Effect of Bariatric Surgery on Cardiovascular Risk Profile

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Obesity is associated with increased risk for cardiovascular (CV) disease (CVD) and CV mortality. Bariatric surgery has been shown to resolve or improve CVD risk factors, to varying degrees. The objective of this systematic review was to determine the impact of bariatric surgery on CV risk factors and mortality. A systematic review of the published research was performed to evaluate evidence regarding CV outcomes in morbidly obese bariatric patients. Two major databases (PubMed and the Cochrane Library) were searched. The review included all original reports reporting outcomes after bariatric surgery, published in English, from January 1950 to July 2010. In total, 637 studies were identified from the initial screen. After applying inclusion and exclusion criteria, 52 studies involving 16,867 patients were included (mean age 42 years, 78% women). The baseline prevalence of hypertension, diabetes, and dyslipidemia was 49%, 28%, and 46%, respectively. Mean follow-up was 34 months (range 3 to 155), and the average excess weight loss was 52% (range 16% to 87%). Most studies reported significant decreases postoperatively in the prevalence of CV risk factors, including hypertension, diabetes, and dyslipidemia. Mean systolic pressure reduced from to 139 to 124 mm Hg and diastolic pressure from 87 to 77 mm Hg. C-reactive protein decreased, endothelial function improved, and a 40% relative risk reduction for 10-year coronary heart disease risk was observed, as determined by the Framingham risk score. In conclusion, this review highlights the benefits of bariatric surgery in reducing or eliminating risk factors for CVD. It provides further evidence to support surgical treatment of obesity to achieve CVD risk reduction. **(Am J Cardiol 2011;xx:xxx)**

Reducing cardiovascular (CV) disease (CVD) risk is a primary public health imperative given the substantial morbidity and mortality associated with the disease. The most effective nonpharmacologic means of achieving such risk reduction is weight loss. Even a moderate 5% to 10% weight loss through diet and lifestyle interventions has been shown to decrease the risk for conversion from impaired glucose tolerance to overt diabetes and can maintain blood pressure reductions over prolonged periods of follow-up.[1] More dramatic weight loss after bariatric surgery has been associated with even greater benefits, such as reduced CV mortality and total mortality in obese patients, particularly those with diabetes.[2] These effects on mortality are due largely to the remarkable consequences of surgical intervention on individual co-morbid conditions such as diabetes, hypertension, and hyperlipidemia. Functional and electrical cardiac investigations also document positive changes in cardiac parameters (structural and electromechanical) after weight reduction.[3] The purpose of this systematic review was to evaluate the current evidence regarding CVD risk reduction after bariatric surgery. We examined the short- and long-term effects of all bariatric interventions on the foremost modifiable traditional risk factors for CVD (hypertension, diabetes mellitus, and hyperlipidemia). We also examined the effects of surgically induced weight loss on objective measures of cardiac function, disease, or risk, by evaluating studies that reported the results of echocardiography, electrocardiography, arterial reactivity testing, C-reactive protein (CRP) levels, and Framingham risk scores pre- and postoperatively.

Methods

The present review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[4] We conducted a comprehensive review of all studies published in English containing data on

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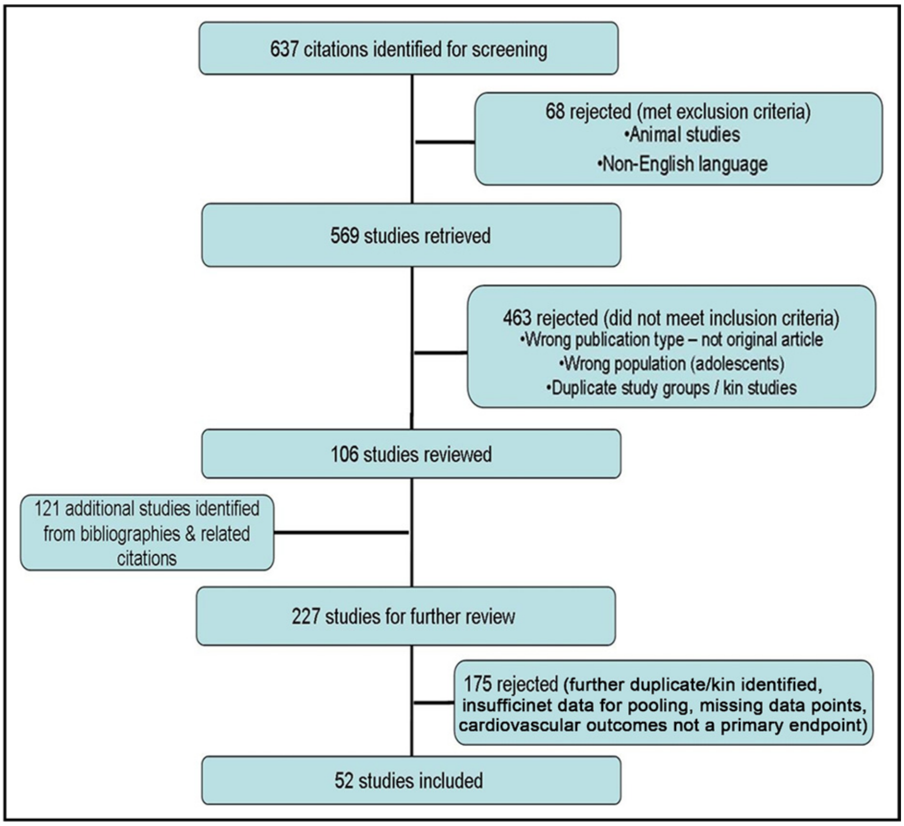

