Is Cardiac Surgery Safe in Extremely Obese Patients (Body Mass Index 50 or Greater)?

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Background. We investigated the impact of extreme obesity (body mass index [kg/m^2] 50 or greater) on short-term clinical outcomes and report 1-year mortality.

Methods. Fifty-seven patients were found to have a body mass index of 50 or greater among 14,449 patients who underwent cardiac surgery between July 2000 and June 2007. Multivariable logistic regression analyses were used to assess the independent influence of extreme obesity on the major outcomes.

Results. Of the 57 patients, the mean age was 58 ± 11 years, mean body mass index was 55.1, and 63% of the patients were women. Forty patients underwent elective surgery. Forty-one patients had isolated coronary artery bypass graft surgery. The overall operative mortality was 9%; the mortality was 5% in isolated coronary artery bypass graft surgery and 5% in elective surgery. Fifteen patients had nonelective isolated coronary artery bypass graft surgery, and 2 patients had emergent active endocarditis surgery. Off-pump coronary artery bypass graft surgery was performed on 23 patients (23 of 41, 54%). After adjusting for known preoperative and operative risk factors through a multivariate logistic model, extreme obesity did not emerge as a significant risk factor for operative mortality (odds ratio, 1.75; $p = 0.47$) and other adverse outcomes ($p > 0.05$) after elective surgery; however, extreme obesity was marginally associated with increased mortality (odds ratio, 2.69; $p = 0.05$) and was a risk predictor for longer intensive care unit stays (odds ratio, 2.43; $p = 0.01$) in overall surgery. The 1-year survival rate was 82.5%.

Conclusions. Extreme obesity is not a contraindication to elective cardiac surgery. Studies stratifying the risk factors of mortality for nonelective surgery in extremely obese patients may be warranted.

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Obesity has traditionally been considered a strong risk factor associated with increased cardiovascular disease and mortality. However, several large clinical studies have found that obese patients have equal or even better clinical outcomes than nonobese patients after coronary surgery [1–3]. Most studies estimated the impact of obesity with two categories: body mass index (BMI, kg/m^2) 30 to 39 defined as obese and 40 or greater as severely obese. This severely obese group (BMI ≥ 40) includes a wide range of patient BMI values. Such wide variations in obesity may dilute or mask the influence of extreme obesity (BMI ≥ 50) on postoperative outcomes. Our study evaluated the clinical consequences of extremely obese patients undergoing cardiac surgery.

Patients and Methods

Patient Population

All patients undergoing cardiac surgery from July 1, 2000, to June 30, 2007, were retrospectively reviewed through a computerized cardiac surgery database at the Washington Hospital Center in Washington, DC. Baseline demographics, procedure data, and perioperative outcomes were recorded and entered concurrently during hospitalization into the computerized database by a data-coordinating center as part of routine clinical practice. All data were defined according to The Society of Thoracic Surgeons national database (version 2.52). Guidelines and definitions are available at http://www.sts.org/sections/stsnationaldatabase/datamanagers. The Medstar Institutional Review Board approved the research protocol before the study and waived the requirement of informed consent as well as the requirement for signed Health Insurance Portability and Accountability Act authorization.

Operative mortality was identified as death occurring during hospital stay or within 30 days after surgery. Patients were contacted by telephone 30 days after hospital discharge as part of our routine clinical follow-up. One-year postoperative all-cause mortality was acquired from the US Social Security death index.

Body Mass Index Category

According to the definition of the Centers for Disease Control and Prevention [4], BMI is categorized into five groups: BMI less than 19 lean, 19 to 24 normal, 25 to 29 overweight, 30 to 39 obese, and 40 or greater severely obese. Because our particular interest was in the surgical outcomes of extremely obese patients, we subcategorized

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the severely obese group (BMI ≥ 40) into two groups, BMI 40 to 49 severely obese, and BMI 50 or greater extremely obese.

Statistics

Data are expressed as percentages, mean value ± standard deviation, and median (minimum, maximum). The univariate analysis was conducted to compare the perioperative variables in extremely obese patients with normal BMI category using χ^2 test, Fisher's exact test, or Wilcoxon two-sided test, as appropriate.

