ELSEVIER

Surgery for Obesity and Related Diseases ■ (2023) 1–7

SURGERY FOR OBESITY AND RELATED DISEASES

Original article

Bariatric surgery improves outcomes of hospitalizations for acute heart failure: a contemporary, nationwide analysis

Russyan Mark Mabeza, M.P.H.[a], Shannon Richardson, M.S.[a], Amulya Vadlakonda, B.S.[a], Nikhil Chervu, M.D., M.S.[a], Jacob Roberts, M.D.[b], Amy Yetasook, M.D.[c], Peyman Benharash, M.D.[a,*]

[a]*Cardiovascular Outcomes Research Laboratories (CORELAB), David Geffen School of Medicine, University of California, Los Angeles, California*

[b]*Department of Medicine, David Geffen School of Medicine, University of California, Los Angeles, California*

[c]*Department of Surgery, Harbor-UCLA Medical Center, Torrance, California*

Received 15 July 2022; accepted 10 December 2022

Abstract

Background: The link between obesity and poor outcomes in heart failure (HF) has been well-established.

Objectives: This retrospective study sought to examine national rates and outcomes of acute HF hospitalizations in obese individuals with a prior history of bariatric surgery.

Setting: Academic, university-affiliated; the United States.

Methods: Adult admissions (≥18 years) including a diagnosis of severe obesity were identified in the 2016–2019 Nationwide Readmissions Database. Patients who previously underwent bariatric operations were categorized into the Bariatric cohort. Multivariable linear and logistic models were used to assess the association of prior bariatric surgery with outcomes of interest.

Results: Of an estimated 10,343,828 admissions for a diagnosis of severe obesity, 925,716 (8.9%) comprised the bariatric cohort. After risk adjustment, bariatric surgery was associated with significantly decreased odds of acute HF hospitalization (adjusted odds ratio [AOR]: .40, 95% confidence interval [CI]: .38–.41). Among acute HF hospitalizations, prior bariatric surgery was linked to lower odds of mortality (AOR: .68, 95% CI: .52–.89), prolonged mechanical ventilation (AOR .44, 95% CI: .32–.61), acute renal failure (AOR: .76, 95% CI: .70–.82), and prolonged hospitalization (AOR: .77, 95% CI: .68–.87). Bariatric surgery was linked to a decrement of 1 day (95% CI: .7–1.1) and $1200 in hospitalization costs (95% CI: 400–1900), but no significant difference in odds of 30-day readmission.

Conclusions: Bariatric surgery is associated with reduced admissions for acute HF. Among acute HF hospitalizations, bariatric surgery is linked to significantly improved clinical and financial outcomes. Given its potential benefits in obesity and related diseases, bariatric surgery holds promise for promoting value-based healthcare for HF. (Surg Obes Relat Dis 2023;■:1–7.) © 2022 American Society for Metabolic and Bariatric Surgery. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

Keywords: Heart failure; Sleeve gastrectomy; Gastric bypass; Outcomes; Costs

* Correspondence: Peyman Benharash, M.D., UCLA Division of Cardiac Surgery, 62-249 Center for Health Sciences, Los Angeles, California 90095.

E-mail address: pbenharash@mednet.ucla.edu (P. Benharash).

https://doi.org/10.1016/j.soard.2022.12.027

Introduction

Heart failure (HF) is a leading cause of hospitalization across the United States with over 35 million related admissions between 2010 and 2017 [1]. With an increasing global prevalence, obesity is a common diagnosis among HF patients and is present in >70% of those with preserved ejection fraction [2,3]. The link between obesity and HF has been extensively examined with several studies implicating adverse metabolic changes and cardiac remodeling in the pathogenesis of HF [4,5]. In the setting of metabolic syndrome, greater insulin resistance leads to elevated levels of atherogenic glycation end products and inflammatory cytokines, increasing the risk for cardiovascular disease [6]. Specifically, ectopic cardiac lipid deposition reduces contractility of cardiomyocytes while obesity-related insulin resistance increases oxygen demand, resulting in excess workload [7,8]. Such stress is compounded by hyperactivation of the renin-angiotensin-aldosterone system and chronic low-grade inflammation in individuals with obesity [7]. Such increase in sympathetic tone is also commonly present in obstructive sleep apnea, which is triggered by apneic and hypopneic events due to airway collapse [9].

