### Title

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# Bariatric surgery is associated with lower risk of acute care use for cardiovascular disease in obese adults

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## Abstract

**Aims—**Studies have suggested relationships between obesity and cardiovascular disease (CVD) morbidity. However, little is known about whether substantial weight reduction affects the risk of CVD-related acute care use in obese patients with CVD. The objective of this study was to determine whether bariatric surgery is associated with decreased risk of CVD-related acute care use.

**Methods and results—**We performed a self-controlled case series study of obese adults with CVD who underwent bariatric surgery, using population-based emergency department (ED), and inpatient samples in California, Florida, and Nebraska from 2005 to 2011. The primary outcome was ED visit or unplanned hospitalization for CVD. We used conditional logistic regression to compare the risk during sequential 12-month periods, using pre-surgery months 13–24 as the reference period. We identified 11 106 obese adults with CVD who underwent bariatric surgery.

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Supplementary material
Supplementary material is available at *Cardiovascular Research* online.

**Conflict of interest:** none declared.

During the reference period, 20.6% [95% confidence interval (CI), 19.8–21.3%] of patients had an ED visit or unplanned hospitalization for CVD. The risk did not significantly change in the subsequent 12-month pre-surgery period [adjusted odds ratio (aOR) 0.98; 95% CI, 0.93–1.04; $P = 0.42$]. By contrast, in the first 12-month period after bariatric surgery, the risk significantly decreased (aOR 0.91; 95% CI, 0.86–0.96; $P = 0.002$). The risk remained reduced in the subsequent 13–24 months post-bariatric surgery (aOR 0.84; 95% CI, 0.79–0.89; $P < 0.001$). There was no reduction in the risk in separate obese populations that underwent non-bariatric surgery (i.e. cholecystectomy, hysterectomy). By CVD category, the risk of acute care use for coronary artery disease (CAD), heart failure (HF), and hypertension decreased after bariatric surgery, whereas that of dysrhythmia and venous thromboembolism transiently increased (Bonferroni corrected $P < 0.05$ for all comparisons).

**Conclusion—**Bariatric surgery is associated with a lower risk of overall CVD-related ED visit or unplanned hospitalization. The decline was mainly driven by reduced risk of acute care use for CAD, HF, and hypertension after bariatric surgery.

**Keywords**

Bariatric surgery; Cardiovascular disease; Obesity; Self-controlled case series study

## 1. Introduction

Cardiovascular disease (CVD) is the leading public health problem in the US, affecting approximately one-third (92 million) of American adults.[1] The burden of healthcare utilization for CVD within the US healthcare system is substantial, accounting for 4.4 million emergency department (ED) visits and 5.8 million hospitalizations in 2010 alone.[1] The estimated direct and indirect costs of CVD were $316 billion in 2012.[1] At the same time, the nation has also experienced an obesity epidemic—approximately 35% of men and 40% of women are obese.[2]

Obese patients often have multiple cardiovascular comorbidities given that obesity is an established risk factor for various CVDs [e.g. coronary artery disease (CAD), heart failure (HF), hypertension, dysrhythmia, and venous thromboembolism (VTE)].[1] Bariatric surgery is the most effective method to achieve substantial and sustained weight loss.[3] However, past studies on the effects of bariatric surgery on CVD have mainly focused on ischaemic cardiovascular outcomes (e.g. myocardial infarction) and atherosclerotic risk factors such as hypertension, dyslipidaemia, and diabetes mellitus.[4–7] No studies have examined the effectiveness of bariatric surgery on the overall CVD morbidities inclusive of ischaemic and non-ischaemic outcomes. Additionally, bariatric surgery may have different effects on the risk of each category of CVD. While bariatric surgery can theoretically decrease the risk of ischaemic cardiovascular events, surgery in general is known to increase the risk of non-ischaemic cardiovascular events such as dysrhythmia and VTE postoperatively.[8,9] However, the effectiveness of bariatric surgery on the risk of acute care use (e.g. ED visit, unplanned hospitalization) for individual CVD categories is largely unknown.

