Metabolism and Target Organ Damage

Review Article

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Bariatric surgery in patients with obesity and end-stage heart failure with left ventricular assist devices: a brief guide

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Abstract

The prevalence of obesity is increasing worldwide, leading to a rise in several comorbidities, and is itself an important risk factor for heart failure. Patients with end-stage heart failure and obesity are often not eligible for heart transplantation (HT) and instead receive cardiac support from left ventricular assist devices (LVAD). In the absence of other contraindications, patients with obesity who are on LVAD support can lose enough weight to later qualify for HT. Bariatric surgery had been explored as an approach for weight loss in this patient population and was found to be a safe and effective option. One recent systematic review and meta-analysis has shown 67.4% of patients with LVAD support are able to be listed for transplantation after bariatric surgery and subsequent weight loss (95%CI: 0.477-0.871). Of these, 32.5% would go on to receive a heart transplant (95%CI: 0.201-0.448). There were also numerous cases of patients whose cardiac function improved after bariatric surgery such that they were delisted for HT and some had subsequent removal of their LVAD. There are many perioperative considerations when evaluating patients with LVADs for bariatric surgery. However, with careful patient selection by a multidisciplinary team and mindful preparation, patients with obesity and end-stage heart failure have an opportunity for longer years of life.

Keywords: Obesity, bariatric surgery, LVAD, left ventricular assist devices, heart failure, heart transplantation, laparoscopic sleeve gastrectomy, Roux-en-Y gastric bypass, review, surgical considerations

INTRODUCTION

The prevalence of obesity [body mass index (BMI) ≥ 30 kg/m^2] is increasing worldwide and has led to an increase in comorbidities such as type 2 diabetes mellitus, hypertension, dyslipidemia, and malignancies[1]. Independent risk factors for heart failure include type 2 diabetes, hypertension, and obesity itself[2]. Compared to patients with normal BMI (18.5-24.9 kg/m^2), Kenchaiah *et al.* found that patients with obesity had nearly twice the risk of heart failure with hazard ratios (HR) of 2.12 (95%CI: 1.51-2.97) in women and 1.90 in men (95%CI: 1.30-2.79)[2]. In fact, approximately 11% of heart failure cases in men and 14% of cases in women in the community are attributable to obesity alone[2].

Proposed mechanisms that link obesity to heart failure include inflammation, insulin resistance, hypertension, and altered left ventricular remodeling via increased hemodynamic load and oxidative stress[2,3]. Adipose tissue was formerly thought to be a passive organ for excess energy storage, though recently, it has also been established as an endocrine organ with the excretion of adipokines, a wide variety of biologically active molecules[4]. Many adipokines mediate the chronic inflammatory state seen in patients with obesity and some are known to be involved as the pathophysiological link for the development of cardiovascular diseases[4]. These pro-inflammatory adipokines include tumor necrosis factor-α, leptin, adiponectin, interleukin-6, and serum amyloid A[4,5].

The current standard of care for end-stage heart failure is heart transplantation (HT), though this is inherently limited by the availability of donor organs and by candidates' suitability for a major operation and life-long immunosuppression. There has long been evidence of increased morbidity and mortality among HT recipients with preoperative obesity of at least class II (BMI ≥ 35-39.9 kg/m^2)[6]. Additionally, Fisher *et al.* found that patients with preoperative BMI > 38 kg/m^2 who received HT are at greater risk for cerebrovascular events, post-transplant dialysis needs, and increased lengths of stay[7]. A systemic review and meta-analysis by Foroutan *et al.* reported an increased mortality risk in heart transplant recipients with any level of preoperative obesity: up to 12% in patients with class I (BMI ≥ 30-34.9 kg/m^2) obesity (HR 1.10, 95%CI: 1.04-1.17) and 22% in patients with at least class II obesity (HR 1.24, 95%CI: 1.12-1.38) independent of transplant period[8].

Due to these findings, the International Society of Heart and Lung Transplantation (2016) recommends that class II or higher obesity be considered a relative contraindication for transplant eligibility[9]. Indeed, most transplant centers largely adhere to this guidance - over 92% of HT recipients have a BMI < 35 kg/m^2 and only 10% of centers transplant patients with a BMI of 40 kg/m^2 or greater[7].

