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ORIGINAL INVESTIGATIONS

Bariatric Surgery and Emergency Department Visits and Hospitalizations for Heart Failure Exacerbation

Population-Based, Self-Controlled Series

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ABSTRACT

BACKGROUND The United States is battling obesity and heart failure (HF) epidemics. Although studies have suggested relationships between obesity and HF morbidity, little is known regarding the effects of substantial weight reduction in obese patients with HF.

OBJECTIVES This study investigated whether bariatric surgery is associated with a decreased rate of HF exacerbation.

METHODS We performed a self-controlled case series study of obese patients with HF who underwent bariatric surgery, using the population-based emergency department (ED) and inpatient sample in California, Florida, and Nebraska. Primary outcome was ED visit or hospitalization for HF exacerbation from 2005 to 2011. We used conditional logistic regression to compare the outcome event rate during sequential 12-month periods, using pre-surgery months 13 to 24 as the reference period.

RESULTS We identified 524 patients with HF who underwent bariatric surgery. During the reference period, 16.2% of patients had an ED visit or hospitalization for HF exacerbation. The rate remained unchanged in the subsequent 12-month pre-surgery period (15.3%; $p = 0.67$). In the first 12-month period after bariatric surgery, we observed a nonsignificantly reduced rate (12.0%; $p = 0.052$). However, the rate was significantly lower in the subsequent 13 to 24 months after bariatric surgery (9.9%; adjusted odds ratio: 0.57; $p = 0.003$). By contrast, there was no significant reduction in the rate of HF exacerbation among obese patients who underwent nonbariatric surgery (i.e., cholecystectomy, hysterectomy).

CONCLUSIONS Our findings indicate that bariatric surgery is associated with a decline in the rate of HF exacerbation requiring ED evaluation or hospitalization among obese patients with HF. (J Am Coll Cardiol 2016;67:895–903)

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ABBREVIATIONS AND ACRONYMS

BMI = body mass index

BNP = B-type natriuretic peptide

CI = confidence interval

CPT = Current Procedural Terminology

ED = emergency department

HCUP = Healthcare Cost and Utilization Project

HF = heart failure

ICD-9-CM = International Classification of Diseases-Ninth Revision-Clinical Modification

LV = left ventricular

LVEF = left ventricular ejection fraction

OR = odds ratio

SEDD = State Emergency Department Database

SID = State Inpatient Database

Heart failure (HF) is a significant public health burden that affects approximately 5.7 million adults in the United States (1); the total number of patients is projected to increase by 46% from 2012 to 2030 (2). HF exacerbations contribute to a substantial proportion of the burden, accounting for 676,000 emergency department (ED) visits and 1.02 million hospitalizations annually (1). The total (direct and indirect) cost for treating patients with HF, within which the majority (80%) is related to hospitalizations, was $30.7 billion in 2012 and is projected to increase to $69.8 billion in 2030 in the United States (2).

SEE PAGE 904

In parallel, the United States also has experienced an obesity epidemic (3). Approximately 40% of patients hospitalized for HF exacerbation are obese (4), and studies have demonstrated an association between obesity and HF-related morbidity. For example, epidemiological studies report a “dose-effect” relationship between body mass index (BMI) and rates of hospitalization for HF exacerbation in patients with obesity, suggesting possible causality (5–7). Additionally, potential pathophysiological mechanisms exist that link obesity to HF exacerbation (e.g., excessive accumulation of adipose tissue leads to hemodynamic changes that may result in alterations in cardiac performance and left ventricular (LV) morphology) (8–10). Therefore, obesity is recognized as a possible risk factor for HF exacerbation (8). Substantial weight loss, on the other hand, has been associated with reversal of several hemodynamic abnormalities and adverse LV remodeling among patients with obesity and HF (8,9). However, little is known about whether substantial weight loss results in a decreased rate of HF-related adverse events (11). Bariatric surgery is the most effective method to achieve substantial weight loss (12) and can theoretically lead to improved HF control among patients with obesity.

In this context, we aimed to investigate whether bariatric surgery, used as an instrument to achieve significant weight loss, is associated with significantly reduced rates of ED visits and hospitalizations for HF exacerbation among obese patients with HF.