To address these major knowledge gaps in the literature, we designed this study to investigate whether bariatric surgery is associated with a reduction in the risk of ED visit or unplanned hospitalization for all CVD among obese adults. We also aimed to determine changes in the risk of individual CVD categories after bariatric surgery.

## 2. Methods

### 2.1 Study design and setting

We performed a self-controlled case series study in obese adults who experienced both the exposure (bariatric surgery) and the outcome (ED visit or unplanned hospitalization for CVD). The present study fulfils the required assumptions of the self-controlled case series design because the exposure is transient and discrete and the outcome is an acute event.[10] We selected this study design because it enables intra-person comparisons where every patient serves as his or her own control.[10] Therefore, a control group was not necessary. This study design also minimizes confounding by unmeasured factors as all time-invariant variables are implicitly controlled.[10]

We used the Healthcare Cost and Utilization Project (HCUP) State Emergency Department Databases (SEDD) and State Inpatient Databases (SID) in three states (California, Florida, and Nebraska) from 1 January 2005 to 31 December 2011.[11,12] We chose these states because of geographic diversity and unique patient identifiers that enabled us to perform longitudinal follow-up throughout the study years. The HCUP is the largest longitudinal hospital care data collection available in the US.[11,12] In the participating states, all ED visits regardless of disposition are captured in the HCUP SEDD,[11] and all inpatient discharges regardless of source of hospitalization are recorded in the SID.[12] By integrating the HCUP SEDD and SID, we identified all ED visits and hospitalizations within the three study states.[11,12] Details of the self-controlled case series study design and databases have been published previously.[5–7,11–14] The institutional review boards of Massachusetts General Hospital and Columbia University Medical Center approved this study.

### 2.2 Study population

To identify all obese adults with CVD who underwent bariatric surgery and also experienced an ED visit or unplanned hospitalization for CVD within the study states, we took the following steps. First, we identified adults aged >_18 years with obesity by using the *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnosis codes 278.0–278.1, V77.8, V85.3x, and V85.4.[5–7,13–15] Second, we selected patients who had at least one hospitalization for bariatric surgery by using the *ICD-9-CM* procedure codes 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.[5–7,13–15] We excluded patients with diagnostic codes for gastrointestinal cancer (*ICD-9-CM* codes, 150.0–159.9).[5–7,13–15] We only included patients who had bariatric surgery between 1 January 2007 and 31 December 2009 to collect data on the outcome event within 2 years before and after surgery. Last, we further identified patients with at least one ED visit or unplanned hospitalization for CVD between 1 January 2005 and 31 December 2011 among these obese adults who underwent bariatric surgery by using the *Clinical Classifications Software* (*CCS*) codes 96–121 in the primary *CCS* field.[16] We excluded residents outside the study states and patients who died during the hospitalization for bariatric surgery, died in-hospital within 2 years after bariatric surgery, or had two or more bariatric surgeries during the study period.[5–7,13–15]

### 2.3 Measurements and outcomes

We retrieved data from the HCUP SEDD and SID on demographics (age, sex, and race/ethnicity), primary insurance type, quartiles for estimated median household income of residents in the patient's ZIP code, *ICD-9-CM* diagnosis, procedures, season of surgery, and state. We used the baseline characteristics information recorded during the index hospitalization for bariatric surgery.

The primary outcome measure was an ED visit or an unplanned hospitalization with a primary diagnosis of CVD. As an additional analysis, we further examined the five most common CVD categories individually (i.e. CAD, HF, hypertension, dysrhythmia, and VTE). These five categories were chosen based on the number of patients with an ED visit or unplanned hospitalization during the reference period (i.e. pre-surgery months 13–24) according to the *CCS* categories for CVDs (i.e. *CCS* category 96–121).[16]