Bariatric surgery has become the standard of care for the treatment of severe obesity, yielding significant long-term survival benefit [10] in both geriatric and younger adults [11]. In fact, bariatric procedures have been shown to reverse the long-term effects of diabetes by up to 83% [12] and may have a protective effect against obesity-associated cancers [13]. With mounting evidence for sustained weight loss, glycemic control, and improvements in blood lipid profile, bariatric surgery has been suggested as a viable treatment option for patients with obesity and HF [7]. Preliminary state-wide and single-center studies have suggested a reduction in HF-related hospitalizations among patients who have received bariatric procedures [14,15]. However, a contemporary examination of the link between bariatric surgery and outcomes of acute HF hospitalizations remains limited.

The present study examined national rates and outcomes of acute HF admissions in a contemporary cohort of individuals with obesity and a history of bariatric surgery. We hypothesized such procedures to be associated with reduced admission rates for acute HF as well as decreased mortality, complications, hospitalization duration, costs, and 30-day readmissions.

Methods

This was a retrospective study using the 2016–2019 Nationwide Readmissions Database (NRD). The NRD is an all-payer database maintained by the Agency for Healthcare Research and Quality as part of the Healthcare Cost and Utilization Project. The NRD uses survey weights to provide accurate estimates for approximately 60% of all hospitalizations in the United States. Using patient-specific linkage numbers, the NRD allows tracking of readmissions across hospitals within each calendar year.

We used International Classification of Diseases, Tenth Revision (ICD-10) codes to identify all adult (≥18 years) hospitalizations including a diagnosis of severe obesity (body mass index [BMI], ≥35; Supplemental Table S1). Hospitalizations with missing data on age or sex were excluded (Fig. 1). As previously described by Cogollo et al. [16], we stratified patients as bariatric based on prior history of bariatric surgery (ICD-10 code: Z98.84) while all others were considered non-bariatric.

The primary outcome of interest was hospitalization with a primary diagnosis of acute HF (Supplemental Table S1), while secondary endpoints included inhospital mortality, prolonged mechanical ventilation, acute renal failure, dialysis use, hospitalization length of stay (LOS), costs, and 30-day readmission. Acute HF was defined as acute or acute on chronic systolic, diastolic, combined, or right HG based on ICD-10 codes. Patients admitted for myocardial ischemia with subsequent HF were not considered for analysis. We first evaluated rates of acute HF admissions in patients with and without prior bariatric surgery. For the secondary analysis, all patients with a primary diagnosis of acute HF were stratified based on the ICD codes for prior bariatric operation and compared across outcomes of interest.

Baseline characteristics included age, sex, chronic comorbidities (diabetes mellitus, hypertension, obstructive sleep apnea, baseline chronic kidney disease stage, history or current tobacco use, and alcohol use disorder), payer status, median income quartile, hospital location, and bed size, as defined by the NRD data dictionary [17]. Prolonged LOS was defined as ≥12 days, the threshold for outliers identified using the interquartile range rule in exploratory analysis, as described elsewhere [18]. Hospitalization costs were calculated by application of Healthcare Cost and Utilization Project hospital-specific charges, and inflation adjustment to 2019 using the Personal Health Care Expenditure Index.

Categorical variables are reported as frequencies (%) and continuous variables as means with standard deviation or medians with interquartile range, if not normally distributed. We used the Chi-square and Kruskal Wallis tests to compare patient and hospital characteristics stratified by prior history of bariatric surgery. Multivariable regression models were utilized to evaluate the association of bariatric surgery with outcomes of interest. The least absolute shrinkage and selection operator was used for variable selection. Briefly, this penalized regularization algorithm reduces model overfitting and improves out-of-sample reliability [19]. We selected models that minimize the mean squared error term on cross-validation and evaluated those using receiver-operating characteristics as well as Akaike and Bayesian information criteria, as appropriate. Regression outputs are reported as adjusted odds ratios (AOR) for dichotomous and beta coefficients (β) for continuous variables with 95% confidence intervals (95% CIs).

