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Metabolic Syndrome Prevalence and Associations in a Bariatric Surgery Cohort from the Longitudinal Assessment of Bariatric Surgery-2 Study

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Abstract

Background: Metabolic syndrome is associated with higher risk for cardiovascular disease, sleep apnea, and nonalcoholic steatohepatitis, all common conditions in patients referred for bariatric surgery, and it may predict early postoperative complications. The objective of this study was to determine the prevalence of metabolic syndrome, defined using updated National Cholesterol Education Program criteria, in adults undergoing bariatric surgery and compare the prevalence of baseline co-morbid conditions and select operative and 30-day postoperative outcomes by metabolic syndrome status.
Methods: Complete metabolic syndrome data were available for 2275 of 2458 participants enrolled in the Longitudinal Assessment of Bariatric Surgery-2 (LABS-2), an observational cohort study designed to evaluate long-term safety and efficacy of bariatric surgery in obese adults.
Results: The prevalence of metabolic syndrome was 79.9%. Compared to those without metabolic syndrome, those with metabolic syndrome were significantly more likely to be men, to have a higher prevalence of diabetes and prior cardiac events, to have enlarged livers and higher median levels of liver enzymes, a history of sleep apnea, and a longer length of stay after surgery following laparoscopic Roux-en-Y gastric bypass (RYGB) and gastric sleeves but not open RYGB or laparoscopic adjustable gastric banding. Metabolic syndrome status was not significantly related to duration of surgery or rates of composite end points of intraoperative events and 30-day major adverse surgical outcomes.
Conclusions: Nearly four in five participants undergoing bariatric surgery presented with metabolic syndrome. Establishing a diagnosis of metabolic syndrome in bariatric surgery patients may identify a high-risk patient profile, but does not in itself confer a higher risk for short-term adverse postsurgery outcomes.

Introduction

Metabolic syndrome is a multiplex risk factor that incorporates central obesity, dyslipidemia, elevated blood pressure, and elevated plasma glucose.[1,2] Individuals with metabolic syndrome are at higher risk for the development of type 2 diabetes mellitus (T2DM) and cardiovascular disease (CVD).[3,4] Bariatric surgery is currently the most efficacious treatment for substantial and sustained weight loss in the morbidly obese and results in marked

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improvement in insulin resistance and diabetes.[5–7] Although prior studies have documented improvements in metabolic syndrome status as well after bariatric surgery,[8–12] the baseline prevalence of metabolic syndrome in obese individuals undergoing bariatric surgery reported in these studies varied greatly, from 39%[10] to 87%,[11] and many did not use the updated National Cholesterol Education Program (NCEP) criteria.[2] A recent analysis of nearly 190,000 subjects undergoing bariatric surgery at a designated Center of Excellence by the American Society for Metabolic and Bariatric Surgery reported a presurgery prevalence of metabolic syndrome of only 12% and found that those with metabolic syndrome had higher rates of 30- and 90-day postoperative adverse events than those without metabolic syndrome.[13] However, that analysis defined metabolic syndrome using non-NCEP criteria,[13] preventing direct comparisons with other studies[8–12] and leaving the true surgical risk conferred by metabolic syndrome status as determined using traditional criteria still unclear.

Therefore, we sought to address these limitations in the current literature by determining the prevalence of metabolic syndrome using current NCEP criteria in patients undergoing bariatric surgery in a large multicenter cohort, and comparing baseline co-morbid conditions and select operative and 30-day postoperative outcomes in those with and without metabolic syndrome (non–metabolic syndrome). Because the presence of metabolic syndrome is a risk factor for a number of co-morbidities, including CVD,[3] nonalcoholic fatty liver disease,[14] and sleep apnea,[15] we hypothesized that the presence of this diagnosis would be associated with a more adverse baseline risk profile, which would translate into higher adverse operative and 30-day postoperative outcomes.

Materials and Methods

Subjects

The Longitudinal Assessment of Bariatric Surgery (LABS) is a series of National Institute of Diabetes and Digestive and Kidney Diseases– (NIDDK) sponsored, multicenter, observational, cohort studies designed to assess the safety and efficacy of bariatric surgery and is registered in the National Institutes of Health web site (www.clinicaltrials.gov).[16] LABS is comprised of several progressively smaller cohorts (LABS-1, LABS-2, and LABS-3) with more detailed and focused data collections. Between 2006 and 2009, patients who were at least 18 years old seeking a first bariatric surgical procedure at one of 10 centers in six geographically diverse centers were enrolled into LABS-2. The study protocol and consent forms were approved by the institutional review board at each center, and all study participants provided written consent.

