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ORIGINAL CONTRIBUTIONS

Bariatric Surgery Provides a "Bridge to Transplant" for Morbidly Obese Patients with Advanced Heart Failure and May Obviate the Need for Transplantation

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Abstract
Background In patients with advanced heart failure, morbid obesity is a relative contraindication to heart transplantation due to higher morbidity and mortality in these patients.
Methods We performed a retrospective analysis of consecutive morbidly obese patients with advanced heart failure who underwent bariatric surgery for durable weight loss in order to meet eligibility criteria for cardiac transplantation.
Results Seven patients (4 M/3 F, age range 31–56 years) with left ventricular ejection fraction (LVEF) ≤25 % underwent laparoscopic bariatric surgery. Median preoperative body mass index (BMI) was 42.8 kg/m^2 (range 37.5–50.8). There were no major perioperative complications in six of seven patients. Median length of hospital stay was 5 days. There was no mortality recorded during complete patient follow-up. At a median follow-up of 406 days, median BMI reduction was 12.9 kg/m^2 (p=0.017). Postoperative LVEF improved to a median of 30 % (interquartile range (IQR) 25–53 %; p=0.039). Two patients underwent successful cardiac transplantation. Two patients reported symptomatic improvement with little change in LV function and now successfully meet listing criteria. Three patients showed marked improvement of their LVEF and functional status, thus removing the requirement for transplantation.
Conclusions Bariatric surgery can achieve successful weight loss in morbidly obese patients with advanced cardiac failure, enabling successful heart transplantation. In some patients, cardiac transplantation can be avoided through surgical weight loss.

Keywords Bariatric surgery · Congestive heart failure · Obesity

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Introduction

Severe obesity is widely considered a contraindication for cardiac transplantation [1]. Patients with severe obesity (body mass index (BMI) ≥35 kg/m^2) have increased morbidity and mortality compared with patients with lower BMI when undergoing cardiac transplantation [2]. After being placed on the transplant waiting list, these patients are also at a disadvantage, often experiencing a lower likelihood of receiving a donor heart and a longer interval from listing to transplantation [3]. Thus, the International Society of Heart and Lung Transplantation has recommended that severely obese patients achieve a BMI <30 kg/m^2 before listing for cardiac transplantation [1].

Weight loss has been shown to be beneficial for heart function [4, 5]. Bariatric surgery should therefore provide a benefit for morbidly obese patients with heart failure, although there is the risk of acute cardiac decompensation due to hemodynamic stresses associated with anesthesia and pneumoperitoneum [6–10]. Indeed, heart failure is associated with a sevenfold increase in the risk of perioperative mortality during bariatric surgery [11].

Few studies have examined the benefits and risks of weight loss surgery in patients with advanced heart failure [12–15]. The aim of this study was to report our experience with bariatric surgery in morbidly obese patients and advanced heart failure who were referred to our heart transplant unit for assessment.

Material and Methods

Study Design and Study Population

We performed a retrospective single-center cohort analysis of seven patients with advanced systolic heart failure and a left ventricular ejection fraction (LVEF) less than 25 % who underwent bariatric surgery at St Vincent's Hospital, Sydney, a tertiary heart transplant referral center, between January 2009 and September 2014.

Data were obtained from the hospital's electronic medical records as well as from individual patient case notes and stored in a central, anonymized database (Microsoft Excel, Microsoft Office 2010, Microsoft Corporation, Redmond WA, USA). Patient demographic data, clinical characteristics, heart failure etiology, preoperative LVEF and New York Heart Association (NYHA) functional class, type of bariatric surgery performed, and intraoperative right heart catheterization data were collected. Weight was measured with the patient in light street clothing.

The following parameters were used to assess the efficacy of surgery: absolute weight loss and body mass index (BMI) reduction, LVEF, and NYHA class at a minimum of 6 months postsurgery. The safety of the procedures was assessed using perioperative complications, hospital and intensive care unit (ICU) length of stay, and mortality at 30 days and 6 months.

Institutional review board approval was obtained for this study, and all patients provided informed consent.