### 2.4 Statistical analysis

Adjusted odds ratios (aORs) were calculated by fitting a conditional logistic regression model—using pre-surgery months 13–24 as the reference period—for 1–12 months before surgery, 0–12 months after surgery, and 13–24 months after surgery. Each patient was matched to his or her own reference period. Several sensitivity analyses were performed to test the robustness of our inferences. First, the main analysis was repeated by stratifying by age group (18–44 years, 45–59 years, and >_60 years), sex, or race/ethnicity (non-Hispanic white, non-Hispanic black, and Hispanic).[17] Second, by fitting a negative binomial regression model, the number of ED visits and unplanned hospitalizations for CVD was modelled as a count, instead of a binary, variable. Third, a sensitivity analysis was performed including patients who died in-hospital during the 2-year post-surgery period. To account for the shorter follow-up duration than 12 months in each 12-month period due to death, the off-set function (i.e. log[patient-years within each 12-month period]) was used with the Poisson regression analysis. Fourth, to address the possibility of loss to follow-up (e.g. out-of-hospital deaths, emigration from the study states), which would downwardly bias the post-surgery estimates, and a subgroup analysis was conducted by limiting the population to those with any ED visit or hospitalization during post-surgery 25–36 months. Fifth, two separate populations were also examined—obese adults who underwent other types of elective abdominal surgery: (i) cholecystectomy (*ICD-9-CM* procedure codes, 51.21–51.24, and 51.41–51.59) and (ii) hysterectomy (*ICD-9-CM* procedure codes, 68.31–68.79, and 68.9).[5,7,13] These two non-bariatric surgeries were selected because of a large sample size, similar characteristics (i.e. common abdominal elective surgery), and no biological plausibility to affect weight or risks of the primary outcome.[5,7,13] Additionally, a formal test for interaction between time (before vs. after surgery) and type of surgery (bariatric vs. non-bariatric surgery) was performed to examine whether changes in the risk differed between bariatric and non-bariatric surgery. Finally, another sensitivity analysis was performed to examine if the risk of ED visit or unplanned hospitalization for any reason changed before and after bariatric surgery.



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All analyses were performed at a two-sided significance level of 0.05. All confidence intervals (CIs) were reported as two-sided values with a confidence level of 95%. For the analyses of the five most common CVD categories, *P*-values were corrected according to the Bonferroni method to account for multiple comparisons. Statistical analyses were performed with R software, version 3.3.2. (www.r-project.org).

## 3. Results

Among adult patients with obesity who underwent bariatric surgery and had at least one ED visit or unplanned hospitalization for CVD, 246 patients died in-hospital and 281 had multiple bariatric surgeries; the remaining 11 106 patients were included in the analysis. The baseline characteristics are described in Table 1. Overall, the median age was 48 years (interquartile range, 40–57 years), 73.6% were female, and 63.7% were non-Hispanic white.

The risk of ED visit or unplanned hospitalization for overall CVD is summarized in Table 2. During the reference period of pre-bariatric surgery 13–24 months, 20.6% (95% CI 19.8–21.3%) experienced an ED visit or unplanned hospitalization for CVD. The risk remained unchanged at 20.3% (95% CI 19.6–21.1%) during the subsequent 1–12 months prior to bariatric surgery with aOR of 0.98 (95% CI 0.93–1.04; $P = 0.42$). By contrast, the risk was significantly lower after bariatric surgery. Within 0–12 months following surgery, 18.9% (95% CI 18.1–19.6%) had an ED visit or unplanned hospitalization for CVD (aOR 0.91, 95% CI 0.86–0.96; $P = 0.002$). The risk remained lower during 13–24 months after bariatric surgery at 17.4% (95% CI 16.7–18.2%), corresponding to an aOR of 0.84 (95% CI 0.79–0.89; $P < 0.001$).

