Clinical and Echocardiographic Outcomes After Bariatric Surgery in Obese Patients With Left Ventricular Systolic Dysfunction

Amanda R. Vest, MBBS, MPH; Parag Patel, MD; Philip R. Schauer, MD; Mary Ellen Satava, BSN, RN; João L. Cavalcante, MD; Stacy Brethauer, MD; James B. Young, MD

Background—Obesity is a risk factor for development of left ventricular systolic dysfunction (LVSD) and can complicate LVSD management, especially for individuals in whom cardiac transplantation is indicated. Bariatric surgery is increasingly recognized as a safe and effective intervention to achieve marked weight loss, but experience is limited in the LVSD population.

Methods and Results—We retrospectively reviewed patients with obesity and left ventricular ejection fraction (LVEF) <50% who underwent bariatric surgery at a tertiary center 2004 to 2013. An analysis of outcomes and efficacy compared 42 surgical patients with LVSD to 2588 without known LVSD. The LVSD group had greater baseline prevalence of comorbidities and showed a slight excess of early postoperative heart failure and myocardial infarction. However, patients with LVSD achieved good weight loss efficacy (mean decrease 22.6%) and no excess in mortality at 1 year. An overlapping cohort of 38 patients with LVSD had both pre- and postoperative echocardiographic images available for review by 2 blinded readers. Obese nonsurgical controls were matched on age, sex, initial LVEF, and interval between echocardiograms. There was a mean pre- to postoperative LVEF improvement of +5.1% ±8.3 (P=0.0005) for surgical subjects, but not for controls (+3.4%±10.5, P=0.056). Among surgical subjects, 11 patients had an LVEF improvement of >10%, whereas only 6 improved by >10% among nonsurgical controls.

Conclusions—At experienced centers, bariatric surgery may be a safe and effective intervention for obese patients with LVSD. Bariatric surgery was associated with an improvement in LVEF, although the magnitude of change was on the cusp of clinical significance. (Circ Heart Fail. 2016;9:e002260. DOI: 10.1161/CIRCHEARTFAILURE.115.002260.)

Key Words: bariatric surgery ■ echocardiography ■ heart failure ■ heart transplantation ■ obesity

See Editorial by Alpert and Pritchett
See Clinical Perspective

Bariatric surgery, including Roux-en-Y gastric bypass, sleeve gastrectomy, gastric banding, and the less common duodenal switch, can achieve marked weight loss and remission of diabetes mellitus, dyslipidemia, and hypertension. The potential for favorable cardiac outcomes after surgical weight loss have been highlighted by the Swedish Obese Subjects cohort. However, the literature on bariatric surgery for obese patients with preoperative LVSD is limited. Case reports and small cohort studies suggest that bariatric surgery is feasible in the population with LVSD and may be associated with improvements in LVEF. Existing reports though are

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potentially biased toward successful cases, do not use double-blinded echocardiogram readers, and do not compare surgical outcomes in patients with LVSD to those of the general bariatric surgery population. Therefore, we aimed to determine (1) if the safety and efficacy of bariatric surgery in patients with preoperative LVSD is comparable with the remainder of the bariatric surgery population and (2) whether bariatric surgery is associated with significant changes in LVEF in patients with LVSD.

Methods

Study Population
We retrospectively identified patients with LVSD, defined as LVEF <50%, who underwent bariatric surgery (Roux-en-Y gastric bypass, adjustable gastric banding, and sleeve gastrectomy) at Cleveland Clinic between January 1, 2004 and June 30, 2013. Institutional Review Board approval was granted for retrospective collection of data for this project; the requirement for informed consent was waived. Identification of the LVSD cohort was achieved by a combination of 2 methods. First, the institutional bariatric surgery database was searched for individuals who had an International Classification of Diseases Ninth Revision code for HF (428 and related subgroups) listed before their surgical date; individual chart review was performed to determine which of these individuals had a preoperative LVEF <50%. Second, the bariatric surgery list was cross-referenced with the institutional echocardiography database and patients with a preoperative LVEF <50% extracted.