Of those consenting, 2458 participants completed a baseline research visit within 30 days prior to surgery. After their surgery, participants were contacted to assess 30-day vital status and postdischarge complication and rehospitalization rates. For this report, 183 LABS-2 participants were missing baseline data points needed to determine metabolic syndrome status and were excluded, leaving a sample size of 2275 participants.

Metabolic syndrome definition

Per the 2009 updated NCEP criteria,[2] participants were classified as having metabolic syndrome if three or more of the following five criteria were positive: Fasting blood glucose ≥ 100 mg/dL or use of a glucose-lowering medication; elevated blood pressure [systolic blood pressure (SBP) ≥ 130 and/or diastolic blood pressure (DBP) ≥ 85 mmHg) or medication for hypertension; fasting triglyceride (TG) levels (≥ 150 mg/dL); fasting high-density lipoprotein cholesterol (HDL-C) values (< 50 mg/dL for females, < 40 mg/dL for males), or central obesity (waist circumference > 88 cm for females, > 102 cm for males).

Baseline measures

Data on baseline demographic, clinical, psychosocial, and surgical characteristics were collected by trained research staff and surgeons using standardized protocols.[16] Co-morbid conditions, such as CVD risk factors and events, sleep apnea, severe walking limitations (defined as inability to walk 200 feet without assistance), prior deep vein thrombosis and pulmonary embolism, and diabetes, were determined via participant self-report, physical examination, medical record abstraction, use of clinical support devices or medical therapy, and laboratory assays.[17]

Waist circumference was measured using the Gulick II Tape Measure (model 67020) around the abdomen horizontally at the midpoint between the highest point of the iliac crest (hip bone) and lowest part of the costal margin (ribs) while the participant was standing. Anterior–posterior abdominal diameter was measured using a T-square while the participant was in a supine position on the operating table. A single measurement of resting heart rate, SBP, and DBP was obtained using a Welch Allyn Spot Vital Signs monitor 4200B. Weight and percent body fat were obtained using a Tanita scale. Height was determined using a wall-mounted stadiometer with the participant in stocking feet.

Surgeons provided operative and intraoperative details for each surgery. The size and overall appearance of the liver was assessed visually. The size of the liver was recorded as normal (liver lobes do not extend outside of the right upper quadrant), large (one or both lobes extend to the level of the umbilicus), or extremely large (one or both liver lobes extend into the pelvis). A composite intraoperative event end point was defined as injuries or lacerations to organs as a result of surgery or equipment failure, bleeding requiring transfusion and/or extended compression, and anesthesia-related complications.

Laboratory assays were performed by the Northwest Lipid Metabolism and Diabetes Research Laboratories (Seattle, WA). Total cholesterol (TC) and TG were quantified using a Roche Modular-P autoanalyzer using methods standardized to the Centers for Disease Control and Prevention Reference Methods. HDL-C was determined using precipitation procedures, and low-density lipoprotein cholesterol (LDL-C) was calculated[18] if TG was ≤ 400 mg/dL or measured directly via beta-quantification when TG levels exceeded 400 mg/dL. Immunonephelometric measurements were used in the determination of high-sensitivity C-reactive protein (hsCRP). Values for insulin were measured using a two-site immunoenzymometeric assay, glucose values were determined using the hexokinase method, alanine and aspartate transaminase levels were quantified using the pyridoxal-5-phosphate method, and glycosylated hemoglobin values were measured on whole blood using high-performance liquid chromatography.

Postoperative events

Length of stay (LOS) was calculated from the date the patient left the operating room until the day of hospital discharge. Death was defined as all-cause mortality. Rehospitalizations after initial discharge were based on any reason but did require that the participant be admitted into the hospital. A composite 30-day end point was defined as death, postbariatric surgical operations, or unplanned postdischarge anticoagulation therapy for suspected venous thromboembolism and failure to be discharged after 30-days postsurgery.[19]