Mechanical circulatory devices, such as left ventricular assist devices (LVAD) [Figure 1], have served as temporary bridges to transplantation for those who may become eligible for HT and as destination therapy for those who are not. These devices function as pumps that direct blood flow from the left ventricle to the ascending aorta to augment cardiac output. Older model LVAD pumps were situated in a pre-peritoneal pocket near the cardiac apex and received blood via an inflow catheter implanted into the left ventricle. More modern models implant directly at the apex within the pericardium, such as with the HeartMate III (Abbott Labs, Chicago, IL), which has accounted for nearly 80% of durable LVADs implanted since 2018 in the United States[10]. An outflow cannula then delivers blood to the ascending aorta and offloads the left ventricle. Modern systems provide this cardiac output in a non-pulsatile continuous manner of flow. A driveline courses subcutaneously at the anterior abdominal wall and connects the LVAD pump to an extracorporeal system controller, which receives power from an outlet or batteries and controls the pump settings. Patients with LVADs typically wear a vest to carry their batteries.
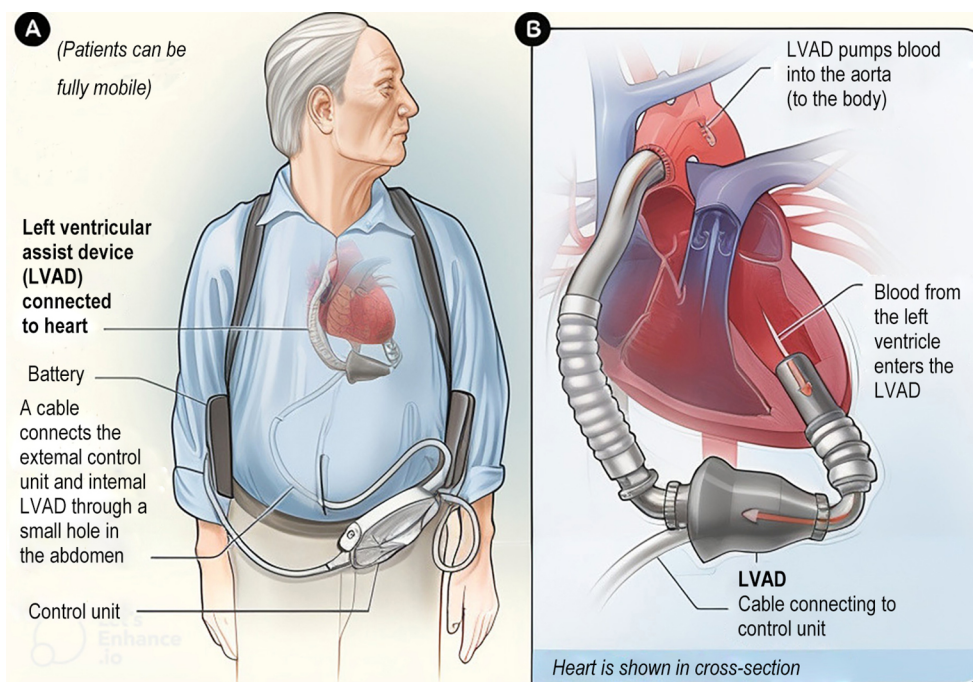
Figure 1. LVAD. (A) shows the location of the heart and the typical equipment needed for an implantable LVAD; (B) shows how the LVAD is connected to the heart. (By National Heart Lung and Blood Institute - Public Domain, https://commons.wikimedia.org/w/index.php?curid=29588216). LVAD: Left ventricular assist device.

Weight loss could benefit patients with end-stage heart failure and obesity by potentially improving cardiac function alone and, as previously hinted, by improving HT eligibility. Loss of weight is accompanied by a decline in levels of pro-inflammatory adipokines, such as serum amyloid A, and is implicated in left ventricular hypertrophy regression in addition to its mediated beneficial effects on coronary risk[4,5]. Standard first-line therapy for weight loss with lifestyle modifications is possible and has a low risk of harm in those with end-stage heart failure[11]. However, this can be particularly challenging given that patients with heart failure are often burdened by multiple comorbid conditions, co-occurrence of frailty, and reduced exercise tolerance[3,11-13].