Clinical Outcomes Cohort
The clinical outcomes cohort was assembled by searching the institutional bariatric surgery quality and outcomes database for patients identified with preoperative LVSD. Data were available from this source for surgeries performed between February 1, 2008 and June 30, 2013. The remaining patients with a primary bariatric surgical procedure in the institutional outcomes database who had not been identified as having LVSD were designated as the clinical outcomes control group. Deidentified information on preoperative demographics, comorbidities, and the index surgical procedure were retrieved for both the LVSD group and the remainder of the bariatric surgery cohort. Clinical outcomes were also collated in a deidentified format, with major efficacy (change in weight) and safety (complications and mortality ≤12 months) recorded for both the LVSD group and the remainder of the cohort. Readmissions and complications were reported within 30 days postoperatively. Myocardial infarction (MI) was defined as an intraoperative or postoperative event (within 30 days) meeting one of the 3 following criteria: (1) documentation of at least 1 acute electrocardiographic change—ST elevation >1 mm in ≥2 contiguous leads; new left bundle branch; new Q wave in ≥2 contiguous leads or (2) new elevation in troponin >3× the upper level of the reference range in the setting of suspected myocardial ischemia or (3) physician diagnosis of MI.

Echocardiographic Outcomes Cohort
The echocardiographic outcomes cohort was assembled from the initial list of patients with preoperative LVSD. Patients were eligible for this cohort if they had echocardiogram images available both preoperatively and at least 60 days postoperatively, up until June 15, 2014. This surgical cohort with pre- and postoperative echocardiograms were matched 1:1 for sex, initial reported LVEF (within ±5%), interval between pre- and postoperative echocardiograms (within ±12 months), and age (within ±1 years, but widened out to ±15 years for 3 young subjects who were difficult to match) to obese nonsurgical controls (BMI ≥30 kg/m²) with LVSD (initial EF <50%) and at least 2 echocardiograms after 2004 in the institutional echocardiographic database. Patients with complex congenital heart disease were excluded from both the surgical and the control groups.

Two physician echocardiography readers independently measured the pre- and postoperative LVEFs from these images, both blinded to the surgical subject or nonsurgical control status of the patients. The 2 readers independently interpreted the same 2- and 4-chamber apical image clips for each study and calculated the end-diastolic and end-systolic volumes as calculated by the modified Simpson method (Syngo Dynamics version 9.0, Siemens Medical Solutions, Malvern, PA). The LVEF was calculated for both the 2- and the 4-chamber images, using the formula (end-diastolic volume-end-systolic volume)/end-diastolic volume, and the LVEFs from the 2 image projections averaged. The mean of the 2 readers’ LVEF values was taken as the final LVEF. The charts of both surgical subjects and nonsurgical controls were also reviewed to identify any intervening surgical or device interventions between the 2 echo dates (cardiac resynchronization therapy, valvular procedure, and revascularization) that could have accounted for a change in LVEF. In addition, chart review was performed to obtain the demographics, comorbidities, blood pressure measurements, and cardiac surgeries received by the subjects and controls in the echocardiographic analysis. Any patients who received heart transplantation were censored at the time of transplantation; no post-transplantation echocardiograms were included.

Statistical Analysis
Information from the institutional outcomes database was tabulated separately for the LVSD subgroup versus the remainder of the surgical cohort. Data were assessed for normal distribution by the D’Agostino and Pearson omnibus normality test and parametric or nonparametric testing selected accordingly. Preoperative risk and postoperative efficacy and safety outcomes were compared between the LVSD and general cohort groups using Fisher exact tests for proportions and unpaired t tests for continuous variables. The denominators for calculating proportions of patients with postoperative complications or mortalities were based on the number of individuals observed to have reached that time point.

The echocardiographic data were unblinded once LVEF measurements were completed. Baseline demographics and clinical variables were compared between the surgical subjects and nonsurgical controls using McNemar test for proportions and paired t tests for continuous variables. The change in LVEF between the first and second echocardiograms was compared by paired t test, separately among the surgical subjects and among the nonsurgical controls. The proportion of patients achieving an LVEF increase of >10% among both subjects and controls was also calculated. Pearson correlation coefficients were calculated to assess the correlations between change in LVEF and change in weight, change in blood pressure, and time interval between the 2 echocardiograms.