METHODS

STUDY DESIGN AND SETTING. We performed a self-controlled case series study utilizing the Healthcare Cost and Utilization Project (HCUP) State Emergency Department Database (SEDD) (13) and State Inpatient Database (SID) (14). The study was designed to perform intraperson comparisons among those who experienced both the exposure and the outcome. No separate control group was necessary because this study design allows each person to function as his or her own control (15). The major advantage of this design is that both measured and unmeasured confounders are controlled as long as they do not change over time during the study period (15). Because the exposure of this study (i.e., bariatric surgery) is transient and discrete, and the outcome is characterized as a short-term event, the present study meets the required assumptions of self-controlled study designs (15). We assessed the rate of ED visits or hospitalizations for HF exacerbation for 4 consecutive years: 2 years before and 2 years after bariatric surgery.

The data were extracted from HCUP SEDD and SID in California, Florida, and Nebraska from 2005 to 2011. HCUP includes all-payer, encounter-level information and is the largest longitudinal hospital care data collection available in the United States. The SEDD is a database from short-term, acute-care, nonfederal hospitals in participating states that encompasses all ED visits, including treat-and-release encounters and transfers. The SID captures all inpatient discharges from short-term, acute-care, nonfederal, general, and other specialty hospitals, and this database includes those admitted through the ED. Taken together, all ED visits regardless of disposition and all hospitalizations regardless of the source of admission were able to be identified. The 3 states were chosen as their data included unique encrypted patient identifiers, making it possible to perform longitudinal follow-up of specific patients across years, and for their high data quality. Details of the study design, databases, and statistical analysis methods have been previously published (13,14,16). The institutional review board of Massachusetts General Hospital waived review of this study.

STUDY POPULATION. Steps were taken to identify all obese patients with HF who underwent bariatric surgery in the databases from the 3 states. First, patients age ≥18 years with at least 1 ED visit or hospitalization for HF exacerbation between January 1, 2005, and December 31, 2011, were identified using the International Classification of Diseases-Ninth Revision-Clinical Modification (ICD-9-CM) diagnosis codes for HF (402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, and 428.0) in the primary diagnosis field (17). Second, among patients who had either an ED visit or hospitalization for HF, patients hospitalized for bariatric surgery with a concurrent diagnosis of obesity were identified. Current Procedural Terminology (CPT) codes used for bariatric surgery were 43.89, 44.31, 44.38, 44.39, 44.50, 44.68, 44.69, 44.93, 44.95, 44.99, 45.51, and 45.90; the ICD-9-CM diagnostic codes for obesity were 278.0 to 278.2, V77.8, V85.3x, and V85.4 (16,18). Patients with diagnostic codes for cancer (150.0 to 159.9) were excluded. The data of patients who underwent bariatric surgery between January 1, 2007, and December 31, 2009, were collected to accommodate the 2-year pre-surgery and 2-year post-surgery periods. Patients excluded were out-of-state residents; patients who died during the index hospitalization for bariatric surgery or died in-hospital during the 2-year post-surgery period; and patients with multiple bariatric surgeries during the study period.

To address potential loss to follow-up (e.g., out-of-hospital deaths, moving out of state), we limited the patient population to those who had at least 1 health care utilization for any reason during post-surgery months 25 to 36. Our population selection method ensured that these patients were alive and living within the study states until at least 2 years post-surgery.

MEASUREMENTS AND OUTCOMES. The databases recorded demographics (age, sex, and race/ethnicity), primary insurance type, estimated household income, ICD-9-CM diagnosis, and procedures. SEDD also collected data on ED disposition. We determined baseline patient characteristics at the time of hospitalization for bariatric surgery. Primary insurance types were categorized into Medicaid, Medicare, private sources, and other. Race/ethnicity was categorized into non-Hispanic white, non-Hispanic black, Hispanic, and other.

The primary outcome was a composite of ED visit or hospitalization for HF exacerbation. The secondary outcomes were an ED visit with HF exacerbation and hospitalization with HF exacerbation as assessed separately.

