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ORIGINAL RESEARCH

Reduced Risk of Cardiovascular Diseases After Bariatric Surgery Based on the New Predicting Risk of Cardiovascular Disease EVENTs Equations

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BACKGROUND: We applied the novel Predicting Risk of Cardiovascular Disease EVENTs equations to evaluate cardiovascular–kidney–metabolic (CKM) health and estimated cardiovascular disease (CVD) risk after bariatric surgery.

METHODS: Among 7804 patients (aged 20–79 years) undergoing bariatric surgery at Vanderbilt University Medical Center during 1999 to 2022, CVD risk factors from before surgery to 2 years after surgery were extracted from electronic health records. The 10- and 30-year risks of total CVD, atherosclerotic CVD, coronary heart disease, stroke, and heart failure (HF) were estimated for patients without CVD history at each time point (n=124–2910), using the social deprivation index–enhanced Predicting Risk of Cardiovascular Disease EVENTs equations. Paired *t* tests or McNemar tests were used to compare pre- with postsurgery CKM health and CVD risk. Two-sample *t* tests were used to compare CVD risk reduction between patient subgroups.

RESULTS: CKM health was significantly improved after surgery with lower systolic blood pressure, non–high-density lipoprotein cholesterol, and diabetes prevalence, and higher high-density lipoprotein and estimated glomerular filtration rate. The 10-year risks of total CVD and its subtypes decreased by 21.7% to 56.3% at 1 year after surgery and by 14.6% to 46.5% at 2 years after surgery, with the largest reduction observed for HF. Younger age, White race, >30% weight loss, and diabetes history were associated with greater HF risk reductions. Similar results were found for the 30-year CVD risk estimates.

CONCLUSIONS: Bariatric surgery significantly improves CKM health and reduces estimated CVD risk, particularly HF, by 47% to 56% within 1 to 2 years after surgery. HF risk reduction may vary by patient's demographics, weight loss, and disease history, which warrants further research.

Key Words: bariatric surgery ■ cardiovascular disease risk ■ cardiovascular–kidney–metabolic health ■ electronic health records ■ PREVENT equations

Cardiovascular diseases (CVDs), including mainly coronary heart disease (CHD), stroke, and heart failure (HF), are leading causes of death, accounting for 1 in every 5 deaths in the United States and 1 in every 3 deaths globally in recent years.[1–3] Obesity, diabetes, hypertension, dyslipidemia, and chronic kidney disease are established risk factors for CVD.[4] Bariatric surgery, the most effective and durable treatment for obesity and its related comorbidities, offers a long-lasting strategy for mitigating CVD

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CLINICAL PERSPECTIVES

What Is New?

- This is the first study applying the new Predicting Risk of Cardiovascular Disease EVENTs equations, which capture socioeconomic status and cardiovascular–kidney–metabolic health, among patients undergoing bariatric surgery to evaluate the cardiovascular disease risk before and after surgery.
- Compared with before surgery, the estimated 10-year risks of total cardiovascular disease and its subtypes (ie, atherosclerotic cardiovascular disease, coronary heart disease, stroke, and heart failure) reduced by 22% to 56% at 1 year after surgery and by 15% to 47% at 2 years after surgery, with the most significant reduction observed in heart failure risk, and the risk reduction may vary by patient's demographics, weight loss amount, and metabolic disease history.

What Are the Clinical Implications?

- Findings from this study provided new evidence on the cardiovascular–kidney–metabolic and cardiovascular disease health benefits of bariatric surgery, which may inform patient counseling and clinical decision making.

Nonstandard Abbreviations and Acronyms

CKM	cardiovascular–kidney–metabolic
FDR-*P*	false discovery rate–corrected *P* value
PREVENT	Predicting Risk of Cardiovascular Disease EVENTs
SDI	social deprivation index
VUMC	Vanderbilt University Medical Center

risk and risk factors. Bariatric surgery leads to a 30% weight loss while reducing hemoglobin A_{1c} (HbA_{1c}) by 0.3% to 2.7%, systolic blood pressure (SBP) by 7.2 to 15.1 mm Hg, and total cholesterol by 21.6 to 66.7 mg/dL and increasing estimated glomerular filtration rate (eGFR) by an average of 14.27 mL/min per 1.73 m^2 at 1 year after surgery.[5–10] In addition, bariatric surgery achieves remission rates ranging from 33% to 90% for diabetes, 43% to 83% for hypertension, 16% to 80% for dyslipidemia at 1 year after surgery, and 77% to 83% for albuminuria at 6 to 12 months.[11–15]