An additional goal was to identify clinical features that may be associated with a significant LVEF improvement after bariatric surgery. Key clinical variables were compared between surgical subjects who did, and did not, achieve an LVEF increase of >10%. Between-group comparisons were made using Fisher exact tests for proportions and unpaired t tests for continuous variables. These clinical variables were also placed into a linear regression model to define their impact on the postoperative LVEF. The variables were selected on the basis of their pathophysiological relevance and the previous literature on postbariatric surgery LVEF recovery, and included sex, age, previous MI, previous hypertension, initial LVEF, and initial BMI. Simple descriptive were performed using GraphPad Prism version 6.0b for Mac (GraphPad Software, La Jolla, CA); Fisher exact tests, McNemar tests, and the linear regression model were performed using SAS (release 9.4, SAS Institute, Cary, NC). P values of <0.05 were considered statistically significant and all tests were 2 tailed.

Results
As illustrated in Figure 1, 57 patients with known preoperative LVSD underwent bariatric surgery between January 1, 2004 and June 30, 2013. The total number of primary bariatric surgeries performed at this center between January 1, 2004 and June 30, 2013 was 3813. Of these, 42 individuals in the
surgical database were eligible for clinical efficacy and safety outcome comparisons. An overlapping cohort of 38 individuals had both pre- and postoperative echocardiographic images available and formed the echocardiographic outcome analysis group. A total of 2588 patients with no known preoperative diagnosis of LVSD underwent a primary bariatric surgery within the date range for capture in the institutional quality and outcomes database (February 1, 2008 to June 30, 2013).

**Clinical Outcomes Analysis**

The mean preoperative LVEF in the LVSD group was 36.2±8%, ranging from 16.0% to 47.6%. The LVSD subgroup had an equal distribution of genders, whereas the remainder of the surgical cohort was predominantly female (Table 1, 50% versus 75% female, \(P=0.001\)). Patients with LVSD were also older and had a significantly greater prevalence of hypertension, hyperlipidemia, MI, previous coronary revascularization, obstructive sleep apnea, and chronic obstructive pulmonary disease (Table 1, \(P<0.05\) for all comparisons). Roux-en-Y gastric bypass was the modal surgical procedure in both the groups, although a greater proportion of patients with LVSD received a gastric band (19% versus 9%, \(P=0.049\)) or sleeve gastrectomy (26% versus 13%, \(P=0.019\)) when compared with the remainder of the surgical cohort.

The weight loss efficacy at 1 year was slightly inferior in the LVSD subgroup (percentage weight loss from baseline 22.6% versus 28.1%, \(P=0.011\), Table 2). A greater proportion of patients with LVSD experienced postoperative HF (4/42 versus 4/2588, \(P<0.001\)) or MI within 30 days (1/42 versus 1/2588, \(P=0.032\)). Despite the higher burden of preoperative comorbidities for subjects with LVSD, the remainder of early postoperative complications was not significantly different between the 2 groups. There were no significant between-group differences in reoperation, endoscopy, tracheostomy, intensive care unit admission, or hospital readmission within the 30 days post surgery. Thirty-day mortality was 0% in the LVSD subgroup; 1 of the 42 patients with LVSD lived outside the United States and could not be contacted after attending a follow-up visit at 4.5 months, but all other patients with LVSD were known to be alive at 12 months. Thirty-day mortality in the remainder of the cohort was 9/2588 (\(P=1.00\) for comparison between the 2 groups). There was also no difference in mortality between the 2 groups at 12 months (mortality in 0/41 within LVSD group versus 27/2559 within the remainder of cohort at 12 months, \(P=1.00\)). We also separately determined the 12-month mortality status of the 15 bariatric surgery patients who were identified to have LVSD, but who were not captured in the institutional outcomes database (9 of whom featured in the echocardiographic outcomes analysis). At 12 months, 14 of these 15 patients were alive, with 1 death at 6 months postoperatively.

**Echocardiographic Analysis**

This analysis comprised 38 surgical subjects with pre- and postoperative echocardiograms and their 38 matched nonsurgical obese controls. The modal surgical procedure was Roux-en-Y gastric bypass (n=24, 63% of cohort), with 5 gastric bands and 9 sleeve gastrectomies. Preoperative echocardiograms were performed at a mean of 233 days before surgery with a mean pre- to postoperative echocardiogram interval of 931 days (mean surgery to postoperative echocardiogram interval 698 days). The bariatric surgery subjects and nonsurgical controls were closely matched on baseline age, sex, LVEF, and interval between echocardiograms (Table 3). The surgical group had a significantly higher initial BMI (47.2 versus 38.2 kg/m², \(P<0.001\)) and trended toward a higher burden of diabetes mellitus, hypertension, and CAD.