Statistical analyses

Participants were stratified by metabolic syndrome status, and descriptive statistics were summarized as medians (interquartile range) for continuous variables and percentages for categorical variables. Anthropometric measures were further stratified by sex and postoperative end points by surgical procedure and were only reported for the most common surgical types. Differences between proportions were assessed by the Pearson chi-squared test or Fisher exact test. Normality for all continuous variables was assessed, and comparisons between those with and without metabolic syndrome were made by the Wilcoxon rank sum test. Generalized linear mixed-effect models were used to evaluate the association between metabolic syndrome and duration of surgery, length of stay, intraoperative events, and the 30-day adverse composite end point. The correlation among patients of the same surgeon was accounted for by the inclusion of different random intercepts for sites and for surgeons within site. The covariates included in the procedural outcome models included age, body mass index (BMI), anesthesia class, and sex, whereas the covariates included in the event outcome models were based on a prior LABS publication (*i.e.*, BMI, history of deep vein thrombosis or pulmonary embolus, sleep apnea, and walking limitations).[19] All statistical analyses were performed with the use of SAS software, version 9.2, and a two-sided P value of 0.05 or less was considered to indicate statistical significance.

Results

Baseline characteristics

Among the 2275 participants enrolled in the LABS-2 cohort, 1818 (79.9%) were classified as having metabolic syndrome (Fig. 1). All of the participants met the criteria for central obesity. The next most common criteria met by those with metabolic syndrome were high blood pressure (89.1%), low HDL-C (80.3%), impaired fasting glucose (68.8%), and hypertriglyceridemia (51.0%).

Baseline demographic characteristics of participants with metabolic syndrome compared to non–metabolic syndrome were older age, male sex, and white race (Table 1). There was no association between the presence of the metabolic syndrome and measures of socioeconomic status or current cigarette smoking. Among females, compared to non–metabolic syndrome participants, those with metabolic syndrome had significantly greater BMI values, larger waist and neck circumferences, and greater anterior–posterior abdominal diameter, but had a similar percentage body fat. Among males, those with metabolic syndrome had a larger median neck circumference compared to non–metabolic syndrome participants. There were no other significant differences in anthropometrics by metabolic syndrome status.

Not unexpectedly, median levels of glucose, TG, and blood pressures were greater and HDL-C levels lower in the metabolic syndrome than the non–metabolic syndrome group (Table 1). In addition, the median fasting insulin and

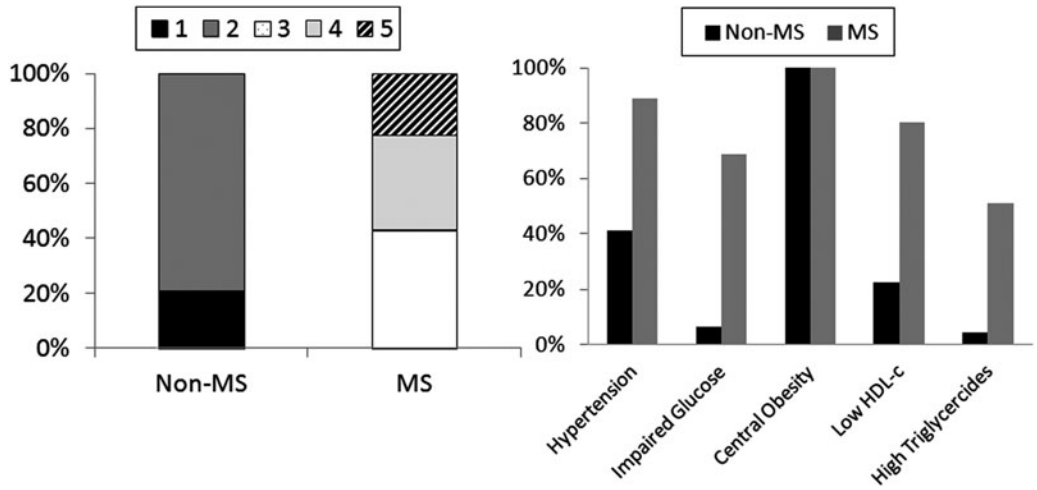

FIG. 1. Metabolic syndrome was defined as present if three or more of the following five criteria were positive: fasting blood glucose ≥100 mg/dL; elevated blood pressure [systolic blood pressure (SBP) ≥130 and/or diastolic blood pressure (DBP) ≥85 mmHg) or medication for hypertension; fasting triglyceride (TG) levels (≥150 mg/dL); fasting high-density lipoprotein cholesterol (HDL-C) values (<50 mg/dL for females, <40 mg/dL for males), or central obesity (waist circumference >88 cm for females, >102 cm for males). Non–metabolic syndrome was defined as having two or less of the above criteria. (Left) Percentage of morbidly obese subjects who met one, two, three, four, or five metabolic syndrome criteria prior to surgery by metabolic syndrome status. (Right) Percentage of subjects meeting National Cholesterol Education Program (NCEP) metabolic syndrome criteria for hypertension, impaired glucose, central obesity, low HDL-C, and high triglyceride levels (metabolic syndrome vs. non–metabolic syndrome for hypertension, impaired glucose, low HDL-C, and high triglyceride levels, $P < 0.001$).