Multivariable logistic regression models were constructed to evaluate the impact of extreme obesity and other BMI groups, compared with normal BMI, on operative mortality and each of the other major outcomes. Stepwise logistic regression was used to select variables to be included in the final logistic regression models. Confounding variables included in the stepwise logistic models were age, female sex, race, diabetes, hypertension, family history of coronary artery disease, history of myocardial infarction (MI), recent MI (within 24 hours), left main disease, preoperative cardiac shock, cardiovascular disease history, preoperative angina, hypercholesterolemia, ejection fraction less than 0.35, intraaortic balloon pump, previous stroke, carotid artery disease, peripheral vascular disease, renal failure, hemodialysis, current smoker, chronic obstructive pulmonary disease, redo coronary artery bypass graft surgery (CABG), elective surgery (versus nonelective surgery), on-pump CABG (versus off-pump), isolated CABG (versus other cardiac surgery), and preoperative use of β-blockers, calcium-channel blockers, angiotensin-converter enzyme inhibitors, and lipid-lowering drugs. The resultant odds ratios are presented with 95% confidence intervals. The relationship between extreme obesity and mortality was explored for overall cardiac surgery, and elective surgery.

All statistical analysis was performed with SAS for Windows Version 9.1 (SPSS Inc, Chicago, IL). Probability values of less than 0.05 were considered significant.

Results

A total of 14,449 patients had cardiac surgery during the study interval. Fifty-seven patients (0.4%) were identified as having a BMI of 50 or greater. Of these, 41 patients with a BMI of 50 or greater underwent isolated CABG surgery.

Table 1. Procedures Performed in 57 Patients With Body Mass Index of 50 or Greater

Procedures	Patients	Nonelective Surgery
Isolated CABG	41 (72%)	15 (37%)
CABG + AVR	6 (10.5%)	0
Myxoma	4 (7%)	0
AVR/MVR	3 (5.3%)	2 (67%), endocarditis
AVR	2 (3.5%)	0
Other	1 (1.8%)	0
Total	57 (100%)	17 (33%)

AVR = aortic valve replacement; AVR/MVR = AVR + MVR; CABG = coronary artery bypass grafting; MVR = mitral valve replacement.

Procedures performed on patients with a BMI of 50 or greater are presented in Table 1. Seventeen patients (33%) underwent nonelective surgery, 15 of these had isolated CABG; the remaining 2 each had endocarditis and both underwent mitral and aortic valve replacement.

Among 41 isolated CABG patients, 75.6% (31 patients) had three or more grafts, and 90% (37 patients) had left internal mammary artery revascularization. More than one-half (23 patients) of these patients (56%) underwent off-pump surgery. Nonelective CABG was performed in 37% (15 patients) of these patients; 53.3% (8 patients) of them had off-pump CABG.

Comparison of preoperative characteristics with the normal BMI group is presented in Table 2. The extremely obese group was predominantly composed of female patients (61%). The mean BMI was 55.1 kg/m^2 (range, 50 to 68.4 kg/m^2); the mean weight was 143.4 kg (range, 82.7 to 230 kg); mean height was 160 cm (range, 118 to 183 cm). By comparison with normal BMI patients, patients with a BMI of 50 or greater were significantly younger and shorter, more likely to be African American (52%), and associated with a higher prevalence of diabetes and hypertension. On further review of the preoperative morbidities of isolated CABG surgery (41 patients), a marginally higher prevalence of hypercholesterolemia ($p = 0.06$), history of family cardiovascular disease ($p = 0.06$), and peripheral vascular disease ($p = 0.06$) were noted. The usage of calcium channel-blockers ($p = 0.01$) was significantly increased, as well as angiotensin-converter enzyme inhibitors and angiotensin II receptor blockers ($p = 0.05$) in this group.

Univariate analysis (Table 3) revealed that the extremely obese patients had a similar incidence of major adverse clinical outcomes compared with patients with normal BMI ($p > 0.05$) in all surgery. In the subanalyses, the mortality in patients with extreme obesity was also not significantly different from normal BMI patients undergoing elective cardiac surgery (5% versus 4%; $p = 0.66$) and isolated CABG surgery (5% versus 3%; $p = 0.17$).

Table 4 depicts the multivariable risk factors for operative mortality in overall surgery and in elective surgery. The adjusted odds ratios for other major outcomes are presented in Table 5. In multivariate analysis, with adjustment by normal BMI and other confounding factors, extreme obesity did not emerge as a risk predictor for operative mortality (odds ratio, 1.75; 95% confidence interval, 0.38 to 8.09; $p = 0.47$; Table 4) and for other adverse outcomes compared with normal BMI after elective surgery ($p > 0.05$; Table 5). Extreme obesity was marginally associated with increased operative mortality and was a risk factor of longer postoperative intensive care unit stays ($p = 0.03$) in overall surgery ($p = 0.05$). A strong association was observed between extreme obesity and decreased requirement of red blood cell products in overall ($p < 0.01$) and in elective surgery ($p < 0.01$).