Patients with end-stage heart failure are also already subject to significant dietary restrictions, particularly of sodium and fluid. The broad application of these restrictions, despite lack of evidence to support such practices, adds to the burden felt by patients with coexisting obesity and heart failure. Moreover, access to affordable and minimally processed foods in the United States can be limited for many patients. This can result in fewer low-sodium options and, ultimately, an increased risk for micro- and macronutrient deficiencies[3]. These risks may also increase with caloric restrictions imposed to facilitate weight loss. Additionally, patients with heart failure on LVAD often require warfarin and are advised to avoid foods rich in vitamin K (e.g., broccoli, spinach, lettuce), further limiting their dietary choices.

Another challenge seen with weight management in patients with obesity and end-stage heart failure is the complexity of accurate weight measurement in the presence of significant fluid retention. Most studies rely on BMI as a measure of adiposity, which itself has limitations in distinguishing between fat mass, lean mass, and fluid compartments. Physical exams and echocardiograms may help distinguish adiposity from muscle mass but are difficult to interpret still due to habitus[3].

Anti-obesity medications have many different mechanisms and vary in their effectiveness for weight loss in patients with obesity. Recently, glucagon-like peptide-1 (GLP-1) receptor agonists, which target the incretin axis, have proven safe and effective for the treatment of obesity[14]. The United States Food and Drug Administration has approved two GLP-1 receptor agonists for the indication of weight loss: semaglutide and liraglutide[15].

Semaglutide is effective in inducing weight loss in a wide variety of patients and is an attractive option for patients with cardiovascular conditions, as it was seen to reduce composite major adverse cardiac events in patients with type 2 diabetes and with or at high risk for cardiovascular conditions including chronic heart failure versus placebo[16]. Moreover, it has been reported that semaglutide has led to larger reductions in heart failure-related symptoms and physical limitations compared to placebo in patients with type 2 diabetes and heart failure with preserved ejection fraction (EF)[17]. Mechanisms of cardiac benefit by GLP-1 receptor agonists are mediated by weight loss, though they have also shown some direct positive effects such as reducing inflammation in the cardiovascular system[18].

However, studies exploring outcomes of GLP-1 receptor agonists in patients with obesity and heart failure thus far have primarily included those with preserved EF and may not be applicable to patients with end-stage heart failure[11]. In fact, earlier studies with liraglutide found that patients with severely reduced EF may not benefit from GLP-1 receptor agonists and may even be at greater cardiac risk[18]. The efficacy and cardiac effects of GLP-1 receptor agonists in patients with heart failure requiring LVAD support is an area that would certainly benefit from additional study.

As metabolic and bariatric surgery has grown as an effective and durable option for significant and rapid weight loss, its role in reducing the risk of heart failure has also been examined. Benotti *et al.* report long-term protective effects of Roux-en-Y gastric bypass (RYGB) surgery against congestive heart failure (HR 0.38, 95%CI: 0.22-0.64) in patients with severe obesity compared to tightly matched nonsurgical control patients[19]. This was further supported by a nationwide observational study in Sweden by Persson *et al.*, who reported a 63% lower risk of heart failure (HR 0.37, 95%CI: 0.30-0.46) in patients who underwent RYGB surgery compared to those who did not[20]. Adding to its potential for cardiovascular benefits, patients with heart failure and obesity who undergo bariatric surgery have also demonstrated improvement in left ventricular EF and strain regardless of whether baseline EF was preserved or reduced[21].

A few recent meta-analyses[22-24] examined the role of bariatric surgery in patients with coexisting obesity and end-stage heart failure managed with LVAD and found that over half of patients were successfully able to lose enough weight to become eligible for HT. Reports by Orandi *et al.* also estimated improvements in EF from 20.5% to 33.2% ($P < 0.0001$, $n = 22$) at an average follow-up of 2 years after bariatric surgery[24]. Additionally, there are case reports of myocardial recovery after bariatric surgery-driven weight loss such that patients had or were planning subsequent LVAD explantation[25-27]. Highlighted here are the advantages and effectiveness of bariatric surgery as a bridge to HT in those who were previously ineligible based on BMI.