As expected, most surgical subjects experienced marked weight loss (mean percentage weight loss from surgery to postoperative echocardiogram, 22.6%), which was not seen in controls (0.08%, \(P<0.001\) for comparison between surgical subjects and controls). The mean percent excess weight loss (in excess of 25 kg/m²) for the surgical subjects was 53.6%. The 38 surgical subjects had an initial BMI range of 34.9 to 46.9 kg/m²; 86% of the patients were women, and the mean age was 47.6±10.6 years. The mean percentage weight loss from baseline to the study echocardiogram was 29.7±13.9% (range, 4.6% to 55.4%). The mean percent excess weight loss (in excess of 25 kg/m²) for the surgical subjects was 53.6%. The 38 surgical subjects had an initial BMI range of 34.9 to 46.9 kg/m²; 86% of the patients were women, and the mean age was 47.6±10.6 years.
88.0 kg/m², with only 1 patient having a BMI below the recommended upper threshold for heart transplantation listing of 35 kg/m². At a mean follow-up of 23 months, 20 patients had achieved a BMI ≤35 kg/m². Two surgical subjects progressed cumulatively to the time of the second echocardiogram, mean 23 months later, (r = -0.284, P = 0.08). Among the surgical subjects, 11 patients had an improvement in LVEF of >10%, whereas only 6 had an improvement >10% among the nonsurgical controls. Surgical subjects who achieved an LVEF increase of >10% trended toward a higher prevalence of hypertension and lower prevalence of history of previous MI (Table 4). A linear regression model demonstrated a significant negative impact of previous MI on the subsequent LVEF postoperatively (β coefficient, −7.63; P = 0.022, Table 5).
This study provides reassuring data on the safety and efficacy of bariatric surgery in patients with LVSD. Despite a high burden of cardiometabolic and respiratory baseline comorbidities, there were no excess in 12-month mortality in patients with LVSD nor an excess in atrial fibrillation, pulmonary embolus, pneumonia, kidney injury, sepsis, or cardiac arrest within 30 days postoperatively. The slight excess in the frequency of postoperative decompensated HF in the LVSD group is to be expected, but did not result in longer lengths of stay or a greater frequency of readmission for patients with LVSD.

There was also good weight loss efficacy in the LVSD group. Mean BMI decreased from 48.2 kg/m² preoperatively to 35.5 kg/m² at 12 months, which is the typical time for the weight loss nadir after surgery. This represented a 22.6% change in weight during the first postoperative year, which was slightly inferior to the 28.1% loss in the general cohort. This may be because of the cardiorespiratory limitations to exercise in the more medically unwell LVSD subjects. It may also be related to patient and procedure selection, with a greater proportion of nonbypass procedures in the patients with LVSD. The less invasive restrictive or resectional procedures (adjustable gastric band and sleeve gastrectomy) are often used for higher risk patients, but typically result in less weight loss and fewer metabolic improvements than gastric bypass. Further research efforts should focus on how to optimize weight loss efficacy for patients with preoperative cardiac disease.

In obese patients without LVSD, bariatric surgery has been associated with favorable changes in left ventricular mass and left atrial enlargement, and a tendency for the LVEF to decrease slightly as the high output state of morbid obesity regresses. For patients with LVSD, the early case reports of LVEF recovery after bariatric surgery were dramatic and compelling. However, these reports focused on predominantly young, severely obese individuals with severely depressed LVEFs, mostly with nonischemic cardiomyopathies. Further publications supporting the potential for bariatric surgery to improve the LVEF in obese patients with LVSD are summarized in the Table I in the Data Supplement. Much of the early data comes from Alpert et al, who first published a prospective analysis of fractional shortening pre- and postvertical band gastroplasty, including 13 patients with abnormal preoperative systolic function. There were modest improvements in fractional shortening (22±2% to 31±2%, P<0.01) at a mean of 4.3 months after surgical weight loss plateaued. In their 1993 study, this group reported limited data on 14 patients with low fractional shortening who again showed systolic function improvements postgastroplasty (fractional shortening 24±3% to 30±4%, P=0.025). Of note, there was a significant correlation between change in systolic blood pressure and change in fractional shortening (r=0.55, P=0.003). A subsequent 1997 article described 14 patients with clinical HF who underwent vertical banded gastroplasty, with nonsignificant trend toward increased fractional shortening (23%–28%).