STATISTICAL ANALYSIS. To compare each patient's rate of outcomes with pre-surgery days 366 to 730 as the reference period, a conditional logistic regression model was fit to calculate odds ratios (ORs) for pre-surgery days 1 to 365, post-surgery days 0 to 365, and post-surgery days 366 to 730. Each patient was matched to his/her own reference period. The 1-year intervals used in the regression model accounted for potential seasonal variations that may affect the rate of HF exacerbation (19).

We performed several sensitivity analyses using different statistical assumptions and patient populations to assess the robustness of our inferences. First, we repeated the analysis without limiting patients to those who had any health care utilization during the 25 to 36 months post-surgery. Second, the frequency of HF exacerbations was modeled as a count variable as opposed to a binary outcome by using a negative binomial regression model. Third, to address the possibility of misdiagnosis after bariatric surgery, we repeated the analysis with a composite endpoint of chronic obstructive pulmonary disease, pneumonia, or dyspnea as the primary diagnosis (ICD-9-CM codes 491.xx, 492.xx, and 496.xx for chronic obstructive pulmonary disease; 486.xx for pneumonia; and 786.0x for dyspnea). We selected these outcomes because these disease conditions can mimic signs and symptoms of HF exacerbation but have no known biological rationale to be modified by bariatric surgery. Fourth, to determine whether reduction in the rate of HF exacerbation was associated with any elective abdominal surgery in general rather than bariatric surgery itself (e.g., due to intensified HF control during the perisurgical period), the analysis was repeated using 2 populations who underwent an elective nonbariatric surgery: cholecystectomy (CPT codes 51.21 to 51.24 and 51.41 to 51.59) and hysterectomy (CPT codes 68.31 to 68.79 and 68.9). We chose these 2 surgeries because of their large sample size, similar characteristics (both are elective abdominal surgeries), and absence of biological plausibility to affect the rate of HF exacerbation (16). Lastly, because our study population was relatively young, we stratified the analysis by age group to address the possibility of differential effects of bariatric surgery by age. All analyses were performed with SAS version 9.3 (SAS Institute, Cary, North Carolina). Results are displayed with 95% confidence interval (CI) when appropriate, and a 2-sided p value <0.05 was considered statistically significant.

RESULTS

All obese adults with HF who underwent bariatric surgery between January 1, 2007, and December 31, 2009, were identified (N = 1,792). Eighty-three patients who underwent multiple bariatric surgeries and 48 patients who died in-hospital during the post-surgery period were excluded (3 patients had both), leaving a total of 1,664 patients. In this population, our final sample for the primary analysis consisted of 524 patients who had at least 1 ED visit or hospitalization during 25 to 36 months after bariatric surgery.

TABLE 1 Baseline Characteristics of HF Patients Who Underwent Bariatric Surgery (n = 524)

Age, yrs	49 (39–58)
Female	365 (69.8)
Race/ethnicity*	
Non-Hispanic white	308 (65.4)
Non-Hispanic black	87 (18.5)
Hispanic	63 (13.4)
Other	13 (2.8)
Primary insurance	
Medicare	148 (28.2)
Medicaid	55 (10.5)
Private	278 (53.0)
Other	43 (8.2)
Quartiles for median household income of patient's zip code	
1 (lowest)	142 (27.6)
2	143 (27.8)
3	140 (27.2)
4 (highest)	89 (17.3)
Season of bariatric surgery	
January–March	103 (19.7)
April–June	133 (25.4)
July–September	137 (26.2)
October–December	151 (28.8)
State	
California	292 (55.7)
Florida	198 (37.8)
Nebraska	34 (6.5)

Values are median (interquartile range) or n (%). *Analyzed for 471 (89.9%) patients with race/ethnicity data. Race/ethnicity data were not available in Nebraska.
HF = heart failure.

Table 1 shows the demographic characteristics of the enrolled patients. The median age of patients was 49 years, and 69.8% were women.