Table 1. Demographic, Anthropomorphic, and Clinical Characteristics of the LABS-2 Subjects by Metabolic Syndrome Status

	Non–metabolic syndrome (n = *457*)	*Metabolic syndrome* (n = *1818*)	P *value*
Age (years)	40 (33, 50)	47 (38, 55)	< 0.001
Sex, % (*n*)			< 0.001
Male	15.1 (69)	23.5 (427)	
Female	84.9 (388)	76.5 (1391)	
Race, % (*n*)			< 0.001
White	84.2 (383)	87.1 (1570)	
Black	14.1 (64)	9.0 (163)	
Other	1.8 (8)	3.9 (70)	
Ethnicity, % (*n*)			0.09
Hispanic	6.4 (29)	4.5 (81)	
Non-Hispanic	93.6 (428)	95.5 (1735)	
Annual personal income, % (*n*)			0.69
≤ $49,999	73.0 (303)	73.8 (1217)	
$50,000–$99,999	22.9 (95)	21.4 (352)	
≥ $100,000	4.1 (17)	4.8 (79)	
Education level, % (*n*)			0.58
≤ High School	22.6 (96)	23.9 (404)	
> High School	77.4 (328)	76.1 (1286)	
Smoking, % (*n*)			0.98
Current/recent	13.4 (61)	13.3 (242)	
Former/never	86.6 (395)	86.7 (1573)	
BMI (kg/m^2)			
Female	44.4 (41.4, 48.9)	46.2 (41.8, 51.7)	< 0.001
Male	48.5 (43.1, 52.8)	46.9 (42.4, 52.9)	0.41
Percent body fat			
Female	51.8 (49.7, 53.9)	51.8 (49.5, 54.1)	0.79
Male	46.6 (42.4, 51.1)	44.8 (38.1, 50.6)	0.12
Waist circumference (cm)			
Female	124.0 (115.4, 132.3)	129.5 (120.1, 139.4)	< 0.001
Male	147.7 (135.9, 158.6)	147.0 (136.5, 157.4)	0.69
Neck circumference (cm)			
Female	39.3 (37.4, 41.7)	41.1 (39.0, 43.5)	< 0.001
Male	46.7 (43.7, 48.3)	48.6 (46.4, 51.3)	< 0.001
Anterior–posterior abdominal diameter (cm)			
Female	30 (25.8, 32.5)	30.8 (27.5, 35)	< 0.001
Male	32.5 (30, 36.3)	33.8 (30.8, 37.5)	0.12
Glucose (mg/dL)	90 (85, 95)	103 (92, 123)	–
Insulin (μU/mL)	14.4 (10.5, 21.6)	21.4 (14.5, 32.4)	< 0.001
HbA1c (mmol/L)	5.3 (5.1, 5.5)	5.7 (5.3, 6.6)	< 0.001
Total cholesterol (mg/dL)	187 (164, 208)	184 (158, 210)	0.40
Triglyceride (mg/dL)	99 (74, 126)	157 (114, 211)	–
LDL-C (mg/dL)	111 (93, 131)	106 (84, 130)	0.004
HDL-C (mg/dL)			
Female	54 (49, 60)	43 (37, 48)	–
Male	43 (40, 49)	35 (31, 40)	–
Systolic blood pressure (mmHg)	124 (117, 131)	131 (121, 141)	–
Diastolic blood pressure (mmHg)	79 (73, 84)	79 (72, 86)	–
C-reactive protein	0.73 (0.36, 1.37)	0.72 (0.40, 1.31)	0.91

Values are either median (interquartile range) or percent.