Surgical Procedure

Following interdisciplinary assessment patients were scheduled to receive either laparoscopic gastric banding (LGB) or laparoscopic sleeve gastrectomy (LSG). The first two patients underwent laparoscopic adjustable gastric band (LAGB) placement because of the safety profile of this operation; a later patient had a preference for LAGB over sleeve gastrectomy (SG). After the anesthesiologist advised that LSG should also be tolerated safely, we performed that operation in the other patients. This change was influenced by reports of better weight loss outcomes with LSG and the patients' difficulty taking their essential oral medications, which tended to get stuck at the band.

LAGB placement used the pars flaccida approach with the Swedish Adjustable Gastric Band (Johnson and Johnson Ethicon, Inc.) anchored with gastro-gastric sutures at the fundus. The SG operation was performed over 32-Fr bougies for females and 36-Fr bougies for males using the Echelon three-layer stapler device (Johnson and Johnson Ethicon, Inc.) with oversewing of the proximal staple line using 0 Ethibond sutures. In one patient, the SG was combined with an anterior partial fundoplication because of severe, highly symptomatic gastro-esophageal reflux disease (GERD). The fundoplication was constructed by suturing the highest part of the fundus to the right crus, in the process burying the staple line at its most proximal part onto the crus. The fundoplication lies anterior to the esophagus with a lateral orientation. All patients were scheduled for ICU monitoring for a minimum of 24 h postsurgery.

All patients were prescribed a calorie-restricted eating plan prior to surgery, with variable caloric intakes based on baseline weight. Where tolerated, very low calorie diets were prescribed, using commercially available meal replacement shakes, under careful medical supervision since these diets can induce rapid and significant fluid flux, electrolyte shifts, and changes in anticoagulant therapy requirements [16]. All patients were scheduled for postoperative outpatient review at 2 weeks, 4 weeks, 3 months, 6 months, and 12 months postsurgery.

Anesthesia

Anesthetic intervention for each surgery was determined at the discretion of the anesthesiologists involved and individual patient health status. All patients had invasive arterial monitoring and central venous catheterization for detailed intraoperative and postoperative monitoring. A pulmonary artery catheter (PAC) (Edwards Lifesciences Swan Ganz CCOmbo, Irvine, CA, USA) was placed in six patients. The anesthetic agents used were midazolam, fentanyl, a muscle relaxant, and either sevoflurane or desflurane. A low-dose propofol infusion was also used in some patients to reduce the dose of the volatile agent. All patients were extubated successfully at the end of the procedure.

Statistical Analysis

Continuous variables were compared using the non-parametric Wilcoxon rank sum and the Kruskal-Wallis test where appropriate. Categorical data were compared using

Fisher's exact test. Data are presented as mean (standard deviation [SD]) and median (interquartile range [IQR]) where applicable unless denoted otherwise. The study was not designed to allow for formal statistical comparison of the two operation types. All p values <0.05 were regarded as statistically significant. All statistical analyses were performed using R Statistical Packages [17] with use of the lattice and ggplot2 packages [18, 19].

Results

Patient Demographics and Cardiac Functions

Seven patients with LVEF ≤25 % underwent bariatric surgery at our center during the study period: four males and three females with a median age of 41 years (IQR 40–51), median patient preoperative weight of 122 kg (IQR 116–126 kg), and median preoperative BMI of 42.8 kg/m^2 (IQR 39.7–43.3 kg/m^2). The median preoperative LVEF was 20.0 % (IQR 20.0–25.0 %). Six patients were NYHA functional class III preoperatively while one patient was NYHA functional class II.

Four patients had idiopathic dilated cardiomyopathy, one patient had ischemic heart disease, and two patients had familial dilated cardiomyopathy. Four patients had cardiac resynchronization therapy defibrillator, two had single-chamber implantable defibrillator, and one patient had no defibrillator. Common patient comorbidities included (insulin-dependent) diabetes mellitus (57 %), gout (57 %), hyperlipidemia (43 %), atrial fibrillation (43 %), hypertension (29 %), obstructive sleep apnea (29 %), and a history of deep vein thrombosis (29 %; Table 1).

Prior to bariatric surgery, all patients were on beta-blockers and either an angiotensin-converting enzyme inhibitor or angiotensin II receptor antagonist. Six patients were on a mineralocorticoid receptor antagonist, three on digoxin, three on aspirin, and three on statins.

