray bars indicate all potentially eligible patients with diabetes, body mass index ≥35 kg/m^2 (or ≥ 32.5 kg/m^2 if Asian race), and no prior bariatric surgery. Light gray bars indicate the subgroup of patients with body mass index ≥40 kg/m^2 (or ≥ 37.5 kg/m^2 if Asian race).

There were 3965 patients (63%) in DCR who had bariatric surgery and at least 180 days of follow-up after surgery (median [IQR] follow-up after surgery 597 days [597–993]; 48% with ≥360 days). Patients who underwent bariatric surgery had large reductions in total body weight over time (−13.1 kg over 2 years, 95% CI −13.7 to −12.6; −10.2% total weight lost, 95% CI −10.6% to −9.8%; Fig. 2). Comparing last follow-up with index visit, patients who underwent bariatric surgery lost an average of 22.6 ± 36.1% of their excess weight but did not have large changes in blood pressure, HbA1c, and cholesterol (Table 2). Notably, 10.2% of surgical patients were on fewer glucose-lowering medications (including 7.5% who discontinued insulin) and 8.4% were on fewer antihypertensives at last follow-up.

DISCUSSION

In a large, contemporary registry of 1.5 million US outpatients with diabetes, over a quarter of patients met BMI criteria for eligibility for bariatric surgery, yet <2% of potentially eligible patients underwent surgery over a median of 2.3 years of follow-up. Despite substantial efforts to increase access to bariatric surgery and to educate both physicians and patients of its safety and benefits, we found that bariatric surgery continues to be markedly underused in US patients with obesity and diabetes, thus missing a potential opportunity to improve the metabolic health and cardiovascular risk of these patients.

Prior studies have used cross-sectional sampled data to calculate national estimates, where the proportion of US adults potentially eligible for bariatric surgery has increased over time, from 6% in 1993 to 15% in 2016 [13]. Cross-referencing these estimates with a nationally-representative inpatient billing dataset, it was estimated that 0.5% of eligible US adults underwent bariatric surgery in 2016 [13] versus ~0.4% in 2006 [11] and 0.6% in 2002 (among those with BMI ≥ 40 kg/m^2) [12]. Our analysis differs from these prior studies in that it involved a longitudinal assessment of patients (as opposed to repeated cross-sectional), included only patients with diabetes, and used clinical data (versus billing). Our more recent annual estimate of ~0.7% of eligible patients undergoing bariatric surgery is only marginally higher than these prior studies, despite the fact that all participants in DCR had access to healthcare, outpatient bariatric surgeries were collected (not captured in inpatient billing databases), and all patients had diabetes—a high-risk comorbidity where bariatric surgery may be most beneficial. These data provide additional evidence that alternate strategies are needed 1) to increase physician referral of eligible patients for bariatric surgery and 2) to encourage patients to consider bariatric surgery as a potentially beneficial and safe treatment option.

It is unclear why bariatric surgery has remained underused over the past 10–20 years despite multi-pronged approaches to increase both referral and availability of surgery. Some patients may be perceived by their physicians to be ineligible for surgery due to cardiovascular risk factors or comorbidities. With improvement in safety of bariatric surgery, physicians may need to recalibrate the type of patient considered eligible for bariatric surgery, with a focus on net clinical benefit [20]. From a patient's perspective, there may be hesitancy to undergo bariatric surgery due to misperceptions of the need for surgery (either a belief they are not obese or they can lose weight without surgery) or an underestimation of cardiometabolic benefits of bariatric surgery [21]. Multidisciplinary cardiometabolic clinics may be a beneficial systems-based approach to overcoming these barriers, including navigating insurance coverage for eligible patients, where confusion on coverage and out-of-pocket costs may hinder referrals. Furthermore, value-based care models are one potential strategy to increase the use of bariatric surgery in high-risk subgroups (e.g., obesity and diabetes), where bariatric surgery is cost-effective and perhaps even cost-saving in the longer term

Table 1. Baseline demographics, comorbidities, and metabolic factors of patients with diabetes eligible for bariatric surgery.