Regarding the risk of future CVD events, we recently reported a ≈34% reduction in 10-year atherosclerotic CVD (ASCVD) risk, in line with a 2020 review noting a 19% to 54% relative reduction in 10-year CVD risk 1 year after bariatric surgery.[9,16] All previous studies used well-known CVD risk models such as the Framingham Risk Score for 10-year CHD risk and the American College of Cardiology/American Heart Association pooled cohort equations for 10-year ASCVD risk. However, previous models have not accounted for the additional risk posed by reduced renal function or socioeconomic disadvantage nor predicted HF risk. Decreased eGFR, increased albuminuria, and living in an area with socioeconomic deprivation have been increasingly recognized for contributing to CVD incidence and death.[17–21] In response to this gap, a new CVD risk assessment tool, termed the Predicting Risk of Cardiovascular Disease EVENTs (PREVENT) equations, was introduced by the American Heart Association in 2023, aiming to assess total CVD risk more accurately, precisely, and equitably across diverse populations.[22] This new tool incorporates traditional risk factors and eGFR in the base model, offers additional predictors of renal (urine albumin-to-creatinine ratio), metabolic (HbA_{1c}), and social (social deprivation index [SDI]) risk in the add-on models for enhancement, and captures total CVD events, including HF, which was not included in previous models.[22]

Herein, by leveraging longitudinal data from the Surgical Weight Loss Clinic at Vanderbilt University Medical Center (VUMC) and electronic health records from all VUMC clinics, we evaluated post–bariatric surgery cardiovascular–kidney–metabolic (CKM) health improvement and CVD risk reduction, including total CVD, ASCVD, CHD, stroke, and HF, using the novel SDI-enhanced PREVENT equations. We also assessed the potential variations in CVD risk reduction among patients with different demographics (ie, age, sex, and race), operation types (Roux-en-Y gastric bypass versus sleeve gastrectomy), weight loss amount, and comorbidities (ie, diabetes, hypertension, and dyslipidemia). The results of this study would provide new evidence on the CKM and CVD health benefits of bariatric surgery, which may inform preoperative clinical discussions, postoperative management strategies, and future research on personalized patient care.

METHODS

To preserve patient confidentiality and private information, restrictions apply to the availability of data generated or analyzed during this study. The corresponding author will, upon reasonable request, detail the restrictions and any conditions under which access to some data may be provided.

Study Population and Data Extraction

This study was conducted in a bariatric surgery cohort, consisting of 7804 patients who were aged 20 to 79 years and underwent first-time bariatric surgery between January 1999 and July 2022 at VUMC.[9,23] The current analysis included patients who were free of CVD and had complete data for calculating pre- and postsurgery CVD risk. As a result, 245, 252, 264, 321, and 2910 patients were involved in comparing the risks of total CVD, ASCVD, CHD, stroke, and HF, respectively, before versus 1 year after surgery, and 124, 130, 136, 180, and 1478 patients were compared before versus 2 years after surgery. A flowchart of participants' inclusion is presented in Figure S1.

The Vanderbilt Metabolic and Bariatric Surgery Quality, Efficacy, and Safety database collected pre- and postsurgery data for up to 120 months at 3-month intervals, including demographics (eg, age, sex, and race), surgery information (eg, surgery date, surgeon, and operation type), disease history (eg, diabetes, hypertension, and dyslipidemia), and clinical outcomes (eg, body weight, body mass index [BMI], and HbA_{1c}). We linked the bariatric Quality Efficacy and Safety database with the complete VUMC electronic health records using medical record numbers and extracted additional data to minimize missingness in the Quality Efficacy and Safety database and obtain information on zip code for deriving SDI, smoking status, blood pressure, blood lipids, blood glucose, eGFR, disease diagnosis, and medication records. Data from before surgery to 2 years after surgery were used in the current study. The study was approved by the VUMC Institutional Review Board, with written informed consent waived for participation because it is a retrospective study based on existing data with minimal risk to the participants.