Operative mortality is characterized in Table 6. All 5 patients were female. Two patients had endocarditis,

Table 2. Characteristics Comparing Normal Body Mass Index With Other Body Mass Index Categories: All Surgery[a]

Variable	BMI 19–24 (3,732)	BMI ≤ 19 (214)	*p* Value	BMI 25–29 (5,551)	*p* Value	BMI 30–39 (4,340)	*p* Value	BMI 40–49 (555)	*p* Value	BMI ≥ 50 (57)	*p* Value
Age (y)	67 ± 12	66 ± 14	0.68[c]	65 ± 11	<0.01[c]	62 ± 11	<0.01[c]	59 ± 11	<0.01[c]	58 ± 11	<0.01
Female sex	1,235 (33%)	117 (55%)	<0.01	1,398 (25%)	<0.01	1,515 (35%)	0.09	297 (54%)	<0.01	36 (63%)	<0.01
Height (inches)	67.4 ± 3.9	66.5 ± 4.1	<0.01[c]	67.9 ± 3.8	<0.01[c]	67.3 ± 4.1	0.12[c]	65.7 ± 4.3	<0.01[c]	63.2 ± 6.6	<0.0[c]
African American	784 (21%)	64 (30%)	<0.01	1,277 (23%)	0.02	1,259 (29%)	<0.01	217 (39%)	<0.01	30 (52%)	<0.01
Diabetes	885 (24%)	46 (22%)	0.46	1,634 (29%)	<0.01	1,963 (45%)	<0.01	314 (57%)	<0.01	38 (67%)	<0.01
Hypertension	2,415 (65%)	134 (63%)	0.53	3,974 (72%)	<0.01	3,448 (79%)	<0.01	469 (85%)	<0.01	47 (82%)	0.01
Chronic heart failure	575 (15%)	57 (27%)	<0.01	692 (12%)	<0.01	633 (15%)	0.30	124 (22%)	<0.01	14 (25%)	0.06
Hypercholesterolemia	2,200 (59%)	94 (44%)	<0.01	3,747 (68%)	<0.01	3,084 (71%)	<0.01	395 (71%)	<0.01	38 (67%)	0.24
Renal failure	206 (6%)	24 (11%)	<0.01	217 (4%)	<0.01	192 (4%)	0.02	28 (5%)	0.65	1 (2%)	0.37[b]
Family history CAD	1,715 (46%)	96 (45%)	0.75	2,813 (51%)	<0.01	2,412 (56%)	<0.01	299 (54%)	<0.01	31 (54%)	0.21
History of MI	1,338 (36%)	99 (46%)	<0.01	2,084 (38%)	0.10	1,697 (39%)	<0.01	220 (40%)	0.08	24 (42%)	0.33
Previous stroke	306 (8%)	25 (12%)	0.07	358 (6%)	<0.01	312 (7%)	0.09	34 (6%)	0.09	5 (9%)	0.81[b]
EF (<0.35 versus ≥0.35)	833 (22%)	66 (31%)	<0.01	1,151 (21%)	0.07	923 (21%)	0.25	119 (21%)	0.62	13 (23%)	0.94
Isolated CABG	2,474 (66%)	119 (56%)	<0.01	4,161 (75%)	<0.01	3,351 (77%)	<0.01	410 (74%)	<0.01	41 (72%)	0.37
Elective surgery (versus nonelective)	2,457 (66%)	128 (60%)	0.07	3,635 (66%)	0.71	2,867 (66%)	0.86	358 (65%)	0.53	40 (70%)	0.34

[a] Values are expressed as number (%), mean ± standard deviation, or median (25th–75th percentile). All comparisons are made using a χ^2 test for independence unless noted otherwise. [b] Fisher's exact test. [c] Student's *t* test.

BMI = body mass index; CABG = coronary artery bypass graft surgery; CAD = coronary artery disease; EF = ejection fraction; MI = myocardial infarction.