	Bariatric surgery *n* = 6310	**No Surgery *n* = 378,549**	***p* value**
Age, years	58.0 (12.5)	59.4 (12.9)	<0.001
Female	3989 (63.2%)	211,515 (55.9%)	<0.001
White race	4292/4910 (87.4%)	226,320/275,960 (82.0%)	<0.001
Type 1 diabetes	379 (6.0%)	21,696 (5.7%)	0.351
Heart failure	794 (12.6%)	43,206 (11.4%)	0.003
Coronary artery disease	1746 (27.7%)	100,682 (26.6%)	0.055
Atrial fibrillation	744 (11.8%)	39,950 (10.6%)	0.001
Peripheral arterial disease	1009 (16%)	46,087 (12.2%)	<0.001
Stroke/TIA	914 (14.5%)	37,931 (10.0%)	<0.001
Depression	1425 (22.6%)	53,370 (14.1%)	<0.001
Current smoker	1574/5848 (26.9%)	96,305/353,992 (27.2%)	0.663
Body mass index, kg/m^2	42.1 ± 6.9	40.6 ± 5.9	<0.001
Weight, kg	118.9 ± 23.5	115.0 ± 21.3	<0.001
Hypertension	4764 (75.5%)	291,793 (77.1%)	0.003
Systolic BP, mmHg	130.8 (17.1)	132.0 (16.9)	<0.001
Diastolic BP, mmHg	77.0 (10.5)	77.7 (10.5)	<0.001
# of antihypertensive medications			<0.001
0	1451 (23.0%)	82,813 (21.9%)	
1	1793 (28.4%)	120,122 (31.7%)	
2+	3066 (48.6%)	175,614 (46.4%)	
Dyslipidemia	4276 (67.8%)	256,612 (67.8%)	
LDL cholesterol, mg/dL	98.0 ± 32.0 (3453)	98.5 ± 33.1 (197,115)	0.347
On statin	2892 (45.8%)	190,966 (50.4%)	<0.001
Hemoglobin A1c, %	7.0 ± 1.5 (3067)	7.1 ± 1.6 (170,122)	<0.001
On insulin	1725 (27.3%)	97,520 (25.8%)	0.004
# of glucose-lowering medications			<0.001
0	2246 (35.6%)	129,507 (34.2%)	
1	1789 (28.4%)	115,148 (30.4%)	
2+	2275 (36.1%)	133,894 (35.4%)	

Data are presented as mean ± SD or *n* (%). *n/N* or mean ± SD (N) if number of observations is different from overall cohort.
TIA transient ischemic attack, *BP* blood pressure, *LDL* low density lipoprotein.

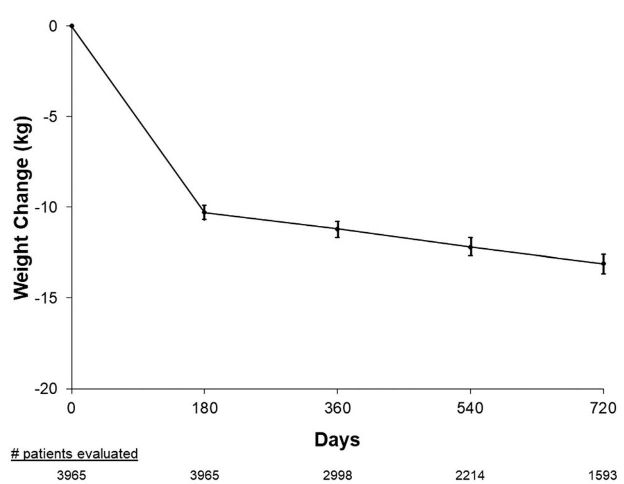

Fig. 2 Change in weight over time after bariatric surgery. Estimates and 95% confidence intervals per the linear repeated measures model.