Figure 1. Study flowchart illustrating the study screening and selection process.

CV outcomes, risk factors, and risk reduction in obese patients after any form of bariatric surgery. We performed an electronic search in 2 databases (PubMed and the Cochrane Library) for relevant interventional or observational studies published from January 1, 1950, to July 1, 2010. The search string used was as follows: bariatric surgery (Medical Subject Headings [MeSH]) OR obesity/surgery (MeSH) OR gastric bypass (MeSH) OR gastroplasty (MeSH) OR biliopancreatic diversion (MeSH) OR jejunoileal bypass (MeSH) OR gastric banding OR duodenal switch AND cardiovascular diseases (MeSH) AND outcome assessment (health care) (MeSH) OR outcomes. In addition to the primary electronic search, we reviewed the "related citations" linked to each citation in PubMed and manually reviewed the bibliographies of selected reports and reviews published in the past 5 years.

Only reports published in English were included for review. Inclusion criteria were as follows; prospective and retrospective series reporting on outcomes related to CVD, CV risk, objective measures of cardiac function, or cardiac disease biomarkers after bariatric surgery in an obese population. Studies were included if they reported clinical outcome (control of hypertension, hyperlipidemia, and diabetes), laboratory-based measures of cardiac disease and risk (echocardiography, electrocardiography, and CRP), or risk estimates of cardiac disease (Framingham risk score) postoperatively. Case reports or small case series involving <50 patients, review articles, and studies reporting on surgical techniques or weight loss only as a primary outcome were excluded. Multiple publications involving the same series of patients (or duplicate patient populations) were identified and grouped together; only the most recent or parent study was included in this review to avoid double counting of patients. In cases in which we were uncertain about duplicate patient groups (the same group or institution reporting outcomes for a similar period, without clear indications that the smaller report was a substudy or interim results), a consensus was reached among the investigators regarding its inclusion or exclusion.

Data extraction from selected studies was based on protocol-defined criteria. Statistical analyses were performed only on the extracted data from the selected studies. Basic descriptive statistics (simple counts and means) were used to summarize the patient and study characteristics, reported weight loss, and CV risk factor data. Average unweighted values were calculated for the weight loss, CV risk factor, and mortality data across all studies and for the different operative procedures. Outcomes collected for CV risk reduction included resolution or reduction of hypertension, dyslipidemia, and diabetes; decrease in CRP level; decrease in Framingham risk score; or other improvements in markers of cardiac disease or function. Other efficacy outcomes collected included percentage excess weight loss (%EWL). Where %EWL was not specifically stated, but weight loss was reported in terms of body mass index (BMI) reduction, %EWL was calculated as (BMI at baseline $-$ BMI postoperatively)/(BMI at baseline $-$ 25) $\times$ 100, on the basis of the assumption that "ideal weight" after bariatric surgery was equivalent to achieving a BMI of 25 kg/m^2. These outcomes were assessed at the longest time point for