CVD Risk Calculation

Based on the new sex-specific, race-free, SDI-enhanced PREVENT equations, we estimated the 10- and 30-year CVD risk before surgery, 1 year after surgery, and 2 years after surgery, respectively, among patients without a diagnosis of CVD or its subtypes at each time point. The components for calculating the risks of total CVD, ASCVD, CHD, and stroke included age, sex, SDI, smoking status, SBP, high-density lipoprotein (HDL) cholesterol, non-HDL, eGFR, diabetes status, antihypertensive use, and statin use; while age, sex, SDI, smoking status, BMI, SBP, eGFR, diabetes status, and antihypertensive use were used for calculating HF risk. We defined 6-month time windows to capture the values of those components before surgery (ie, 6 months to 1 week before surgery), 1 year after surgery (ie, 9–15 months after surgery), and 2 years after surgery (ie, 21–27 months after surgery). To avoid being influenced by extreme values or potential errors, the median value of all measurements during the 6-month time window was used for calculation, after excluding outliers that fell below quartile 1–1.5 interquartile range or above quartile 3+1.5 interquartile range. Due to the requirement for smoking cessation before bariatric surgery, we extended the presurgery time window by 6 months to assess smoking status (ie, 1 year to 1 week before surgery). In addition, antihypertensive drug or statin use was defined by any recorded use of any of those medications during the 6-month time window. Diabetes status was defined if any of the following was met: *International Classification of Diseases*, *Ninth Revision* (*ICD-9*): 250/*International Classification of Diseases*, *Tenth Revision*, *Clinical Modification* (*ICD-10-CM*): E10-E11 (including type 1 and type 2 diabetes), using diabetes treatments, random glucose ≥200 mg/dL, or HbA_{1c} ≥6.5%.

Statistical Analysis

Participants with pre- and postsurgery measures for estimating CVD risk were included. Components for calculating ASCVD risk and HF risk before and after surgery were summarized as mean±SD for continuous variables and number (percentage) for categorical variables and compared using paired *t* tests or McNemar tests. Pre- versus 1- and 2-year postsurgery CVD risk were compared by paired *t* tests; results were presented as absolute reduction (95% CI) and relative reduction (95% CI). Subgroup analyses for assessing the relative reduction of CVD risk were conducted by age (≤45 versus >45 years), sex (women versus men), race (White versus Black), operation (Roux-en-Y gastric bypass versus sleeve gastrectomy), weight loss at 1 or 2 years after surgery (≤30% versus >30%), and presurgery history of diabetes (no versus yes), hypertension (no versus yes; defined by any of the following indications: *ICD-9*: 401–405/*ICD-10-CM*: I10-I16, pharmaceutical treatment, SBP ≥140 mm Hg, or diastolic blood pressure ≥90 mm Hg), and dyslipidemia (no versus yes; defined by any of the following indications: *ICD-9*: *272*/*ICD-10-CM*: E78, pharmaceutical treatment, total cholesterol ≥240 mg/dL, low-density lipoprotein ≥160 mg/dL, triglycerides ≥200 mg/dL, or HDL <40 mg/dL for men/<50 mg/dL for women); mean (95% CI) of relative risk reduction was presented, and *P* value for difference between subgroups was calculated by 2-sample *t* test. Multivariable linear regression was used to compute least squares mean (95% CI) of relative risk reduction and *P* value for difference between subgroups after mutually adjusting for age; sex; race; operation type; surgery year; weight loss at 1 or 2 years after surgery; history of diabetes, hypertension, and dyslipidemia; and presurgery CVD risk. False discovery rate–corrected *P* values (FDR-*P*s) were calculated to adjust for multiple comparisons using the Benjamini–Hochberg method. FDR-*P*<0.05 was considered statistically significant. All analyses were performed in SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

PREVENT Equations

Table 1 presents the pre- and postsurgery values of the 9 components included in the HF risk model and 11 components in the ASCVD risk model. A total of 2910 patients were included to compare the HF risk at 1 year after surgery versus before surgery. Of these patients (82% women), the mean age was (46.0±10.8) years. Compared with before surgery, patients had significant improvements in BMI (47.3 versus 32.4 kg/m^2), SBP (134.3 versus 123.6 mm Hg), and eGFR (93.2 versus 100.2 mL/min per 1.73 m^2) at 1 year after surgery; the prevalence of diabetes (43.4% versus 35.1%) and antihypertensive drug use (62.6% versus 49.4%) also decreased at 1 year after surgery (all P<0.0001). Sustained CKM improvements were observed at 2 years after surgery among 1478 patients. For ASCVD risk, 252 and 130 patients were included for 1 and 2 years after surgery versus presurgery comparisons. In addition to improvements in SBP and eGFR, patients showed significant improvements in blood lipids,

Table 1. Components of SDI-Enhanced PREVENT Equations for Predicting the 10-Year HF and ASCVD Risk

