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ORIGINAL CONTRIBUTIONS

A Population-Based Study of Early Postoperative Outcomes in Patients with Heart Failure Undergoing Bariatric Surgery

Andrew T. Strong[1,2] · Gautam Sharma[1] · Chao Tu[1,3] · Ali Aminian[1] · James B. Young[2,4,5] · John Rodriguez[1,2] · Matthew Kroh[1,2,6]

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Abstract

Background Weight loss following bariatric surgery can improve cardiac function among patients with heart failure (HF). However, perioperative morbidity of bariatric surgery has not been evaluated in patients with HF.

Study Design The National Surgical Quality Improvement Project (NSQIP) database for 2006–2014 was queried to identify patients undergoing adjustable gastric band, gastric bypass, sleeve gastrectomy, and biliopancreatic diversion-duodenal switch. Patients with HF were propensity matched to a control group without HF (1:5). Univariate analyses evaluated differences in complications, and multivariate analysis was completed to predict all-cause morbidity.

Results There were 237 patients identified with HF (mean age 52.8 years, 59.9% female, mean body mass index 50.6 kg/m^2) matched to 1185 controls without HF who underwent bariatric surgery. Preoperatively, patients with HF were more likely to be taking antihypertensive medication and have undergone prior percutaneous cardiac intervention and cardiac surgery. There was no difference in operative time, surgical site infections, acute renal failure, re-intubation, or myocardial infarction. HF was associated with increased likelihood of length of stay more than 7 days, likelihood to remain ventilated > 48 h, venous thromboembolism, and reoperation. For patients with HF, the adjusted odds ratio for all-cause morbidity was 2.09 (1.32–3.22).

Conclusion The NSQIP definition of HF, which includes recent hospitalization for HF exacerbation or new HF diagnosis 30 days prior to surgery, predicts a more than two-fold increase in odds of morbidity following bariatric surgery. This must be balanced with the longer-term potential benefits of weight loss and associated improvement in cardiac function in this population.

Keywords Bariatric surgery · Heart failure · Complications · NSQIP

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✉ Andrew T. Strong
stronga@ccf.org

Gautam Sharma
sharmag@ccf.org

Chao Tu
tuc@ccf.org

Ali Aminian
aminiaa@ccf.org

James B. Young
youngj@ccf.org

John Rodriguez
rodrigj3@ccf.org

Matthew Kroh
krohm@ClevelandClinicAubDhabi.ae

1 Department of General Surgery, Digestive Disease and Surgery Institute, Cleveland Clinic, 9500 Euclid Avenue, Desk A-100, Cleveland, OH 44195, USA

2 Cleveland Clinic Lerner College of Medicine, Case Western Reserve University, Cleveland, OH, USA

3 Department of Quantitative Health Sciences, Lerner Research Institute, Cleveland Clinic, Cleveland, OH, USA

4 Endocrinology and Metabolism Institute, Cleveland Clinic, Cleveland, OH, USA

5 Heart and Vascular Institute, Cleveland Clinic, Cleveland, OH, USA

6 Digestive Disease Institute, Cleveland Clinic Abu Dhabi, Abu Dhabi, United Arab Emirates

Introduction

The rapid increase in overweight/obese status among the United States population over 18 years of age over the past three decades is well known, with more than 60% now classified as overweight or obese by body mass index (BMI) criteria [1]. An increase in the prevalence of heart failure (HF) has been observed over the same time period, and the American Heart Association estimates 6.5 million adults in the United States are now living with HF [2, 3]. Heart failure describes a specific clinical syndrome wherein structural or functional impairment inhibits the ability of the cardiac ventricles to either fill or eject blood [2]. This results in elevated venous pressure, fluid retention, and poor oxygen delivery to tissues. As pathophysiologic understanding has increased, HF has been further characterized based upon echocardiographic estimates of the left ventricular ejection fraction (EF). Heart failure with reduced EF (HFrEF) indicates that the left ventricular EF is less than or equal to 40%, which was classically called systolic heart failure [3, 4]. Alternatively, patients may have heart failure with preserved EF (HFpEF), where EF is in the near normal or normal range (40–75%) and is more reflective of diastolic dysfunction [3, 4]. HFpEF is more common in women and among patients with obesity [2].