Table 1
Summary of studies included in review

First Author	Year	Country	n	Follow-Up (Months)	Mean Age (Years)	Women	Baseline BMI (kg/m^2)	Study Procedures
Traditional CV risk factor studies								
Adami[8]	2005	Italy	461	36	41.5	59%	49	BPD
Ahmed[10]	2009	United States	100	12	42	89%	49	RYGB
Ahroni[11]	2005	United States	195	12	43.8	83%	49	LGB
Alexandrides[9]	2007	Greece	137	26	41.4	77%	46	RYGB and BPD
Anderson[12]	2007	United States	50	12	43	74%	56	RYGB
Bacci[13]	2002	Italy	50	12	42	94%	55	LGB
Batsis[14]	2007	United States	197	40	44	8%	51	RYGB
Bowne[15]	2006	United States	106	40	42	80%	44	LGB and RYGB
Brancatisano[16]	2008	Australia	838	36	44	8%	50	LGB
Cottam[17]	2006	United States	362	36	43	85%	56	LGB and RYGB
Cowan[18]	1998	United States	82	12	38	74%	44	RYGB
Fernstrom[19]	2006	United States	347	18	40	77%	42	RYGB and VBG
Frigg[20]	2004	Switzerland	295	48	41	79%	47	LGB
Goergen[21]	2007	Luxemburg	110	24	41	76%	47	RYGB and VBG
Khalaileh[22]	2008	Israel	50	12	37	66%	54	RYGB
Larrad-Jimenez[23]	2007	Spain	343	120	41	80%	45	BPD
Lee[24]	2004	Taiwan	645	12	30	6%	45	RYGB and VBG
Maher[25]	2008	United States	450	12	42	80%	47	RYGB
Mattar[26]	2005	United States	70	15	47	69%	56	RYGB, LGB, and SG
Müller[27]	2008	Switzerland	50	48	38	80%	43	RYGB
Obeid[28]	2005	United States	925	3	45	87%	45	RYGB
O'Brien[29]	2002	Australia	709	12	41	85%	47	LGB
Papasavas[30]	2002	United States	116	6	42	87%	52	RYGB
Paran[31]	2007	Israel	115	85	39	76%	43	VBG
Peluso[32]	2007	United States	400	24	45	84%	39	RYGB
Pinheiro[33]	2008	Brazil	105	48	54	71%	50	RYGB
Ponce[34]	2004	United States	402	24	42	83%	46	LGB
Pontiroli[35]	2009	Italy	101	65	45	83%	51	LGB and BPD
Prachand[36]	2010	United States	350	36	40	83%	45	RYGB and BPD with DS
Puzziferri[37]	2006	United States	155	36	48	92%	49	RYGB
Sampalis[7]	2006	Canada	1,035	30	45	66%	47	RYGB and VBG
Scopinaro[38]	1998	Italy	1,356	155	37	68%	48	BPD
Sears[39]	2008	United States	75	12	NA	NA	54	RYGB
Singhal[40]	2008	United Kingdom	122	12	45	75%	46	LGB
Sjöström[5,6,*]	2007 2004	Sweden	2,010	131	47	71%	48	LGB, RYGB and VBG
Spivak[41]	2004	United States	271	6	25	87%	58	LGB
Steffen[42]	2009	Switzerland	388	84	43	77%	48	LGB and RYGB
Sugerman[43]	2003	United States	1,025	144	39	78%	NA	RYGB
Valera-Mora[44]	2005	Italy	107	24	37	79%	47	BPD
Vila[45]	2009	Spain	115	24	45	NA	52	BPD
White[46]	2005	New Zealand	342	48	43	76%	53	RYGB (and Silastic ring)
Yan[47]	2008	United States	59	60	49	NA	52	RYGB
Novel CV risk factor/score								
Agrawal[48]	2009	United States	62	15	46	82%	47	RYGB
Arterburn[49]	2009	United States	92	12	46	78%	45	RYGB
Chen[50]	2009	Taiwan	640	12	31	69%	43	LGB and "mini-bypass"
Habib[51]	2009	United States	50	12	44	76%	53	RYGB
Hsuan[52]	2010	Taiwan	66	3	31	65%	52	RYGB and SG
Kligman[53]	2007	United States	97	12	43	89%	49	RYGB
Lin[54]	2007	Taiwan	69	6	34	71%	52	VBG
Serra[55]	2006	Spain	70	12	42	59%	46	RYGB
Torquati[56]	2007	United States	500	12	45	81%	48	RYGB
Total			16,867	34	42	78%	48	

DS = duodenal sleeve; LGB = laparoscopic gastric banding; NA = not available; SG = sleeve gastrectomy; VBG = vertical banded gastroplasty.
* Data taken from 2 publications by the same group on the same cohort of obese surgical patients.