Table 3. Clinical Outcomes by Body Mass Index Category in All Surgery[a]

Variable	BMI 19–24 (3,732)	BMI ≤ 19 (214)	*p* Value	BMI 25–29 (5,551)	*p* Value	BMI 30–39 (4,340)	*p* Value	BMI 40–49 (555)	*p* Value	BMI ≥ 50 (57)	*p* Value
Operative mortality	218 (6%)	27 (13%)	<0.01	228 (4%)	<0.01	171 (4%)	<0.01	27 (5%)	0.36	5 (9%)	0.38[b]
Stroke	115 (3%)	11 (5%)	0.10	103 (2%)	<0.01	84 (2%)	<0.01	19 (3%)	0.67	4 (7%)	0.10[b]
MI	84 (2%)	8 (4%)	0.16[b]	97 (2%)	0.09	67 (2%)	0.02	7 (1%)	0.13	2 (4%)	0.37[b]
Atrial fibrillation	1,183 (32%)	79 (37%)	0.11	1,617 (29%)	0.01	1,276 (29%)	0.03	195 (35%)	0.11	17 (30%)	0.76
Renal failure	147 (4%)	10 (5%)	0.59	165 (3%)	0.01	167 (4%)	0.83	41 (7%)	<0.01	3 (5%)	0.49[b]
Days in ICU	1 (1–2)	9 (1–5)	<0.01[c]	1 (0.9–1.2)	<0.01[c]	1 (0.9–1.6)	<0.01[c]	1 (0.9–2)	0.17[c]	1 (0.8–2.4)	0.23[c]
Length of stay	3 (1–6)	4 (1–9)	<0.01[c]	3 (1–6)	<0.01[c]	3 (1–6)	0.21[c]	3 (1–6)	0.70[c]	2 (1–4)	0.69[c]
Prolonged ventilation	573 (15%)	63 (29%)	<0.01	638 (11%)	<0.01	574 (13%)	0.01	108 (19%)	0.01	14 (25%)	0.06
Reoperation owing to bleed	168 (5%)	17 (8%)	0.02	183 (3%)	<0.01	95 (2%)	<0.01	15 (3%)	0.05	2 (4%)	1.00[b]
Total amount of PRBC transfused	750 (500–1250)	1000 (750–2250)	<0.01[c]	750 (500–1000)	<0.01[c]	750 (500–1250)	<0.01[c]	750 (500–1250)	0.31[c]	875 (500–1750)	0.49[c]
Sternal deep infections	21 (0.6%)	1 (0.5%)	1.00[b]	34 (0.6%)	0.76	39 (0.9%)	0.08	8 (1.4%)	0.04[b]	1 (1.8%)	0.28[b]
Sternal superinfections	8 (0.2%)	0 (0)	1.00[b]	14 (0.3%)	0.71	30 (0.7%)	<0.01	15 (2.7%)	<0.01[b]	1 (1.8%)	0.13[b]

[a] Values are expressed as number (%), mean ± standard deviation, or median (25th–75th percentile). All comparisons are made using a χ^2 test for independence unless noted otherwise. [b] Fisher's exact test. [c] Wilcoxon two-sided test.

BMI = body mass index; ICU = intensive care unit; MI = myocardial infarction; PRBC = product of red blood cells.

underwent emergent mitral and aortic valve replacement surgery, and died of postoperative endocarditis. Another nonemergent mitral and aortic valve replacement patient died of postoperative multiple organ failure. The death of both isolated CABG patients was related to cardiac dysfunction. The mortality in overall surgery was 8.7%; 5% in isolated CABG surgery, 5% in elective surgery, 17.6% in all nonelective surgery, and 6.7% in nonelective isolated CABG surgery.

Using the US Social Security Death Index, the overall survival after 1 year was found to be 82.5% (47 of 57 patients). Five patients died between 30 days and 6 months after surgery. Of the 5 patients, 80% had isolated CABG surgery (Table 6).

Comment

The relationship between obesity and short-term mortality after CABG surgery has remained controversial [1–3, 5, 6]. Recently, two large-scale studies [5, 6] demonstrated severe obesity (BMI ≥ 35) was associated with higher operative mortality compared with normal and overweight patients. In our study, extreme obesity (BMI ≥ 50) was not associated with increased mortality after elective cardiac surgery.

Villavicencio and associates [7] conducted an analysis of 57 patients with a BMI of 50 or greater and found the operative mortality was 7%, a mortality of 15% in emergent or urgent surgery, and a mortality of 15% in nonisolated CABG surgery. Our study observed similar results. Although the mortality in nonelective surgery in this group of patients was higher than expected in patients after regular cardiac surgery, it still compares favorably with the results previously published [8–10]. Mortality for nonelective CABG has remained from 9% to 17% [8, 9], or even higher in patients with left main coronary disease [10].