Historically, HF has been associated with early mortality [3]. However, numerous studies have demonstrated that obesity appeared to be relatively protective among patients with heart failure [2, 5, 6]. Obesity increases risk of HF; however, for patients with established HF, there is an inverse relationship between body mass index and cardiac-related mortality, such is the "obesity paradox" [2, 6–9], Later studies, summarized in systematic reviews, have demonstrated decreased mortality risk with increased body mass index (BMI) for both HFpEF and HFrEF subpopulations [9].

Pathophysiologic development of HF in patients with obesity is complex and likely multifactorial. Obesity, while customarily associated with increased fat mass, is also linked to an increase in lean body mass. The increase in lean body mass requires greater oxygen delivery, and demand is primarily met by chronically increased left ventricular EF. Mild left ventricular dilation and hypertrophy compensates for this change. However, overlying hypertension (an increased afterload), ischemic changes, ectopic fat deposition, and decreased sympathetic activation to augment heart rate to increase cardiac output together contribute to both systolic and diastolic dysfunction [2]. Recent work has begun to improve mortality among patients with HFrEF, by optimizing pharmacologic interventions targeting aspects of the renin-angiotensin-aldosterone axis [4]. However, the same interventions have not been as effective in the HFpEF subgroup. Weight loss following bariatric surgery can lead to dramatic improvements in several echocardiographic specific indices that collectively demonstrate improved left ventricular geometry and function [2, 10, 11]. These effects have occurred as early as 3 months and reduce cardiac events for more than a decade after surgery [12, 13].

Among patients undergoing bariatric surgery, the role HF plays in the perioperative care of the patient is unclear. Prior predictive models developed from the American College of Surgeons National Surgical Care Improvement Project (ACS-NSQIP) database for perioperative morbidity and mortality have demonstrated that HF was a significant predictor among patients undergoing surgical procedures in general [14, 15]. Bariatric surgery specific calculators developed from the later iterations of the same database have failed to identify HF as a significant predictor of morbidity [16, 17]. In other studies using state or national level administrative databases, HF has been associated with hospital readmissions, venous thromboembolic events, all-cause morbidity, and in-hospital mortality after bariatric surgery [18–22]. Prospective studies with HF as a primary exposure variable are limited to small, single-center studies, and have shown modest improvement in cardiovascular specific outcomes with an acceptable risk profile [23–27]. The largest of these series included 38 patients, and no large-scale study exists. Thus, our aim was to evaluate the effect of HF on perioperative morbidity and mortality of patients undergoing an initial bariatric operation.

Methods

Patient Population

This retrospective cohort study utilized data contained in the American College of Surgeons National Quality Improvement Program (ACS-NSQIP) public user files from years 2006 to 2014. The ACS-NSQIP database prospectively collects more than 300 variables relating to demographic, preoperative comorbid conditions, and morbidity and mortality within 30 days of major surgical operations. Participation is voluntary and currently includes more than 400 centers. Patients are sampled based on overall surgical volume of the center and data is abstract from medical records and/or follow-up questionnaires and telephone calls. The ACS-NSQIP has been extensively validated and uses numerous mechanism to ensure consistency and reliability. Aggregated data are available in de-identified public user files.

From the overall database, we identified patients over 18 years of age and with a BMI > 35 kg/m^2 who underwent adjustable gastric banding (AGB), sleeve gastrectomy (SG), roux-en-Y gastric bypass (RYGB), or biliopancreatic diversion-duodenal switch (BPD-DS) using their respective Current Procedural Terminology (CPT) codes [AGB: 43770; SG: 43775; RYGB: 43644 and 43645; BPD-DS: 43845]. Records coded as revisional or emergent or who had another operation within 30 days prior to their bariatric operation were excluded. Patients with preoperative sepsis and with disseminated cancer were additionally excluded.

The main exposure variable for this study was heart failure (*hxchf* = yes). ACS-NSQIP variable definition of HF is either newly diagnosed HF or an acute exacerbation of chronic HF within 30 days of the surgical procedure profiled. Baseline demographic variables that were included were age, sex, BMI, race, and ethnicity as well as active smoking. Comorbid conditions included diabetes mellitus as well as insulin usage, hypertension, prior myocardial infarction, history of percutaneous coronary intervention, history of cardiac surgery, chronic obstructive pulmonary disease, peripheral vascular disease, history of transient ischemic attacks and stroke. Preoperative laboratory variables included serum sodium, hematocrit, albumin, and creatinine. Operative variables considered were the American Society of Anesthesiologists (ASA) classification, bariatric procedure performed, and operative time. All variables are clearly defined in the ACS-NSQIP database user guides [28] (reference is for single year, definitions are generally conserved across years).