Components	HF risk model					
	Before surgery vs 1 y after surgery (N=2910)		*P* value	Before surgery vs 2 y after surgery (N=1478)		*P* value
Age, y	46.0±10.8	…	…	47.0±10.6	…	…
Sex, male	523 (18.0)	…	…	242 (16.4)	…	…
SDI decile			…			…
1–3	866 (29.8)	…		451 (30.5)	…	
4–6	798 (27.4)	…		438 (29.6)	…	
7–10	1008 (34.6)	…		513 (34.7)	…	
Missing	238 (8.2)	…		76 (5.1)	…	
Current smoking	140 (4.8)	23 (0.8)	<0.0001	60 (4.1)	25 (1.7)	<0.0001
BMI, kg/m^2	47.3±7.6	32.4±6.3	<0.0001	46.8±7.4	31.9±6.4	<0.0001
SBP, mm Hg	134.3±12.4	123.6±13.9	<0.0001	134.1±12.5	124.2±14.3	<0.0001
eGFR, mL/min per 1.73 m^2	93.2±22.4	100.2±22.4	<0.0001	93.3±23.3	98.0±22.7	<0.0001
Diabetes	1263 (43.4)	1021 (35.1)	<0.0001	687 (46.5)	614 (41.5)	<0.0001
Antihypertensive use	1821 (62.6)	1437 (49.4)	<0.0001	991 (67.1)	807 (54.6)	<0.0001
Components	**ASCVD risk model**					
	Before surgery vs 1-y after surgery (N=252)		***P* value**	**Before surgery vs 2-y after surgery (N=130)**		***P* value**
Age, y	46.8±9.6	…	…	46.5±9.9	…	…
Sex, male	55 (21.8)	…	…	22 (16.9)	…	…
SDI decile			…			…
1–3	77 (30.6)	…		44 (33.9)	…	
4–6	61 (24.2)	…		35 (26.9)	…	
7–10	70 (27.8)	…		36 (27.7)	…	
Missing	44 (17.5)	…		15 (11.5)	…	
Current smoking	6 (2.4)	0 (0.0)	…	7 (5.4)	3 (2.3)	0.29
SBP, mm Hg	133.3±12.4	124.9±14.0	<0.0001	133.4±11.6	125.8±14.4	<0.0001
HDL, mmol/L	1.23±0.30	1.50±0.34	<0.0001	1.27±0.33	1.59±0.40	<0.0001
Non-HDL, mmol/L	3.44±0.84	2.82±0.80	<0.0001	3.46±0.77	2.91±0.85	<0.0001
eGFR, mL/min per 1.73 m^2	93.1±23.0	100.3±23.5	<0.0001	92.2±23.1	97.7±23.3	0.002
Diabetes	150 (59.5)	125 (49.6)	<0.0001	72 (55.4)	69 (53.1)	0.47
Antihypertensive use	159 (63.1)	139 (55.2)	0.002	94 (72.3)	77 (59.2)	0.002
Statin use	102 (40.5)	84 (33.3)	0.0007	56 (43.1)	45 (34.6)	0.01

Data are presented as mean±SD or n (%).

ASCVD indicates atherosclerotic cardiovascular disease; BMI, body mass index; eGFR, estimated glomerular filtration rate; HDL, high-density lipoprotein; HF, heart failure; PREVENT, Predicting Risk of Cardiovascular Disease EVENTs; SBP, systolic blood pressure; and SDI, social deprivation index.

including both non-HDL (3.44 versus 2.82 mmol/L, $P<0.0001$) and HDL (1.23 versus 1.50 mmol/L, $P<0.0001$) at 1 year after surgery, which were also observed at 2 years after surgery.

The baseline characteristics of study patients included in the HF risk model (N=2910) were similar to those of the whole cohort (N=7084), while patients included in the ASCVD risk model (N=252) were more likely to undergo Roux-en-Y gastric bypass and had a higher prevalence of diabetes or dyslipidemia compared with the overall cohort (Table S1).

CVD Risk Reduction After Surgery

Substantial reductions in estimated 10- and 30-year CVD risk were observed after surgery (Table 2). Specifically, the estimated 10-year total CVD risk decreased from 6.51% before surgery to 4.74% at 1 year after surgery, corresponding to a relative reduction of 26.52% (95% CI, 20.58%–32.46%). Regarding CVD subtypes, relative reductions of 29.03% (95% CI, 23.27%–34.79%), 33.50% (95% CI, 27.82%–39.19%), 21.74% (95% CI, 16.65%–26.83%), and 56.25% (95% CI, 54.96%–57.53%) were observed for ASCVD, CHD, stroke, and HF risk, respectively. Sustainable risk reductions, ranging from 14.56% to 46.53%, were observed at 2 years after surgery, similarly, with the least reduction observed for stroke and the greatest reduction for HF.

The estimated 30-year total CVD risk was 26.61% before surgery, which decreased to 20.14% at 1 year after surgery and 20.05% at 2 years after surgery. The relative reductions of the 30-year total CVD risk and its subtypes ranged from 22.14% to 47.03% at 1 year and from 17.90% to 39.27% at 2 years after surgery, with the least reduction observed for stroke and the greatest reduction for HF.