McCloskey and Ramani reported on an overlapping cohort of patients with HF who underwent bariatric surgery. Ramani et al used an independent echocardiogram reader.
and matched their 12 subjects to 10 nonsurgical obese controls. At 12 months postoperatively, mean LVEF significantly improved for surgical subjects (LVEF 21.7±6.5% to 35.0±14.8%, P=0.005), but not for controls. Garza et al described a subset of 9 patients with LVEF ≤50%, within a 57-patient cohort of obese subjects who underwent Roux-en-Y gastric bypass. Although these 9 surgical subjects trended toward an improvement in LVEF (44.8±7% to 59.5±10.1%), the nonsurgical controls also experienced a rise in mean LVEF (44.9±7.9% to 58.6±14.1%). Most recently, Lim et al described 7 patients with LVEF ≤25% who underwent bariatric surgery. Subsequently, 2 patients lost sufficient weight to undergo cardiac transplantation, 2 others lost sufficient weight to meet listing criteria, and 3 had LVEF and symptomatic improvement such that transplant listing was no longer indicated. In the individuals who did not undergo transplantation, the median LVEF at follow-up was 30% (mean 39%).

This analysis presents a relatively large bariatric surgery cohort with depressed LVEFs and provides a more robust assessment of postoperative systolic function with a dual-blinded echocardiogram reader design. It also adds more extensive safety and efficacy information. The use of readers who were blinded to the surgical status of the patient removes the potential for a bias toward postoperative LVEF improvement. It is important to note that although there was a significant change in LVEF from baseline to mean 23 months postoperatively, the overall mean increase was 5.1%, which is typically considered to be the approximate range of error for measurements of LVEF, and only marginally exceeded the 3.4% increase for matched nonsurgical controls. Therefore, it seems reasonable to conclude that although bariatric surgery is associated with an increase in LVEF in some patients, this is not a universal finding. Further studies are required to understand this heterogeneity in LVEF response.

Our analysis of baseline factors that may be associated with a greater LVEF improvement was inconclusive in this small cohort, but supported the hypothesis that surgical subjects without a history of MI may be more likely to experience an improvement in systolic function. This would be consistent with other settings in which LV remodeling is more likely in patients without a significant burden of myocardial scar. The observation that 53% of surgical subjects had BMI ≤35 kg/m² at the time of the postoperative echocardiogram is an important message for cardiologists who may be considering transplant listing for an obese HF patient. Thresholds vary between transplant programs, but many avoid listing potential candidates with BMI ≥35 kg/m² because of the low likelihood of healthy weight-matched donor heart availability and the possibility of poorer outcomes. The 2016 International Society of Heart and Lung Transplantation guidelines recommend weight loss to achieve a BMI of ≤35 kg/m² before listing for cardiac transplantation. Therefore, bariatric surgery is a reasonable consideration for patients with advanced HF who are ambulatory and sufficiently stable to undergo noncardiac surgery in preparation for future heart transplantation. None of our cohort were on mechanical circulatory support at the time of bariatric surgery, but there are a growing number of case reports of patients who receive a left ventricular assist device followed by a bariatric procedure to facilitate a bridge to transplantation, or to myocardial recovery.

**Limitations**

These analyses are exploratory and were prompted by the sparsity of published data on bariatric surgery outcomes specific to patients with LVSD. The LVSD subgroup at our single institution is relatively small and, therefore, the power to detect modest differences in outcomes, when compared with the remainder of the bariatric surgery cohort, is limited. Although we did not detect any major excess of mortality in the LVSD subgroup, we cannot exclude a type II error. Also given the exploratory nature of these analyses, we did not adjust P values for multiple comparisons and hence a type I error is possible for the characteristics/ outcomes that were unbalanced between the LVSD subgroup and remainder of the cohort.