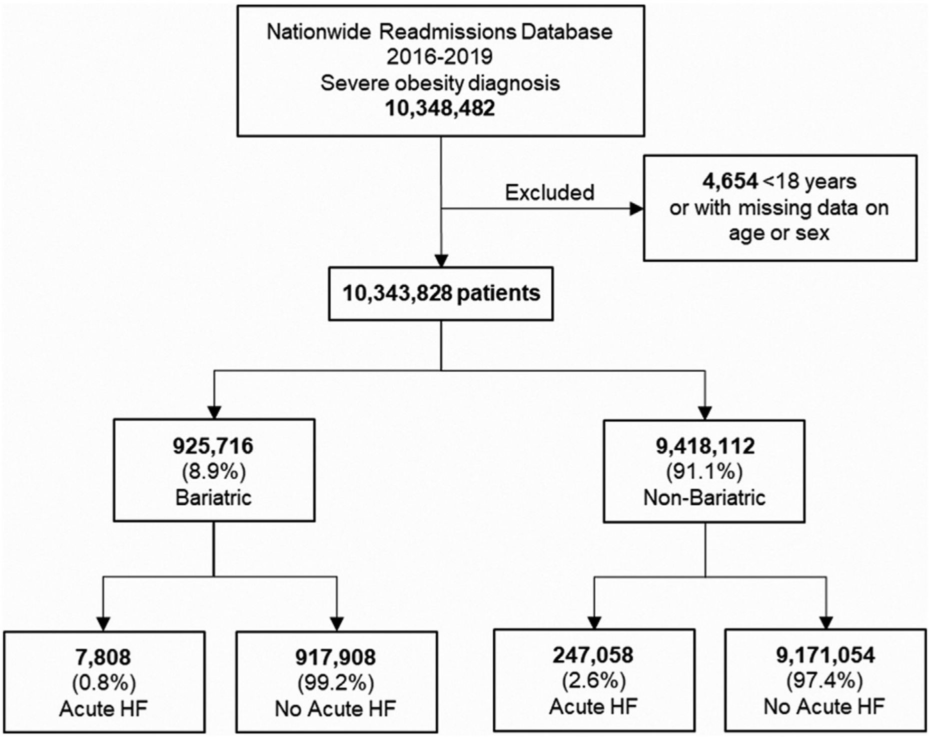

Fig. 1. Patient selection criteria and stratification. HF = heart failure.

The Stata *margins* command was used to generate risk-adjusted outcomes. We performed a sensitivity analysis using entropy balancing, which searches for the set of sample weights that satisfy prespecified balance constraints while preserving the entire cohort for analysis [20]. A P value < .05 was considered statistically significant for all comparisons. All statistical analyses were performed using Stata 16.0 (StataCorp, College station, Texas). This study was deemed exempt from full review by the Institution Review Board at the University of California, Los Angeles.

Results

Of an estimated 10,343,828 hospitalizations with a diagnosis of severe obesity, 925,716 (8.9%) had a prior history of bariatric surgery. Compared to others, the bariatric cohort was on average older (55.4 ± 13.3 versus 54.9 ± 16.3 yr; P < .001), more frequently female (78.1% versus 64.2%; P < .001), and had a lower prevalence of diabetes, hypertension, obstructive sleep apnea, and chronic kidney disease (CKD) (Table 1). The bariatric group had a higher proportion of patients with tobacco (23.6% versus 23.2%; P < .001) and alcohol use disorders (7.3% versus 2.8%, P < .001, Table 1) compared to others. The unadjusted rate of acute HF as the primary reason for hospitalization was significantly lower for patients with history of bariatric surgery compared to others (.8% versus 2.6%, P < .001, Fig. 1).

After adjusting for relevant patient and hospital characteristics (model C-statistic = .71), bariatric surgery remained associated with significantly decreased odds of hospitalization due to acute HF (.40, 95% CI: .38–.41, Table 2). Prior bariatric operation was linked to a significantly lower risk-adjusted rate of acute HF hospitalization (.8 [.8–.8]% versus 2.6 [2.6–2.6]%; P < .001). Furthermore, nonprivate insurance, lower income quartiles, and several comorbidities were associated with increased odds of acute HF admission (Table 2).