End Points

The primary end point was 30-day all-cause postoperative morbidity, which was defined as the presence of one or more adverse events including infection complications (superficial and deep surgical site infections, and organ space infections, pneumonia, urinary tract infection), sepsis, acute renal failure, pulmonary complications (ventilator dependence > 48 h and unplanned re-intubation), cardiovascular outcomes (deep venous thrombosis, myocardial infarction, cardiac arrest, and stroke), wound disruption, and return to the operating room. All-cause morbidity was divided into minor morbidity (composite of deep venous thrombosis, urinary tract infection, pneumonia, superficial wound infection) and major morbidity (composite of organ space surgical site infection, sepsis, septic shock, acute renal failure, unplanned re-intubation, prolonged ventilation > 48 h, myocardial infection, cardiac arrest, stroke, wound disruption, re-operation), which were evaluated as secondary outcomes. Other secondary outcomes include the incidence of each unique adverse event.

Statistics

Propensity score matching was performed with 1:5 ratio based on age, sex, BMI, race, diabetes, and type of surgery. Final dataset contains 237 cases and 1185 controls. Data were described using mean and standard deviation for continuous variables and counts and percentages for categorical variables. Congestive heart failure was compared on demographics, operative characteristics, and outcomes after matching, using Chi-square, Fisher's exact, and Student's *t* test (Wilcoxon rank sum test). Multivariate logistic regression models were built to assess the association between the heart failure and different outcomes adjusted for sex, procedure type, and admission quarter. Missing data was not tabulated as its inclusion failed to change significance in univariable analyses; thus, all analyses were performed on a complete-case basis. All tests were two-tailed and performed at a significance level of $\alpha = 0.05$. R (v3.3.1, 2016-06-21) software was used for all analyses. The Institutional Review Board approved this study under exempt status.

Results

The dataset contained 143,260 total records from 2006 to 2014. After the inclusion and exclusion criteria were applied, 237 patients with heart failure (*hxchf* = "Yes"), who underwent primary bariatric operations, were matched to 1185 controls using propensity scores. The preoperative characteristics of both cohorts appear in Table 1. There were no differences among the variables used for matching. Within HF cohort, both hypertension requiring medication (92.0 vs 77.3%, $p < 0.001$) and COPD were more common (16.5 vs 4.3%, $p < 0.001$). In addition, a greater proportion of patients in the HF cohort had a prior percutaneous coronary intervention (12.2 vs 5.4%, $p = 0.024$) and prior cardiac surgery (11.1 vs 3.0%, $p = 0.001$), though there was no difference in history of myocardial infarction (1.1 vs 0%, $p = 0.13$). In terms of preoperative laboratory values, there was a higher mean creatinine (1.2 vs 1.1 mg/dL, $p = 0.009$) and lower mean hematocrit (39.5 vs 40.1%, $p = 0.026$) in the HF group, suggesting worse baseline renal function and concomitant anemia at the time of bariatric surgery. Perhaps the slightly elevated creatinine was influenced by the higher proportion of patients in the HF group on hemodialysis (2.1 vs 0.7%, $p = 0.05$). As a global assessment of preoperative state, the distribution of the American Society Anesthesiologists (ASA) class is skewed toward more severe disease in the HF group who was more ill, with a greater proportion classified as ASA Class 4, indicating an overall group (25.3 vs 6.3% (see Table 2).

In terms of operative details, operations were evenly distributed across the year. However, it appears that the annual distribution of bariatric operations performed favors the second quarter of the year in the HF group (see Table 2). There was no difference in the distribution of specific operations performed between the groups, with more than half undergoing RYGB in both groups and around 28% undergoing SG (see Table 2). Overall mean operative time was not different between the groups either in aggregate or stratified by procedure type.