which data were available on ≥50% of the initial patient population. In studies with control groups, the change in values between baseline and follow-up indicators of CV risk was obtained for the surgical cohort only. For studies that reported results by gender, age, or race, we calculated the overall results using the proportional mix of genders (or other variables) and individual scores. CVD risk reduction indicators were expressed as the percentage of patients who had resolution or reduction of hypertension, dyslipidemia, and diabetes as determined by clinical or laboratory measurements (blood pressure readings, serum lipid profiles, and fasting blood glucose and glycosylated hemoglobin measures, respectively) or changes in medication requirements for each co-morbidity postoperatively. Mean patient characteristics were synthesized by calculating raw weighted means; the denominator used to obtain results varied according to the individual characteristics reported. Comparisons of the different bariatric procedures with respect to improvements in CV outcomes postoperatively were performed using the chi-square test and/or 1-way analysis of variance, as appropriate, for the pooled data across all studies.

Results

After the initial screening of titles and abstracts (n = 637), 68 were excluded, and 569 studies were reviewed to determine whether they met the inclusion criteria. Of these, 463 were excluded at this stage of the review because they were not original reports of adult bariatric populations, involved duplicate patient groups, or were substudies of larger series. On review of the remaining 106 publications in full, a further 121 studies were identified from bibliographies and related citations that were deemed suitable for inclusion. Of these 227 primary studies, only 52 contained sufficient detail to merit inclusion in the extractable and analyzable data set (Figure 1).

The data set consisted of 52 original studies involving 16,867 patients who had undergone primary bariatric procedures. Of these 52 studies, most from United States (n = 25) and Europe (n = 16), with the remaining 11 from Taiwan (n = 4), Australia (n = 2), New Zealand (n = 1), Canada (n = 1), South America (n = 1), and Israel (n = 2). Data from 2 studies published by the Swedish Obese Subjects Study Scientific Group[5,6] were included and merged to ensure that the patient cohort was counted only once. Regarding study design, there were 2 randomized prospective trials, 3 nonrandomized prospective trials, 1 comparative prospective study, 4 comparative retrospective studies, 2 observational case-control studies, 20 uncontrolled prospective case series, and 20 retrospective case series. Each of the extracted studies included >1of the outcomes of interest. Of the 52 studies, 43 addressed the impact of bariatric surgery on traditional CV risk factors, including hypertension, diabetes, and dyslipidemia, and 9 studies examined the effects of surgically induced weight loss on novel CV risk factors (CRP, albuminuria, and proinflammatory markers), risk scores, and CV-related biochemical or functional investigations (Table 1[7–56]).

In total, 16,867 patients were investigated in the 52 studies. At baseline, the mean age of the patients was 42 years (range of mean ages 25 to 54), 78% of the population were women, and the mean BMI was 49 kg/m^2 (range of mean BMIs reported 39 to 58). The baseline prevalence of those obesity-related co-morbidities, which increase the risk for CVD, is listed in Table 2. Malabsorptive or bypass procedures were most commonly performed, with Roux-en-Y gastric bypass (RYGB) and biliopancreatic diversion (BPD) accounting for 62.0% of cases (Figure 2). The mean follow-up duration was 34 months (range 3 to 155), with 23% of studies reporting medium- to long-term results of >48 months. Weight loss after bariatric surgery (all types) was quantified and reported in all but 1 study, and the overall mean %EWL was 52% (range 16% to 87%). Examining weight loss according to the various procedures performed revealed that malabsorptive procedures such as RYGB and BPD resulted in greater weight loss (65% and 69%, respectively) than restrictive procedures (Figure 3). Laparoscopic gastric banding resulted in the lowest %EWL overall (42%).

Table 2
Baseline prevalence of obesity-related co-morbidities and percentage resolution or reduction after bariatric surgery

Co-Morbidity	Baseline	Percentage Resolution or Reduction*
Hypertension	49%	68%
Diabetes mellitus	28%	75%
Dyslipidemia	46%	71%

* After a mean follow-up period of 34 months.