We subsequently conducted a subgroup analysis of the patients who had a primary admission diagnosis of acute HF. Of an estimated 254,865 such patients, 3.1% previously underwent bariatric surgery. Consistent with the overall study population, the bariatric cohort was on average older (64.2 ± 11.6 versus. 63.8 ± 13.6 yr; P = .04) and more commonly female (65.3% versus. 52.7%; P < .001, Table 3). Similarly, the bariatric group had a significantly lower prevalence of diabetes, hypertension, obstructive sleep apnea, and CKD, but higher proportion of patients with tobacco and alcohol use disorder compared to others (Table 3).

Unadjusted outcomes are shown in Table 4. Of the acute HF patients, those with a history of bariatric surgery had lower crude rates of inhospital mortality, prolonged mechanical ventilation, and acute renal failure, but no significant difference in dialysis use (Table 4). In addition, the bariatric cohort had lower unadjusted rates of prolonged LOS and hospitalization costs but not 30-day readmission (Table 4). After risk-adjustment, bariatric surgery remained associated with significantly lower odds of mortality (AOR: .68, 95% CI: .52–.89), prolonged mechanical ventilation

Table 1
Patient and hospital characteristics stratified by prior history of bariatric surgery

Variable	Bariatric (n = 925,716)	Non-bariatric (n = 9,418,112)	*P*-value
Age, yr	55.4 ± 13.3	54.9 ± 16.3	<.001
Female, %	78.1	64.2	<.001
Diabetes mellitus, %	27.5	42.3	<.001
Hypertension, %	57.4	67.8	<.001
Obstructive sleep apnea, %	20.1	28.5	<.001
Tobacco use (current or history), %	23.6	23.2	<.001
Alcohol use disorder, %	7.3	2.8	<.001
CKD stages, %			<.001
No CKD	91.6	85.8	
CKD stages 1–3	5.3	9.5	
CKD stages 4–5	1.2	2.3	
ESRD	1.9	2.4	
Insurance coverage, %			<.001
Private	38.6	33.6	
Medicare	42.2	41.8	
Medicaid	13.1	17.8	
Other*	6.1	6.8	
Income quartile, %			<.001
>75th	18.7	14.9	
51–75th	26.5	24.4	
26–50th	28.8	28.9	
≤25th	26.0	31.8	
Hospital location, %			<.001
Rural	7.1	8.6	
Urban, nonacademic	22.0	22.2	
Urban, academic	70.9	69.2	
Hospital bed size, %			.02
Large	54.0	54.1	
Medium	28.4	27.8	
Small	17.6	18.1	

CKD = chronic kidney disease; ESRD = end-stage renal disease.
* Indicates a combined insurance status including self-pay, uninsured, and other.

(AOR: .44, 95% CI: .32–.61), acute renal failure (AOR: .76, 95% CI: .70–.82), and prolonged LOS (AOR: .77, 95% CI: .68–.87, Fig. 2). There was no significant difference in odds of dialysis use based on prior bariatric operation (Fig. 2). Furthermore, bariatric surgery was linked to a decrement of 1 day (95% CI: .7–1.1) and $1200 in attributable hospitalization costs (95% CI: 400–1900), but no significant difference in odds of 30-day readmission (Fig. 2). After application of entropy balancing weights, similar results as the regression models were observed. Findings from the sensitivity analysis are reported in Supplemental Table S2.

Discussion

Given the growing consensus regarding the role of bariatric surgery in mitigating cardiovascular disease risk, critical assessment of its outcomes in acute HF is warranted. In the largest and most recent examination of this association to date, we made several key observations. We found that prior bariatric surgery was associated with significantly reduced odds of hospitalization for acute HF. Of those admitted for acute HF, bariatric patients faced lower odds of mortality, prolonged mechanical ventilation, acute renal failure, and prolonged hospitalization. While previous metabolic surgery was associated with a decrement in LOS and costs, it did not confer significant differences in 30-day readmission. Several of these findings warrant further discussion.