The sensitivity analyses demonstrated the robustness of the findings. The stratified analyses by age group (Supplementary material online, Figure S1), sex (Supplementary material online, Figure S2), and race/ethnicity (Supplementary material online, Figure S3) showed a similar temporal risk pattern. When the outcome was modelled as a count variable as opposed to a binary variable with the use of negative binomial regression model, the risk of primary outcome also decreased during 0–12 months and 13–24 months after bariatric surgery (both $P < 0.001$; Supplementary material online, Table S1). The sensitivity analysis including those who died after surgery was also consistent with the main analysis (Supplementary material online, Table S2). Subgroup analysis limiting to those with any healthcare utilization during 25–36 months after bariatric surgery replicated the results with a reduced statistical power (Supplementary material online, Table S3). Contrary to the findings in the population with bariatric surgery, the risk of ED visit or unplanned hospitalization for CVD did not decrease in obese populations that underwent an elective non-bariatric abdominal surgery (Table 3, Supplementary material online, Tables S4 and S5). There was a significant interaction between time period (before vs. after surgery) and type of surgery (bariatric vs. non-bariatric) with *P*-interaction of <0.001, indicating that the risk reduction after surgery was significantly different between bariatric and non-bariatric surgery. The sensitivity analysis including all ED visits and unplanned hospitalizations for any reason showed no decrease in the risk after bariatric surgery (Supplementary material online, Table S6).

With further classification of CVDs according to the *CCS* category, the five most common CVD categories were CAD, HF, hypertension, dysrhythmia, and VTE (Table 4). Compared with the reference period of 13–24 months before bariatric surgery, the risk of ED visit or unplanned hospitalization for CAD, HF, and hypertension decreased significantly after bariatric surgery (Figure 1A–C). By contrast, there was an increase in the risk of dysrhythmia and VTE during the 3-month post-surgery period, which returned to the baseline level during 3–6 months after surgery (Figure 1D and E).

## 4. Discussion

### 4.1 Principal findings

In this self-controlled case series study using population-based data of 11 106 patients with obesity and CVD, we found that the risk of acute care use for CVD was significantly reduced after bariatric surgery, and the lower risk lasted for at least 2 years. The significant temporal changes in the risk persisted across several subpopulations and analytical assumptions. Additionally, the observed decline in the risk was primarily driven by the lower risk of acute CVD events related to CAD, HF, and hyper-tension. By contrast, we observed a transiently increased risk of dysrhythmia and VTE after bariatric surgery. This is the first study that has investigated the association of bariatric surgery with acute care use for the overall (inclusive of ischaemic and non-ischaemic) and individual CVDs.

### 4.2 Results in context

There is emerging evidence that supports the effectiveness of bariatric surgery to prevent CVD-related healthcare utilization.[4–6] For example, in a cohort study of 2010 obese adults who underwent bariatric surgery and 2037 controls who received usual care, bariatric surgery was associated with lower incidence of a composite of cardiovascular death, myocardial infarction, and stroke.[4] However, prior studies on bariatric surgery have examined its effects exclusively on ischaemic cardiovascular outcomes and atherosclerotic risk factors (e.g. hypertension, dyslipidaemia, and diabetes mellitus) except for our recent report on HF exacerbation.[4–7] Furthermore, the risk reduction associated with bariatric surgery observed in ischaemic CVD and HF may not be universal in all categories of CVD. Surgery in general increases the risk of dysrhythmia and VTE post-operatively, particularly in obese individuals.[8,9] Indeed, the effect size of the present study on the overall CVD (aOR 0.84) was smaller than that in the prior reports on myocardial infarction and stroke (aOR 0.67),[4] CAD (aOR 0.33),[6] HF (aOR 0.57),[5] and hypertension-related acute care use (aOR 0.71).[7] This apparent discrepancy in the effect size may be attributable to the concurrent increase in the risk of dysrhythmia and VTE. Our study builds on these prior reports, and extends them by demonstrating the favourable association of bariatric surgery with the all-inclusive CVD as well as the divergent effectiveness on the individual CVD categories.