Intraoperative Course

Figure 1 shows intraoperative measurements taken from intraarterial lines and PACs during the procedure. Longer procedures have more data points, and one patient had the PAC placed postinduction.

Intraoperative right heart catheter data were available in six patients. At the start of surgery, mean cardiac index was 1.9±0.7 L/min/m^2, mixed venous oxygen concentration (SVO_2) 67.0±15.2 %, systemic vascular resistance index 3077.8±1212.6 dyne s m^2/cm^5, mean arterial pressure 79.8±10.7 mmHg, central venous pressure 13.2±5.7 mmHg, and mean pulmonary artery pressure 30.8±9.3 mmHg. Two of the patients had stable hemodynamic readings throughout their intraoperative course even though their preoperative

Table 1 Patient demographics and clinical parameters presurgery and postsurgery

Patient	Gender	Age	Heart failure etiology	Comorbidities	Surgery	Preop cardiac index (L/min/m^2)	Preop weight, BMI (kg, kg/m^2)	Postop weight, BMI (kg, kg/m^2)[c]	Preop LVEF (%)	Postop LVEF[c] (%)	Preop NYHA	Postop NYHA[c]	Follow-up (months)
P1[a]	M	40	DCMP	IDDM, gout, AF	AGB	1.4	123.7, 43.8	91.3, 32.3	20	HTx	3	3	46
P2[b]	F	40	Familial CMP	HL	AGB	2.1	104.8, 39.9	90.1, 34.3	20	25	3	3	44
P3[a]	M	52	IHD	IDDM, gout, HL, CKD	SG	0.9	121.5, 37.5	76.5, 23.6	20	HTx	3	LVAD	21
P4	M	49	DCMP	DM, gout, CKD, AF	SG	2.7	128, 42.8	107, 35.8	20	25	3	3	13
P5	F	41	DCMP	DM, HT, gout, OSA, DVT, seronegative arthritis	SG	2.6	122, 50.8	86, 35.8	25	60	3	1	12
P6	F	31	Familial CMP	Nil	AGB	1.9	110, 39.4	90, 32.3	25	30	2	1	10
P7	M	56	DCMP	HT, HL, OSA, AF, DVT	SG	NA	169.1, 48.9	114, 33.0	25	55	3	1	6

AGB adjustable gastric band, *AF* atrial fibrillation, *BMI* body mass index, *CKD* chronic kidney disease, *CMP* cardiomyopathy, *DCMP* idiopathic dilated cardiomyopathy, *IDDM* insulin-dependent diabetes mellitus, *DVT* deep vein thrombosis, *F* female, *HL* hyperlipidemia, *HT* hypertension, *IHD* ischemic heart disease, *LVAD* left ventricular assist device, *LVEF* left ventricular ejection fraction, *M* male, *OSA* obstructive sleep apnea, *NA* not available, *NYHA* New York Heart Association, *SG* sleeve gastrectomy, *AGB* adjustable gastric band