CVD Risk Reduction Among Patient Subgroups

Similar reductions in the estimated 10-year risks of total CVD, ASCVD, CHD, and stroke were observed at 1 year after surgery among male and female patients, Black and White patients, Roux-en-Y gastric bypass and vertical sleeve gastrectomy–treated patients, and those with/without a history of diabetes, hypertension, or dyslipidemia (Figure 1), while ASCVD

Table 2. Comparison of CVD Risk Before and After Surgery

	Pairs	Before surgery	After surgery	Absolute reduction	Relative reduction
10-y CVD risk	Before surgery vs 1 y after surgery				
Total CVD risk, %	245	6.51 (5.84–7.17)	4.74 (4.17–5.32)	1.76 (1.39–2.14)	26.52 (20.58–32.46)
ASCVD, %	252	3.98 (3.60–4.36)	2.80 (2.47–3.12)	1.18 (0.95–1.42)	29.03 (23.27–34.79)
CHD, %	264	2.08 (1.87–2.30)	1.35 (1.18–1.51)	0.74 (0.60–0.88)	33.50 (27.82–39.19)
Stroke, %	321	2.37 (2.18–2.56)	1.84 (1.66–2.01)	0.53 (0.42–0.64)	21.74 (16.65–26.83)
HF, %	2910	7.86 (7.52–8.20)	2.99 (2.85–3.13)	4.87 (4.63–5.11)	56.25 (54.96–57.53)
	Before surgery vs 2 y after surgery				
Total CVD risk, %	124	5.98 (5.08–6.87)	4.92 (4.05–5.78)	1.06 (0.63–1.50)	18.36 (10.52–26.20)
ASCVD, %	130	3.77 (3.26–4.28)	3.07 (2.56–3.57)	0.70 (0.43–0.98)	20.90 (13.66–28.14)
CHD, %	136	1.90 (1.63–2.17)	1.45 (1.20–1.70)	0.45 (0.30–0.61)	25.59 (18.03–33.15)
Stroke, %	180	2.40 (2.14–2.65)	2.04 (1.79–2.29)	0.36 (0.22–0.49)	14.56 (8.51–20.62)
HF, %	1478	8.13 (7.66–8.60)	3.63 (3.40–3.86)	4.50 (4.18–4.82)	46.53 (44.16–48.89)
30-y CVD risk	Before surgery vs 1 y after surgery				
Total CVD risk, %	245	26.61 (24.88–28.33)	20.14 (18.49–21.78)	6.47 (5.43–7.51)	25.63 (21.44–29.83)
ASCVD, %	252	16.49 (15.40–17.58)	11.81 (10.81–12.80)	4.68 (3.93–5.44)	28.77 (24.37–33.17)
CHD, %	264	9.46 (8.75–10.17)	6.18 (5.60–6.75)	3.28 (2.76–3.81)	33.90 (29.30–38.50)
Stroke, %	321	9.76 (9.22–10.30)	7.60 (7.08–8.12)	2.16 (1.81–2.52)	22.14 (18.27–26.01)
HF, %	2910	27.17 (26.52–27.82)	14.12 (13.70–14.54)	13.05 (12.66–13.44)	47.03 (45.89–48.16)
	Before surgery vs 2 y after surgery				
Total CVD risk, %	124	25.25 (22.92–27.58)	20.05 (17.72–22.38)	5.20 (3.80–6.60)	20.72 (14.57–26.87)
ASCVD, %	130	15.69 (14.29–17.10)	12.17 (10.75–13.59)	3.52 (2.59–4.45)	23.26 (17.21–29.30)
CHD, %	136	8.71 (7.85–9.57)	6.28 (5.47–7.09)	2.43 (1.83–2.03)	28.29 (21.78–34.81)
Stroke, %	180	9.72 (9.00–10.45)	7.93 (7.24–8.62)	1.80 (1.34–2.25)	17.90 (13.06–22.74)
HF, %	1478	28.04 (27.14–28.93)	16.02 (15.42–16.63)	12.01 (11.46–12.57)	39.27 (37.39–41.15)

Data are presented as mean (95% CI). Absolute reduction = presurgery − postsurgery. Relative reduction = (presurgery − postsurgery)/presurgery×100. ASCVD indicates atherosclerotic cardiovascular disease; CHD, coronary heart disease; CVD, cardiovascular disease; and HF, heart failure.