The primary outcome was all-cause morbidity, which was more frequent in the HF group (13.5%) compared to the matched non-HF group (7.2%, $p = 0.002$). Subdividing these into minor complications (pneumonia, superficial surgical site

Table 1 Baseline characteristics of the study cohort

Factor	No HF ($n = 1185$)	Yes HF ($n = 237$)	p value
Mean age (year, ±SD)	52.8 ± 10.2	53.0 ± 10.2	0.81
Female sex	59.9% (710)	59.9% (142)	> 0.99
Mean BMI (kg/m^2, ±SD)	50.6 ± 9.9	50.8 ± 11.0	0.74
Ethnicity			> 0.99
White	59.9% (710)	59.8% (141)	
Black or African American	30.3% (359)	30.5% (72)	
Other	9.7% (115)	9.8% (23)	
Diabetes mellitus	57.0% (675)	57.0% (135)	> 0.99
Insulin dependent	35.4% (420)	35.4% (84)	
No insulin/oral agents only	21.5% (255)	21.5% (51)	
Hypertension requiring medication	77.3% (916)	92.0% (218)	< 0.001
History of COPD	4.3% (51)	16.5% (39)	< 0.001
History of MI	0	1.1% (1)	0.13
History of PCI	5.4% (31)	12.2% (11)	0.024
History of cardiac surgery	3.0% (17)	11.1% (10)	0.001
History of peripheral vascular disease	1.4% (8)	2.2% (2)	0.63
Prior CVA	1.4% (8)	3.3% (3)	0.18
On hemodialysis	0.7% (8)	2.1% (5)	0.050
Current systemic corticosteroids	2.4% (29)	5.1% (12)	0.047
Smoked tobacco within 1 year of operation	7.3% (87)	9.7% (23)	0.27
Mean preoperative blood/serum laboratory values (±SD)			
Serum sodium (mg/dL)	139.3 ± 2.6	139.1 ± 3.3	0.48
Creatinine (mg/dL)	1.1 ± 0 .8	1.2 ± 0.8	0.009
Albumin (g/dL)	4.0 ± 0.4	4.0 ± 0.5	0.13
Hematocrit (%)	40.1 ± 4.1	39.5 ± 4.2	0.026

SD standard deviation, *BMI* body mass index, *COPD* chronic obstructive pulmonary diseases, *MI* myocardial infarction, *PCI* percutaneous coronary intervention, *CVA* cerebrovascular disease, *mg* milligram, *dL* deciliter, *g* grams

Table 2 Operative characteristics of the study cohort

Factor	No HF	Yes HF	p value
Calendar quarter when operation performed			0.15
1 (Jan–Mar)	22.4% (265)	18.1% (43)	
2 (Apr–Jun)	23.7% (281)	30.0% (71)	
3 (July–Sept)	28.1% (333)	25.3% (60)	
4 (Oct–Dec)	25.8% (306)	26.6% (63)	
ASA class			< 0.001
Class 1	0	0.4% (1)	
Class 2	15.4% (182)	4.2% (10)	
Class 3	78.2% (927)	70.0% (166)	
Class 4	6.3% (75)	25.3% (60)	
Operation type			> 0.99
RYGB	54.5% (646)	54.4% (129)	
AGB	10.1% (120)	10.1% (24)	
SG	28.6% (339)	28.7% (68)	
BPD-DS	5.1% (60)	5.1% (12)	
Other	1.7% (20)	1.7% (4)	
Mean operative time (minutes, ±SD)	125.9 ± 64.1	128 ± 77.52	0.70
RYGB	143.3 ± 64.0	144.2 ± 82.3	0.91
AGB	76.9 ± 38.8	85.8 ± 36.2	0.29
SG	100.9 ± 47.3	106.0 ± 64.5	0.53
BPD-DS	170.8 ± 78.5	176.8 ± 93.0	0.84
Other	147.8 ± 69.6	87.0 ± 32.4	0.023

ASA American Society of Anesthesiologists, *RYGB* Roux-en-Y gastric bypass, *AGB* adjustable gastric band, *SG* sleeve gastrectomy, *BPD-DS* biliopancreatic diversion duodenal switch

infection, urinary tract infection, or deep venous thrombosis) and serious complication showed no difference in minor complications, but a strong association between HF and serious complications (9.7 vs 3.8%, $p < 0.001$). The operation performed was a strong predictor of complications, with BPD-DS being strongly associated with all-cause morbidity and minor morbidity ($p = 0.006$ and $p = 0.002$). There was no variation in morbidity across calendar quarters. Regarding the incidence of specific complications investigated, there was no difference in urinary tract infection, pneumonia, superficial or deep incisional surgical site infections, acute renal failure, unplanned intubation, postoperative myocardial infarction, cardiac arrest, or stroke (see Table 3). HF status was associated with a higher incidence of deep venous thrombosis requiring therapy (1.7 vs 0.34%, $p = 0.047$) and prolonged intubation (4.2 vs 0.25%, $p < 0.001$). HF was also associated with return to the operating room within 30 days (5.9 vs 2.3%, $p < 0.005$). Data for operation performed during return to the operating room was not evaluated, as it was not included for all years in the dataset. A subset analysis of the complications among patients with heart failure stratified by procedure appears in Table 4. This subgroup analysis suggests that while a statistical difference exists the overall proportion of patients with HF undergoing RYGB, SG, BPD-DS, and AGB, there are similar rates of pneumonia, superficial and deep surgical site infections, unplanned intubation, prolonged ventilation, and death.