The impact of BMI on the outcomes of endocarditis surgery has been rarely reported. In our study, 2 patients had emergent valve surgery for active endocarditis, and died of refractory sepsis in the intensive care unit. Both patients had multiple preoperative hospital admissions owing to pulmonary edema, intractable heart failure, central nervous system syndrome, syncope, annular abscess, and severe mitral insufficiency. Villavicencio and colleagues [7] found that the incidence of endocarditis was 9% in 57 patients with a BMI of 50 or greater who underwent cardiac surgery at the Mayo Clinic, which was significantly higher than in normal patients or those in other obese categories ($p < 0.001$); the operative mortality was 22%. A mortality rate of 36% was reported for endocarditis patients who underwent emergent or urgent surgery [11]. Studies have reported that no patients with preoperatively complicated septic shock survived after emergent surgery [12, 13]. In our study the number of patients with endocarditis was too small to enable formal analysis and meaningful conclusions, but the combination of an increased preoperative incidence, disease nature, and high operative mortality in this extremely obese

Table 4. Multiple Logistic Regression With Operative Mortality as an Outcome

Variable	All Surgery OR (95% CI)[a]	*p* Value	Elective Surgery OR (95% CI)[b]	*p* Value
BMI categories versus BMI 19–24				
<19	1.54 (0.96–2.49)	0.08	1.24 (0.59–2.61)	0.58
25–29	0.81 (0.66–1.01)	0.06	0.94 (0.68–1.29)	0.68
30–39	0.86 (0.68–1.09)	0.21	0.85 (0.59–1.22)	0.37
40–49	1.05 (0.66–1.67)	0.84	0.78 (0.36–1.70)	0.53
≥50	2.69 (1.00–7.25)	0.05	1.75 (0.38–8.09)	0.47
Age (y)	1.05 (1.04–1.06)	<0.01	1.07 (1.05–1.08)	<0.01
Female	1.60 (1.34–1.91)	<0.01	1.76 (1.34–2.31)	<0.01
Diabetes	1.48 (1.22–1.79)	<0.01	1.99 (1.49–2.65)	<0.01
Hypertension	0.99 (0.80–1.23)	0.93	0.88 (0.63–1.22)	0.43
Family history CAD	0.91 (0.76–1.09)	0.32	0.88 (0.67–1.15)	0.34
Renal failure	1.65 (1.18–2.31)	<0.01	1.48 (0.87–2.51)	0.15
Hemodialysis	2.42 (1.63–3.58)	<0.01	3.60 (2.06–6.30)	<0.01
History of MI	1.40 (1.15–1.70)	<0.01	1.45 (1.09–1.93)	0.01
Recent MI (within 24 h)	1.64 (1.08–2.48)	0.02		
Previous stroke	1.32 (1.01–1.72)	0.04	1.14 (0.75–1.72)	0.55
Redo CABG	2.38 (1.82–3.11)	<0.01	2.57 (1.76–3.76)	<0.01
Left main disease	1.02 (0.80–1.30)	0.89	1.21 (0.80–1.83)	0.36
PVD	1.28 (1.02–1.61)	0.03	1.39 (1.00–1.92)	0.05
Carotid artery disease	1.37 (0.88–2.15)	0.17	1.92 (1.02–3.62)	0.04
EF (≥0.34 versus <0.34)	2.01 (1.67–2.42)	<0.01	1.95 (1.46–2.61)	<0.01
Preoperative cardiac shock	2.55 (1.71–3.79)	<0.01	1.81 (0.37–8.23)	0.46
Elective surgery	0.46 (0.38–0.55)	<0.01		
Cardiovascular disease history	2.49 (1.69–3.67)	<0.01	2.29 (1.21–4.31)	0.01
On-pump (versus off-pump CABG)	1.75 (1.36–2.23)	<0.01	1.60 (1.11–2.30)	0.01
Isolated CABG	0.31 (0.25–0.39)	<0.01	0.33 (0.24–0.46)	<0.01
COPD	1.56 (1.18–2.06)	<0.01	1.29 (0.82–2.03)	0.26
Current smoker	0.93 (0.71–1.22)	0.60	0.95 (0.61–1.49)	0.83
IABP	1.21 (0.82–1.79)	0.34	0.39 (0.04–3.55)	0.40
Hypercholesterolemia	0.68 (0.56–0.84)	<0.01	0.57 (0.42–0.78)	<0.01
ß-Blockers	0.96 (0.80–1.16)	0.68	1.21 (0.92–1.60)	0.18
Calcium-channel blockers	1.02 (0.81–1.28)	0.85	1.12 (0.81–1.55)	0.50
ACE inhibitors and ARB	1.00 (0.84–1.20)	0.98	1.12 (0.86–1.47)	0.41
Lipid-lowering medication	0.90 (0.74–1.10)	0.32	0.97 (0.72–1.32)	0.86
Preoperative angina	1.10 (0.91–1.32)	0.32	1.33 (1.01–1.74)	0.04

