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Review Article

Bariatric surgery to achieve transplant in end-stage organ disease patients: A systematic review and meta-analysis

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ABSTRACT

Background: As obesity prevalence grows, more end-stage organ disease patients will be precluded from transplant. Numerous reports suggest bariatric surgery in end-stage organ disease may help patients achieve weight loss sufficient for transplant listing.
Methods: We performed a systematic review/meta-analysis of studies of bariatric surgery to achieve solid organ transplant listing.
Results: Among 82 heart failure patients, 40.2% lost sufficient weight for listing, 29.3% were transplanted, and 8.5% had sufficient improvement with weight loss they no longer required transplantation. Among 28 end-stage lung disease patients, 28.6% lost sufficient weight for listing, 7.1% were transplanted, and 14.3% had sufficient improvement following weight loss they no longer required transplant. Among 41 cirrhosis patients, 58.5% lost sufficient weight for listing, 41.5% were transplanted, and 21.9% had sufficient improvement following weight loss they no longer required transplant. Among 288 end-stage/chronic kidney disease patients, 50.3% lost sufficient weight for listing and 29.5% were transplanted.
Conclusions: Small sample size and publication bias are limitations; however, bariatric surgery may benefit select end-stage organ disease patients with obesity that precludes transplant candidacy.

Introduction

Approximately 38% of U.S. adults are obese.[1] By 2030, nearly 50% are projected to have at least class 1 obesity, defined as a body-mass index (BMI) of 30–35 and nearly 25% will have class 3 obesity (BMI≥40).[2] This growing obesity epidemic is also reflected in the transplant candidate and recipient population. For example, from 2016 to 2030, the number of annual listings for nonalcoholic steatohepatitis is expected to increase by 55%.[3] In 2017, 36% of all liver transplant recipients had at least class 1 obesity and 14% had class 3 obesity.[4] Based on a review of the Organ Procurement and Transplant Network Standard Analytic Files (file date March 2019), 34.7% of kidney transplant recipients were obese in 2018, compared to only 25.7% in 2000. In 2016, the number of obese pancreas transplant recipients increased 29% from the year prior.[5]

Importantly, the available epidemiological data on obesity in transplant candidates and recipients fail to account for patients who are too obese to be considered for transplant listing. Most transplant centers endorse using BMI cutoffs for transplant listing.[6–8] Indeed, current guidelines suggest various body-mass index (BMI) cutoffs depending on the organ to be transplanted, and recommend lifestyle interventions to promote weight loss to achieve a lower BMI prior to transplantation.[9–12] However, significant weight loss with lifestyle interventions may not be feasible, particularly in end-stage organ disease.

Bariatric surgery in the general population is associated with a 5-year BMI reduction of 12–17 kg/m^2, and significant remission rates of diabetes (92%), hypertension (75.2%), and dyslipidemia (75.8%).[13] Compared to lifestyle changes, bariatric surgery is more

Abbreviations: BMI, body mass index; ESRD, end-stage renal disease.
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likely to yield sustained weight loss (1% versus 18% body weight loss at 20 years), reversal of comorbidities, and 29% lower all-cause mortality.[14] While longer follow-up is necessary, increasing evidence suggests that endoscopic bariatric interventions provide significant short-term weight loss as well.[15,16]

Increasingly, reports are being published of bariatric surgery in patients with end-stage organ diseases, with the goal of achieving weight loss that allows for transplant listing.[17–20] In some cases, end-stage organ disease is reversed with significant weight loss following bariatric surgery, obviating the need for transplant.[17,20,21] We performed a systematic review and meta-analysis to characterize the clinical outcomes achieved by bariatric surgery in the context of bridging patients with end-stage organ disease to listing and subsequent transplant.

Methods

We followed the statement on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses[22] and registered our review (PROSPERO Identifier: CRD42020142899). This study was exempt from institutional review board review. All authors had access to the study data and reviewed and approved the final manuscript.

Data sources and searches

An English language-only search strategy for PubMed/MEDLINE was developed in conjunction with an academic librarian and searched from inception to June 28, 2019 (Supplement S1). We reviewed the reference lists of eligible studies and meta-analyses to screen for additional studies. After removal of duplicate reports, titles and abstracts of the search results were independently screened for relevance by two authors (BJO, JWP). Relevant studies were screened independently in full text for inclusion. Using a standardized form, 2 reviewers worked independently to screen titles, abstracts, and full-text articles to identify potentially eligible studies. The final list of studies to be included was agreed upon by independent reviewers.

Eligibility criteria

Included studies involved bariatric surgery performed on patients with end-stage heart, lung, liver, kidney, and/or pancreas disease with the goal of reversing end-stage organ disease and/or achieving sufficient weight loss to be eligible for solid organ transplant to cure their end-stage organ disease. We made the decision *a priori* to include case reports and case series as we anticipated that they would form the bulk—if not the totality—of the existing literature. We excluded studies reporting outcomes of transplanted patients with remote histories of bariatric surgery prior to onset of end-stage organ disease, as well as studies in which transplant was performed to rescue patients with complications from bariatric surgery. We excluded primary case series if secondary studies were more inclusive of patients and reported on relevant outcomes, except to supplement missing clinical data as needed. Finally, we excluded studies of endoscopic weight loss modalities (e.g., intragastric balloon placement, endoscopic gastric suturing) because of the paucity of relevant studies and insufficient sample sizes for inclusion in subgroup analyses.

Data extraction

Abstracted data included study and patient characteristics, number of participants, organ involved, etiology of end-stage organ disease, type of bariatric surgery, change in weight and/or BMI, follow-up time, achievement of listing for transplant, achievement of transplant, resolution of obesity-related comorbidities, resolution of end-stage organ disease, operative complications, hospital length of stay, and hospital readmission. The distinction between case series and cohort studies in the context of a systematic review was based on the ability of the latter to provide a measure of association for the exposure of interest, rather than just an effect measure.[23] The primary outcome was achievement of listing for transplant. Secondary outcomes included achievement of transplant, weight loss, and resolution of comorbidities. Determination of listing for transplant was based on authors explicitly stating that the patients were listed or underwent transplant. Studies with heterogeneous patient populations in which the characteristics and/or results of bariatric surgery in patients with end-stage organ disease were indistinguishable from patients without end-stage organ disease were included in the qualitative synthesis only.

Quality grading of studies

To grade study quality, we assessed studies on compliance with the American Society of Metabolic and Bariatric Surgery and the Surgery for Obesity and Related Diseases bariatric surgery outcome reporting standards.[24] These guidelines specifically address best practices for reporting follow-up, resolution of comorbidities, complications, and weight loss. Duration of follow-up was considered adequate to achieve short-, medium- and long-term follow-up for any duration of post-bariatric surgery follow-up less than 3 years, 3–5 years, and greater than 5 years. Adequate comorbidity outcomes reporting required sufficient information to categorize outcomes using predetermined criteria as set forth in the guidelines for diabetes mellitus (complete remission, partial remission, improvement, unchanged, recurrence), hypertension (improvement, partial remission, complete remission), dyslipidemia (improvement, remission), obstructive sleep apnea (complete remission, objective improvement, subjective improvement), and gastroesophageal reflux disease (complete objective resolution, complete subjective resolution, objective improvement, self-reported improvement) (see Supplement S2).[24] Reporting of complications was divided into reporting of early (<30 days) and late (>30 days) complications. Complications were reported according to the Clavien-Dindo Classification system, which grades the severity of surgical complications based on the therapy required to treat them.[25] Failure to comment on the absence of complications was not considered sufficient reporting to assume that no complications had occurred. Reporting of weight loss was graded according to four criteria, all of which are recommended for complete reporting: mean initial BMI of the cohort (initial BMI in individual case reports), change in BMI, percent of total weight loss, and percent excess BMI loss.