### 4.3 Advantages of the study design and databases

The influence of residual confounding by unmeasured variables is inherent in the traditional case-control or other cohort study designs. By contrast, the self-controlled case series design controls for all time-invariant confounders (e.g. patient characteristics, genetic background), both measured and unmeasured, because each patient serves as his or her own control.[10]

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This study design augments the internal validity by eliminating inter-personal variations to accurately determine the effects of the exposure (i.e. bariatric surgery in the present study).[10] These advantages of the self-controlled case series design have let to successful demonstration of the associations between surgical weight reduction and morbidity in a variety of cardiopulmonary conditions (e.g. asthma, stable angina, HF, hypertension, and atrial fibrillation).[5–7,13,14]

A large-scale, high-quality randomized controlled trial would be required to further delineate the efficacy of bariatric surgery on the risk of acute cardiovascular events. However, the financial and logistic burden associated with such a trial can be substantial. Moreover, the external validity of randomized controlled trials is sometimes limited because the participants may be selected and motivated individuals or may behave differently in the highly controlled environment.[18,19] In most of randomized controlled trials on bariatric surgery, for example, less than 10% of screened patients were enrolled and they had to be compliant with dietary and exercise instructions as well as follow-up visits.[20,21] By contrast, the external validity of the present study is strengthened because the HCUP SEDD and SID captured all ED visits and hospitalizations that occurred within the study states, thereby allowing for collection of large general population-based data of patient care in the natural setting. Further, our study population was racially/ethnically, socioeconomically, and geographically diverse. The comprehensiveness of the databases and inclusion of diverse populations in the real world enhance the external validity of the inferences derived from our study.

### 4.4 Potential limitations

Our study has several potential limitations. First, misclassification can occur with any study using administrative data. However, the HCUP databases and the *ICD-9-CM* codes have been extensively utilized and the quality has been tested in multiple prior studies.[5–7,13,14,22] For example, our method to identify obese patients was reported to have specificity of 99.4%.[23] With respect to the outcome, it has been shown that administrative data to identify HF- and hypertension-related acute care use perform well with a high specificity and positive predictive value, most reporting values of >95%.[24–26] Second, due to the observational nature of the present study, it does not prove causality or yield the same strength of evidence as a randomized controlled trial would. Third, patients might have lost to follow-up or died after bariatric surgery, thereby downwardly biasing our estimates during the post-surgery period. However, the sensitivity analysis showed consistent findings when we limited the population to patients who were confirmed to be alive for at least 2 years after surgery. Fourth, the observed decrease in the risk may be attributable to intensified management during the peribariatric surgery period, which may not be unique to bariatric surgery. However, it would be difficult to postulate that the reduction in the risk after bariatric surgery is fully attributable to intensified non-invasive treatment for the following reasons: (i) the substantial and immediate weight reduction after bariatric surgery reported in the literature[3] was paralleled by a significant decline in the risk in our study and (ii) no reduction in the risk was observed with elective non-bariatric surgery. Further, the formal test for interaction revealed that the change in the risk after surgery was significantly different between bariatric and non-bariatric populations. Fifth, our database did not include some potentially useful clinical data such as body mass index. Last, our study population of interest was obese adults with an ED visit or hospitalization for CVDs. Thus, our findings might not be generalizable to those with well-controlled CVDs. Yet, our study population contributes a large healthcare burden, and hence is the one for which targeted interventions are urgently needed.