DATA SUPPORTING BARIATRIC SURGERY FOR PATIENTS WITH LVADS

One systematic review and meta-analysis by daSilva-deAbreu *et al.* evaluated individual participant data for patients with obesity and end-stage heart failure on LVAD support[22]. They identified thirteen full articles and one abstract (nine case reports and five cohort studies) that collectively included 29 patients who underwent bariatric surgery. Of 23 patients whose listing status was reported, 18 (78.3%) were listed for or underwent HT after bariatric surgery. Out of 28 patients, 13 (46.4%) underwent HT, with a mean time of

14.4 ± 7.0 months between bariatric surgery and HT.

Another systematic review and meta-analysis by Sharma *et al*. identified eleven unique cohort studies, encompassing 271 patients who underwent bariatric surgery either during (*n* = 49, 18.1%) or after (*n* = 222, 81.9%) LVAD implantation[23]. The pooled preoperative BMI across all included studies was 44.2 kg/m^2 (95%CI: 42.5-45.9, I^2 = 65.2%, *n* = 223) and the BMI at the most recent follow-up prior to HT was 33.4 kg/m^2 (95%CI: 32.0-34.8, I^2 = 53.7%, *n* = 186). The pooled mean difference of BMI before bariatric surgery and at last follow-up among nine studies was 10 kg/m^2 (95%CI: 8.6-11.5, I^2 = 81.3%, *n* = 161). Accordingly, the pooled mean percent of total body weight loss among six studies was 24.6% (95%CI: 14.3-34.9, I^2 = 98.2%, *n* = 42) and the percent excess weight loss among three studies was 61.8% (95%CI: 38.1-85.5, I^2 = 82.6%, *n* = 16).

Eight studies showed that 44 of the 63 patients who had their listing status reported were listed for HT after bariatric surgery for a pooled estimate of 67.4% (95%CI: 0.477-0.871, I^2 = 73.5%)[23]. However, eight studies reported patients who were listed but had not received a transplant at the time of follow-up and the pooled proportion was 44.9% (95%CI: 0.315-0.584, I^2 = 0%, *n* = 65). There were no reasons provided by Sharma *et al*. for these patients who had not yet undergone transplantation at the time of follow-up, so we cannot know if any of these patients no longer required HT[23]. All included studies showed 67 out of the 271 included patients underwent HT at a pooled mean rate of 32.5% (95%CI: 0.201-0.448, I^2 = 58.0%). The mean time from bariatric surgery to HT in this meta-analysis among seven studies was 13.8 months (95%CI: 11.8-15.9, I^2 = 31.5%, *n* = 65)[23].

Lastly, Orandi *et al*. identified 19 studies and reported that 33 (40.2%) of 82 total patients lost sufficient weight to be listed for HT after bariatric surgery, and 29.3% (*n* = 24) achieved HT at an average of 13.9 ± 5.4 months after bariatric surgery[24]. A summary of findings from discussed meta-analyses and reviews evaluating outcomes after bariatric surgery in patients with LVAD support is shown in Table 1.

Of note, doubling the time spent on the transplant list is associated with a 10% increased risk of graft failure at 1 year[28]. Despite improved survival for patients on the HT waiting list in more recent decades, the risk of death increases as wait time increases, even in those with LVAD support[29]. In recognizing this established direct relationship between time spent on the transplant list and transplantation failure or success, the consistent duration of around 14 months from bariatric surgery to HT is an appealing finding that reduces the time patients spend on a transplant waitlist[22-24]. Ultimately, decisions for bariatric surgery in patients with obesity and end-stage heart failure with LVAD support are driven primarily by its promising weight loss outcomes.

BARIATRIC SURGERY MAY LEAD TO HEART TRANSPLANT DELISTING

Of particular interest are reports of functional cardiac improvement after bariatric surgery in patients with end-stage heart failure and obesity, specifically functional recovery to the point where transplantation was no longer required. There were three such cases described in the review by daSilva-deAbreu *et al*.[22]. Two patients had cardiac recovery after bariatric surgery and dramatic weight loss with subsequent LVAD explantation[25,26]. The third patient had an EF improvement from 30% to 55%, with plans for weaning off of circulatory support and eventual LVAD explantation[27]. These three patients had significant reductions in their BMI (≥ 8.4 kg/m^2), with BMIs at the time of recovery ranging from 31 to 39 kg/m^2, and two had LVAD support for at least a year prior to bariatric surgery[22]. Given such limited sample sizes, statistical analyses to identify accurate predictors of recovery were not feasible.