Data synthesis and analysis

Abstracted data were summarized using descriptive statistics. Pooled means and standard deviations were provided for continuous variables, and frequencies and percentages reported for dichotomous variables. Cuzick's nonparametric test for trend was used to examine secular trends. Given the non-comparative nature of almost all of the studies in the literature, it was not feasible to report relative measures of association and therefore only proportions are reported. Analyses were performed using Stata version 13.1 (StataCorp) and Excel version 16 (Microsoft). A two-tailed P-value <0.05 was statistically significant.

Results

Systematic study review

Excluding duplicate reports, our search strategy identified 790 records. After reviewing titles and abstracts, a total of 173 full-text articles were reviewed, which identified a total of 48 individual studies for inclusion in the systematic review (20 for heart, 3 for lung, 4 for liver, 21 for kidney, and 2 for pancreas) (Fig. 1) published between 2002 and 2019. Almost all were retrospective and observational. Not surprisingly, there were no studies of patients undergoing bariatric surgery to achieve intestinal transplant.

There were 13 case reports, 30 case series (totaling 293 patients; median 6.6 patients per study [interquartile range 3–11]; minimum 2, maximum 41), and 4 cohort studies. One matched cohort study compared 12 morbidly obese heart failure patients who underwent bariatric surgery to 10 matched controls who did not.[26] Kim and colleagues studied the learning curve of laparoscopic sleeve gastrectomies in end-stage renal disease (ESRD) patients by comparing the outcomes of the first 25 to subsequent patients.[27] Another cohort study compared outcomes of 14 ESRD patients who had Roux-en-Y gastric bypass prior to kidney transplant to 19 morbidly obese kidney transplant recipients who did not have bariatric surgery.[28] Finally, Modanlou et al. used the U.S. Renal Data System to compare the outcomes of ESRD patients who had bariatric surgery before listing ($n = 72$) to those who had it after listing ($n = 29$) and to those who had bariatric surgery after transplant.[29] One study was a prospective, single-center, non-randomized trial of 8 ESRD patients who underwent sleeve gastrectomy prior to transplant listing.[30]

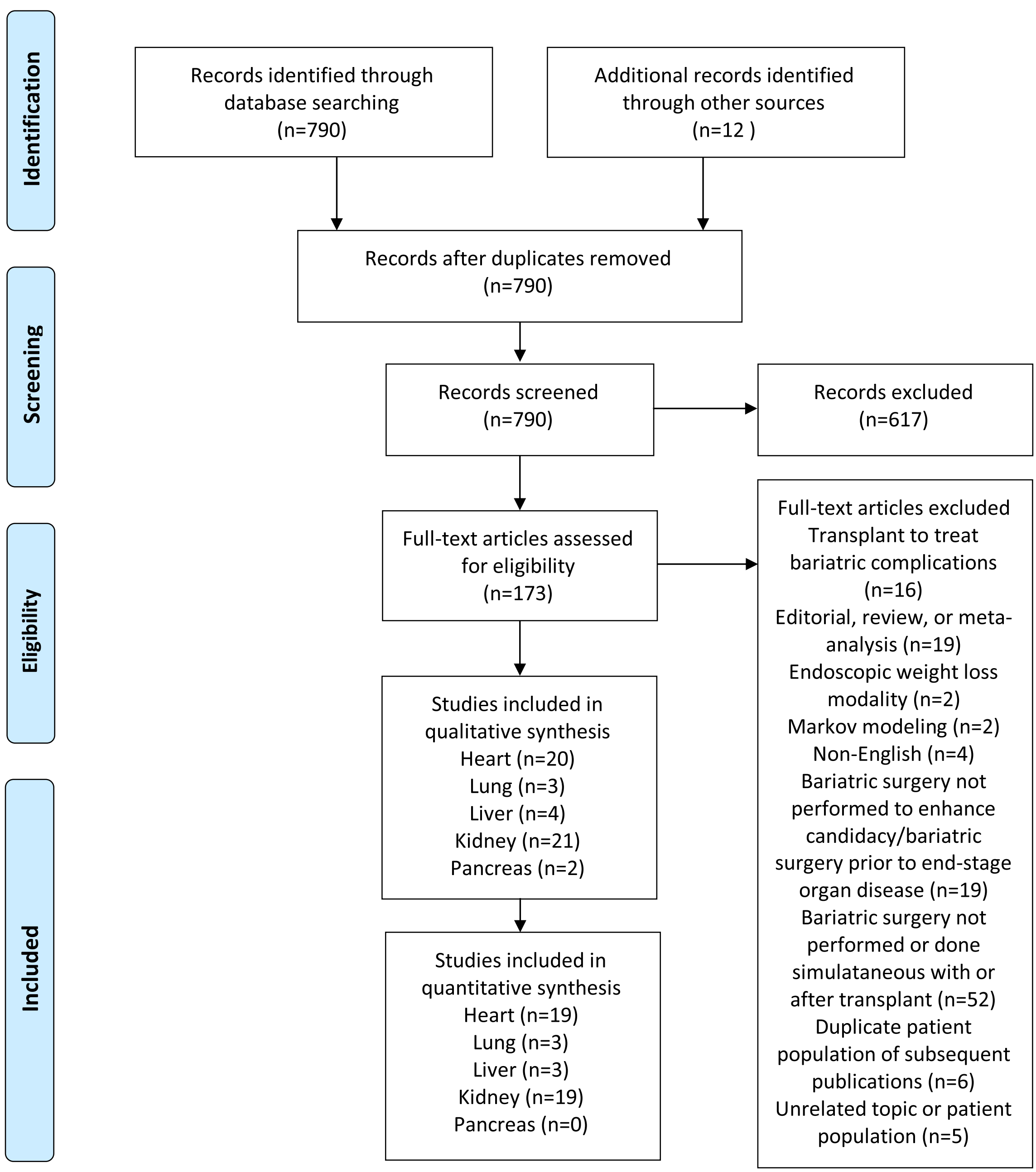

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) study selection flow diagram.

Table 1
Study design and quality of standardized metric reporting of studies included in the systematic review and meta-analysis, by organ.