The Central Illustration depicts the rate of ED visits or hospitalizations for HF exacerbation during the pre- and post-surgery periods by 6-month intervals. In the reference period (i.e., 13 to 24 months before bariatric surgery), 16.2% (95% CI: 13.1% to 19.4%) of patients had at least 1 ED visit or hospitalization for HF exacerbation (Table 2). In the subsequent period of 1 to 12 months before surgery, the rate did not materially change (15.3%; 95% CI: 12.2% to 18.4%), with a corresponding adjusted OR of 0.93 (95% CI: 0.67 to 1.30; p = 0.67). By contrast, there was a nonsignificantly reduced rate of ED visits or hospitalizations for HF exacerbation occurring within 12 months post-bariatric surgery (12.0%; 95% CI: 9.2% to 14.8%), corresponding to an adjusted OR of 0.71 (95% CI: 0.50 to 1.00; p = 0.052). In the subsequent period of 13 to 24 months after bariatric surgery, the rate was significantly lower (9.9%; 95% CI: 7.4% to 12.5%), corresponding to an adjusted OR of 0.57 (95% CI: 0.39 to 0.82; p = 0.003). In the analysis of secondary outcomes, the rate of HF exacerbation after bariatric surgery declined for the 2 component events individually in 2 years: ED visit and hospitalization (Table 2).

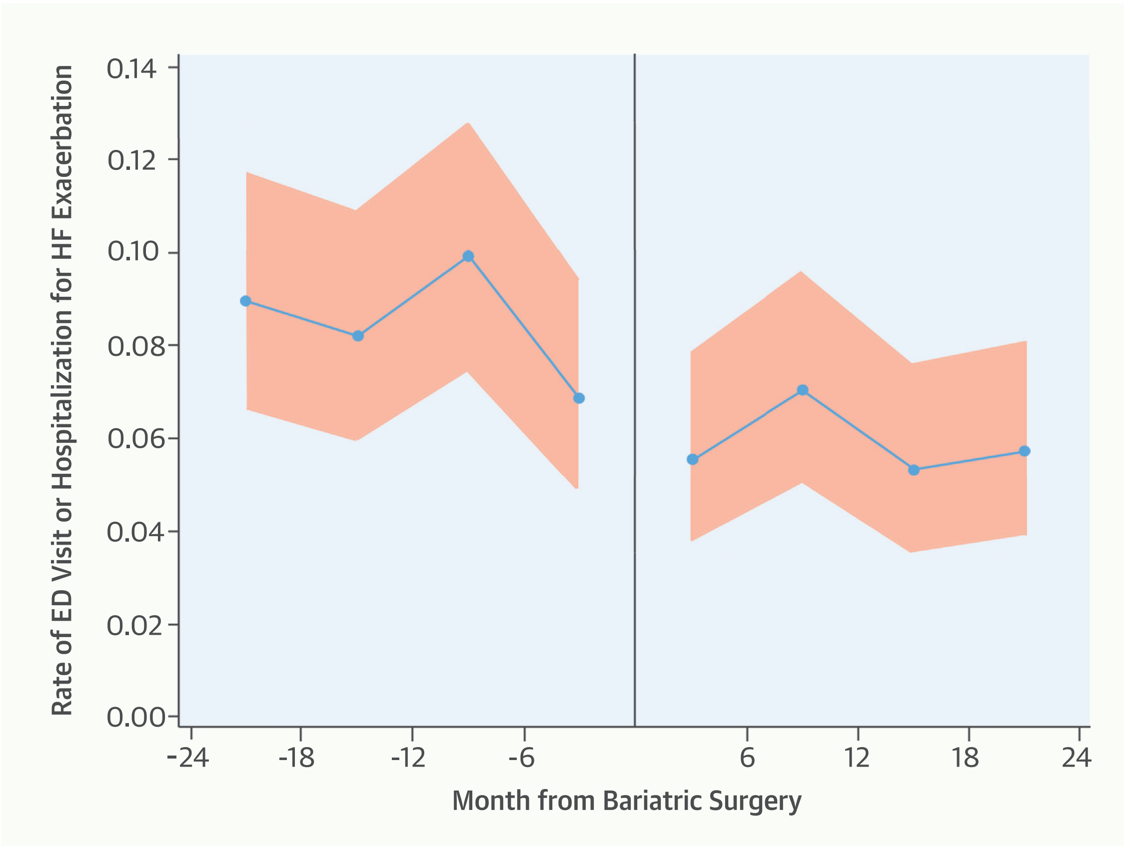
In the sensitivity analysis, without limiting the patient population to those with any health care utilization during 25 to 36 months after bariatric surgery (n = 1,664), the results did not change materially, but had a greater statistical significance (Online Table 1). Similarly, the temporal pattern in the rate of HF exacerbation persisted with modeling the outcome as a count variable (Table 3). By contrast, the rate of ED visits or hospitalizations with a non-HF diagnosis (chronic obstructive pulmonary disease, pneumonia, or dyspnea) did not change before and after bariatric surgery (Table 4). Additionally, in separate self-controlled case series analyses using the obese adults with HF who underwent cholecystectomy (n = 2,240) or hysterectomy (n = 851), the rate of ED visits or hospitalizations for HF exacerbation either increased or did not change significantly after these nonbariatric surgeries (Table 5). The rate reduction after bariatric surgery was consistent across the age strata (Online Table 2).