Most studies reported significant decreases postoperatively in the prevalence of obesity-related co-morbidities that present a risk for CVD; on average, hypertension remitted or resolved in 68%, diabetes in 75%, and dyslipidemia in 71% (Table 2). These improvements occurred as early as 3 months (when investigators looked at short-term effects, or serially over a longer duration of follow-up) and persisted throughout the duration of follow-up (up to 155 months). Examining the change in co-morbidity status postoperatively according to the different bariatric procedures performed showed that BPD and vertical banded gastroplasty resulted in greater remission or reduction rates of all 3 co-morbidities compared to RYGB and laparoscopic gastric banding. Overall, laparoscopic gastric banding resulted in the lowest rates of remission or reduction of diabetes (71%) and hypertension (58%), although the differences between procedures were marginal (Figure 3). Blood pressure measurements pre- and postoperatively were documented in 42% of studies. Mean systolic pressure reduced from to 139 to 124 mm Hg and mean diastolic pressure from 87 to 77 mm Hg (Table 3). Lipid profiles were also reported pre- and postoperatively in 42% of studies and had altered significantly after surgical intervention. Mean total cholesterol, low-density lipoprotein cholesterol, and triglyceride levels decreased, while high-density lipoprotein increased (Table 3). Postoperative changes in fasting blood glucose and glycosylated hemoglobin were reported in 27% and 11.5% of studies, respectively. Average fasting glucose level decreased from 119 to 92 mg/dl, and glycosylated hemoglobin decreased by 1.5%, which would be considered a clinically significant reduction.

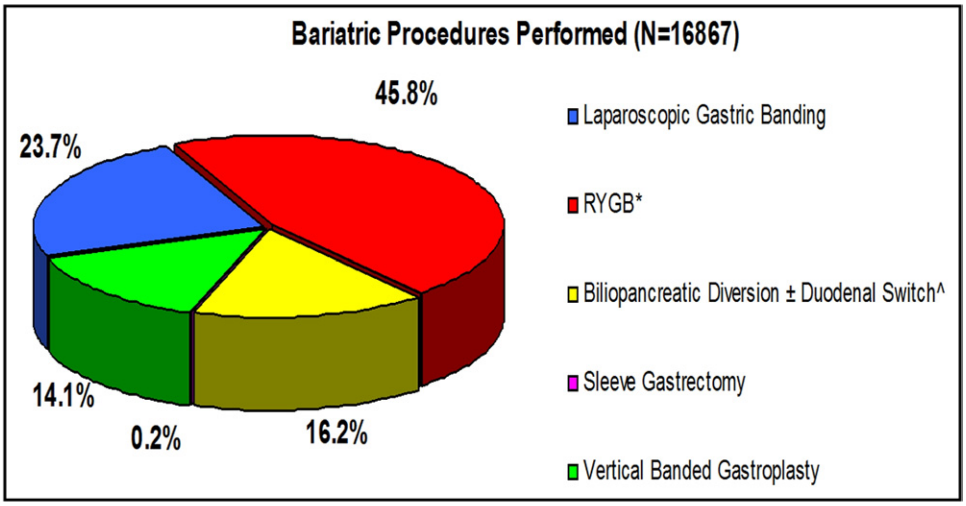

Figure 2. Breakdown of the various bariatric procedures performed. *Includes a series of 522 "mini-gastric bypasses."[50] It was not possible to accurately determine the proportions of open and laparoscopic procedures, because several reports did not specify which approach was used. ^Prachand et al[36] performed BPD with duodenal switch in 198 patients.