Organ	Author	Year	Study Design	Post-Bariatric Surgery Follow-up			Resolution of Comorbidities					Complications Reporting		Weight Loss Reporting				
				Short-term (<3 years)	Medium-term (3–5 years)	Long-term (>5 years)	DM	HTN	DL	OSA	GERD	Early	Late	Mean Initial BMI	Change in BMI	Percent of Total Weight Loss	Percent Excess BMI loss	Percent Excess Weight Loss
Heart	Amro[38]	2015	CR	Y	N	N	N	N	N	N	N	N	N	Y	Y	Y	N	Y
	Caceres[39]	2013	CR	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
	Chaudhry[40]	2015	CS	Y	Y	Y	N	N	N	N	N	Y	N	Y	Y	N	N	Y
	DeNino[41]	2013	CR	Y	N	N	N	N	N	N	N	Y	N	Y	Y	N	N	N
	Gill[42]	2012	CS	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
	Greene[43]	2017	CS	Y	Y	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	Y
	Hawkins[18]	2018	CS	Y	Y	N	N	N	N	N	N	Y	N	Y	Y	N	N	Y
	Jeng[44]	2016	CR	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N	N
	Lim[45]	2016	CS	Y	Y	N	N	N	N	N	N	Y	N	Y[a]	Y	N	Y	N
	Lockard[46]	2013	CS	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
	McCloskey[47]	2007	CS	Y	Y	Y	N	N	N	N	N	Y	N	Y	Y	N	N	Y
	Moulla[48]	2018	CS	Y	N	N	N	N	N	N	N	Y	N	N	N	N	N	N
	Punchai[49]	2019	CS	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	Y	N	Y
	Ramani[26]	2008	CoS	Y	N	N	Y	Y	N	Y	N	Y	N	Y	Y	N	N	N
	Ristow[21]	2008	CS	Y	N	N	N	N	N	Y	N	N	N	Y	Y	N	N	N
	Saeed[50]	2012	CR	Y	N	N	N	N	N	N	N	N	N	Y	Y	N	N	N
	Samaras[51]	2012	CS	Y	N	N	Y	N	Y	N	N	Y	N	Y	Y	N	N	N
	Shah[52]	2015	CS	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N
	Taylor[53]	2002	CR	Y	N	N	Y	N	N	N	N	Y	Y	Y	N	N	N	N
	Wikiel[54]	2014	CS	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	Y
Lung	Ardila-Gatas[17]	2019	CS	Y	Y	Y	N	N	N	N	N	Y	N	Y[a]	Y[a]	Y	N	Y
	Martin[31]	2007	CR	Y	N	N	N	N	N	N	N	Y	N	Y	N	N	N	N
	Takata[32]	2008	CS	Y	N	N	Y	Y	N	Y	N	Y	N	Y	N	N	N	Y
Liver	Garcia-Sesma[55]	2019	CS	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	N	Y
	Moulla[48]	2018	CS	Y	N	N	N	N	N	N	N	Y	N	N	N	N	N	N
	Sharpton[20]	2019	CS	Y	N	N	Y	Y	N	N	N	Y	Y	Y[a]	Y[a]	N	N	Y
	Taneja[33]	2013	CR	Y	N	N	N	N	N	N	N	Y	N	Y	N	N	N	N
Kidney	Adani[56]	2015	CS/Letter to Editor	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	Al Sabah[57]	2017	CR	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	N	N	N
	Al-Bahri[58]	2017	CS	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	N	Y
	Alexander[59]	2007	CS	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	N	N	N	N
	Buch[60]	2006	CR	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	Carandina[61]	2017	CS	Y	N	N	Y	Y	N	Y	N	Y	Y	Y	Y	N	N	Y
	Contreras-Villamizar[62]	2019	CR	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N
	Hidalgo[63]	2012	CS	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N
	Jamal[64]	2015	CS	Y	Y	N	Y	N	N	N	N	Y	Y	Y	Y	N	N	Y
	Kienzl-Wagner[30]	2017	Single-arm trial	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	N	Y	N
	Kim[19]	2017	CoS	Y	Y	N	Y	Y	N	N	N	Y	N	Y	Y	N	N	N
	Koshy[65]	2008	CS	Y	Y	N	N	N	N	N	N	N	N	Y	Y	Y	N	Y
	Lin[66]	2013	CS	Y	N	N	Y	N	N	N	N	Y	Y	Y	Y	N	N	Y
	MacLaughlin[67]	2012	CS	Y	Y	N	Y	Y	Y	N	N	Y	Y	Y[a]	Y[a]	N	N	Y
	Marszalek[68]	2012	CR	Y	N	N	N	N	N	N	N	Y	Y	Y	Y	N	N	N
	Modanlou[29]	2009	CoS	Y	Y	N	N	N	N	N	N	N	N	Y	Y	N	N	Y
	Newcombe[69]	2005	CS	Y	N	N	Y	N	N	N	N	N	N	Y	Y	N	N	N
	Proczko[70]	2013	CS	Y	N	N	Y	Y	N	N	N	N	N	Y	Y	N	N	N

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Table 1 (*continued*)

Organ	Author	Year	Study Design	Post-Bariatric Surgery Follow-up			Resolution of Comorbidities					Complications Reporting		Weight Loss Reporting				
				Short-term (<3 years)	Medium-term (3–5 years)	Long-term (>5 years)	DM	HTN	DL	OSA	GERD	Early	Late	Mean Initial BMI	Change in BMI	Percent of Total Weight Loss	Percent Excess BMI loss	Percent Excess Weight Loss
	Takata[32]	2008	CS	Y	N	N	Y	Y	N	Y	N	Y	N	Y	N	N	N	Y
	Thomas[28]	2018	CoS	Y	Y	Y	Y	Y	N	N	N	Y	N	Y	Y	N	N	Y
	Yemeni[34]	2019	CS	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N	Y
Pancreas	Bonatti[71]	2018	CR	Y	Y	N	N	N	N	N	N	N	N	Y	N	N	N	N
	Gullo-Neto[72]	2014	CS	Y	N	N	Y	N	Y	N	N	Y	Y	Y	Y	N	N	N

N indicates statements provided about change in comorbidities after bariatric surgery that were too vague to categorize the degree of change.
Studies in bold indicate those that were only involved in the qualitative component of the systematic review.
CR – case report; CS – case series; CoS – cohort study; DM – diabetes mellitus; HTN – hypertension; DL – dyslipidemia; OSA – obstructive sleep apnea; GERD – gastroesophageal reflux disease.
[a] Reported median BMI rather than mean BMI.

Quality grading of studies

No study reported on all 15 recommended domains, with the median number of domains reported being 6 (interquartile range 4–7.5) (Table 1, Supplement 3a, 3b). Reporting was more robust after publication of reporting guidelines in 2015.[24] There were 25 studies published prior to the release of the reporting guidelines and 23 subsequent to that. The average number of domains reported in the guideline pre-publication era was 5.0 ± 2.0, compared to 6.8 ± 2.6 after publication ($P = 0.01$).

No study provided complete recommended reporting of weight loss. Four studies (8.3%) provided 0 of 5 of the recommended weight loss domains, 4 (8.3%) provided 1 of 5, 19 (39.6%) provided 2 of 5, 14 (29.2%) provided 3 of 5, and 7 (14.6%) provided 4 of 5 domains. Reporting of weight loss improved after publication of reporting guidelines (2.7 ± 1.2 versus 2.0 ± 0.9 domains reported; $P = 0.03$).

Overall, all studies were considered to be at high risk of bias given their study design, generally small sample sizes, retrospective nature, limited outcome reporting, and potential for publication bias (Table 1).

Meta-analysis

Trends in publications of bariatric surgery in end-stage organ disease patients

There was a single case report of an end-stage organ disease patient undergoing biliopancreatic diversion in 2002. The number of patients in published reports peaked in 2017 ($n = 137$; $P = 0.009$) (Fig. 2). Performance of Roux-en-Y gastric bypass has generally decreased over time ($P = 0.014$) and sleeve gastrectomy has increased ($P = 0.002$).

Baseline characteristics of pooled populations

Heart

Of 82 patients across 19 studies, mean age was 42.9 ± 10.7 years, and 41.5% were female (Table 2). The majority (74.4%) had non-ischemic cardiomyopathy as the etiology of their heart failure, 37.8% had a left ventricular assist device in place at the time of bariatric surgery, and 9.7% had a left ventricular assist device placed simultaneous with their bariatric surgery. Fifty percent of patients underwent Roux-en-Y gastric bypass, 36.6% underwent sleeve gastrectomy, 12.2% had an adjustable gastric band, and 1.2% had a biliopancreatic diversion.