Adjusted analyses were also performed. Covariates were chosen *a priori* and included surgery type given differences in complication profile unique to each operation and sex, which has emerged as a significant predictor of postoperative complications in several prior series. In addition, because HF exacerbations have a seasonal variation, peaking in winter months, the calendar quarter was additionally included [29]. In adjusted analysis, the odds of any complication occurring if a patient had HF was 2.09 (95% CI 1.32–3.22; see Table 5). Specifically, the odds of a serious complication occurring was 2.78 (95% CI: 1.61–4.67). While death within 30 days emerged as more frequent in the HF group in univariate

Table 3 Thirty-day postoperative outcomes of bariatric surgery in stratified by diagnosis of HF

Factor	No HF	Yes HF	p value
Total Length of stay in days (mean±SD)	2.73 ± 2.86	3.57 ± 3.15	0.11
Length of stay > 7 days	4.3% (13)	14.3% (6)	0.019
Morbidity/adverse events			
Composite all morbidity	7.2% (85)	13.5% (32)	0.002
Minor[a]	4.3% (51)	6.8% (16)	0.15
Serious[b]	3.8% (45)	9.7% (23)	< 0.001
DVT requiring therapy	0.34% (4)	1.7% (4)	0.047
Urinary tract infection	1.1% (13)	0.42% (1)	0.49
Pneumonia	0.76% (9)	1.3% (3)	0.43
Surgical site infection			
Superficial incisional SSI	2.1% (25)	3.4% (8)	0.34
Deep incisional SSI	0.42% (5)	0.84% (2)	0.33
Organ/space SSI	0.59% (7)	0	0.61
Sepsis	0.59% (7)	3.4% (8)	0.001
Septic shock	0.42% (5)	0.42% (1)	> 0.99
Acute renal failure	0.34% (4)	1.3% (3)	0.095
Unplanned intubation	0.68% (8)	1.3% (3)	0.41
On ventilator greater than 48 h	0.25% (3)	4.2% (10)	< 0.001
Myocardial infarction	0.085 (1)	0.42% (1)	0.31
Cardiac arrest requiring CPR	0	0.42% (1)	0.17
Stroke/CVA	0.085 (1)	0.42% (1)	0.31
Wound disruption	0.17% (2)	0	> 0.99
Return to OR	2.3% (27)	5.9% (14)	0.005
Death	0	1.7% (4)	< 0.001

HF heart failure, *SD standard deviation, DVT* deep venous thrombosis, *SSI* surgical site infection, *CPR* cardiopulmonary resuscitation, *CVA* cerebrovascular accident, *OR* operating room

[a] Minor morbidity is defined as composite of DVT, UTI, pneumonia, superficial wound infection

[b] Serious morbidity is defined as a composite of organ space SSI, sepsis, septic shock, acute renal failure, unplanned reintubation, prolonged ventilation > 48 h, MI, cardiac arrest, stroke, coma, wound disruption reoperationThese are generally consistent with Clavien-Dindo class IV or V complication. Class IV Clavien-Dindo complications were defined as organ dysfunction requiring admission to intensive care unit

analysis (1.7 vs 0, $p < 0.001$), because there were no deaths in the non-HF group, an adjusted odds ratio could not be calculated.

Discussion

This is the first population-based study to examine the effect that HF may have on perioperative complications following bariatric surgery. In this study, HF was associated with a higher incidence of sepsis (3.4 vs 0.59%, $p = 0.001$). However, there was no difference in the incidence of any of the infectious complications collected, including surgical site infections, urinary tract infections, or pneumonia. It may be that the lower baseline systolic blood pressure that often accompanies HF patients leads to a diagnosis of sepsis, despite being a relatively normal range for that individual patient. There was also an association with prolonged intubation in the HF group, but that group also had a higher proportion of patients with COPD. It is not possible to determine if HF or COPD was the more significant driver of prolonged intubation in this study. Prior series have demonstrated that HF was associated with postoperative pneumonia and respiratory failure [22]. Pulmonary infections explain part of the seasonal variation in HF-related mortality, which may need to be considered when planning bariatric surgery [29].