In the present study, hospitalization rates for acute HF were significantly lower for individuals with history of bariatric surgery. Specifically, these patients faced less than one third the risk-adjusted rate of acute HF hospitalizations compared to others (.8% versus. 2.6%). This finding is consistent with prior work establishing a reduction in risk of major adverse cardiovascular events associated with bariatric surgery [7,21,22]. In a retrospective study of the National Inpatient Sample, Nguyen et al. found a 1.6-fold decrease in odds of major adverse cardiovascular events for hospitalized patients with obesity who underwent bariatric operations previously [23]. Such findings may be attributable to several underlying mechanisms, including improvement in cardiac geometry, diastolic function, and left ventricular ejection fraction [21]. Given the potentially protective role of bariatric surgery against development of HF, a prospective, multicenter clinical trial analysis is

Table 2
Factors independently associated with need for acute heart failure hospitalization. (C-statistic: .71)

Variable	AOR	95% CI	*P*-value
Prior bariatric surgery	.41	.39–.42	<.001
Age/yr	1.03	1.03–1.03	<.001
Female	.72	.71–.73	<.001
Diabetes mellitus	1.33	1.31–1.35	<.001
Hypertension	1.11	1.09–1.14	<.001
Obstructive sleep apnea	1.45	1.43–1.47	<.001
Current or history of tobacco use	1.04	1.03–1.06	<.001
Alcohol use disorder	1.25	1.21–1.30	<.001
CKD stage			
No CKD	Ref		
CKD1-3	1.83	1.79–1.86	<.001
CKD4-5	2.35	2.28–2.41	<.001
ESRD	1.66	1.61–1.72	<.001
Insurance coverage			
Private	Ref		
Medicare	1.41	1.38–1.44	<.001
Medicaid	1.79	1.75–1.84	<.001
Other*	1.66	1.60–1.71	<.001
Income quartile			
Highest	Ref		
Third	1.08	1.05–1.11	<.001
Second	1.13	1.09–1.17	<.001
Lowest	1.28	1.23–1.33	<.001

AOR = adjusted odds ratio; CI = confidence interval; CKD = chronic kidney disease; ESRD = end-stage renal disease.

* Indicates a combined category including self-pay, uninsured, and other.

warranted to ascertain the prophylactic efficacy of bariatric operations. As argued by Schauer and Nissen, such a study must include major cardiovascular endpoints to adequately elucidate the role of bariatric surgery in preventing and treating obesity-related cardiac complications [24].

Among patients admitted for acute HF, we observed a 31% relative reduction in the odds of death in those that previously underwent bariatric operations. Our findings are consistent with prior work reporting the beneficial role of bariatric surgery on mortality in acute HF [25]. Furthermore, we found history of bariatric procedures to be linked to significantly decreased odds of prolonged mechanical ventilation and acute renal failure. Consistent with these findings, prolonged hospitalization was diminished in the bariatric cohort. To our knowledge, our study is the first to assess the association of metabolic surgery with such complications in a large, national cohort of patients with acute HF. Such superior outcomes may be attributable, in part, to a lower severity of HF in patients who have undergone bariatric surgery [22] A reduced burden of disease may lead to lower HF complexity in bariatric surgery patients upon admission. Of note, the bariatric surgery cohort had a lower prevalence of diabetes, hypertension, obstructive sleep apnea, and CKD compared to others, which could be due to disease remission resulting from metabolic surgery. Because patients undergoing bariatric surgery must first meet criteria allowing them to undergo these procedures, those in the bariatric group may have had better underlying health profiles than those who were not. Additionally, due to the costs associated with this intervention, patients with prior history of bariatric surgery may have had better access to healthcare, as indicated by a higher percentage of these patients having private insurance. Given the complex relationship between comorbidity burden and barriers to care, further work is necessary to elucidate the causal relationship between bariatric procedures and severity of HF.