Table 1. Summary of systematic reviews and meta-analyses for bariatric surgery in patients with obesity and end-stage heart failure requiring LVAD support

	daSilva-deAbreu *et al.*[22]	Sharma *et al.*[23]	Orandi *et al.*[24]a
Year published	2021	2023	2020
#of references included	14	11	19
#of total patients included	29	271	82
Average age, in years	41.9 ± 12.2	35.7 - 56.0	42.9 ± 10.7
Average BMI, in kg/m^2	45.5 ± 6.6	44.2	48.8 ± 6.6
%female (*n*/N)	36.4% (8/22)	29.5% (79/271)	41.5% (34/82)
%sleeve gastrectomy (*n*)b	82.8% (24)	95.6% (259)	36.6% (30)
%Roux-n-Y gastric bypass (*n*)	17.2% (5)	4.4% (12)	50.0% (42)
OUTCOMES			
%listed for transplant after BS (*n*/N)	78.3% (18/23)	67.4%c (44/63)	40.2% (33/82)
%underwent HT after BS (*n*/N)	46.4% (13/28)	32.5%c (67/271)	29.3% (24/82)
Average time after BS to HT, in months	14.4 ± 7	13.8	13.9 ± 5.4
n delisted after BS due to improved cardiac function	3	NR	7

Values in the table were input as reported by authors. aReview and meta-analysis by Orandi *et al.*[24] explored bariatric surgery in patients with various types of end-stage organ disease. This table reports only data pertaining to heart failure; bIf *n* reported alone, assume sample is #of total patients included; cPercentages reported by Sharma *et al.*[23] that are pooled estimates. These do not represent the percent of *n*/N which is also reported. LVAD: Left ventricular assist device; BMI: body mass index; *n*: #outcome; N: #sample; BS: bariatric surgery; HT: heart transplant; NR: not reported.

Orandi *et al.*[24] discussed seven additional patients with end-stage heart failure and obesity who achieved cardiac recovery and no longer required HT after bariatric surgery[30-33]. Interestingly, they also reported similar benefits of bariatric surgery in patients with other types of end-stage organ diseases, where the recovery of organ function negated the need for organ transplantation in at least four (14.3%, *n* = 28) patients with lung disease and nine (27.3%, *n* = 41) with liver disease[24].

PATIENT SELECTION CRITERIA

While none of the previously mentioned systematic reviews proposed patient criteria for selection to undergo bariatric surgery while on LVAD support, they provide that patients included in analyzed studies were at least 18 years of age and had a BMI ≥ 35 kg/m². A greater proportion of those with non-ischemic cardiomyopathy versus ischemic cardiomyopathy were analyzed by daSilva-deAbreu *et al.*[22] (13/20), Sharma *et al.*[23] (32/39), and Orandi *et al.*[24] (61/80). However, no between-group analyses were performed based on the etiology of heart failure in any of the discussed reviews.

Ultimately, bariatric surgery should be considered only for patients with obesity and LVAD support who have no absolute contraindications for HT. These may include severe pulmonary hypertension, severe lung disease, multisystem disease with poor long-term survival, severe local or systemic infection not caused by LVAD, active smoking or substance abuse, and severe neurological deficit/significant psychiatric illness[34]. Careful patient selection and special consideration are recommended in those who are older than 70 years of age, have a history of cancer (multidisciplinary cardio-oncology team evaluation is recommended), or have certain viral infections (e.g., hepatitis B, hepatitis C, HIV) with detectable viral titers[9]. Patients should otherwise meet eligibility criteria for bariatric surgery and HT separately, though the cardiac transplant team should be on board regardless for potential rescue HT if a patient further decompensates soon after bariatric surgery.

Sharma *et al.* discussed possible ascertainment bias among reviewed studies that patients with fewer comorbid conditions and fewer relative contraindications for HT were more likely selected for bariatric surgery[23]. There are also risks of publication bias and reporting bias, particularly among case reports that do not report all major outcomes of interest[35]. This reinforces the need for thoughtful patient selection when considering bariatric surgery for patients with end-stage heart failure.