## 5. Conclusions

In this self-controlled case series study with the use of large population-based data from three states in the US, we found that bariatric surgery is associated with a significantly lower risk of CVD-related acute healthcare utilization among obese adults with CVD. The risk reduction was mainly driven by the lower risk of morbidities related to CAD, HF, and hypertension after bariatric surgery. Our study also demonstrated a post-surgical increase in the risk of dysrhythmia and VTE. The present study provides the best evidence to date on the effectiveness of bariatric surgery on morbidities associated with CVD. Yet, many obese patients with CVD choose non-surgical weight reduction interventions due to concerns for peri-operative complications or other reasons (e.g. lack of insurance coverage, cost, and compliance). Our data stress the importance of developing safe and effective weight loss strategies, both surgical and non-surgical, to mitigate the large societal burden of CVD in obese patients.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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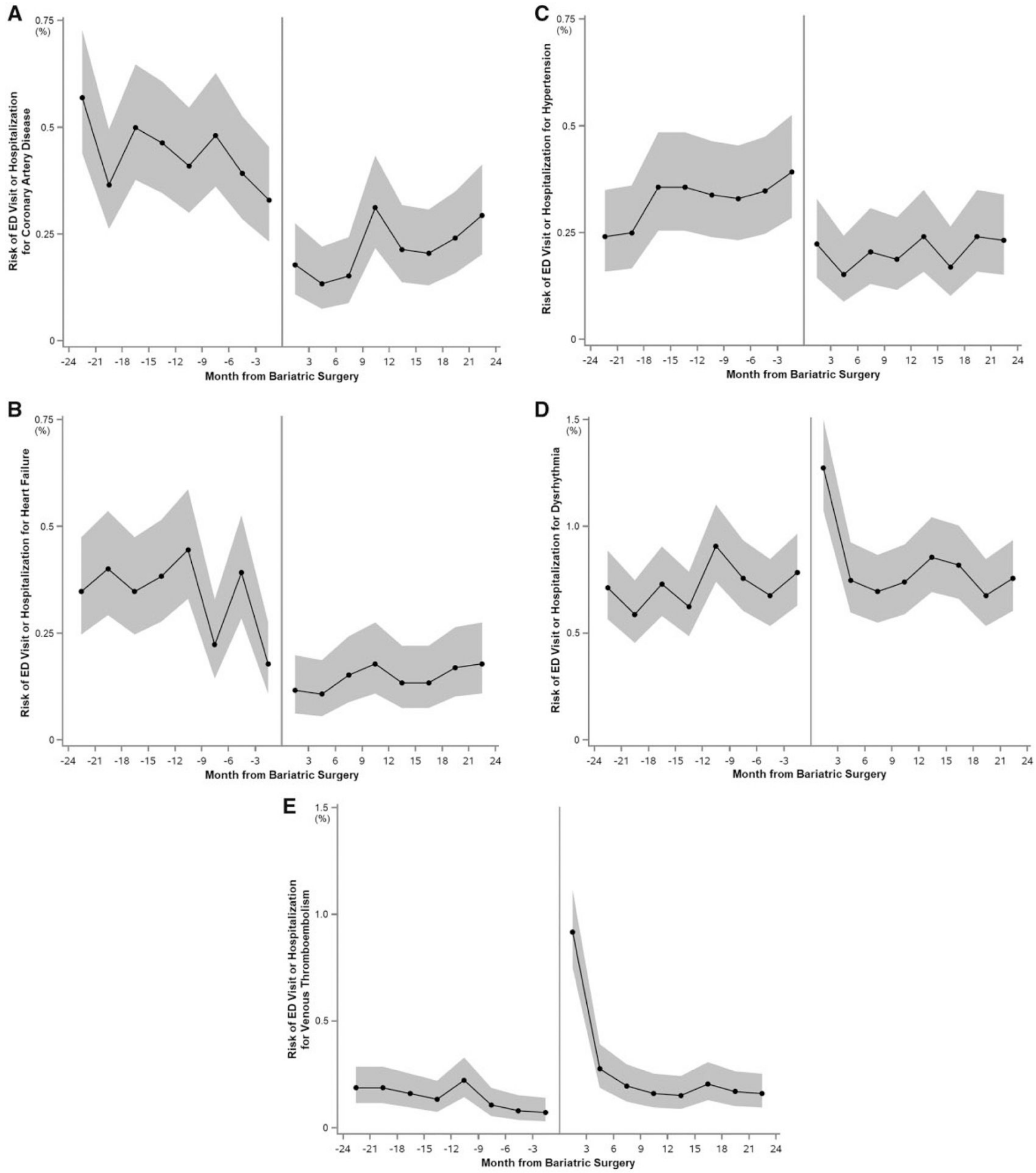


**Figure 1.**

Risk of emergency department visit or unplanned hospitalization for individual categories of cardiovascular disease before and after bariatric surgery in 3 months of interval. Proportion of patients with an ED visit or unplanned hospitalization for (*A*) coronary artery disease, (*B*) heart failure, (*C*) hypertension, (*D*) dysrhythmia, and (*E*) venous thromboembolism, with the 95% CIs for the 2 years before and after bariatric surgery in 3 months of intervals (*n* = 11 106). The periods were centred on the date of bariatric surgery of each patient. CI, confidence interval; ED, emergency department.