Given the high degree of variation in quality and cost of healthcare services, national attention has shifted towards optimizing value [26]. Maximizing quality and minimizing costs are particularly relevant in the context of acute HF, where annual expenditures exceed $11 billion [27]. Moreover, previous studies have reported increased resource use among patients with obesity, with acute HF. In an assessment of variations in hospitalization cost for acute HF, Ziaeian et al. identified obesity along with other comorbidities, to be predictive of increased resource utilization [28]. Although increased BMI has been reportedly associated with higher hospitalization costs, prior work has noted bariatric operations to reduce resource use [29,30]. In the present study, we found a decrement of 1 day in LOS and $1200 in costs for those that previously underwent bariatric surgery. This cost reduction is beneficial to both patients and healthcare systems, suggesting that bariatric surgery may play a critical role in optimizing value-based care for patients with obesity admitted for acute HF. In addition, we found no significant difference in odds of 30-day readmission based on prior history of metabolic surgery. Whether or not bariatric surgery benefits long-term readmission rates and resource use requires further exploration through longitudinal analysis.

The present work has several limitations. Of note, the retrospective design of the study precludes any causal conclusions. Although the NRD provides an accurate estimate of approximately 60% of all U.S. hospitalizations, it is also subject to variation due to differences in hospital or provider billing practices. Inherent to the nature of ICD-10 coding of bariatric procedures, we are not able to distinguish between primary and repeat interventions. We are also unable to distinguish between individual bariatric procedures or whether they were performed as preventive therapy or treatment for HF. In addition, our bariatric cohort did not include patients with ICD-10 codes Z98.0 (intestinal bypass and anastomosis status) and Z90.3 (acquired absence of stomach [part of]), which may lead to underestimation of the bariatric surgery population. This approach is consistent with previously published methodology [16], which would exclude those who might have undergone intestinal bypass or gastrectomy for traumatic, oncologic, or other emergent general surgical causes. Since the NRD is an administrative database, it also lacks granular clinical data such as laboratory values, patient weight or BMI, echocardiogram parameters, and functional status. Nonetheless, we utilized robust statistical methodology to mitigate the effect of these

Table 3
Patient and hospital characteristics of patients with a primary diagnosis of acute heart failure stratified by prior history of bariatric surgery

Variable	Bariatric (n = 7807)	Non-bariatric (n = 247,058)	*P*-value
Age, yr	64.2 ± 11.6	63.8 ± 13.6	.04
Female, %	64.3	52.7	<.001
Diabetes mellitus, %	43.9	60.2	<.001
Hypertension, %	75.1	83.6	<.001
Obstructive sleep apnea, %	36.2	41.2	<.001
Tobacco use (current or history) , %	31.4	28.0	<.001
Alcohol use disorder, %	4.8	3.2	<.001
CKD stages, %			<.001
No CKD	73.1	67.7	
CKD stages 1–3	17.0	21.7	
CKD stages 4–5	4.8	6.4	
ESRD	5.1	4.2	
Insurance coverage, %			<.001
Private	21.6	17.6	
Medicare	66.9	62.3	
Medicaid	1.8	13.7	
Other*	3.7	6.3	
Income quartile, %			<.001
$>75^{th}$	17.1	13.1	
51^{st}–75^{th}	26.7	23.2	
26^{th}–50^{th}	28.9	28.9	
$\leq 25^{th}$	27.3	34.7	
Hospital location, %			<.001
Rural	8.7	10.9	
Urban, non-academic	23.7	24.2	
Urban, academic	67.6	64.9	
Hospital bed size, %			.02
Large	54.5	53.9	
Medium	27.3	27.5	
Small	18.1	18.6	

CKD = chronic kidney disease; ESRD = end-stage renal disease.
* Indicates a combined insurance status including self-pay, uninsured, and other.

limitations in the largest, contemporary national assessment of bariatric surgery and acute HF outcomes to date.

In summary, prior history of bariatric surgery was linked to reduced odds of hospitalization due to acute HF. Among patients with HF, bariatric surgery was also associated with improved clinical outcomes and resource utilization. With the broad set of comorbidities common in patients with severe obesity, bariatric surgery should be considered for qualified individuals as a preventative intervention. Given the resource intensive nature of HF hospitalizations, bariatric surgery holds promise for promoting value-based healthcare.