Lung

Of 28 patients across 3 studies, mean age was 54.7 ± 5.8 years and 78.6% were female (Table 2). The majority had idiopathic pulmonary fibrosis (92.8%) as the etiology of their lung disease and 64.2%, 32.1%, and 3.6% underwent Roux-en-Y gastric bypass, sleeve gastrectomy, and adjustable gastric band placement.

Liver

Of 41 patients across 3 studies, mean age was 50.9 ± 11.2 years, and 70.7% were female (Table 2). The etiology of liver disease was hepatitis C, nonalcoholic steatohepatitis, alcoholic liver disease, hepatitis B, and other in 41.5%, 39.0%, 9.7%, 4.9%, and 4.9% of cases. At bariatric surgery, 51.2% had Child's Class A liver disease and 48.8% had Child's Class B liver disease. There were no Child's Class C patients. All patients underwent sleeve gastrectomy.

Kidney

Of 288 patients across 19 studies, the mean age was 49.7 ± 7.4 years, and 54.6% were female (Table 2). Amongst studies that

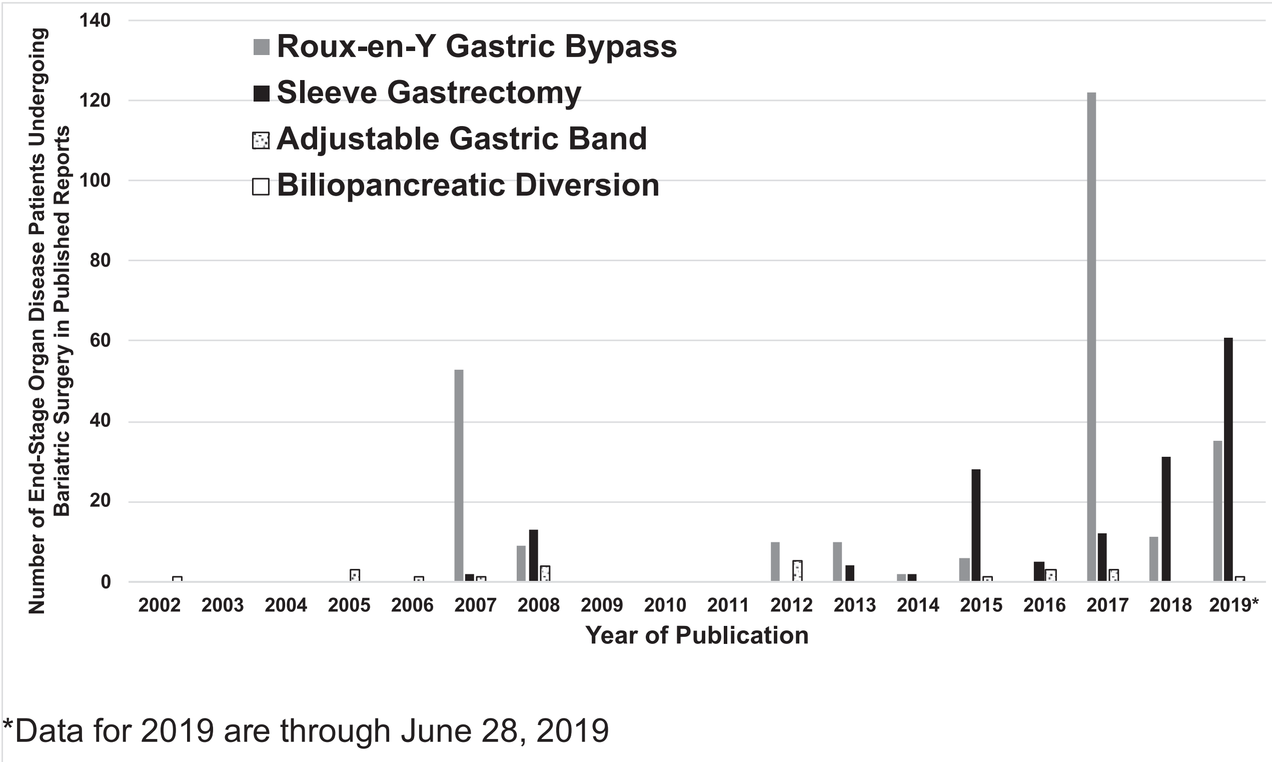

Fig. 2. Number of end-stage organ disease patients undergoing bariatric surgery in published reports by bariatric surgery type and year.

provided the information (n = 126 patients), kidney disease etiology was diabetic nephropathy, hypertensive nephropathy, focal segmental glomerulosclerosis, glomerulonephritis, and other/unknown in 46.8%, 19.0%, 6.3%, 0.8%, and 27.0% of patients, and 83.7% had end-stage renal disease (ESRD) and 16.3% had chronic kidney disease, though the degree of chronic kidney disease was not reported. Roux-en-Y gastric bypass was performed in 69.0%, sleeve gastrectomy in 27.1%, and adjustable gastric band in 3.8%.

Effect of bariatric surgery

Heart

There was a significant reduction in mean BMI from bariatric surgery to last follow-up (48.4 ± 6.6 versus 37.1 ± 5.8; P < 0.001) (Table 3). There was an overall decrease in the severity of heart disease by New York Heart Association Functional Classification as well (Fig. 3). Of the 22 patients who had left ventricular ejection fraction reported at the time of bariatric surgery and at last follow-up (excluding patients who got transplanted), the average ejection fraction improved from 20.5% ± 4.8 to 33.2% ± 14.4 (P < 0.001) over an average of 23.9 ± 20.6 months of follow-up. Of the 82 total patients, 40.2% (n = 33) lost sufficient weight to be listed, 29.3% (n = 24) achieved heart transplantation at an average of 13.9 ± 5.4 months post-bariatric surgery, and 8.5% (n = 7) had sufficient clinical improvement following bariatric surgery that they no longer needed heart transplantation. In other words, 46.3% (n = 38) of end-stage heart failure patients were listed or improved clinically to the point that they no longer required transplant.

Lung

A summary statistic of weight or BMI loss could not be calculated for end-stage lung disease patients (Table 3). One study of 25 patients reported a change in median BMI from bariatric surgery of 39 kg/m^2 (interquartile range 37–44) to 30 kg/m^2 (interquartile range 25–36) at last follow-up.[17] A case report stated a patient had a BMI of 37 kg/m^2 at bariatric surgery to <30 kg/m^2 at last follow-up.[31] The third study of end-stage lung disease patients reported a BMI of 41 kg/m^2 and 50 kg/m^2 in two patients and they lost 50 and 73% of excess body weight at 12 and 13 months follow-up, respectively.[32] Of the 28 total patients, 28.6% (n = 8) were waitlisted, 7.1% (n = 2) were transplanted, and 14.3% (n = 4) had clinical improvement that precluded the need for listing. In other words, 42.8% (n = 12) lost sufficient weight that they were listed or improved to the point that they no longer required transplant. Only one study reported change in pulmonary function tests from the time of bariatric surgery to last follow-up.[17]

Liver

By 6 months post-bariatric surgery, 66.7% (20 of 30) of cirrhotic patients had achieved BMI <40 kg/m^2 (Table 3), a common BMI cutoff for liver transplant programs. By 12 months, 65.8% (27/41) had achieved BMI <40 kg/m^2. Of the 41 patients, 58.5% achieved listing and 41.5% (17/41) were transplanted at a mean of 9.0 ± 2.6 months post-bariatric surgery. Nine patients (21.9%) had sufficient clinical improvement following bariatric surgery that they no longer needed liver transplantation. In other words, 75.6% (31/41) of patients with cirrhosis were listed or improved clinically to the point that they no longer required transplant.