[a] Patient underwent heart transplantation

[b] Patient on heart transplant waiting list

[c] All postoperative measurements are at last patient follow-up

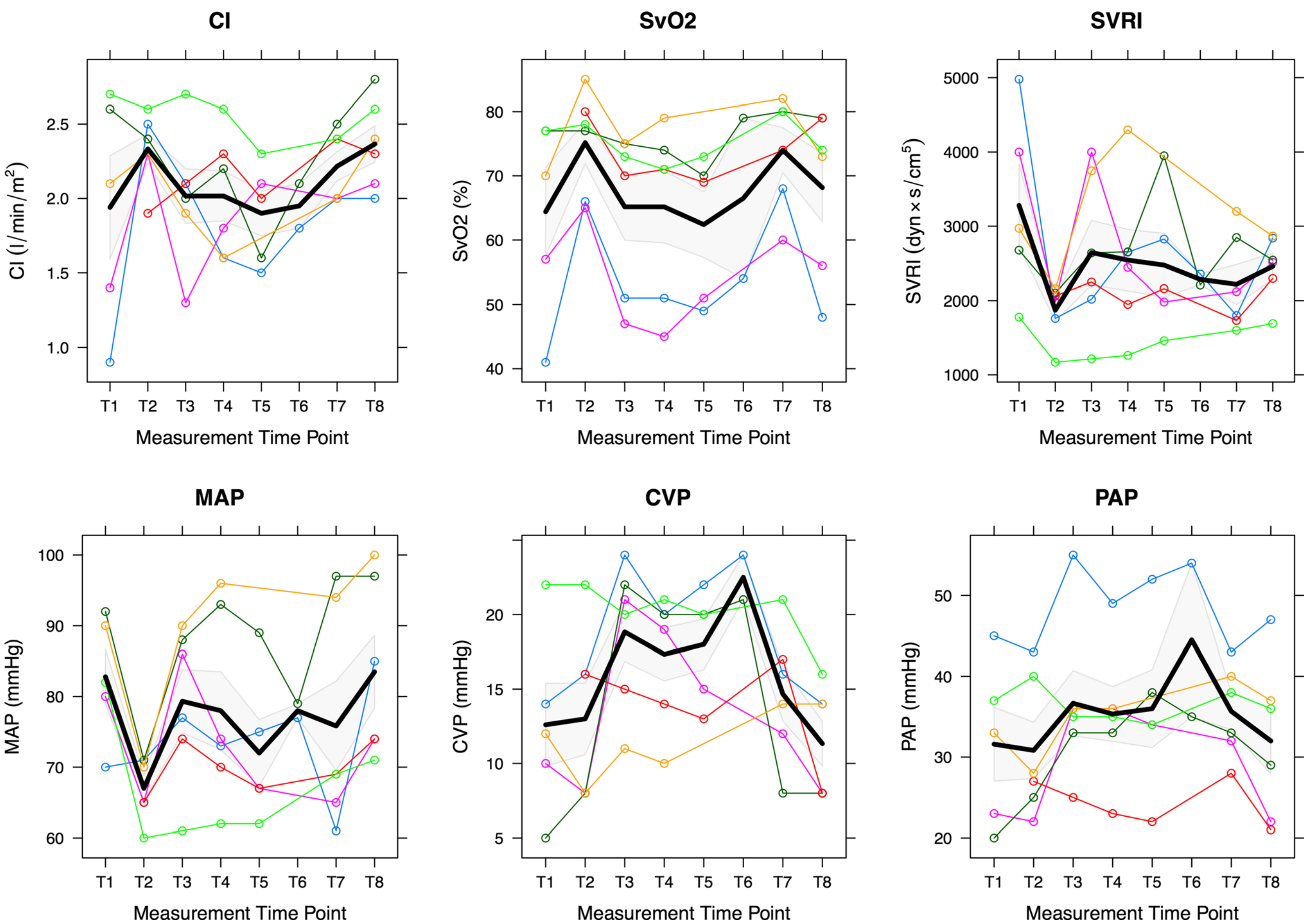


Fig. 1 Intraoperative cardiovascular measurements. *Colored lines* are individual patients' data. *Solid black line* indicates the mean of all patients with *gray shading* indicating the standard error of mean. Measurement time points are as follows: T1: preinduction, T2: postinduction, T3: postinsufflation and head up, T4: 30 min postinsufflation, T5: 60 min postinsufflation, T6: 120 min postinsufflation, T7: postexsufflation with table level, and T8: postextubation. *CI* cardiac index, *SvO2* mixed venous oxygen saturation, *SVRI* systemic vascular resistance index, *MAP* mean arterial pressure, *CVP* central venous pressure, *PAP* pulmonary artery pressure. Units are provided in *y*-axes

echocardiograms demonstrated severe dilated cardiomyopathy. The other four displayed the characteristic fall in cardiac index (CI) and rise in SVRI [20–23]. The SvO_2 fell below 50 % in the two patients who had a CI <2.0 L/min/m^2 preinduction. Two patients were treated with infusions of dobutamine.

Operative Procedures and Postoperative Course

All patients underwent laparoscopic bariatric surgery. Three patients underwent adjustable gastric banding, and four patients underwent SG.