Table 4
Unadjusted outcomes of acute heart failure hospitalizations stratified by prior history of bariatric surgery

Outcomes	Bariatric	Non-bariatric	*P*-value
Inhospital mortality (%)	1.8	2.6	<.001
Prolonged mechanical ventilation (%)	1.1	2.6	<.001
Acute renal failure (%)	24.7	32.6	<.001
Dialysis (%)	2.3	2.3	.91
Index LOS (d, median, and IQR)	4 (3–7)	5 (3–8)	<.001
Prolonged LOS (%)	9.2	11.8	<.001
Hospitalization cost ($1,000, median, IQR)	10.8 (6.6–19.7)	11.4 (6.8–20.8)	<.001
30-d readmission (%)	17.8	16.5	.05

LOS = length of stay; IQR = interquartile range.

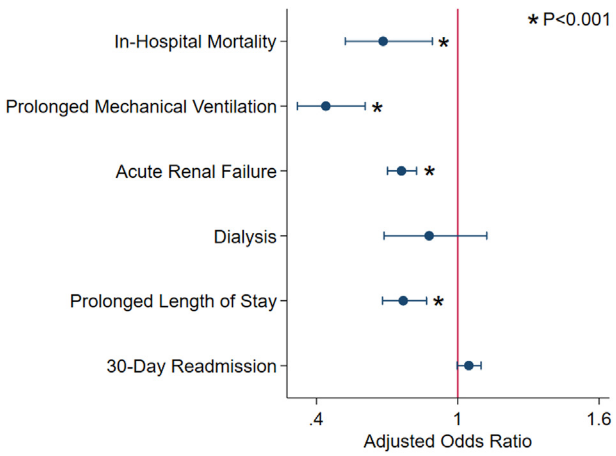

Fig. 2. Association of bariatric surgery with outcomes of acute heart failure hospitalizations. Outcomes are reported as adjusted odds ratio with 95% confidence interval and non-bariatric as reference. Models include adjustment for demographics (age, sex, primary payer, and income), comorbidities (diabetes mellitus, hypertension, obstructive sleep apnea, current or history of tobacco use, alcohol use disorder, and chronic kidney disease stage), and hospital characteristics (hospital location, bed size). $*P < .001$.

Disclosures

The authors have no commercial associations that might be a conflict of interest in relation to this article.

Supplementary data

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.soard.2022.12.027.