Kidney

Over an average of 32.9 ± 21.4 months of follow-up, mean BMI decreased from 43.9 ± 5.3 kg/m^2 to 33.7 ± 5.4 kg/m^2 (P = 0.003) (Table 3). Of the 288 patients, 145 were listed (50.3%), and 29.5% (85 of 288) were transplanted at a mean of 19.9 + 14.3 months post-bariatric surgery. No study described an occurrence of a patient stopping dialysis after weight loss, nor did any study describe an

Table 2
Study and patient characteristics of end-stage organ disease patients undergoing bariatric surgery.

Study	Number of patients	Age (Mean and standard deviation, except as indicated)	Male (n)/Female (n)	Etiology of End-Stage Organ Disease					Roux-en-Y Gastric Bypass (n)	Sleeve Gastrectomy (n)	Adjustable Gastric Band (n)	Bilio-pancreatic Diversion (n)	End-Stage Organ Disease-Specific Factors		
Heart Failure															
				NICM (n)	ICM (n)	Not Reported (n)							VAD Status Relative to Bariatric Surgery		
													Pre-Bariatric Surgery (n)	Simultaneous (n)	No VAD (n)
Amro	1	34	1/0	1	0	0	–	–	1	0	0	0	1	0	0
Caceres	1	56	0/1	1	0	0	–	–	1	0	0	0	1	0	0
Chaudhry	6	median 34 (range 31–66)[a]	3/3	4	2	0	–	–	0	6	0	0	3	0	3
DeNino	1	24	0/1	1	0	0	–	–	1	0	0	0	1	0	0
Gill	2	24, 36	2/0	2	0	0	–	–	0	0	2	0	0	2	0
Greene	3	48.7 (SD 6.1)	3/0	1	2	0	–	–	3	0	0	0	3	0	0
Hawkins	11	43.3 (SD not reported; range 31–66)[a]	6/5	11	0	0	–	–	11	0	0	0	11	0	0
Jeng	1	25	1/0	1	0	0	–	–	0	1	0	0	1	0	0
Lim	7	44.1 (SD 8.6)	4/3	6	1	0	–	–	0	4	3	0	0	0	7
Lockard	2	37, unclear	2/0	0	0	2	–	–	2	0	0	0	1	1	0
McCloskey	14	46.2 (SD 9.2)	10/4	10	4	0	–	–	11	2	1	0	0	0	14
Punchai	7	43.6 (SD 15.0)	3/4	3	4	0	–	–	0	7	0	0	7	0	0
Ramani	12	41 (SD 10)	3/9	10	2	0	–	–	9	2	1	0	0	0	12
Ristow	2	35, 36	1/1	2	0	0	–	–	0	2	0	0	0	0	2
Saeed	1	50	1/0	1	0	0	–	–	0	0	1	0	0	1	0
Samaras	2	42, 40	1/1	2	0	0	–	–	0	0	2	0	0	0	2
Shah	4	46.5 (SD 13.9)	4/0	1	3	0	–	–	0	4	0	0	0	4	0
Taylor	1	57	0/1	0	1	0	–	–	0	0	0	1	0	0	1
Wikiel	4	42.0 (SD 11.1)	3/1	4	0	0	–	–	2	2	0	0	2	0	2
TOTAL	**82**	**42.9 (SD 10.7)**	**48 (58.5%)/34 (41.5%)**	**61 (74.4%)**	**19 (23.2%)**	**2 (2.4%)**	**–**	**–**	**41 (50.0%)**	**30 (36.6%)**	**10 (12.2%)**	**1 (1.2%)**	**31 (37.8%)**	**8 (9.7%)**	**43 (52.4%)**
End-Stage Lung Disease															
				ILD (n)	IPF (n)	COPD (n)									
Ardila-Gatas	25	median 53 (IQR 42–58)[a]	4/21	25	0	0	–	–	17	7	1	0	–	–	–
Martin	1	48	0/1	1	0	0	–	–	1	0	0	0	–	–	–
Takata	2	57, 59	2/0	0	1	1	–	–	0	2	0	0	–	–	–
TOTAL	**28**	**54.7 (SD 5.8)**	**6 (21.4%)/22 (78.6%)**	**26 (92.8%)**	**1 (3.6%)**	**1 (3.6%)**	**–**	**–**	**18 (64.3%)**	**9 (32.1%)**	**1 (3.6%)**	**0 (0%)**	**–**	**–**	**–**
Cirrhosis															
				HCV (n)	NASH (n)	Alcohol (n)	HBV (n)	Other (n)					Child's Score		
													Class A (n)	Class B (n)	Class C (n)
Garcia-Sesma	8	53.6 (8.1)	2/6	2	5	1	0	0	0	8	0	0	6	2	0
Sharpton	32	median 55 (IQR 50–61)[a]	9/23	15	10	3	2	2	0	32	0	0	15	17	0
Taneja	1	29	1/0	0	1	0	0	0	0	1	0	0	0	1	0

TOTAL	**41**	**50.9 (SD 11.2)**	**12 (29.3%)/29 (70.7%)**	**17 (41.5%)**	**16 (39.0%)**	**4 (9.7%)**	**2 (4.9%)**	**2 (4.9%)**	**0 (0%)**	**41 (100%)**	**0 (0%)**	**0 (0%)**	**21 (51.2%)**	**20 (48.8%)**	**0 (0%)**
Chronic Kidney Disease/End-Stage Renal Disease															
				Diabetes (n)	HTN (n)	FSGS (n)	GN (n)	Other/ Unknown (n)					Disease Severity CKD	ESRD	
Adani	3	NR	NR	NR	NR	NR	NR	NR	3	0	0	0	NR	NR	–
Al Sabah	1	52	1/0	1	0	0	0	0	1	0	0	0	0	1	–
Al Bahri	16	55.1 (SD 6.5)	10/6	2[c]	–	1	–	1	1	12	3	0	0	16	–
Alexander	41	44.4 (SD not reported)[a]	NR	NR	NR	NR	NR	NR	41	0	0	0	32[b]	0	–
Buch	1	59	0/1	1	0	0	0	0	0	0	1	0	0	1	–
Carandina	9	53.2 (SD 5.5)	1/8	5	3	1	0	0	9	0	0	0	0	9	–
Contreras-Villamizar	1	44	1/0	0	0	1	0	0	1	0	0	0	0	1	–
Jamal	21	50.6 (SD 10.3)	12/9	11	8	0	0	2	2	18	1	0	0	21	–
Kienzl-W	8	48 (SD 13)	3/5	3	0	0	1	4	8	0	0	0	0	8	–
Kim	100	median 50 (IQR 43.8–58.3)[a]	41/59	NR	NR	NR	NR	NR	100	0	0	0	0	100	–
Koshy	3	40.7 (11.9)	2/1	2	0	1	0	0	0	0	3	0	1	2	–
Lin	6	NR	NR	NR	NR	NR	NR	NR	6	0	0	0	6	0	–
MacLaughlin	9	46.1 (SD 7.0)	3/6	1	3	2	0	3	9	0	0	0	4	5	–
Marszalek	1	55	0/1	0	0	0	0	1	1	0	0	0	0	1	–
Newcombe	3	43.7 (19.1)	3/0	0	0	0	0	3	0	0	3	0	1	2	–
Proczko	3	55.0 (SD 6.0)	1/2	2	1	0	0	0	0	3	0	0	0	3	–
Takata	7	45.9 (SD 6.8)	0/7	0	0	0	0	7	0	7	0	0	0	7	–
Thomas	31	45 (SD 2.2)	14/17	16	9	0	0	6	0	31	0	0	1	30	–
Yemeni	24	54 (SD 3.1)	16/8	15	0	2	0	7	17	7	0	0	0	24	–
TOTAL	**288**	**49.7 (SD 7.4)**	**108 (45.4%)/130 (54.6%)**	**59 (46.8%)**	**24 (19.0%)**	**8 (6.3%)**	**1 (0.8%)**	**34 (27.0%)**	**199 (69.1%)**	**78 (27.1%)**	**11 (3.8%)**	**0 (0%)**	**45 (16.3%)**	**231 (83.7%)**	**–**