Six of the seven patients were monitored in ICU for a minimum of 24 h postsurgery, with one patient being sufficiently stable to allow for postoperative admission to the regular ward. There were no major perioperative complications in six out of seven patients (86 %). The patient who underwent SG combined with partial fundoplication required laparoscopic reoperation on the first postoperative day with stapled resection of the fundus segment that was used to construct the fundoplication because of postoperative ischemia. This patient had an SvO_2 of 41 % prior to induction of anesthesia and the most abnormal hemodynamic profile at anesthetic induction with an initial CI <1.0 L/min/m^2 and had profound postoperative hypotension requiring high inotropic support. The patient subsequently developed acute kidney and liver dysfunction due to hemodynamic insufficiency and intractable heart failure requiring intraaortic balloon pump (IABP) support and left ventricular assist device (LVAD) implantation prior to successful transplantation at a later admission. Only one patient (14 %) was readmitted within 30 days of discharge, for treatment of pneumonia.

Six out of seven patients were admitted to the intensive care unit (ICU) for monitoring postoperatively. The median length of stay in the ICU was 1 day (IQR 1–1), and the median length of stay was 5 days (IQR 4–7). The patient with gastric tube ischemia requiring reoperation was in ICU for 26 days and had a total hospital length of stay of 89 days. No mortality was recorded during complete patient follow-up.

Follow-Up and Patient Outcome

The median length of follow-up was 406 days (IQR 348–992). At last follow-up, median surgery-induced weight loss per patient was 28 kg (IQR 20.5–38.7 kg; p=0.04) with a median BMI reduction of 12.9 kg/m^2 (IQR 9.6–14.6 kg/m^2; p=0.017; Fig. 2) equating to a median percent excess BMI loss (%EBML) of 64.4 (IQR 48.8–78.0). There were no statistically significant differences between the two operation types with regard to weight loss in the follow-up period (data not shown). All patients lost sufficient weight to meet eligibility criteria for heart transplantation. Two patients (including the LVAD-supported patient) underwent successful cardiac transplantation.

The non-transplanted patients' postoperative LVEF improved to a median of 30 % (IQR 25–53 %; p=0.039). The difference in LVEF improvement in LAGB versus SG patients is shown graphically in Fig. 3. At last follow-up, three patients reported an improvement to NYHA class I and three patients remained in NYHA class III. The LVAD-supported patient improved to NYHA class II.

Discussion

While bariatric surgery is an effective and safe means of achieving durable weight loss [24–27], the efficacy and safety of bariatric surgery in patients with advanced heart failure has only been reported in a small number of studies [12–15].

In this case series, all patients presented with advanced cardiac failure with an LVEF ≤25 %, but none of the patients was eligible for cardiac transplantation because their BMI was above the Australian national transplant limit of 30 kg/m^2.

As expected, bariatric surgery resulted in significant weight reduction in all patients. Although caution is required when interpreting statistical analysis for small patient numbers, it is noteworthy that the overall LVEF improvement was statistically significant. The markedly greater improvement in LVEF after SG compared to LAGB in this study (see Fig. 3) may be merely a chance finding due to the few patients in each group, but it will be interesting to see if this extent of benefit in LVEF continues to be found in patients treated by SG in the future. Three patients experienced sufficient symptomatic and left ventricular function improvement that cardiac transplantation was not required. These findings are consistent with earlier studies that have demonstrated the cardiac benefits of surgical weight loss [12]. In a similar case series including 14 patients with severe cardiomyopathy at the University of Pittsburgh, weight loss after bariatric surgery was associated with significant improvement in LVEF and NYHA functional class [12]. In a matched case series, Ramani et al. noted a significant improvement in LVEF in 12 patients who underwent bariatric surgery, but not in the 10 patients who were given diet and exercise counseling [13]. Ristow and colleagues further reported on two patients who no longer required heart transplantation after successful weight reduction and improvement in LVEF after bariatric surgery [15]. Further, a meta-analysis involving 19,543 subjects reported reduction in cardiovascular risk factors and evidence for left ventricular hypertrophy regression and improvement in diastolic function in patients undergoing bariatric surgery [28].