References

[1] Agarwal MA, Fonarow GC, Ziaeian B. National Trends in heart failure hospitalizations and readmissions from 2010 to 2017. JAMA Cardiol 2021;6(8):952–6.
[2] Powell-Wiley TM, Poirier P, Burke LE, et al. Obesity and cardiovascular disease A Scientific Statement from the American heart association. Circulation 2021;143(21):E984–1010.
[3] Haass M, Kitzman DW, Anand IS, et al. Body mass index and adverse cardiovascular outcomes in heart failure patients with preserved ejection fraction results from the irbesartan in heart failure with preserved ejection fraction (I-PRESERVE) trial. Circ Heart Fail 2011;4(3):324–31.
[4] Bazzano LA, Belame SN, Patel DA, et al. Obesity and left ventricular dilatation in young adulthood: the bogalusa heart study. Clin Cardiol 2011;34(3):153–9.
[5] Ndumele CE, Coresh J, Lazo M, et al. Obesity, subclinical myocardial injury, and incident heart failure. JACC Heart Fail 2014;2(6):600–7.
[6] Scott J. Pathophysiology and biochemistry of cardiovascular disease. Curr Opin Genet Dev 2004;14(3):271–9.
[7] Rodriguez Flores M, Aguilar Salinas C, Piché ME, Auclair A, Poirier P. Effect of bariatric surgery on heart failure. Expert Rev Cardiovasc Ther 2017;15(8):567–79.
[8] Larsen TS, Jansen KM. Impact of obesity-related inflammation on cardiac metabolism and function. J Lipid Atheroscler 2021;10(1):8–23.
[9] Bauters F, Rietzschel ER, Hertegonne KBC, Chirinos JA. The link between obstructive sleep apnea and cardiovascular disease. Curr Atheroscler Rep 2016;18(1):1–11.
[10] Migliore E, Brunani A, Ciccone G, et al. Effect of bariatric surgery on survival and hospitalizations in patients with severe obesity. A retrospective cohort study. Nutrients 2021;13(9):1–13.
[11] Mabeza RM, Mao Y, Maynard K, Lee C, Benharash P, Yetasook A. Bariatric surgery outcomes in geriatric patients: a contemporary, nationwide analysis. Surg Obes Relat Dis 2022;18(8):1005–11.
[12] Meijer RI, van Wagensveld BA, Siegert CE, Eringa EC, Serné EH, Smulders YM. Bariatric surgery as a Novel treatment for Type 2 diabetes mellitus: a Systematic review. Arch Surg 2011;146(6):744–50.
[13] Schauher DP, Feigelson HS, Koebnick C, et al. Bariatric surgery and the risk of cancer in a large multisite cohort. Ann Surg 2019;269(1):95–101.
[14] Shimada YJ, Tsugawa Y, Brown DFM, Hasegawa K. Bariatric surgery and emergency department visits and hospitalizations for heart failure exacerbation: population-based, self-controlled Series. J Am Coll Cardiol 2016;67(8):895–903.
[15] Datta T, Lee AJ, Cain R, McCarey M, Whellan DJ. Weighing in on heart failure: the potential impact of bariatric surgery. Heart Fail Rev 2022;27(3):755–66.
[16] Cogollo VJ, Valera RJ, Botero-Fonnegra C, et al. Bariatric surgery decreases hospitalization rates of patients with obstructive lung diseases: a nationwide analysis. Surg Obes Relat Dis 2022;18(8):1042–8.
[17] NRD Description of Data Elements. Available from: https://www.hcup-us.ahrq.gov/db/nation/nrd/nrddde.jsp. Accessed July 14, 2022.
[18] Freitas A, Silva-Costa T, Lopes F, et al. Factors influencing hospital high length of stay outliers. BMC Health Serv Res 2012;12(1):265.
[19] Tibshirani R. Regression shrinkage and selection via the Lasso. J R Stat Soc Ser B 1996;58(1):267–88.
[20] Hainmueller J. Entropy balancing for causal effects: a multivariate reweighting method to produce balanced samples in observational studies. Polit Anal 2012;20(1):25–46.
[21] Kindel TL, Strande JL. Bariatric surgery as a treatment for heart failure: review of the literature and potential mechanisms. Surg Obes Relat Dis 2018;14(1):117–22.
[22] Mottel BH, Lindsay DA, Frishman WH. Effect of bariatric surgery on cardiovascular function and heart failure outcomes. Cardiol Rev 2021;29(4):187–94.
[23] Nguyen T, Alzahrani T, Mandler A, Alarfaj M, Panjrath G, Krepp J. Relation of bariatric surgery to inpatient cardiovascular outcomes (from the national inpatient sample). Am J Cardiol 2021;144:143–7.
[24] Schauer PR, Nissen SE. After 70 Years, metabolic surgery has earned a cardiovascular outcome trial. Circulation 2021;143(15):1481–3.
[25] Aleassa EM, Khorgami Z, Kindel TL, et al. Impact of bariatric surgery on heart failure mortality. Surg Obes Relat Dis 2019;15(7):1189–96.
[26] Porter ME. What is value in health care? N Engl J Med 2010;363(26):2477–81.
[27] Jackson SL, Tong X, King RJ, Loustalot F, Hong Y, Ritchey MD. National burden of heart failure events in the United States, 2006 to 2014. Circ Heart Fail 2018;11(12):e004873.
[28] Ziaeian B, Sharma PP, Yu TC, Johnson KW, Fonarow GC. Factors associated with variations in hospital expenditures for acute heart failure in the United States. Am Heart J 2015;169(2):282–289.e15.
[29] Krishna SG, Rawal V, Durkin C, et al. Weight loss surgery reduces healthcare resource utilization and all-cause inpatient mortality in morbid obesity: a propensity-matched analysis. Obes Surg 2018;28(10):3213–20.
[30] Han H, Zhu T, Guo Y, Ruan Y, Herzog E, He J. Impact of prior bariatric surgery on outcomes of hospitalized patients with heart failure: a population-based study. Surg Obes Relat Dis 2019;15(3):469–77.