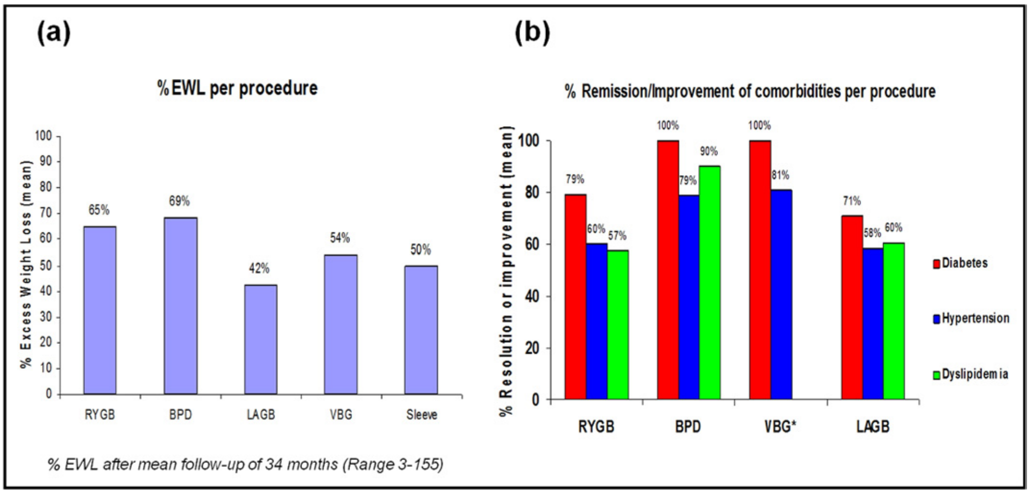

Figure 3. Efficacy outcomes according to the type of bariatric procedure performed. (a) Mean %EWL for the various surgeries. (b) Rates of co-morbidity remission or reduction for the different procedures. LAGB = laparoscopic gastric banding. *Data were not clearly reported for the effect of vertical banded gastroplasty (VBG) on dyslipidemia resolution or reduction in any of the 7 studies in which this procedure was performed.

Of the 52 studies in this review, 9 investigated the effect of bariatric surgery on novel and emerging risk factors for CVD. The most commonly reported biomarker was CRP, which was determined pre- and postoperatively in 5 studies. Mean CRP levels were elevated at baseline in obese patients (4.5 mg/L) but decreased by 61.6% (to 1.7 mg/L) after surgically induced weight loss. The impairment of endothelial function is a recognized early component of atherosclerotic CVD and can be characterized by flow-mediated vasodilation (FMD) of a conduit artery, typically the brachial artery.[57] FMD has been shown to be an independent predictor of CV risk and future adverse CV events.[58–60] Three studies in this review measured FMD before and after bariatric surgery. Determined noninvasively by ultrasonography (brachial artery reactivity testing), normal FMD of the brachial artery is 10% to 15%. The 3 studies reported a mean baseline FMD of 6%, and postoperatively, the mean FMD had increased substantially to 16%. The Framingham risk score, which determines a subject's 10-year risk for coronary heart disease on the basis of categorical values including age, total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, smoking status, blood pressure, and diabetes history, was measured in 3 studies. The Framingham risk score was found to have decreased significantly after bariatric surgery in all 3 studies, from 6.3% preoperatively to 3.8% postoperatively, representing a 40% relative risk reduction for 10-year coronary heart disease risk (Figure 4).

The only study in this review that specifically reported on CV mortality after bariatric surgery was the Swedish Obese Subjects Study. Sjöström et al[5,6] reported lower CV mortality in a large cohort of obese patients (n = 2,010) who had undergone bariatric surgery compared to a matched cohort of obese controls who were managed nonoperatively (n = 2,037). Total CV mortality in the surgical cohort was 2.1% compared to 2.6% in obese controls. Spe-

Table 3
Changes in blood pressure and laboratory measurements of cardiovascular disease risk factors

Variable	Baseline	Postoperatively‡
Fasting blood glucose (mg/dl)	126	92
Glycosylated hemoglobin (%)	7.5	6.0
Systolic blood pressure (mm Hg)	139	124
Diastolic blood pressure (mm Hg)	87	77
Total cholesterol (mg/dl)	205	169
LDL (mg/dl)	118	94
HDL (mg/dl)	49	52
Triglycerides (mg/dl)	169	103
CRP (mg/L)*	4.5	1.7
Flow-mediated diameter of brachial artery (% change)†	6%	16%

HDL = high-density lipoprotein; LDL = low-density lipoprotein.
* Based on 5 studies.
† Based on 3 studies.
‡ After a mean follow-up period of 34 months.

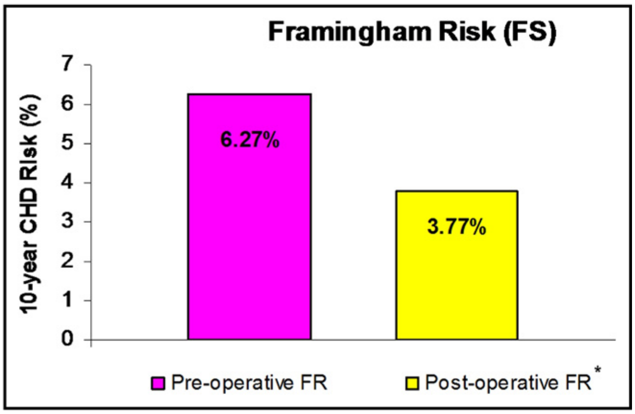

Figure 4. Framingham risk (FR) pre- and postoperatively, as determined by the Framingham risk score. *There was a 40% relative reduction in 10-year CVD risk after surgically induced weight loss at a mean follow-up time of 34 months (range 3 to 155). CHD = coronary heart disease.

cifically, the mortality secondary to myocardial infarctions decreased almost twofold from 1.2% to 0.65%. It should be noted that most procedures reported in this study were gastroplasty (68.1%) and gastric banding procedures (18.7%), with a relatively small proportion of bypass procedures (13.2%).