## Table 1

Baseline characteristics of obese adults with cardiovascular disease who underwent bariatric surgery

| Characteristics | *n* = 11 106 |
|---|---|
| Age (years), median (IQR) | 48 (40–57) |
| Female sex | 8171 (73.6) |
| Race/ethnicity[a] | |
| Non-Hispanic white | 7071 (63.7) |
| Non-Hispanic black | 1406 (12.7) |
| Hispanic | 1628 (14.7) |
| Other | 308 (2.8) |
| Primary insurance | |
| Medicare | 2232 (20.1) |
| Medicaid | 880 (7.9) |
| Private | 6993 (63.0) |
| Other | 1001 (9.0) |
| Quartiles for median household income of patient’s ZIP code | |
| 1 (lowest) | 2799 (25.2) |
| 2 | 3020 (27.2) |
| 3 | 2816 (25.4) |
| 4 (highest) | 2251 (20.3) |
| Season of bariatric surgery | |
| January–March | 2518 (22.7) |
| April–June | 2691 (24.2) |
| July–September | 2963 (26.7) |
| October–December | 2934 (26.4) |
| State | |
| California | 7285 (65.6) |
| Florida | 3608 (32.5) |
| Nebraska | 213 (1.9) |

Data were expressed as *n* (%), unless otherwise indicated.

IQR, interquartile range.

[a]Analyzed for 10 413 (93.8%) patients with race/ethnicity data. Race/ethnicity data were not available in Nebraska.

## Table 2

Number of patients and risk of emergency department visit or unplanned hospitalization for cardiovascular disease

| **Time interval** | **Number of patients** | **Risk (%) (95% CI)** | **aOR (95% CI)[a]** | ***P*-value** |
|---|---|---|---|---|
| ED visit or unplanned hospitalization[b] | ($n$ = 11 106) | | | |
| 13–24 months before bariatric surgery | 2284 | 20.6 (19.8–21.3) | Reference | – |
| 1–12 months before bariatric surgery | 2259 | 20.3 (19.6–21.1) | 0.98 (0.93–1.04) | 0.42 |
| 0–12 months after bariatric surgery | 2096 | 18.9 (18.1–19.6) | 0.91 (0.86–0.96) | 0.002 |
| 13–24 months after bariatric surgery | 1937 | 17.4 (16.7–18.2) | 0.84 (0.79–0.89) | <0.001 |

aOR, adjusted odds ratio; CI, confidence interval; ED, emergency department.

[a] Adjusted odds ratios are for each 12 months of period vs. the reference period (i.e. 13–24 months before bariatric surgery), as calculated with conditional logistic regression.

[b] Composite of at least one ED visit or unplanned hospitalization for cardiovascular disease.

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## Table 3

Number of patients and risk of emergency department visit or unplanned hospitalization for cardiovascular disease, among obese patients with cardiovascular disease who underwent non-bariatric surgery

| **Time interval and surgery** | **Number of patients** | **Risk (%) (95% CI)**[a] | **aOR (95% CI)**[b] | ***P*-value** |
|---|---|---|---|---|
| Cholecystectomy | (*n* = 10 554) | | | |
| 13–24 months before surgery | 2174 | 20.6 (19.8–21.4) | Reference | – |
| 1–12 months before surgery | 3013 | 28.5 (27.7–29.4) | 1.42 (1.34–1.50) | <0.001 |
| 0–12 months after surgery | 2602 | 24.7 (23.8–25.5) | 1.23 (1.16–1.30) | <0.001 |
| 13–24 months after surgery | 2485 | 23.5 (22.7–24.4) | 1.17 (1.10–1.24) | <0.001 |
| Hysterectomy | (*n* = 6194) | | | |
| 13–24 months before surgery | 1127 | 18.2 (17.2–19.2) | Reference | – |
| 1–12 months before surgery | 1381 | 22.3 (21.3–23.4) | 1.24 (1.14–1.34) | <0.001 |
| 0–12 months after surgery | 1385 | 22.4 (21.3–23.4) | 1.25 (1.15–1.35) | <0.001 |
| 13–24 months after surgery | 1472 | 23.8 (22.7–24.8) | 1.34 (1.24–1.45) | <0.001 |

aOR, adjusted odds ratio; CI, confidence interval.