SD – standard deviation; NICM – non-ischemic cardiomyopathy; ICM – ischemic cardiomyopathy; VAD – ventricular assist device; IQR – interquartile range; ILD – interstitial lung disease; IPF – idiopathic pulmonary fibrosis; COPD – chronic obstructive pulmonary disease; NASH – non-alcoholic steatohepatitis; HCV – hepatitis C virus; HBV – hepatitis B virus; CKD – chronic kidney disease; ESRD – end-stage renal disease; HTN – hypertension; FSGS – focal segmental glomerulosclerosis; NR – not reported.

[a] Not included in calculation for group mean and standard deviation.

[b] Study reports 32 patients with CKD, but does not provide information on the remaining 9.

[c] One of the patients was classified as having both diabetic nephropathy and hypertensive kidney disease.

Table 3
End-stage organ disease patients: weight loss, ability to get listed, and ability to get transplanted after bariatric surgery.

Study	Number of Patients	BMI (kg/m2) at Bariatric Surgery (Mean and standard deviation, except as indicated)	BMI at Last Follow-up (kg/m^2) (Mean and standard deviation, except as indicated)	Waitlisted (%)	Transplanted (%)	Clinical Improvement Precluding Need for Listing	Months from Bariatric Surgery to Transplant (Mean and standard deviation, except as indicated)	Months of Follow-up After Bariatric Surgery (Mean and standard deviation, except as indicated)
Heart Failure								
Amro	1	50	44	NR	NR	NR	NR	6
Caceres	1	37.4	29	1 (100%)	1 (100%)	NR	10	22
Chaudhry	6	47.6 (SD 3.0)[a]	NR[a]	4 (66.7%)	0 (0%)	1 of 6	NR	median 22 (range 12–70)[a]
DeNino	1	50	30.4	1 (100%)	1 (100%)	NR	13	16
Gill	2	46.6, 43.7	34.7, 38.5	0 (0%)	0 (0%)	NR	NR	5, 14
Greene	3	52.3 (SD 2.5)	29.7 (SD 3.2)	2 (66.7%)	2 (66.7%)	0 of 3	17, 24	43.7 (SD 12.0)
Hawkins	11	mean 45.2 (range 39–58)[a]	mean 33.1 (range 26–39)[a]	7 (63.6%)	4 (36.4%)	NR	median 12 (range 5–44)[a]	median 12 (range 6–39)[a]
Jeng	1	40	32	1 (100%)	1 (100%)	NR	7	71
Lim	7	43.3 (SD 5.0)	32.4 (SD 4.2)	4 (57.1%)	2 (28.6%)	3 of 7	NR	21.7 (SD 16.5)
Lockard	2	48.8, 52.2	38.6, 40.8	1 (50.0%)	1 (50.0%)	NR	18	NR, 24
McCloskey	14	50.8 (SD 7.6)	37.1 (SD 7.2)	2 (14.3%)	2 (14.3%)	NR	6, 8	6.7 (SD 2.2)
Punchai	7	44.3 (SD 6.4)	35.0 (SD 7.9)	3 (42.8%)	3 (42.8%)	NR	17.7 (SD 5.7)	20.6 (SD 24.2)
Ramani	12	53 (SD 7.0)	47 (SD 4.0)	2 (16.7%)	1 (8.3%)	NR	NR	NR
Ristow	2	43, 56	23, 37	2 (100%)	0 (0%)	2 of 2	NR	24, 24
Saeed	1	41.6	41	1 (100%)	1 (100%)	0 of 1	13	21
Samaras	2	42, 40	31.2, 34.7	1 (50.0%)	1 (50.0%)	1 of 2	13	12, 13
Shah	4	49.2(SD 5.9)	5.5 (4.6)	2 (50.0%)	1 (25.0%)	NR	9	7.0 (SD 2.3)
Taylor	1	48.6	28.5	1 (100%)	1 (100%)	NR	19	25
Wikiel	4	47.7 (SD 4.4)	35.3 (SD 4.1)	3 (75.0%)	3 (75.0%)	NR	13.3 (SD 4.7)	48.5 (SD 42.1)
TOTAL	**82**	**48.4 (SD 6.6)**	**37.1 (SD 5.8)**	**33 (40.2%)**	**24 (29.3%)**	**7 (8.5%)**	**13.9 (SD 5.4)**	**21.8 (SD 22.2)**
End-Stage Lung Disease								
Ardila-Gatas	25	median 39 (IQR 37–44)[a]	median 30 (IQR 25–36)[a]	6 (24%)	1 (4%)	3 (12%)	88	NR
Martin	1	37	<30[a]	0 (0%)**	0 (0%)**	1 (100%)	N/A	5
Takata	2	46 (4.5)	NR[a]	2 (100%)	1 (50%)	0 (0%)	NR	12.5 (SD 0.7)
TOTAL	**28**	**42.7 (5.4)**	**–**	**8 (28.6%)**	**2 (7%)**	**4 (14.3%)**	**88**	**10 (SD 4.3)**
Cirrhosis								
		Reached BMI<40 kg/m2 by 6 Months	Reached BMI<40 kg/m2 by 12 Months					
Garcia-Sesma	8	6 (of 7; 85.7%	6 (75.0%)	2 (25.0%)	2 (25.0%)	–	7, 8	33.2 (SD 23.6
Sharpton	32	13 (of 22; 59.1%	20 (62.5%)	21 (65.6%)[a]	14 (43.7%)	9 (28.1%)	median 22 (IQR 14–88)**	–
Taneja	1	1 (100%)	1 (100%)	1 (100%)	1 (100%)	0 (0%)	12	12
TOTAL	**41**	**20 (of 30; 66.7%)**	**27 (65.8%)**	**24 (58.5%)**	**17 (41.5%)**	**9 (of 33; 27.3%)**	**9.0 (SD 2.6)**	**30.9 (23.2)**
Chronic Kidney Disease								
		BMI (kg/m^2) at Bariatric Surgery	BMI (kg/m^2) at Last Follow-up					
				2 (67%)	2 (67%)	–	NR[a]	NR[a]
				1 (100%)	1 (100%)	–	29	6
Al Bahri	16	47.5 (SD 7.5)	30.9 (6.4)	4 (25%)	9 (56%)	–	53.2 (SD 16.3)	42.0 (32.8)
Alexander	41	48 (SD NR)[a]	NR[a]	9 (22%)	9 (22%)	–	NR	NR[a]
Buch	1	NR[a]	NR[a]	1 (100%)	1 (100%)	–	24	NR[a]
Carandina	9	47.0 (SD 7.1)	33.6 (7.4)	1 (11%)	5 (56%)	–	21	15.7 (10.6)
Contreras-Villamizar	1	42	28.6	0 (0%)	1 (100%)	–	No transplant	12
Jamal	21	47.1 (SD 5.5)	35.3 (8.4)	2 (10%)	18 (86%)	–	NR	27.6 (22)
Kienzl-Wagner	8	38.8 (SD 3.8)	30.7 (6.0)	7 (88%)	8 (100%)	–	17.6 (SD 10.5)	38.4 (16.8)