DISCUSSION

PRINCIPAL FINDINGS AND CONTEXT. This self-controlled case series study using the largest dataset of patients with HF who underwent bariatric surgery showed that the rate of ED visits or hospitalizations for HF exacerbation was reduced by 40% after bariatric surgery (Central Illustration). A major strength of this study is that each patient functioned as a control for him/herself, effectively controlling for both measured and unmeasured confounders. The observed decrease in the rate of HF exacerbation was substantial and consistent across different statistical assumptions. The rate of ED visit and hospitalization for other diseases that can mimic HF exacerbation remained stable after bariatric surgery, limiting the possibility of misdiagnosing HF exacerbations as non-HF events post-surgery. We also addressed the possibility that the reduction in the rate of HF exacerbation was related to intensified HF management during the perisurgical period by demonstrating that nonbariatric surgeries had no favorable impact on the rate of HF exacerbation.

The evidence regarding the effectiveness of weight reduction on HF-related symptoms and health care utilization is scarce. A few small, single-center retrospective studies showed improvement in some clinical endpoints (11,20–22). Of these, the best evidence comes from a retrospective chart review study

CENTRAL ILLUSTRATION Bariatric Surgery and HF Exacerbation: Rate of HF Exacerbation Before and After Bariatric Surgery in a 6-Month Interval



Shimada, Y.J. et al. J Am Coll Cardiol. 2016; 67(8):895–903.

Obesity has been linked to HF exacerbations; however, it is unknown whether substantial weight loss lowers the rate of HF exacerbations. The present study analyzed 524 patients to investigate whether bariatric surgery is associated with decreased rate of HF exacerbation. This graph shows the proportion of patients who had an ED visit or hospitalization for HF exacerbation before and after surgery. The rate declined significantly after bariatric surgery in 2 years. This study provides the best evidence on the effectiveness of bariatric surgery on HF morbidity, and will prompt further investigation into the underlying mechanisms and optimal weight management strategies for obese patients with HF. ED = emergency department; HF = heart failure.

(n = 22). This study reported that morbidly obese patients with HF who underwent bariatric surgery had a lower rate of hospital readmission at 1 year and improvement in LV ejection fraction (LVEF) and New York Heart Association functional class compared with matched controls (11). Our rigorously designed study with a much larger sample size (n = 524) and longer follow-up period corroborated these findings and extended prior research by demonstrating the robustness of the observed benefit in a real-world setting.

OBESITY PARADOX AND MORTALITY DATA AFTER BARIATRIC SURGERY. There is emerging evidence of an "obesity paradox" in patients with chronic HF wherein mild-to-moderate obesity is associated with improved survival (23,24). However, no study has reported increased mortality or HF morbidity with weight reduction interventions in morbidly obese patients. Indeed, in a retrospective cohort study of moderately to severely obese patients with type 2 diabetes mellitus, the 2,580 patients who underwent bariatric surgery showed reduced mortality compared with nonbariatric control patients (1.6% vs. 7.5% with a median follow-up period of 20 months) (25). Hence, current American, Canadian, and European guidelines recommend weight reduction in this population. Bariatric surgery is known to have low post-operative mortality: 0.05% to 0.1% at 30 days (26), 0.38% to