It was not possible to present an accurate assessment of subjects’ HF symptom status by the available retrospective chart review. Potential HF symptoms, HF clinical examination findings, and serum brain natriuretic protein levels can all be confounded by manifestations of obesity, making a clinical HF diagnosis difficult in many cases. In addition, many of the patients with LVSD attended this institution specifically for the bariatric surgery and so we did not have access to longitudinal information on their symptom and volume status, frequency of HF hospitalizations or cardiac medication changes after surgical weight loss.
The main limitation for the LVEF measurements was echocardiographic image quality, as expected in an obese cohort. Two blinded readers each measured volumes in 2 views to try to maximize LVEF accuracy, and contrast-enhanced images (with an intravenous perfluor lipid microsphere suspension) were used when clinically available. However, magnetic resonance imaging would provide more reproducible cardiac chamber measurements and would likely be the imaging technique of choice for a prospective study of bariatric surgery in patients with HF.

Conclusions

Bariatric surgery achieved slightly lower weight loss efficacy at 1 year in a small subgroup of patients with LVSD, when compared with the general cohort. Patients with LVSD undergoing bariatric surgery were older and had a higher burden of comorbidities. As anticipated, there were a small number of events in the early postoperative phase, predominantly exacerbations of HF. In spite of this, there was no excess in mortality ≤1 year after bariatric surgery in the LVSD group.

Patients with LVSD undergoing bariatric surgery achieved significant LVEF improvement at a mean of 23 months postoperatively, which was independent of the degree of weight loss. There was not a significant change in LVEF for nonsurgical control subjects. However, the magnitude of the mean postoperative LVEF change was only on the cusp of clinical significance, and there was considerable heterogeneity in LVEF response within the surgical group. Patients with a previous MI may be less likely to experience LVEF improvement after bariatric surgery.

In summary, bariatric surgery seems to be safe and effective in patients with preoperative LVEF <50% who are clinically compensated and managed at an experienced bariatric and cardiac center. Prospective trials of bariatric surgery for HF patients with both reduced and preserved ejection fractions are urgently needed to better define the optimal management of obesity within the population with HF.

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CLINICAL PERSPECTIVE

Bariatric surgery is increasingly used for morbid obesity in medically comorbid patients. Obesity is a risk factor for left ventricular systolic dysfunction (LVSD) development, but there is a paucity of data on the safety and efficacy of bariatric surgery within the population with LVSD. We retrospectively reviewed the Cleveland Clinic experience and compared 42 patients with prebariatric surgery LVSD (left ventricular ejection fraction [LVEF] <50%; range, 16.0%–47.6%) to the remainder of the surgical cohort 2004 to 2013 (n=2588). There was no excess in mortality associated with LVSD in the first postoperative year. The LVSD group’s weight loss efficacy was good, but statistically inferior to the remainder of the cohort (mean weight decrease 22.6% versus 28.1% at 1 year, P=0.011). Specific postoperative focus may be required to ensure that individuals with LVSD maximize their weight loss potential. We also built on previous small reports of LVEF improvement after bariatric surgery. The mean increase in LVEF of 5.1% at 23 months (n=38 surgical subjects) was statistically significant and not present in the matched controls, but was more modest than previous published reports. There is clearly some heterogeneity in the LVEF response to surgical weight loss—we found that a history of myocardial infarction was a negative predictor of LVEF improvement—and we recommend minimizing expectations of LVEF recovery after a bariatric procedure. However, surgical weight loss may be effective in facilitating future cardiac transplantation, with most of our echocardiographic cohort achieving a body mass index of 35 kg/m² or less within 2 years.
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### Supplemental Table. Summary of Existing Data on Post-Bariatric Surgery Systolic Function for Subjects with Pre-Operative Left Ventricular Systolic Dysfunction

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<td>Vest (present echo study)</td>
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<td>47.2</td>
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**Weighted means:**

- N = 137
- 20 months
- 46 years
- 52% female
- **modal procedure**: RYGB
- Pre BMI (kg/m²) = 50
- Post BMI (kg/m²) = 35
- Pre LVEF (%) = 32%
- Post LVEF (%) = 42%

**Abbreviations:** AGB, adjustable gastric band; BPD, biliopancreatic diversion; FS, fractional shortening; HF, heart failure; kg, kilograms; LVEF, left ventricular ejection fraction; n/a, not available; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; VBG, vertical band gastrectomy

* Two kin studies containing an overlapping population from the same institution; only Ramani 2008
used for calculation of weighted means

Supplemental References