Metabolic syndrome was defined as present if three or more of the following five criteria were positive: fasting blood glucose ≥ 100 mg/dL; elevated blood pressure [systolic blood pressure (SBP) ≥ 130 and/or diastolic blood pressure (DBP) ≥ 85 mmHg) or medication for hypertension; fasting triglyceride (TG) levels (≥ 150 mg/dL); fasting HDL-C values (< 50 mg/dL for females, < 40 mg/dL for males), or central obesity (waist circumference > 88 cm for females, > 102 cm for males). Non–metabolic syndrome was defined as having two or less of the above criteria.

P values not provided for characteristics that comprise the definition of metabolic syndrome. Missing values (*n*) by characteristic: percent body fat, *n* = 366; waist circumference, *n* = 132; neck circumference, *n* = 123; anterior–posterior abdominal diameter, *n* = 344; glucose, *n* = 42; insulin, *n* = 40; HbA1c, *n* = 53; total cholesterol, *n* = 41; triglyceride, *n* = 41; LDL-C, *n* = 279; HDL-C, *n* = 41; SBP and DBP, *n* = 36; high-sensitivity C-reactive protein, *n* = 286.

LABS-2, Longitudinal Assessment of Bariatric Surgery-2; BMI, body mass index; HbA1c, glycosylated hemoglobin; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol.

glycosylated hemoglobin (HbA1c) levels were significantly higher, whereas LDL-C levels were significantly lower in the metabolic syndrome group. Total cholesterol and hsCRP protein levels were similar in the metabolic syndrome and non–metabolic syndrome groups.

The prevalence of prior CVD events, including myocardial infarction, angina, a prior revascularization procedure (coronary artery bypass graft surgery and percutaneous coronary intervention), or congestive heart failure, was low but significantly more common in participants with metabolic syndrome (Table 2). Use of cardiac-related medications to treat blood pressure and cholesterol levels was significantly greater in those with the metabolic syndrome compared to non–metabolic syndrome participants. Given that the presence of diabetes mellitus did not automatically classify participants as having metabolic syndrome, both participants with and without metabolic syndrome presented for bariatric surgery with a history of diabetes mellitus. As expected, however, the prevalence of diabetes mellitus was significantly higher in those with metabolic syndrome as was the use of antidiabetic medications. Other co-morbid conditions reported more frequently in bariatric surgery patients with the metabolic syndrome included sleep apnea and severe walking limitations. Significantly more subjects with metabolic syndrome had an extremely large liver size. Furthermore, median values of both alanine transaminase and aspartate transaminase were significantly higher in participants with the metabolic syndrome. Finally, while the prevalence of history of venous thromboembolism events was higher in those with the metabolic syndrome, statistical significance was not reached.

The type of bariatric surgical procedure (chi-squared test, $P=0.01$) and the anesthesia risk classification (chi-squared test, <0.001) differed based on metabolic syndrome status (Table 3). Compared with non–metabolic syndrome subjects, those with metabolic syndrome underwent laparoscopic gastric banding less frequently ($P=0.01$), were more likely to undergo open Roux-en-Y gastric bypass (RYGB) ($P=0.06$), and underwent laparoscopic RYGB and sleeve gastrectomy procedures with equal frequency ($P=$NS). The presence of metabolic syndrome was associated with higher anesthesia risk classes, with a majority of metabolic syndrome participants ($\sim$74%) versus slightly more than one-half ($\sim$56%) of the non–metabolic syndrome participants classified as anesthesia risk stage III or IV (test for trend, <0.001).

There was no statistically significant difference in duration of surgery by metabolic syndrome status when stratified by type of surgical procedure (Table 3), and there was no change with covariate adjustment. Length of hospital stay was significantly longer following laparoscopic RYGB and gastric sleeve procedures for participants with metabolic syndrome, but not following open RYGB or laparoscopic adjustable gastric banding (LAGB). With adjustment, length of stay remained longer only among those with metabolic syndrome undergoing sleeve gastrectomy [adjusted odds ratio (aOR] 1.29, 95% confidence interval (CI) 1.37–9.65, $p=0.009$). Within those undergoing the two most common LABS-2 surgical types—laparoscopic adjustable gastric band and laparoscopic RYGB—there was no difference in the proportion and the adjusted risk of composite intraoperative events by metabolic syndrome status. Furthermore, at 30-days postsurgery, there was no difference in the frequency or the risk of the composite postoperative end point by metabolic syndrome status (aOR 1.10, 95% CI 0.58–2.07, $P=0.78$).