Patients entered into the ACS-NSQIP database recorded as having HF are likely among the most critically ill HF patients, since that variable is defined as an acute exacerbation or new diagnosis of HF within 30 days of the index operation. Providing further evidence of this is the incidence of patients requiring hemodialysis, which may be suggestive of cardiorenal syndrome, and concomitant COPD and hypertension. The significant preoperative risk and the increased risk of perioperative complications presented here should be considered in light of the longer-term benefits demonstrated in other studies. The authors underscore that the NSQIP definition of HF includes patients with a new diagnosis of HF, or HF exacerbation within 30 days of surgery—it does not accurately account for patients with long-standing, well-compensated heart failure.

Weight loss following bariatric surgery leads to a reduction in numerous cardiovascular risk indices [30, 31], including up to a 53% reduction in hazard of cardiovascular specific mortality [12]. Among patients with normal preoperative cardiac function as assessed by echocardiogram, bariatric surgery is associated with reduction in left ventricular mass as early as 3 months after surgery [10, 13, 32–34]. Left ventricular remodeling has been shown to be independent of improvements in hypertension [27]. Diastolic function has also been shown to be improved with postoperative weight loss [35]. In a small prospective series of 12 patients undergoing vertical banded gastroplasty, there were improvements in fractional shortening of the left ventricle, and despite no change in systolic function, there was an improvement in New York Health Association (NYHA) classification [32]. In a separate study, 12 patients with obesity and HF undergoing bariatric surgery were compared to non-surgical controls. A t 1 year, the surgical group had a statistically better left ventricular EF and reduction in NYHA stage [25]. There are additional reports of dramatic improvements in cardiac function after bariatric surgery, especially among relatively young patients with advanced heart failure [36–38]. In some settings, bariatric surgery has been used to bridge patients with obesity to transplant, by facilitating BMI reduction to below the 25 kg/m^2 threshold often used as a criteria for listing for transplant [39–41]. Taken together,

Table 4 Thirty-day postoperative outcomes of bariatric surgery among patients with HF stratified by procedure type

Factor	RYGB $n = 129$	AGB $n = 24$	SG $n = 68$	BDP-DS $n = 12$	Other $n = 4$	p value[c]
Morbidity/adverse events						
Composite all morbidity	13.2% (17)	–	11.8% (8)	41.7% (5)	50% (2)	0.003
Minor[a]	6.2% (8)	–	5.9% (4)	25% (3)	25% (1)	0.047
Serious[b]	8.5% (11)	–	10.3% (7)	25% (3)	50% (2)	0.016
DVT requiring therapy	1.6% (2)	–	–	8.3% (1)	25% (1)	0.022
Urinary tract infection	–	–	–	8.3% (1)	–	0.068
Pneumonia	0.8% (1)	–	2.9% (2)	–	–	0.58
Surgical site infection						
Superficial incisional SSI	3.9% (5)	–	2.9% (2)	8.3% (1)	–	0.67
Deep incisional SSI	0.8% (1)	–	–	8.3% (1)	–	0.14
Organ/space SSI	–	–	–	–	–	NA
Sepsis	3.1% (4)	–	1.5% (1)	25% (3)	–	0.025
Septic shock	0.8% (1)	–	–	–	–	> 0.99
Acute renal failure	2.3% (3)	–	–	–	–	0.74
Unplanned intubation	0.8% (1)	–	1.5% (1)	8.3% (1)	–	0.26
On ventilator greater than 48 h	3.1% (4)	–	5.9% (4)	8.3% (1)	25% (1)	0.13
Myocardial infarction	0.8% (1)	–	–	–	–	> 0.99
Cardiac arrest requiring CPR	–	–	1.5% (1)	–	–	0.46
Stroke/CVA	–	–	–	8.3% (1)	–	0.068
Wound disruption	–	–	–	–	–	NA
Return to OR	5.4% (7)	–	5.9% (4)	8.3% (1)	50% (2)	0.039
Death	1.6% (2)	–	1.5% (1)	8.3% (1)	–	0.36