Discussion

Bariatric surgery has been performed for the treatment of obesity since 1953, when Dr. Richard Varco of Minnesota performed the first jejunoileal bypass specifically to induce weight loss from malabsorption. Although fraught with nutritional complications, this procedure was noted to induce marked weight reduction, and it had a remarkable effect on circulating lipid levels in severely hyperlipidemic patients, with a 90% decrease in plasma cholesterol and an even greater (96%) reduction in plasma triglycerides.[61] In the following decades, the jejunoileal bypass was modified and refined to reduce the severity of the malabsorptive nutritional complications while retaining its weight loss and lipid-lowering benefits, hence the emergence of procedures such as the biliopancreatic diversion (Scopinaro) and duodenal switch (Marceau), followed by limited bypass or restrictive procedures such as the gastric bypass and vertical banded gastroplasty. Indeed, as the field of bariatric surgery has evolved over the past 50 years, weight loss has almost been overshadowed by the extraordinary effects on obesity-related co-morbidities such as hyperlipidemia, hypertension, and diabetes.

Many groups have reported the effects of bariatric surgery on single co-morbidities, particularly diabetes mellitus. More recently, an interest has arisen in examining the effects of surgically induced weight loss on constellations of CVD risk factors using traditional and novel biomarkers of CVD. In this review, we have summarized the evidence for the effects of bariatric surgery on CVD risk. We clearly demonstrate that weight loss after bariatric surgery can lead to major reductions in CV risk factors as well as a decrease in predicted CV risk. The data show marked rates of remission or improvement for hypertension, diabetes, and dyslipidemia (68%, 75%, and 71% respectively) at a mean follow-up of 34 months. These resolutions were verified by mean decreases in systolic and diastolic blood pressure to within normal ranges, as well as positive alterations in lipid parameters. Although the effects of bariatric surgery on CV mortality have not been extensively investigated thus far, the Swedish Obese Subjects Study[6] demonstrated a decrease in CV mortality among 2,010 patients who had undergone bariatric intervention for morbid obesity, compared to a matched cohort of obese control patients who had been managed conservatively. This study, which had 2-, 5-, and 10-year follow-up, showed a near twofold reduction in deaths secondary to myocardial infarction in bariatric patients. Sampalis et al,[7] in their large observational case-control study comparing CV outcomes in 1,035 obese patients treated with bariatric surgery versus 5,746 morbidly obese nonoperatively treated controls, demonstrated a significant reduction in the diagnosis and treatment of CV conditions, including ischemic heart disease, myocardial infarction, and pulmonary edema secondary to congestive heart failure, in the surgically treated group.

Although not included in this review because of our exclusion criteria, the Program on the Surgical Control of the Hyperlipidemias (POSCH) trial merits discussion, given the remarkable results observed in this large secondary intervention trial that investigated the effect of a partial ileal bypass operation on lipid lowering and atherosclerotic coronary heart disease mortality compared to medically treated hyperlipidemia in a nonobese patient cohort. This arteriographic and clinical trial reported arrest and regression of atherosclerotic coronary artery disease on sequential arteriography with up to 10 years of follow-up and demonstrated significant reductions in overall mortality, coronary heart disease mortality, the incidence of recurrent myocardial infarctions, coronary artery bypass grafting, and percutaneous transluminal coronary angioplasty in the surgery group.[62,63]

There is currently a paucity of comparative data regarding efficacy outcomes for the various bariatric procedures.

This review illustrates that malabsorptive procedures, RYGB and BPD, result in greatest weight loss (65% and 69%, respectively), similar to results of Buchwald et al's[64] meta-analyses in 2009, which assessed the effects of bariatric surgery on weight and type 2 diabetes. BPD had the greatest effect on resolution or reduction of co-morbidities (Figure 3). Although these data are encouraging, the long-term nutritional complications of this procedure, consequent to malabsorption, must be kept in mind when interpreting these findings. Overall, all procedures resulted in >50% rates of remission or reduction in hypertension, diabetes, and dyslipidemia. Surgical research awaits the publication of large randomized trials comparing the different surgical options with regard to these outcomes.