Discussion

The criteria for metabolic syndrome capture several "nontraditional" risk factors for CVD, and its presence has been shown to predict future CVD events and mortality in men and women.[3] Instead of relying on body weight for a diagnosis, metabolic syndrome identifies those with central obesity and the adverse metabolic manifestations that often accompany central weight distribution, including dyslipidemia, dysglycemia, and elevated blood pressure. It is notable that all the LABS-2 participants met the metabolic syndrome waist circumference criteria, most likely because those seeking or referred for bariatric surgery have *a priori* Class II or greater obesity. Interestingly, greater central obesity as defined by either waist circumference or anterior–posterior abdominal diameter characterized women with metabolic syndrome but not men, whereas both women and men with metabolic syndrome had higher median neck circumferences than non–metabolic syndrome patients. Larger neck circumference has been reported to be associated with metabolic syndrome and cardiometabolic risk factors in a number of population studies.[20–22] Our data suggest that in severely obese subjects, neck circumference may provide greater discriminatory power than waist circumference for adverse metabolic outcomes in both sexes, possibly due to it acting as a risk factor for obstructive sleep apnea,[23] which has been shown to promote insulin resistance.[24] Indeed, in this study both the prevalence of sleep apnea and insulin resistance (elevated insulin levels) were higher in the metabolic syndrome subjects than non–metabolic syndrome subjects.

Because the total cholesterol levels were the same in both groups, but LDL and HDL cholesterol levels were lower in the metabolic syndrome group, this indicates that the metabolic syndrome group had more cholesterol in very-low-density lipoprotein (VLDL) and remnant particles than those without metabolic syndrome. VLDL and remnant particles are considered atherogenic[25] and likely contribute to the higher prevalence of CVD in the metabolic syndrome group. Finally, it is of note that despite previously reported positive relationships between metabolic syndrome and hsCRP,[26] a marker of inflammation and cardiovascular risk, median levels of hsCRP were not different between the LABS-2 participants with and without metabolic syndrome in this study, possibly reflecting a relatively high use of lipid-modifying medications in the metabolic syndrome versus the non–metabolic syndrome groups ($\sim$37% vs. $\sim$10%) as statins have been shown to lower hsCRP levels.[27]

The association of greater liver fat, steatohepatitis, and metabolic syndrome has been described previously.[28] Greater liver fat has been implicated in expression of insulin resistance and is predictive of future risk for metabolic syndrome.[14] In the present study, we show that metabolic syndrome is associated with both higher levels of liver enzymes as well as a larger liver size as assessed intraoperatively by the surgeon, likely reflecting a greater hepatic fat accumulation. This relationship between enlarged liver, steatohepatitis, and insulin resistance (elevated insulin levels) is consistent with the observed higher prevalence in other co-morbid conditions in the participants with metabolic syndrome compared to non–metabolic syndrome participants in this study, including sleep apnea, type 2 diabetes, and CVD.

Previously, the LABS-1 study had reported that while 30-day adverse event rates after bariatric surgery are low,