TABLE 2 Rates of ED Visits or Hospitalizations for HF Exacerbation

Time Interval and Outcome	Number of Patients (N = 524)	Rate, % (95% CI)	aOR (95% CI)*	p Value
13–24 months before bariatric surgery				
ED visit or hospitalization†	85	16.2 (13.1–19.4)	Reference	–
ED visit‡	18	3.4 (1.9–5.0)	Reference	–
Hospitalization§	73	13.9 (11.0–16.9)	Reference	–
1–12 months before bariatric surgery				
ED visit or hospitalization†	80	15.3 (12.2–18.4)	0.93 (0.67–1.30)	0.67
ED visit‡	10	1.9 (0.7–3.1)	0.51 (0.22–1.17)	0.11
Hospitalization§	75	14.3 (11.3–17.3)	1.03 (0.73–1.46)	0.86
0–12 months after bariatric surgery				
ED visit or hospitalization†	63	12.0 (9.2–14.8)	0.71 (0.50–1.003)	0.052
ED visit‡	8	1.5 (0.5–2.6)	0.40 (0.16–0.97)	0.043
Hospitalization§	58	11.1 (8.4–13.8)	0.77 (0.53–1.11)	0.16
13–24 months after bariatric surgery				
ED visit or hospitalization†	52	9.9 (7.4–12.5)	0.57 (0.39–0.82)	0.003
ED visit‡	7	1.3 (0.3–2.3)	0.34 (0.13–0.87)	0.016
Hospitalization§	48	9.2 (6.7–11.6)	0.62 (0.42–0.91)	0.025

*Adjusted odds ratios are for each 12-month period versus the reference period (13 to 24 months before the index bariatric surgery), as calculated with conditional logistic regression. †Composite of at least 1 ED visit or hospitalization for HF exacerbation. ‡At least 1 ED visit for HF exacerbation, not resulting in hospitalization. §At least 1 hospitalization for HF exacerbation.

aOR = adjusted odds ratio; CI = confidence interval; ED = emergency department; HF = heart failure.

0.6% at 1 year (27), and 2.5% with 8 to 14 years of follow-up, which was lower than that in an age-, sex-, and race/ethnicity-matched general population (28). Additionally, the mortality rates after bariatric surgery are comparable to those after nonbariatric surgeries such as cholecystectomy (0.5% at 30 days [29] and 1.0% at 1 year [30]), and hysterectomy (0.7% at 30 days [31] and 1.8% at 3 years [32]). However, it should also be noted that previous studies consistently reported that HF is associated with a 5- to 10-fold increase in post-operative mortality (26,27,33,34). Findings from the present study add to the body of knowledge by indicating that bariatric surgery for patients with obesity and HF may offer additional benefit by reducing the rate of HF exacerbation.

STRENGTHS OF THE STUDY DESIGN. To further investigate the effectiveness of bariatric surgery on HF-related clinical outcomes such as exercise capacity and mortality, a high-quality randomized controlled trial involving obese patients who are at high risk of developing HF exacerbation would be necessary. However, such a trial may pose significant financial and logistical challenges (35). Furthermore, patients enrolled in randomized controlled trials may be different or behave differently from the general population in the real world, thereby undermining external validity (generalizability) of such trials (36,37). By contrast, our population-based cohort of patients receiving care in the natural setting enhanced the external validity of the findings. The self-controlled case series study design also augmented the internal validity of our findings because it effectively eliminated interpersonal variations and allowed for more precise assessment of exposure effects. Moreover, because each patient served as a control for him/herself, this study design controlled for all time-invariant confounders, addressing the influence of residual confounding inherent in traditional case-control or other observational study designs.

TABLE 3 Rate Ratios for ED Visits and Hospitalizations for HF Exacerbation, Using Negative Binomial Regression Model

ED Visit or Hospitalization*	Rate Ratio (95% CI)†	p Value
13–24 months before bariatric surgery	Reference	–
1–12 months before bariatric surgery	0.99 (0.73–1.35)	0.95
0–12 months after bariatric surgery	0.77 (0.54–1.09)	0.14
13–24 months after bariatric surgery	0.63 (0.42–0.93)	0.021

*Number of ED visits and hospitalizations for HF exacerbation. †Rate ratios are for each 12-month period versus the reference period (13 to 24 months before the index bariatric surgery), as calculated with the negative binomial regression model with generalized estimating equations.