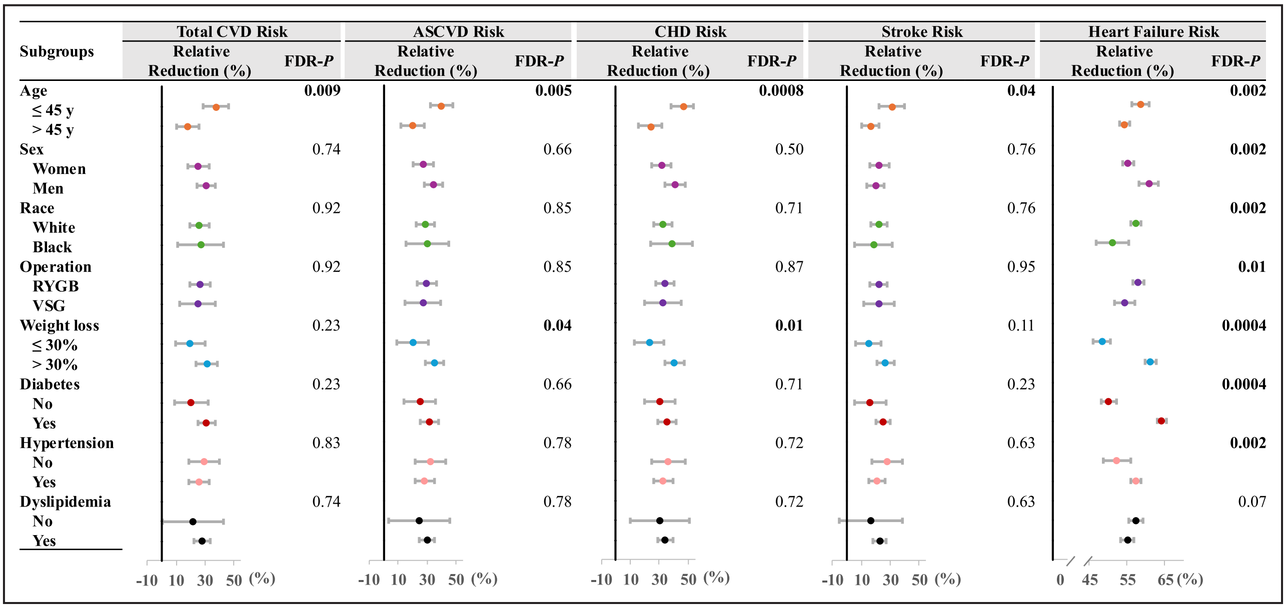

Figure 1. The relative reduction of 10-year CVD risk in subgroups at 1 year after surgery.

Mean (95% CI) of the relative risk reduction was presented for each subgroup. FDR-*P* values were calculated to adjust for multiple comparisons using the Benjamini–Hochberg method. ASCVD indicates atherosclerotic cardiovascular disease; CHD, coronary heart disease; CVD, cardiovascular disease; FDR-*P*, false discovery rate–corrected *P* value; RYGB, Roux-en-Y gastric bypass; and SG, sleeve gastrectomy.

and CHD risk reductions were more evident in patients aged ≤45 years or those with >30% weight loss than their counterparts (all FDR-*P* for heterogeneity <0.05; Figure 1). Results remained similar after mutually adjusting for age, sex, race, operation type, surgery year, weight loss, cardiometabolic disease history, and presurgery CVD risk (Table S2). Of note, 10-year HF risk reduction was significant and substantial across all patient subgroups, while younger patients, White patients, those with >30% weight loss, and those who had a history of diabetes or hypertension showed more reductions than their counterparts with or without mutual adjustment (all FDR-*P* for heterogeneity <0.05) (Figure 1 and Table S2).

At 2 years after surgery, reductions in the 10-year risk of total CVD, ASCVD, CHD, and stroke were all similar between patient subgroups; however, for 10-year HF risk, patients who were younger, White race, achieved >30% weight loss, or had a history of diabetes remained showing greater reductions than their counterparts after mutual adjustment (all FDR-*P* for heterogeneity <0.05; Figure 2 and Table S3). Similar patterns were observed for the estimated 30-year CVD risk (Figure S2 through S5).

DISCUSSION

In this single-center electronic health record–based, longitudinal cohort of bariatric surgery patients, we observed significant improvements in CKM health after surgery, including reduced BMI, SBP, non-HDL, diabetes prevalence, and use of antihypertensive drugs and statins, as well as increased HDL and eGFR. The estimated 10-year risks of total CVD, ASCVD, CHD, and stroke decreased by 22% to 34% and 15% to 26% at 1 and 2 years after surgery, and remarkably, 56% and 47% reductions were observed for estimated 10-year HF risk at 1 and 2 years after surgery, respectively. Furthermore, we found that younger age, White race, >30% weight loss, and diabetes history were associated with greater reductions in HF risk after bariatric surgery.