We do not specifically discuss the outcomes between patients who have had simultaneous bariatric surgery and LVAD implantation versus a staged approach. However, there is concern that patients who have both surgeries within the same admission are likely sicker, which confounds findings of increased short-term mortality in these patients[36]. We also do not discuss the potential role of bariatric surgery in patients with end-stage heart failure requiring LVAD support as destination therapy, though this area may benefit from additional exploration.

OPERATIVE APPROACH FOR BARIATRIC SURGERY

There are currently no studies comparing the safety and efficacy of various bariatric surgical approaches in patients with end-stage heart failure, and there is also a lack of consensus regarding the preferred approach. However, sleeve gastrectomy (SG) was the predominant approach performed and studied versus RYGB in the meta-analyses by daSilva-deAbreu *et al.*[22] (24 *vs.* 5) and Sharma *et al.*[23] (259 *vs.* 12). It is also worth noting that all RYGB operations were performed no later than 2015 in one meta-analysis[22].

There is a trend toward greater utilization of SG seen in the general population undergoing bariatric surgery, owing to its favorable safety and efficacy outcomes, shorter operative duration, and lower technical complexity[37]. Additionally, daSilva-deAbreu *et al.* present that SG is preferred given the single staple line and the lower risk of malabsorption, which theoretically would have a lower potential to interfere with immunosuppressant absorption needed after HT[22]. One case report supported this theory and discussed unchanged institutional practices and protocols, including immunosuppression management, in a patient who received HT after gaining eligibility after SG and subsequent significant weight loss[38].

COMPLICATIONS OF BARIATRIC SURGERY

Bariatric surgery carries considerable operative and anesthetic risk for patients with LVAD support. Sharma *et al.* demonstrated an overall 1-year mortality rate of 10.2%, which is significantly higher than that observed in the general bariatric surgery population at 0.11%-0.23%[23]. Yet, this risk is lower compared to mortality at 1 year in patients with LVAD support as destination therapy, which approaches 48%[23]. There were 43 reported postoperative complication incidents among 33 patients, which included 13 (30.2%) major adverse cardiac events, 9 (20.9%) gastrointestinal bleeds including staple-line bleeding, and 5 (11.6%) LVAD pump thromboses[23]. Authors also report postoperative intensive care unit admissions at 70.5% (95%CI: 0.408-1.001, I^2 = 85.1%, n = 20) and 30-day readmission rates of 23.6% (95%CI: 0.103-0.370, I^2 = 0%, n = 9)[23].

The meta-analysis by daSilva-deAbreu *et al.* reported 30-day morbidities, which included: 14.3% (n = 4) gastrointestinal bleeds, 7.1% (n = 2) infection, and 3.6% (n = 1) staple line leak requiring readmission and endoluminal drainage[22]. Of the infection cases, one patient had a urinary tract infection and the other had acute cholecystitis which progressed to sepsis. Notably, no deaths were reported at 1-year HT-free follow-up in this meta-analysis[22].

Orandi *et al.* reported a 30-day readmission rate of 17.2% (5/29)[24]. There were 16 complications within 30 days among 65 patients with heart failure who underwent bariatric surgery that was reported based on their Clavien-Dindo Classification, a system that grades the severity of surgical complications based on the

therapy required to treat them[24,39]. Accordingly, two complications required surgical, endoscopic, or radiological intervention (Clavien-Dindo III), while five were deemed life-threatening and required immediate care or intensive care unit management (Clavien-Dindo IV). Again, there were no reported deaths (Clavien-Dindo V) within 30 days reported by Orandi *et al.*[24,39].

SPECIAL PERIOPERATIVE AND PRACTICAL CONSIDERATIONS

Special considerations are necessary when considering bariatric surgery in end-stage heart failure patients with LVAD support. Most importantly, a multidisciplinary approach is essential in the preoperative planning and perioperative care of this patient population, with close postoperative follow-up. Ideally, bariatric surgery is performed at a center with experience in implanting and managing patients with LVADs. A cardiovascular surgeon and heart failure team should be involved in planning and preoperative optimization, and readily available for consultation[40]. The bariatric surgeon should also ideally have experience operating on patients with LVAD support.