Table 2. Co-Morbidities of LABS-2 Subjects by Metabolic Syndrome Status

Characteristic	*Non–metabolic syndrome* (n = *457*)	*Metabolic syndrome* (n = *1818*)	P *value*
Diabetes, % (*n*)			< 0.001
No	97.1 (431)	57.4 (1012)	
Yes	2.9 (13)	42.6 (750)	
Insulin/oral hypoglycemia agent			0.005
No	38.5 (5)	9.2 (69)	
Yes	61.5 (8)	90.9 (681)	
Cardiovascular disease history, % (*n*)			
Prior ischemic heart disease			< 0.001
No	97.5 (435)	92.4 (1647)	
Yes	2.5 (11)	7.6 (136)	
Prior myocardial infarction			0.001
No	99.1 (453)	96.1 (1747)	
Yes	0.9 (4)	3.9 (71)	
History of angina			0.02
No	98.2 (449)	96.1 (1743)	
Yes	1.8 (8)	3.0 (71)	
Prior CABG			0.001
No	100 (457)	98.3 (1784)	
Yes	0 (0)	1.7 (31)	
Prior PCI			< 0.001
No	99.8 (456)	97.6 (1771)	
Yes	0.2 (10	2.4 (44)	
History of CHF			< 0.001
No	99.8 (456)	97.5 (1769)	
Yes	0.2 (1)	2.5 (46)	
Resting heart rate (bpm)	75 (68, 84)	78 (69, 86)	< 0.001
Antihypertensive medication			< 0.001
No	79.3 (356)	32.2 (580)	
Yes	20.7 (93)	67.8 (1222)	
Lipid-modifying medication			< 0.001
No	90.3 (400)	63.2 (1130)	
Yes	9.7 (43)	36.8 (657)	
Anti-ischemic medication			0.02
No	100 (438)	98.9 (1712)	
Yes	0 (0)	1.1 (19)	
History of sleep apnea, % (*n*)			< 0.001
No	57.1 (261)	45.4 (824)	
Yes	42.9 (196)	54.6 (991)	
Severe walking limitation, % (*n*)			< 0.001
No	97.1 (404)	92.0 (1540)	
Yes	2.9 (12)	8.0 (133)	
History of DVT or PE, % (*n*)			0.08
No	97.8 (447)	96.1 (1747)	
Yes	2.2 (10)	3.9 (71)	
Extremely large liver, % (*n*)			0.002
No	97.1 (435)	93.1 (1669)	
Yes	2.9 (13)	6.9 (124)	
Alanine transaminase (U/L)	24 (19, 35)	30 (22, 42)	< 0.001
Aspartate transaminase (U/L)	25 (21, 31)	28 (22, 36)	< 0.001

Values are either median (interquartile range) or percent.

Missing values (*n*) by characteristic: resting heart rate, $n = 59$; alanine transaminase and aspartate transaminase, $n = 8$.

Metabolic syndrome was defined as present if three or more of the following five criteria were positive: fasting blood glucose ≥ 100 mg/dL; elevated blood pressure [systolic blood pressure (SBP) ≥ 130 and/or DBP ≥ 85 mmHg) or medication for hypertension; fasting triglyceride (TG) levels (≥ 150 mg/dL); fasting high-density lipoprotein cholesterol (HDL-C) values (< 50 mg/dL for females, < 40 mg/dL for males), or central obesity (waist circumference > 88 cm for females, > 102 cm for males). Non–metabolic syndrome defined as having 2 or less of the above criteria.

LABS-2, Longitudinal Assessment of Bariatric Surgery-2; CABG, coronary artery bypass graft surgery; PCI, percutaneous coronary intervention; CHF, congestive heart failure; DVT, deep vein thrombosis; PE, pulmonary embolism.

several characteristics conferred a higher event rate, including procedure type (RYGB > LAGB), obstructive sleep apnea, impaired functional status, history of venous thromboembolism, and BMI.[19] In the present report, metabolic syndrome status, either alone or after the inclusion of these covariates, did not confer a higher risk by 30 days for our composite postoperative end point. Although our data did not agree with a previous report by Ballantyne et al.[29] that the presence of metabolic syndrome in men was associated with longer duration of surgery for RYGB, we do

Table 3. Select Characteristics and 30-Day End Points in LABS-2 Subjects by Metabolic Syndrome Status and Surgical Type

	Non–metabolic syndrome (n = *457*)	*Metabolic syndrome* (n = *1818*)	P *value*
Bariatric surgical procedure, % (n)			0.01
LAGB	28.9 (132)	23.1 (420)	
Lap RYGB	62.4 (285)	63.1 (1147)	
Open RYGB	5.3 (24)	9.0 (163)	
SG	2.0 (9)	2.6 (48)	
Other	1.5 (7)	2.2 (40)	
Anesthesia risk class, % (*n*)			< 0.001
Stage I	0.2 (1)	0.1 (2)	
Stage II	43.7 (199)	26.0 (470)	
Stage III	55.2 (251)	69.6 (1258)	
Stage IV	0.9 (4)	4.3 (78)	
Duration of surgery (min)			
LAGB	114 (95, 135)	118 (97, 145)	0.16
Lap RYGB	191.5 (162.5, 222)	195 (162, 236)	0.19
Open RYGB	190 (152, 261)	169 (140, 224)	0.51
SG	177 (159, 213)	204 (180, 235)	0.28
Other	242 (153, 315)	202.5 (159, 260)	0.38
Intraoperative events, % (*n*)			
LAGB			0.40
No	95.4 (126)	97.1 (406)	
Yes	4.6 (6)	2.9 (12)	
Lap RYGB			0.60
No	94.7 (268)	93.9 (1074)	
Yes	5.3 (15)	6.1 (70)	
Length of stay (days)			
LAGB	1 (1, 1)	1 (0, 1)	0.77
Lap RYGB	2 (2, 2)	2 (2, 3)	0.001
Open RYGB	4 (3, 4.5)	4 (3, 4)	0.63
SG	2 (2, 3)	3 (2, 4)	0.03
Other	3 (4, 4)	4 (3, 4)	0.20
30-day composite postoperative events, % (*n*)			
LAGB			
No	99.2 (130)	99.0 (416)	1.0
Yes	0.8 (1)	1.0 (4)	
Lap RYGB			
No	96.5 (275)	95.2 (1092)	0.35
Yes	3.5 (10)	4.8 (55)	