Although the significant CVD benefits of bariatric surgery have been well recognized, to our knowledge, this is the first study applying the new sex-specific, race-free PREVENT equations, which include SDI and eGFR as predictors to capture patients' socioeconomic status and overall CKM health and predict 10- and 30-year HF risk. Our findings on CKM health improvements were consistent with the literature and results reported in our recent publication, which showed significant reductions in blood pressure, blood lipids, glucose, and HbA_{1c}, as well as 32% to 50% remission rates of diabetes, hypertension, and dyslipidemia 1 year after bariatric surgery.[9,11,24] In addition, we observed 29% and 21% reductions in 10-year ASCVD risk at 1 and 2 years after surgery, which is in line with previous reports, ranging from 19% to 54%,[16] although the reductions appear to be smaller than our previous results based on the American College

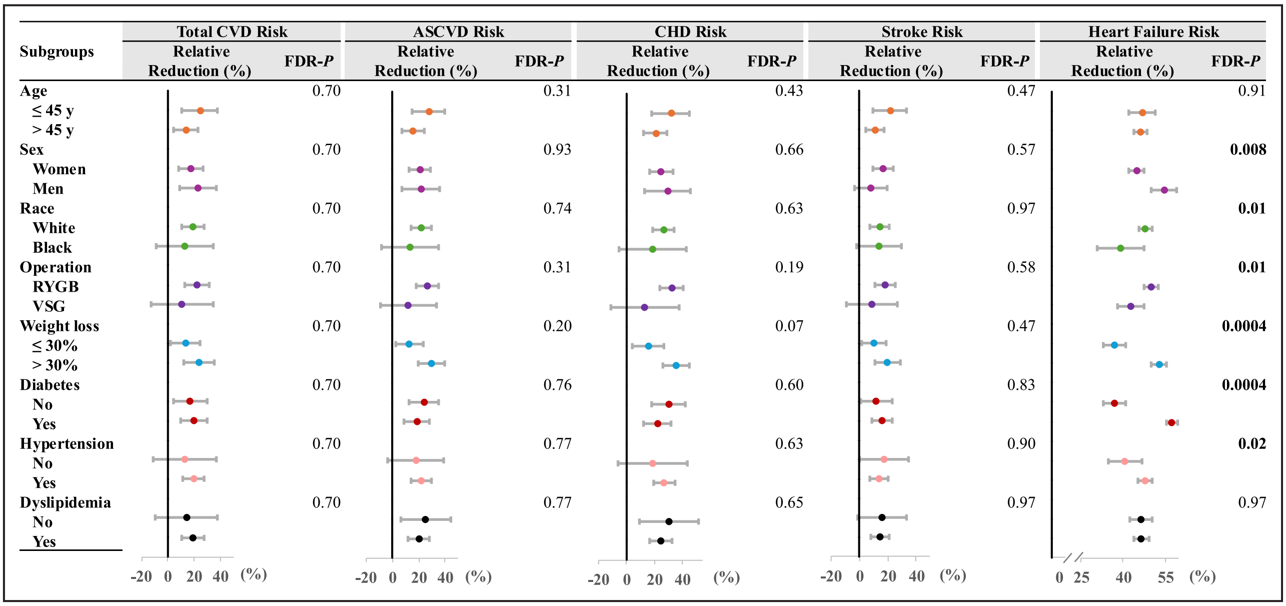

Figure 2. The relative reduction of 10-year CVD risk in subgroups at 2 years after surgery.

Mean (95% CI) of the relative risk reduction was presented for each subgroup. FDR-*P* values were calculated to adjust for multiple comparisons using the Benjamini–Hochberg method. ASCVD indicates atherosclerotic cardiovascular disease; CHD, coronary heart disease; CVD, cardiovascular disease; FDR-*P*, false discovery rate–corrected *P* value RYGB, Roux-en-Y gastric bypass; and SG, sleeve gastrectomy.

of Cardiology/American Heart Association equations (34% and 23%).[9] This discrepancy could be explained by differences in CVD risk prediction models. The new PREVENT equations were derived among >6 million people aged 30 to 79 years from 46 cohorts,[22] while the American College of Cardiology/American Heart Association equations were race-specific risk prediction models developed in ≈25 000 non-Hispanic White and Black people aged 40 to 79 years from only 5 cohorts.[25] In addition, the PREVENT equations newly included eGFR as a predictor, which has been associated with increased risk of ASCVD, independent of traditional CVD risk factors.[17]