Kim	100	43.4 (SD 5.9)	36.9 (5.7)	19 (19%)	19 (19%)	–	NR	NR[a]
Koshy	3	40.7 (SD 4.9)	37.2 (1.9)	3 (100%)	3 (100%)	–	NR	13.7 (1.2)
Lin	6	NRBO[a]	NRBO[a]	1 (17%)	6 (100%)	–	NRBO	NR[a]
MacLaughlin	9	median 44.2[a]	median 34.7 (range 29.2–38.8)[a]	0 (0%)	3 (33%)	–	No transplant	12[a]
Marszalek	1	41.5	29	1 (100%)	1 (100%)	–	10	10
Newcombe	3	44.6 (SD 5.5)	33.8 (5.0)	3 (100%)	3 (100%)	–	16.3 (SD 10.2)	16.3 (8.3)
Proczko	3	39.9 (SD 2.1)	31.1 (2.4)	1 (33%)	3 (100%)	–	3	3 (0)
Takata	7	49.9 (SD 5.7)	NR[a]	0 (0%)	7 (100%)	–	No transplant	NR[a]
Thomas	31	43.5 (SD 0.7)	28.1 (SD 0.8)	14 (67%)	25 (81%)	–	median 33[a]	NR[a]
Yemeni	24	41.5 (SD 0.8)	29 (SD 1.3)	16 (67%)	21 (88%)	–	18 (1–51.6)[a]	47.0 (6.5)
TOTAL	**288**	**44.0 (5.5)**	**33.7 (5.3)**	**85 (30%)**	**145 (50%)**	**–**	**24.8 (14.2)**	**32.9 (21.4)**

SD – standard deviation; BMI – body-mass index; IQR – interquartile range; NR – not reported; NRBO – not reported by organ.
[a] Not included in calculation for group mean and standard deviation.

occurrence of pre-dialysis patient who had improvement in kidney function that precluded the need for dialysis.

Comorbidities

Among studies that reported sufficient information to determine evolution of diabetes after bariatric surgery, 39.6%, 10.4%, 14.2%, and 35.8% of diabetic patients had complete remission, partial remission, improvement, and no change in diabetes status after bariatric surgery (Fig. 4). Among hypertensive patients, 16.5%, 1.0%, 42.7%, and 39.8% had complete remission, partial remission, improvement, and no change after bariatric surgery. There was insufficient reporting of dyslipidemia, obstructive sleep apnea, and gastroesophageal reflux disease to pool data.

Length of stay, readmissions, and complications

Heart

Mean hospital length of stay was 8.0 ± 5.7 days (Supplement S4a). Of the 29 patients in studies reporting 30-day readmissions, there were 5 (17.2%) readmissions within 30 days. Of the 65 patients in studies that reported complications, there were 4, 5, 2, 3, and 2 Clavien-Dindo Classification class I, II, III, IVa and IVb complications. There were no class V complications.

Lung

Mean hospital length of stay was 4.0 ± 1.0 days (Supplement S4b). None of the studies of end-stage lung disease patients reported 30-day readmissions. Of the 28 patients, there was 1 grade II and 3 grade IIIB Clavien-Dindo Classification complications.

Liver

Only one study[20] reported hospital length of stay (median 3 days [IQR 2–3; range 1–6]), and no studies reported on readmissions after bariatric surgery (Supplement S4c). Of 41 patients in the three studies, there were 2 and 1 Clavien-Dindo Classification class I and IIIa complications. One study noted that a patient had progressive liver disease in the 6 months following bariatric surgery, but the authors were unable to definitively link worsening jaundice, ascites, and hepatic encephalopathy to the sleeve gastrectomy.[33]

Kidney

Mean hospital length of stay was 2.9 ± 1.7 days (Supplement S4d). Of 275 patients in studies reporting complications, there were 10, 3, 3, 4, 3, 0, and 1 Clavien-Dindo Classification class I, II, IIIa, IIIb, IVa, IVb, and V complications reported.

Mortality

Across all studies, there was only one death that was directly attributable to a complication of bariatric surgery (Supplement 5). In this case, an end-stage renal disease patient died following a gastric staple line leak on post-operative day 21.[34] Most of the remaining mortalities (18 of 25, 72%) were from cardiovascular and infectious etiologies, and mostly were temporally remote from bariatric surgery.

Discussion

In the current study, moderate-to-low quality evidence suggests that bariatric surgery in end-stage organ disease can facilitate sufficient weight loss in appropriately selected patients to render them transplant-eligible. In heart failure, end-stage lung disease, cirrhosis, and chronic kidney disease/end-stage renal disease,

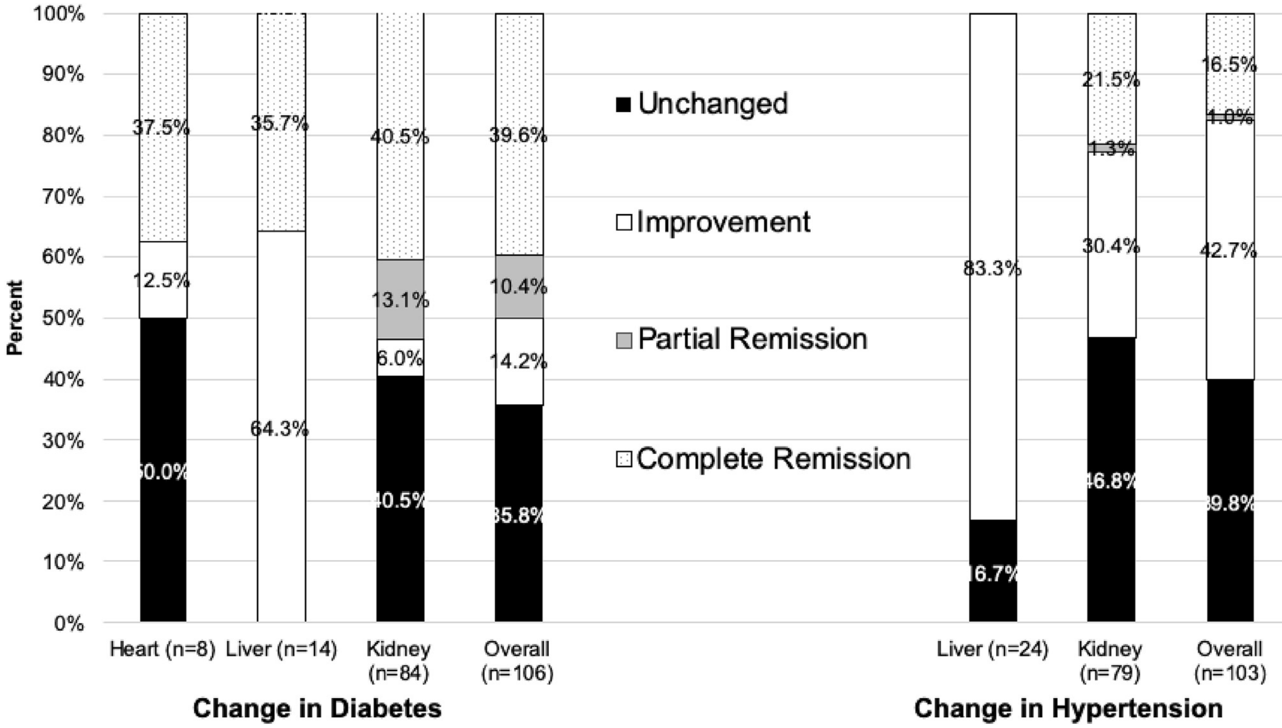

Fig. 3. Change in New York Heart Association Functional Classification in heart failure patients from the time of bariatric surgery to last follow-up.