Abbreviations as in Table 2.

ACCURACY OF EXPOSURE AND OUTCOME IDENTIFICATION. As with any studies using administrative data, misclassification of the exposure and outcome is possible. With regard to obesity, the specificity of ICD-9-CM coding for obesity was reported to be 99.4% (95% CI: 98.7% to 99.8%), which essentially excluded patients without obesity from the present study (38). With regard to the outcome, patients with morbid obesity can develop dyspnea due to non-HF causes, such as restrictive lung disease and deconditioning. Such non-HF events could also be coded as HF because of concomitant lower extremity edema due to venous insufficiency. However, physical examination findings of HF (e.g., jugular venous distention and crackles in the lungs) may be more difficult to detect and B-type natriuretic peptide (BNP) concentrations are known to be falsely low (39,40) in morbidly obese patients presenting with HF exacerbation. Both of these factors would have led to more frequent detection of HF after bariatric surgery, thereby biasing the results towards the null. It has been shown that the algorithms and definitions to identify HF using administrative data perform well, particularly when using a primary hospital discharge diagnosis (18,41). A systematic review of more than 30 studies reported that these ICD-9-CM codes for HF had a high specificity and positive predictive value, with most reporting values >95% (41). Most of these studies used the Framingham Heart Study criteria, whereas others utilized the Carlson and National Health and Nutrition Examination Survey criteria for

TABLE 4 Rates of ED Visits or Hospitalizations for COPD, Pneumonia, or Dyspnea

ED Visit or Hospitalization*	Number of Patients (N = 524)	Rate % (95% CI)	aOR (95% CI)†	p Value
13–24 months before bariatric surgery	29	5.5 (3.6–7.5)	Reference	–
1–12 months before bariatric surgery	33	6.3 (4.2–8.4)	1.17 (0.67–2.06)	0.57
0–12 months after bariatric surgery	34	6.5 (4.4–8.6)	1.22 (0.70–2.13)	0.48
13–24 months after bariatric surgery	34	6.5 (4.4–8.6)	1.22 (0.70–2.13)	0.48

*Composite of at least 1 ED visit or hospitalization for chronic obstructive pulmonary disease (COPD), pneumonia, or dyspnea. †Adjusted odds ratios are for each 12-month period versus the reference period (13 to 24 months before the index bariatric surgery), as calculated with conditional logistic regression.
Abbreviations as in Table 2.

validation (41). Additionally, our sensitivity analysis addressed, at least partially, possible differential misclassification by demonstrating unchanged rates of ED visit and hospitalization for non-HF conditions (i.e., chronic obstructive pulmonary disease, pneumonia, or dyspnea) after surgery. Therefore, it would be unlikely that more HF events were misclassified as non-HF conditions that can cause dyspnea preferentially after bariatric surgery.

POTENTIAL MECHANISMS LINKING OBESITY AND HF. A large body of evidence supports an important role for obesity in HF-related morbidity. Indeed, several epidemiological studies reported strong associations between obesity and HF exacerbation, and displayed a dose-response relationship between BMI and the rate of hospitalizations for HF exacerbation in obese patients (5–7). There are also plausible pathophysiological links between obesity and HF-related morbidity. Prior research has linked obesity with increased cardiac output; LV hypertrophy and diastolic dysfunction; right heart failure through LV dysfunction or sleep apnea; and neurohormonal and metabolic abnormalities, such as activation of the renin-angiotensin-aldosterone axis and sympathetic nervous system or hyperinsulinemia, hyperleptinemia, and lipotoxicity, in patients with HF (8,10).

If a causal relationship exists between obesity and HF-related morbidity, weight loss can theoretically reduce the rate of HF exacerbation. Physiological studies using human models have indicated that a substantial weight loss can reverse some of these obesity-HF links (8,9). Furthermore, in the present study, bariatric surgery was associated with a large and sustained decline in the rate of HF exacerbation. Taken together, these data lend significant support to the concept that substantial weight reduction can reverse the obesity-HF morbidity link.