[a]Adjusted odds ratios are for each 12 months of period vs. the reference period (i.e. 13–24 months before surgery), as calculated with conditional logistic regression.

[b]Composite of at least one emergency department visit or unplanned hospitalization for cardiovascular disease.

## Table 4

Number of patients and risk of emergency department visit or unplanned hospitalization for five most common categories of cardiovascular disease

| Time interval and CVD category[a] | Number of patients ($n$ = 11 106) | Risk (%) (95% CI)[b] | aOR (95% CI)[c] | Bonferroni-corrected $P$-value[d] |
|---|---|---|---|---|
| Coronary artery disease | | | | |
| 13–24 months before surgery | 190 | 1.7 (1.5–2.0) | Reference | – |
| 1–12 months before surgery | 170 | 1.5 (1.3–1.8) | 0.88 (0.71–1.08) | 0.99 |
| 0–12 months after surgery | 83 | 0.7 (0.6–0.9) | 0.42 (0.32–0.54) | <0.001 |
| 13–24 months after surgery | 99 | 0.9 (0.7–1.1) | 0.51 (0.40–0.65) | <0.001 |
| Heart failure | | | | |
| 13–24 months before surgery | 138 | 1.2 (1.0–1.5) | Reference | – |
| 1–12 months before surgery | 104 | 0.9 (0.8–1.1) | 0.75 (0.58–0.97) | 0.14 |
| 0–12 months after surgery | 52 | 0.5 (0.3–0.6) | 0.37 (0.27–0.51) | <0.001 |
| 13–24 months after surgery | 60 | 0.5 (0.4–0.7) | 0.42 (0.31–0.57) | <0.001 |
| Hypertension | | | | |
| 13–24 months before surgery | 127 | 1.1 (1.0–1.3) | Reference | – |
| 1–12 months before surgery | 151 | 1.4 (1.2–1.6) | 1.19 (0.94–1.51) | 0.73 |
| 0–12 months after surgery | 82 | 0.7 (0.6–0.9) | 0.64 (0.49–0.85) | 0.01 |
| 13–24 months after surgery | 94 | 0.8 (0.7–1.0) | 0.74 (0.57–0.97) | 0.14 |
| Dysrhythmia | | | | |
| 13–24 months before surgery | 271 | 2.4 (2.2–2.7) | Reference | – |
| 1–12 months before surgery | 322 | 2.9 (2.6–3.2) | 1.20 (1.02–1.41) | 0.13 |
| 0–12 months after surgery | 351 | 3.2 (2.8–3.5) | 1.31 (1.12–1.54) | 0.004 |
| 13–24 months after surgery | 315 | 2.8 (2.5–3.5) | 1.17 (1.00–1.38) | 0.27 |
| Venous thromboembolism | | | | |
| 13–24 months before surgery | 74 | 0.7 (0.5–0.8) | Reference | – |
| 1–12 months before surgery | 51 | 0.5 (0.3–0.6) | 0.69 (0.48–0.98) | 0.20 |
| 0–12 months after surgery | 162 | 1.5 (1.2–1.7) | 2.20 (1.67–2.90) | <0.001 |
| 13–24 months after surgery | 73 | 0.7 (0.5–0.8) | 0.98 (0.71–1.36) | 0.99 |

aOR, adjusted odds ratio; CI, confidence interval; CVD, cardiovascular disease.

[a]Five most common CVD categories were determined according to the number of patients with an emergency department visit or unplanned hospitalization during 13–24 months before bariatric surgery. The other tables include all CVD categories.

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[b] Composite of at least one emergency department visit or unplanned hospitalization.

[c] Adjusted odds ratios are for each 12 months of period vs. the reference period (i.e. 13–24 months before the index bariatric surgery), as calculated with conditional logistic regression.

[d] Corrected for comparisons of five categories.