While experienced noncardiac anesthesiologists may care for a patient stable on their LVADs without pharmacotherapy, this is limited to cases under monitored anesthesia care. A cardiac anesthesiologist is necessary in major cases, especially when hemodynamic changes may be expected. Adverse events have been seen with systolic BP > 140 mmHg and diastolic BP > 90 mmHg in patients with pulsatile-LVADs, such as the HeartMate III. The high peripheral vascular tone increases afterload and limits the pump output at any given speed. Moreover, constant high pressure on the aortic valve may worsen or cause aortic regurgitation and may precipitate in-pump thrombosis. With older LVAD models, rapid sequence intubation is recommended[40].

A dedicated ventricular assist device coordinator or clinician/nurse trained in the operation of these devices should monitor the LVAD throughout the time when the patient is in the operating room (OR)[40]. It has been reported that the presence of such personnel brings comfort and confidence to the nursing and medical team if they are involved throughout the care of the patient[41]. The LVAD power source should be switched to a unit connected to a wall power supply.

It is imperative to understand the components and location of the LVAD. The surgical team should review radiographs to understand this. In the experience of our authors, a C-arm is useful in this regard to map the course of the pre-peritoneal driveline cable prior to sterile preparation. This can also be done in the OR via ultrasound[42]. The marked course of the driveline cable will also help guide laparoscopic port placement. If within the operative field, the surgical team may consider covering the percutaneous site of the driveline with sterile occlusive adhesives. It is also important that care is taken while draping to protect the driveline from pressure or kinking, and that external components abutting the patient are padded for skin protection[42].

A laparoscopic approach is preferable to an open approach, given the course of drivelines in the pre-peritoneal space, which is standard in bariatric surgery. The LVAD is preload-dependent, and this should be highlighted in the preoperative briefing. All OR personnel should recognize that venous return and preload are reduced as the patient moves into reverse Trendelenburg and possibly during abdominal insufflation. Therefore, it is important to limit intra-abdominal pressure from excessive insufflation. A Veress needle may be used initially for insufflation, with reported success via a right subcostal approach[40]. Pneumoperitoneum should be introduced in a stepwise fashion to allow for calibrated volume therapy and, if possible, maintained at 10-12 mmHg[40].

Patients with LVADs start anticoagulation and antiplatelet therapy as soon as hemostasis is achieved after implantation. Currently, warfarin is the anticoagulation of choice in patients with LVADs. The targeted International Normalized Ratio (INR) is 2.0-3.0 for patients with the HeartMate III[43]. These patients will typically also take 81-100 mg of aspirin daily. Warfarin and aspirin may be continued perioperatively if the bleeding risk is deemed low, though warfarin may be held and bridged with heparin infusion or subcutaneous low molecular weight heparin (LMWH) injection when there is higher concern for bleeding risk. Thienopyridine antiplatelet agents, such as clopidogrel, should be stopped at least 5 days prior to surgery. Both may be resumed after surgical bleeding risk is acceptable, with bridging while target INR is reached, as necessary. However, it is important to note that warfarin dosing should be adjusted after bariatric surgery, as resuming preoperative dosing could lead to supratherapeutic INR and an increased risk of bleeding. Warfarin dosing is expected to decrease by 25% after both RYGB and SG to maintain a therapeutic INR, though eventually, it may trend toward a dosage increase and should continue to be monitored closely[44].

CONCLUSION

Bariatric surgery is an effective and safe approach for weight loss in patients with obesity and end-stage heart failure with LVAD support whose BMI precludes them from HT. Over half of these patients may be able to be listed for HT after bariatric surgery, and nearly a third may potentially go on to have HT. Moreover, bariatric surgery alone has been shown to improve cardiac function in heart failure patients and, in some cases, lead to HT delisting with subsequent LVAD explantation. Careful patient selection by a multidisciplinary team, with perioperative preparation and management, can offer patients with obesity and end-stage heart failure an opportunity for longer years of life.

DECLARATIONS

Authors' contributions
Provided interpretation and valuable input from their respective specialties and experiences: Parikh MS, Orandi BJ, Ren-Fielding CJ
Made substantial contributions to the conception and design of the review, collected and reviewed literature, interpreted data, drafted and critically revised the article: Em ST, Parikh MS, Orandi BJ, Ren-Fielding CJ.

Availability of data and materials
Not applicable.

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All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate
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