The impressive CV risk reduction produced by bariatric surgery, as evidenced by a 40% reduction in 10-year Framingham risk score, should be considered from the perspective of what co-morbid patients consider a significant impact that deems medication ministration worthwhile. Additionally, the perspectives of relevant health care providers should be considered when evaluating the proposed benefits of bariatric surgery. In light of the evidence presented here for the surgical treatment of obesity, and the data supporting nonoperative CV risk reduction, what should caregivers recommend and prescribe for their patients to improve the likelihood of morbidity-free survival? First, compared to the impact of modifying individual risk factors with antihypertensive agents or lipid-lowering therapies, bariatric surgery compares favorably, demonstrating more powerful effects than those achieved with so-called "primary" and "secondary" prevention strategies.[65] It should also be considered that the effects of medications are dependent on patient compliance with taking their prescribed treatments, and benefits attained generally persist only for the duration of therapy. This necessitates lifelong commitment to multidrug regimens. In contrast, once bariatric surgery is performed, the physiologic impact is relatively constant. Also important is the fact that patients and their caregivers expect high returns on their efforts if CV risk factor reduction is the prescriptive target, because frequently, medications cause substantive challenges to patients.[66,67] Not always are these expectations achievable with medical management alone. Bariatric surgery has other significant issues such as surgical morbidity and long-term consequences associated with the various procedures, such as nutritional deficiencies. Nonetheless, in appropriately selected obese patients, surgical intervention compares extremely favorably to nonsurgical therapy and should be considered more often as a lifesaving interdiction rather than a cosmetic operation.

There were a number of limitations to the present study. First, the diagnostic criteria for obesity-related co-morbidities varied across the studies in this review. Although most used laboratory data to diagnose diabetes and hyperlipidemia, some groups used subjective patient histories or medication use as their diagnostic factors. Similarly, for determining resolution or reductions in co-morbidities, the definitions of such were often vague and based only on discontinuation or reduction in medication use, with no biochemical data for verification. Most groups did not distinguish remission from improvement, so it was not possible to distinguish further the exact proportions in each category.

Second, the long-term outcomes of bariatric surgery are limited by high attrition of patients available for follow-up. Although we tried to control for this as much as possible by including only studies in which >50% of the initial study cohort was included in the latter stages of follow-up, there is still the possibility that patients who were lost to follow-up may have skewed the results of individual studies. Similarly, this review, like all systematic reviews and meta-analyses, is limited by the publication bias of availability. The trend is to publish positive data, and investigators may be unlikely to submit or have accepted their reports of negative or disappointing postoperative results.

Third, regarding the small number of studies reporting on novel CV biomarkers and risk assessment included in this review, we excluded studies involving <50 patients to increase the quality of data analyzed in this review. Several smaller cohort and observational studies do exist documenting equally impressive CV risk reductions and positive alterations in cytokines and inflammatory markers that are considered risk factors for cardiac disease. Additionally, some studies included in this review focused their investigations on very specific patient populations, which may skew a systematic review that generalizes all results. Examples include the study by Adami et al,[8] which involved only obese patients who had preexisting diagnoses of hypertension, or that by Alexandrides et al,[9] who included only obese patients with diabetes in their study of the effects of BPD on metabolic disease.

Finally, the procedures and operative techniques used in the studies included in this review were varied. Malabsorptive procedures achieved greater weight loss and co-morbidity remission rates compared to restrictive procedures, as expected. However, even among all studies reporting outcomes after RYGB, for example, there were variations with respect to pouch size (range 15 to 50 ml, approximately) and lengths of the Roux limb, all of which could have affected efficacy outcomes.

Perhaps the greatest limitation of this review, however, is the diversity of reporting formats for outcomes after bariatric surgery. The reporting of bariatric surgery outcomes, whether operative morbidity and mortality or efficacy outcomes such as weight loss and effects on co-morbidities, is not standardized. Investigators have discretion to report data in a variety of formats and often use descriptive, nonnumeric, or colloquial terms to document important outcomes such as weight loss and remission of metabolic co-morbidities after bariatric procedures. There is certainly a case to be made for developing a standardized reporting format to which health care professionals managing obese patients should adhere when reporting their results and outcomes. This should include standardized numeric formats for documenting quantitatively the amount of weight loss (actual weight lost and %EWL) and the baseline prevalence and subsequent remission or reductions of all metabolic co-morbidities, with biochemical data and medication use for verification.

Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.amjcard.2011.06.076.

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