Values are either median (interquartile range) or percent.

Missing values (*n*) by characteristic: Duration of surgery, $n = 60$.

Metabolic syndrome was defined as present if three or more of the following five criteria were positive: fasting blood glucose ≥ 100 mg/dL; elevated blood pressure [systolic blood pressure (SBP) ≥ 130 and/or diastolic blood pressure (DBP) ≥ 85 mmHg) or medication for hypertension; fasting triglyceride (TG) levels (≥ 150 mg/dL); fasting high-density lipoprotein cholesterol (HDL-C) values (<50 mg/dL for females, < 40 mg/dL for males), or central obesity (waist circumference > 88 cm for females, > 102 cm for males). Non–metabolic syndrome was defined as having two or less of the above criteria.

Other surgical procedures include biliopancreactic diversion with duodenal switch and banded gastric bypass.

LABS-2, Longitudinal Assessment of Bariatric Surgery-2; LAGB, laparoscopic adjustable gastric banding; Lap, Laparoscopic; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy.

show that the presence of metabolic syndrome was associated with a longer median length of hospital stay in those undergoing laparoscopic RYGB and sleeve gastrectomy. Interestingly, the higher baseline risk profile of those with metabolic syndrome did not translate into higher rates for adverse short-term outcomes. This may be explained by preoperative identification and optimization of these risks factors, which although not a part of standard protocol for LABS-2 sites, is seen by the greater use of medications to treat hypertension and hyperlipidemia in those with metabolic syndrome. These findings differ from a recent report of 190,000 patients that underwent bariatric surgery[13] and found a prevalence of metabolic syndrome of only 12% of the total surgical population. This report also showed higher adverse morbidity and mortality rates at both 30 and 90 days after surgery in those with metabolic syndrome compared to non–metabolic syndrome subjects. However, because that study used a large national registry that did not include specific clinical or laboratory measures, the criteria used to define metabolic syndrome were very conservative and nontraditional, preventing direct comparison to the results with this and other metabolic syndrome reports,[8–12] which used NCEP criteria.

There are several limitations to our study. LABS-2 is a nonrandomized, observational study lacking a nonsurgical obese control group for comparison. Because patients self-select or are referred in for bariatric surgery, selection bias can influence subject characteristics. This is most evident in

the typically larger percentage of women studied in this and most other bariatric surgery studies. In addition, because of the BMI criteria for consideration of surgical management of obesity, our analysis is limited to adults with class II or greater obesity. All of these considerations limit the generalizability of our findings to the population of adults with morbid obesity seeking or having bariatric surgery. Furthermore, this study was designed to evaluate the efficacy of bariatric surgery in relation to long-term events and as such is underpowered with respect to many 30-day outcomes (small effect sizes).

In conclusion, this is the largest study to date using updated NCEP criteria to show that metabolic syndrome is highly prevalent in severely obese patients that present to major surgical centers for bariatric surgery. Patients with metabolic syndrome were older, more likely to be male, to have a greater BMI, to have significantly greater frequency of cardiac, pulmonary, metabolic, and hepatic co-morbidities, and were more likely to have poorer functional status (*i.e.*, severe walking limitation). Establishing a diagnosis of metabolic syndrome in patients considering bariatric surgery may help surgeons identify patients who also have cardiovascular and pulmonary related co-morbidities. Although the designation of metabolic syndrome itself did not confer a higher risk for short-term outcomes post–bariatric surgery, decisions on clinical management of people seeking bariatric surgery in the short and long-run may vary based on their metabolic syndrome status. Extended follow-up is warranted to establish whether or not metabolic syndrome is related to longer-term adverse health outcomes.

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