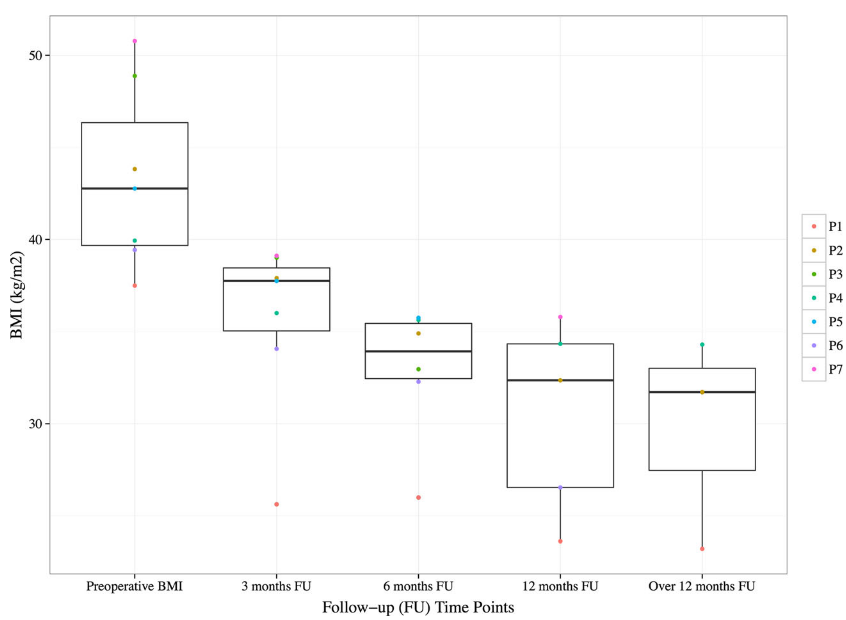
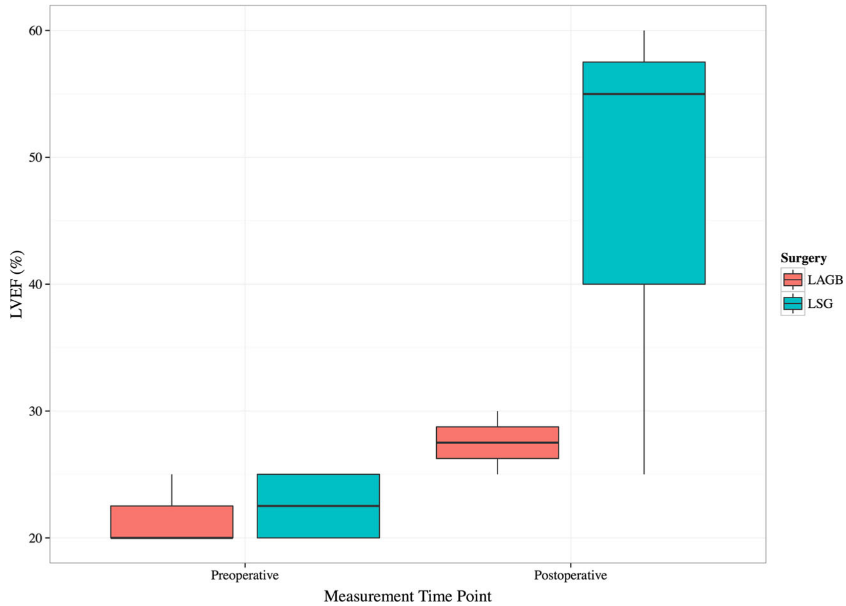


Fig. 2 Presurgery vs. postsurgery BMI changes at various follow-up time points. Boxplot of cohort body mass index measurements. *Solid horizontal bar* indicates median, and *box* shows interquartile range (25th and 75th percentile). Single points indicate individual patient data

Fig. 3 Presurgery vs. postsurgery LVEF changes by surgery type. Boxplots of cohort left ventricular ejection fraction (LVEF) changes. *Solid horizontal bar* indicates median, and *box* shows interquartile range (25th and 75th percentile). As no lower LVEF than 20 % was included in our cohort, the median of the left boxplot simultaneously represents the lowest LVEF measurement recorded



The weight reduction achieved postbariatric surgery in this cohort resulted in two patients eventually undergoing successful heart transplantation. All other patients achieved sufficient weight loss to meet listing criteria. This experience was shared by Wikiel et al. in 2014, who also reported bariatric surgery to be a safe and effective conduit to cardiac transplantation [29]. The potential role of successful bariatric surgery in obese patients on LVAD support as a bridge to heart transplant has also been reported [30].