RYGB Roux-en-Y gastric bypass, *AGB* adjustable gastric band, *SG* sleeve gastrectomy, *BPD-DS* biliopancreatic diversion duodenal switch, *DVT* deep venous thrombosis, *SSI* surgical site infection, *CPR* cardiopulmonary resuscitation, *CVA* cerebrovascular accident, *OR* operating room, *NA* not applicable

[a] Minor morbidity is defined as composite of DVT, UTI, pneumonia, superficial wound infection

[b] Serious morbidity is defined as a composite of organ space SSI, sepsis, septic shock, acute renal failure, unplanned reintubation, prolonged ventilation > 48 h, MI, cardiac arrest, stroke, coma, wound disruption reoperationThese are generally consistent with Clavien-Dindo class IV or V complication. Class IV Clavien-Dindo complications were defined as organ dysfunction requiring admission to intensive care unit

[c] All comparisons made with Fisher exact test/Chi square statistical tests. Small sample sizes mean that these groups are underpowered, and conclusion from these p = values should be interpreted cautiously

Table 5 Adjusted odds ratio of predictors of 30-day postoperative mortality and morbidity

	Odds of morbidity and mortality	
Outcome	Adjusted OR	95% CI
Any	2.09	(1.32, 3.22)
Minor[a]	1.64	(0.88, 2.89)
Serious[b]	2.78	(1.61, 4.67)
Return OR	2.74	(1.37, 5.26)

OR odds ratio

[a] Minor morbidity is defined as composite of DVT, UTI, pneumonia, superficial wound infection

[b] Serious morbidity is defined as a composite of organ space SSI, sepsis, septic shock, acute renal failure, unplanned reintubation, prolonged ventilation > 48 h, MI, cardiac arrest, stroke, coma, wound disruption reoperation. These are generally consistent with Clavien-Dindo class IV or V complication. Class IV Clavien-Dindo complications were defined as organ dysfunction requiring admission to intensive care unit

these data suggest that weight loss associated with bariatric surgery can contribute to left ventricular remodeling, with reduced left ventricular mass, more favorable geometry, and improved systolic and diastolic function in a manner proportional to weight loss [5, 24, 32]. In addition to weight loss, the specific improvement in cardiac function following bariatric surgery, compared to other types of intended weight loss, may be related to surgery-induced biochemical changes [42]. Thus, bariatric surgery may both mechanically and metabolically unload the heart [42].

This study has several limitations. This is a retrospective study utilizing data from an administrative database. While this allows broad generalizability, patient level data is limited. For instance, current classification schema for HF stratified by left ventricular ejection fraction are not possible. Because the definition of HF utilized in the ACS-NSQIP database identifies patients with new diagnoses or recent HF exacerbations, there are likely patients with a clinical history of HF not identified. Specifically, the NSQIP definition omits patients with well-compensated HF. The unidentified cohort likely has less severe cardiac disease and may not experience the same frequency or distribution of complications as those with more severe HF or a recent exacerbation. Criteria used for propensity matching between the HF and non-HF cohorts were chosen *a priori* and resulted in some differences between the groups in terms of preoperative characteristics as noted in Table 1. Some differences, such as the higher proportion of individuals with hypertension requiring medication, and a skewed ASA class distribution in the HF group are likely related to the underlying HF diagnosis. Other differences, notably the difference in incidence of COPD in the HF cohort evaluated here, may not have a direct physiologic link. Another important consideration is variability by center, which is not available within the ACS-NSQIP public user files. Some bariatric centers have developed protocols and multidisciplinary teams to specifically care for patients with heart failure, and outcomes may thus differ by center. However, this is the only population-based study to examine the influence of preoperative HF on perioperative outcomes specific to bariatric surgery that currently exists. The data in this study will be a valuable aid to surgeons discussing surgical weight loss among patients with heart failure, especially in the setting of a recent HF exacerbation or new HF diagnosis.

Conclusion

Patients with a recent HF diagnosis or recent HF exacerbation undergoing bariatric surgery are more than twice as likely to experience complications and significantly more likely to experience serious complications. However, there is no difference in cardiovascular specific outcomes compared to a patient population with normal cardiac function. Increased risk of short-term complications must be balanced against long-term goals for the patient, and these should likely be discussed with the patient and family at the time of operative consent.

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Compliance with Ethical Standards

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Ethical Statement All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

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