We observed the greatest CVD benefit in HF prevention, with a 47% to 56% risk reduction within 1 to 2 years after surgery. Several studies have suggested reduced HF risk after bariatric surgery,[26–30] including a 2018 meta-analysis reporting a hazard ratio of 0.44 (95% CI, 0.36–0.55) for incident HF following bariatric surgery compared with nonsurgical controls.[30] The dramatic reduction of HF risk is likely driven by the decrease in BMI (47.3 kg/m^2 before surgery to 32.4 kg/m^2 at 1 year after surgery in our study sample), a strong predictor in the PREVENT equations for HF risk. In a pooled analysis of 10 prospective cohorts in the United States, obesity was significantly associated with increased CVD morbidity and death; of note, BMI showed the strongest association with incident HF, around a 5-fold increase compared with other CVD subtypes.[31]

We further observed that HF risk reduction was greater among younger or White patients than among older or Black patients. Previous studies have linked younger age with more pronounced cardiometabolic improvements after surgery, consistent with our findings.[9,32,33] However, evidence regarding effect modification by race has been inconsistent. Our previous results showed a greater reduction in ASCVD risk in White patients than in Black patients, while another study reported the opposite.[9,34] There remains a significant gap in the representativeness of participants in studies of bariatric surgery or obesity pharmacotherapy.[35–37] Non-White and male patients are underrecruited, which limits the generalizability of findings to the broad population living with obesity and restricts the exploration of how different patients may respond to obesity treatments. Future studies should prioritize the inclusion of diverse participants, including various ethnicities, sexes, and socioeconomic backgrounds, to better reflect the real-world scenario and inform the development of effective obesity treatments for diverse patients. Our study also found greater weight loss was associated with a greater HF risk reduction, which is expected given the central role of obesity in CKM health and CVD pathogenesis.[38] In the Swedish Obese Subjects cohort study, patients in the highest quartile of weight loss after 1 year (mean, 41 kg) showed the greatest reduction of incident HF (≈40%).[29] We also found that patients with a history of diabetes showed greater HF risk reductions than those without, which may be attributed to the high remission rate of diabetes after surgery (≈32%). However, previous research has generally suggested more cardiometabolic improvements and ASCVD risk reduction among patients without a history of metabolic diseases.[9,33,39,40] Currently, few HF risk prediction models have been developed and externally validated,[41] and few studies have applied HF risk models among patients undergoing bariatric surgery. Thus, although substantial HF risk reductions were observed in all patient subgroups in our study (48%–64% 1 year after surgery), future studies are needed to clarify the potential heterogenetic effects of bariatric surgery on HF risk by race and comorbidities.

This study has considerable strengths. First, we applied the novel PREVENT equations, which newly added eGFR as a predictor, to fully capture the CKM benefits of bariatric surgery. Second, we used the SDI-enhanced PREVENT equations to capture social determinants of health. Third, we had a large sample size (n=≈3000 for estimating the HF risk) and noted sustained CKM health improvements and HF risk reduction 2 years after bariatric surgery. Fourth, we used electronic health record data from all VUMC clinics to improve data completeness and quality. There are also several limitations. First, the sample sizes for estimating the total CVD and ASCVD risk were much smaller than the ones for HF risk. Total CVD and ASCVD risk estimation required blood lipid data, which were not routinely measured for patients with obesity. Small sample sizes and group imbalances (eg, smaller numbers of male patients and Black patients) may lead to insufficient statistical power to detect differences between patient subgroups, although we observed significant risk reductions among total patients at both 1 and 2 years after surgery. Second, given the observational and retrospective nature, our results may be affected by confounding and selection biases. For example, patients with a history of dyslipidemia are often required to get repeated lipid tests, making them more likely to be included in the total CVD and ASCVD risk model. Third, the predicted CVD risk score, while useful for identifying high-risk individuals and guiding preventive strategies, is limited by its reliance on surrogate markers, population specificity, and short-term focus. Future studies with large sample sizes, long-term follow-ups, comprehensive lab measurements, and hard cardiovascular end points are needed to evaluate the sustainability of CKM and CVD benefits and the potential heterogeneity effect of bariatric surgery in patient subgroups. Finally, given the increasing prevalence of obesity and the efficacy of new antiobesity medications (eg, glucagon-like peptide-1 receptor agonists), which are commonly used among patients undergoing bariatric surgery,[42] future studies need to assess the combined impacts of surgical and medical weight loss on CVD risk.

In conclusion, our study demonstrated that bariatric surgery significantly improved CKM health and reduced the risk of total CVD and its subtypes, particularly HF, with an estimated 47% to 56% risk reduction at 1 to 2 years after surgery, which may help guide clinical decision making and patient counseling. The observed differences in HF risk reduction among patients with varied demographics and disease history may help guide tailored treatment plans and provide a basis for comparison with future studies.

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Disclosures

None.

Supplemental Material

Tables S1–S5
Figures S1–S3

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