All patients underwent laparoscopic bariatric surgery by either SG or adjustable gastric band placement. Although gastric band placements tend to be associated with less weight loss when compared to SG or Roux-en-y gastric bypass, it is the least hazardous bariatric operation [31]. The SG operation is similarly safer than Roux-en-Y gastric bypass, with comparable clinical outcomes [32, 33]. A risk-benefit analysis first led us to choose laparoscopic gastric banding for these severely ill patients, but the potential need for reoperations for band complications such as slippage or erosion, the less reliable weight loss outcomes, and the patients' difficulties with swallowing their medications due to the narrow internal diameter of the band led us to change to the SG operation.

SG with partial fundoplication was performed in one patient, who had severe daily GERD symptoms uncontrolled by maximal PPI therapy. This operation was devised by one of us (RVL), and although it had been used successfully to treat the combination of morbid obesity with GERD in more than 20 patients without heart failure without major complications previously, the operation choice was, in retrospect, a less safe option than routine SG and we would not perform the SG plus fundoplication operation in patients with heart failure in future. Despite intact right and left gastric arteries, the fundoplication segment became ischemic most likely due to relative hypoperfusion associated with folding over of the small fundus pouch and the use of very high inotropic support causing reduced local gastric perfusion. This patient's postoperative course, with multi-organ failure due to hemodynamic insufficiency and the need for LVAD support prior to successful cardiac transplantation, demonstrates clearly the potential for life-threatening catastrophic complications in these patients. Fortunately, the ischemic fundus could be resected easily at a second laparoscopic operation on the first postoperative day; dealing with a staple line leak could be an even more difficult problem in these sick individuals. Due to the possibility of patients being subsequently referred for cardiac transplantation and thus requiring immunosuppression, malabsorptive procedures were not considered appropriate.

Although there are associated anesthetic risks when applying pneumoperitoneum in patients with cardiac failure [10], these were generally well tolerated in our patient cohort. We believe that perioperative care and intraoperative anesthesia played a critical part in the successful surgery and recovery thereafter. While most patients were admitted on the day of the surgery, all were seen at the anesthetic preadmission clinic within a week prior to surgery

Intraoperative management of these patients with severely depressed cardiac function was challenging. Some key observations included (1) the reduction in CI and a rise in systemic vascular resistance with the insufflation of carbon dioxide to create pneumoperitoneum during surgery in four patients, (2) the need for inotropic support in two patients, and (3) a significant drop in mixed venous oxygenation to less than 50 % in two patients. There was no consistent association between baseline readings and the severity of adverse changes with abdominal inflation. The critical nature of the hemodynamic effects in some patients may not have been recognized without the PAC measurements. Some of these observations have been described in previous studies [7, 9, 10, 34].

In our high-risk cohort, bariatric surgery was associated with a low rate of perioperative complications. Most patients had uncomplicated recoveries postbariatric surgery, with minor complications that were readily resolved and did not require extended hospitalization, and the median length of hospital stay was only 5 days. While previous case reports and case series have reported safe and successful bariatric surgery in obese patients with severe cardiomyopathy [12–15], our case series demonstrates that the perioperative course in this group of high-risk patients is not always smooth. It should also be noted that in a registry study involving more than 150,000 patients, a sevenfold increase in 30-day mortality in patients with a history of congestive heart failure undergoing bariatric surgery has been reported [11]. Therefore, we strongly believe that the availability of a high level of intensive care and cardiology support is an important prerequisite to handle the serious complications that could arise in these patients.

Conclusion

While bariatric surgery is an effective means of weight loss in patients with severe systolic heart failure, it can be associated with serious complications and therefore should be performed only in centers by experienced specialist trained foregut surgeons, with advanced anesthetic, intensive care, and cardiac support. Successful weight loss in these patients can improve cardiac function and functional capacity, obviating the need for cardiac transplantation assessment in some patients and providing a "bridge to transplant" in others.

Conflict of Interest The authors have no conflicts of interest to declare.

Ethical Approval 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.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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