40.2%, 28.6%, 58.5%, and 50.3% of previously ineligible patients were listed for transplant after bariatric surgery. Furthermore, even in the context of end-stage organ disease, some patients were able to reverse the course of their disease with dramatic weight loss after bariatric surgery such that they no longer required a transplant, at least during the follow-up periods of the reports.

Because of variations in reporting, change in BMI after bariatric surgery was not able to be calculated for end-stage lung disease and

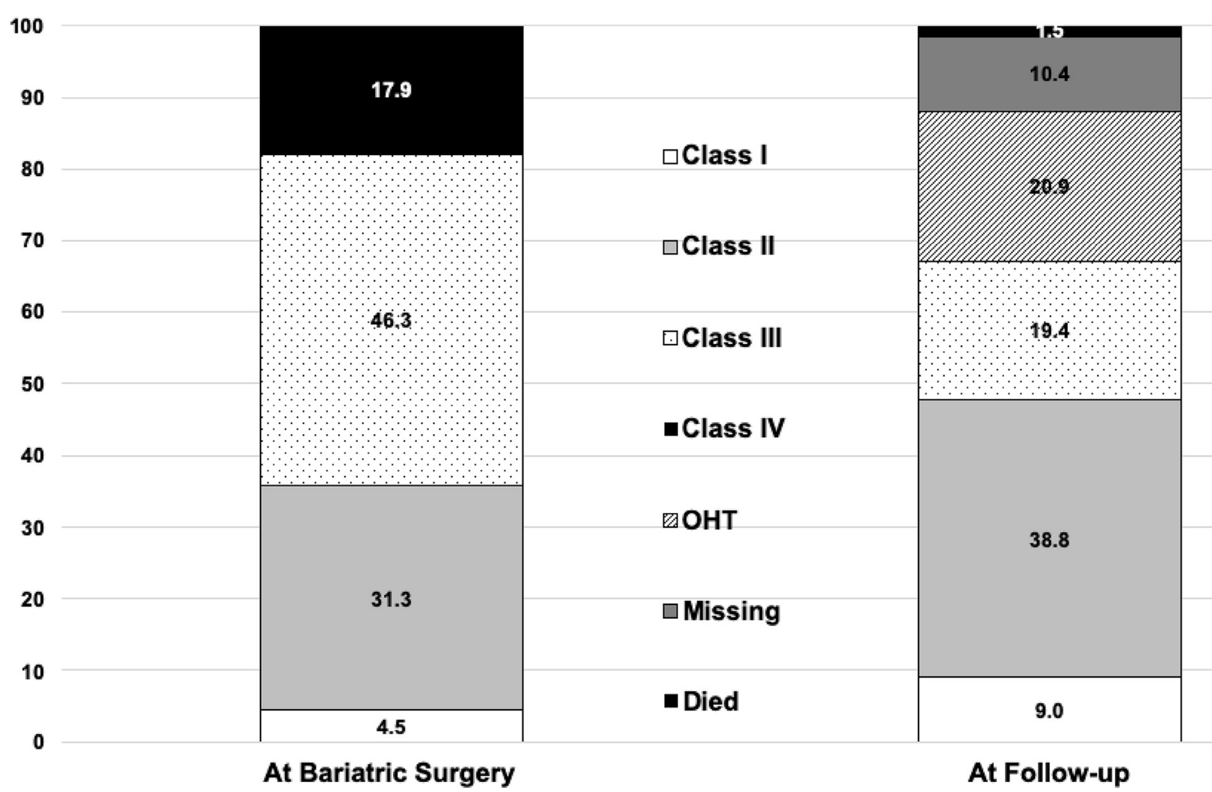

Fig. 4. Improvement in diabetes mellitus and hypertension after bariatric surgery, by organ affected by end-stage organ disease.

cirrhotic patients; however, heart failure and chronic kidney disease/end-stage renal disease patients lost an average of 11 kg/m^2 over an average of 22 and 33 months follow-up, respectively. This compares favorably to a 13 kg/m^2 and 11.8 kg/m^2 decrease in BMI at 24 and 36 months in the general bariatric population.[13]

Even in what is considered a high-risk population, post-bariatric surgery mortality was a rare and often remote phenomenon. Indeed, we could only identify one case in which bariatric surgery was the proximate cause of death. However, caution is required in interpreting these results as publication bias is likely. Furthermore, it is not known how much of a role bariatric surgery and the potential for ensuing nutritional deficiencies and malnutrition might play in contributing to an increased risk of mortality,[35] particularly in patients who succumb to infectious causes of death—a salient consideration for potential transplant candidates who will need immunosuppressive therapy. The risk of mortality without transplant in end-stage organ disease patients is high and a survival benefit may exist for interventions that render obese patients eligible for transplant. Indeed, in the general obese population, bariatric surgery is associated with a significant survival benefit compared to usual care nonsurgical obesity management[14]; however, the current state of the literature cannot answer that question for end-stage organ disease patients.

As endoscopic bariatric techniques have proliferated, studies of endoscopic sleeve gastroplasty have demonstrated 18–21% total body weight loss at two years in the general bariatric population.[36,37] While more modest weight loss than is achieved with bariatric surgery, these data offer the tantalizing possibility of using endoscopic techniques in high-risk end-stage organ disease patients to allow them to achieve sufficient weight loss for transplant listing; however, further study will be needed in this population.

Obese end-stage organ disease patients face barriers to transplantation because of their weight. In addition, they face barriers to bariatric surgery from regulatory and insurance hurdles. For example, many insurance payers mandate a trial of medical weight management prior to approving bariatric surgery. This mandate may not be feasible for many patients, particularly those that are frequently hospitalized because of their end-stage organ disease. In addition, because centers that perform bariatric surgery need to maintain their Bariatric Surgery Center of Excellence designation, there may be a disincentive to perform bariatric surgery in patients perceived as being at high risk of complications and death. While the data presented here suggest that bariatric surgery can be done safely, the limitations of the included studies require further validation in higher quality studies.

Limitations of the included studies and therefore of this meta-analysis include the fact that most of the studies were case reports and uncontrolled case series with small sample sizes, with a high likelihood of publication bias. This limits external validity of bariatric surgery applied to the general end-stage organ disease population and therefore estimates obtained likely represent the best-case scenario. Furthermore, these study designs precluded the derivation of a pooled measure of association (i.e., likelihood of transplant listing for obese end-stage organ disease patients who underwent bariatric surgery compared to those who did not). Additionally, there was significant variability across studies in terms of the outcomes reported and the heterogeneous manner in which they were reported.

In conclusion, this study suggests that bariatric surgery in end-stage organ disease may help patients achieve sufficient weight loss to be eligible for transplant listing. Further high-quality studies are needed to address whether these benefits exist. If so, a number of additional questions arise, including the optimal timing and approach of surgical intervention, durability of weight loss in this population, and whether a survival benefit is achieved.

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Writing – review & editing: BJO, JWP, RMC, ABS, CEL, NAT, JEL.

Declaration of competing interest

The authors all confirm that they have no potential financial, professional, or personal conflicts of interest to disclose.
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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2020.04.041.

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