[22–24]. It is also important to recognize that we need greater investment in upstream public health approaches in the treatment of obesity and diabetes, where US prevalence projections continue to skyrocket [25].

Regarding limitations to our study, it is difficult to determine the exact number of patients eligible for bariatric surgery from the available data, as some patients were likely excluded due to comorbidities and psychosocial factors not captured in DCR. However, many patients excluded due to comorbidities may be the patients who should be targeted with surgical treatment due to potential for benefit. Second, information regarding patient preferences, use of non-surgical weight loss treatments, and local availability of surgery were not available. Third, as data from DCR are from outpatient clinics, nearly all patients have medical insurance and access to healthcare; therefore, the rate of bariatric surgery among eligible patients in the general US population would be even lower. Fourth, type of bariatric surgery was inconsistently captured in DCR, preventing us from examining trends and stratification of metabolic outcomes among types of surgery performed. This is important as some forms of bariatric surgery typically result in more weight loss and metabolic benefit

Table 2. Change in metabolic parameters from baseline to last follow-up among patients who underwent bariatric surgery.

	Bariatric surgery $n = 3965$
Body mass index, kg/m^2	-4.3 ± 6.7 (3030)
Weight, kg	-11.8 ± 18.5 (3513)
Total body weight, %	-9.3 ± 14.0 (3513)
Excess weight, %	-22.6 ± 41.4 (3512)
Hemoglobin A1c, %	-0.16 ± 0.73 (2062)
Discontinued insulin	87/1158 (7.5%)
On fewer glucose-lowering medications	405 (10.2%)
Low-density lipoprotein cholesterol, mg/dL	-2.9 ± 15.0 (2256)
Systolic blood pressure, mmHg	-2.3 ± 20.2 (3755)
Diastolic blood pressure, mmHg	-2.1 ± 12.1 (3754)
On fewer antihypertensive medications	335 (8.4%)

Among patients with ≥180 days of follow-up after surgery; data presented as mean ± SD or *n* (%). *n*/*N* (%) or mean ± SD (N) if number of observations is different from overall cohort.

than others (e.g., gastric bypass versus banding). Finally, although follow-up within DCR for the occurrence of bariatric surgery was excellent (median 854 days), long-term follow-up after bariatric surgery was less complete, which may have attenuated the metabolic changes observed after surgery.

In conclusion, despite multiple efforts over the past two decades to make bariatric surgery both safer and more accessible, we found that fewer than one in fifty patients with diabetes and obesity underwent bariatric surgery. Given the large proportion of patients potentially eligible for metabolic surgery, our study demonstrates a substantial missed opportunity to impact weight loss, diabetes management, and cardiovascular risk factor control. Increasing the penetration of bariatric surgery will likely require a multi-pronged approach at the levels of the physician, patient, health system, and public policy.

DATA AVAILABILITY

The data that support the findings of this study are available from Veradigm upon reasonable request.

CODE AVAILABILITY

Statistical analyses were performed using SAS version 9.4 software (SAS Institute, Inc., Cary, NC). Statistical code used to generate results available on request from authors.

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AUTHOR CONTRIBUTIONS

PJ: Conceptualization, Data Interpretation, Writing Original Draft; VH: Conceptualization, Methodology, Data Interpretation, Writing Original Draft; MBT: Methodology, Data Interpretation, Writing Review & Editing, Supervision; RAG: Data Interpretation, Writing Review & Editing, Supervision; KFK: Methodology, Formal analysis, Writing Review & Editing; AG: Data Interpretation, Writing Review & Editing; LS: Data Interpretation, Writing Review & Editing; SRD: Data Interpretation, Writing Review & Editing; SH: Data Interpretation, Writing Review & Editing; JRE: Data Interpretation, Writing Review & Editing, Supervision; SVA: Conceptualization, Methodology, Formal analysis, Data Interpretation, Writing Original Draft, Supervision.

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COMPETING INTERESTS
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ADDITIONAL INFORMATION
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