STUDY LIMITATIONS. First, our study did not have information on body weight reduction. However, it is well documented in the literature that bariatric surgery leads to a substantial, rapid, and sustained weight loss (42). For instance, after a Roux-en-Y gastric bypass surgery, a prompt weight loss occurs within a few months and persists for the next 12 to 18 months in patients with obesity. The mean weight loss was 35%, corresponding to approximately 70% reduction of excess weight (42). These data support

TABLE 5 Rates of ED Visits or Hospitalizations for HF Exacerbation: Patients Who Underwent Nonbariatric Surgery

Time Interval and Surgery	Number of Patients	Rate % (95% CI)*	aOR (95% CI)†	p Value
Cholecystectomy (n = 2,240)				
13–24 months before surgery	339	15.1 (13.6–16.6)	Reference	–
1–12 months before surgery	417	18.6 (17.0–20.2)	1.30 (1.11–1.53)	0.001
0–12 months after surgery	435	19.4 (17.8–21.1)	1.38 (1.17–1.62)	<0.001
13–24 months after surgery	424	18.9 (17.3–20.6)	1.33 (1.13–1.57)	<0.001
Hysterectomy (n = 851)				
13–24 months before surgery	92	10.8 (8.7–12.9)	Reference	–
1–12 months before surgery	101	11.9 (9.7–14.0)	1.12 (0.82–1.52)	0.48
0–12 months after surgery	118	13.9 (11.5–16.2)	1.35 (1.001–1.82)	0.049
13–24 months after surgery	125	14.7 (12.3–17.1)	1.45 (1.08–1.95)	0.014

*Composite of at least 1 ED visit or hospitalization for HF exacerbation. †Adjusted odds ratios are for each 12-month period versus the reference period (13 to 24 months before surgery), as calculated with conditional logistic regression.
Abbreviations as in Table 2.

JACC VOL. 67, NO. 8, 2016
MARCH 1, 2016:895–903

bariatric surgery being used as an instrument for substantial weight loss. Additionally, the expected weight reduction after bariatric surgery reported in the literature was paralleled by the decline in the rate of HF exacerbation observed in our study. Second, we did not have data on LVEF. However, in our database, 184 HF events were coded as either systolic (43%) or diastolic HF (57%). This is consistent with another study of morbidly obese patients with HF; 40% had HF with reduced LVEF (43). Third, our datasets did not capture data on BNP. However, obese patients are known to have falsely low BNP (39,40), which undermines the value of baseline BNP measurement in our target population. Moreover, BNP values after bariatric surgery might be affected by the change in the patient's weight, further limiting the value of BNP data in this population of interest. Finally, the probability of bariatric surgery (the exposure) may not be independent from a prior HF exacerbation event (the outcome). For example, an episode of HF exacerbation during the pre-surgical period might have lowered the probability of undergoing bariatric surgery. However, this possibility would have created an upward bias in the post-surgical period, thereby pulling the results towards the null (15,44).

CONCLUSIONS

Using a large real-world population and a self-controlled case series study design, we found that bariatric surgery was associated with a significant reduction in the rate of ED visits and hospitalizations for HF exacerbation in obese adults with HF. Supported by prior studies demonstrating links between obesity and HF exacerbation, the present study provided the best evidence on the effectiveness of substantial weight loss on HF morbidity. Because a large proportion of obese patients with HF would not undergo bariatric surgery for various reasons, including initial high cost and risk of perisurgical complications, the present study also stressed the importance of developing effective nonsurgical interventions that achieve a substantial and sustained weight reduction. Research for establishing such methods should progress hand-in-hand with extensive public health programs to prevent development of obesity to begin with, which will, in turn, benefit many obese patients with HF.

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PERSPECTIVES

COMPETENCY IN PATIENT CARE AND PROCEDURAL SKILLS: In patients with obesity, bariatric surgery was associated with a lower likelihood of emergency department visits or hospitalizations for HF exacerbation within 2 years post-operatively.

TRANSLATIONAL OUTLOOK: Additional investigation is needed to identify the mechanism by which bariatric surgery reduces the risk of HF exacerbations.

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APPENDIX For supplemental tables, please see the online version of this article.