[a] Hosmer and Lemeshow goodness-of-fit test: $\chi^2 = 16.80$, df = 8, $p = 0.03$, C statistic = 0.85, in overall surgery (N = 13,990). [b] Hosmer and Lemeshow goodness-of-fit test: $\chi^2 = 12.34$, df = 8, $p = 0.14$, C statistic = 0.84, in elective surgery (N = 9,236).

ACE = angiotensin-converting enzyme; ARB = angiotensin II receptor blockers; BMI = body mass index; CABG = coronary artery bypass graft surgery; CAD = coronary artery disease; CI = confidence interval; COPD = chronic obstructive pulmonary disease; EF = ejection fraction; IABP = intraaortic balloon pump; MI = myocardial infarction; OR = odds ratio; PVD = peripheral vascular disease.

group underscores the critical need for baseline risk stratification to avoid devastating complications.

Most of the previous studies have been conducted focusing on the comparisons of short-term outcomes between obese and nonobese patients after cardiac surgery [1–3, 5]. The impact of obesity on long-term outcome has rarely been reported. Our study found that the 1-year mortality differed from the operative mortality in surgery distribution. Extreme obesity did not affect operative mortality of elective isolated CABG, but mortality from CABG surgery accounted for 80% of the 1-year mortality. Schwann and associates [14] found better short-term outcomes in obese patients but worse long-term outcomes after coronary surgery. In our study, extremely obese patients had a higher prevalence of diabetes, hypertension, and hypercholesterolemia. These comorbidities may play a critical role in predisposing obese patients to long-term adverse outcomes.

In our study, extremely obese patients (58 ± 11 years) were 10 years younger than nonobese patients (68 ± 10 years) at the time of cardiac surgery. We noted a consistent trend toward younger age for cardiac surgery as BMI increased. Yap and coworkers [15] found obesity to be most prevalent in the age of 35 to 54 years, and obese patients were 1.4 times more likely to undergo CABG or valve surgery.

Female sex predominated the operative mortality in our study (100% female). Although women have been

Table 5. Impact of Extreme Obesity on Major Outcomes Other Than Mortality

Outcomes	All Surgery OR (95% CI)[a]	p Value	Elective Surgery OR (95% CI)[a]	p Value
Stroke	2.57 (0.88–7.50)	0.08	2.76 (0.79–9.66)	0.11
MI	1.26 (0.29–5.45)	0.76	0.86 (0.11–6.58)	0.88
Renal failure	1.45 (0.43–4.96)	0.55	1.58 (0.35–7.08)	0.55
AF	1.77 (0.97–3.22)	0.06	1.47 (0.69–3.12)	0.31
Days of ICU stays	2.02 (1.09–3.73)	0.03	1.25 (0.59–2.65)	0.56
Length of stay	1.00 (0.48–2.10)	0.99	0.92 (0.39–2.17)	0.85
PRBC transfusion	0.18 (0.10–0.35)	<0.01	0.21 (0.1–0.43)	<0.01
Sternal superinfection	3.2 (0.08–127.13)	0.54	...	...
Sternal deep infection	3.69 (0.13–106.87)	0.45	...	...

[a] The odds ratios were adjusted for the cofounders that were described in the method section.

AF = atrial fibrillation; CI = confidence interval; ICU = intensive care unit; MI = myocardial infarction; OR = odds ratio; PRBC = product of red blood cells.

identified as experiencing greater mortality and morbidities after isolated CABG, valve, and combination surgery of valve and CABG [16–18], we cannot appreciate a similar observation in our study owing to the small sample size. All 5 of these patients underwent nonelective and redo surgery, which highly indicated the possibility of preoperative critical conditions or surgical reluctance.

Previous studies have demonstrated a prominent association between obesity and a number of adverse outcomes, such as atrial fibrillation, prolonged mechanical ventilation, longer intensive care unit stay, and sternal infection [1–3]. We were only able to identify a significant association between extreme obesity and longer intensive care unit stay. We found extremely obese patients had a decreased requirement for blood products transfusion. This is consistent with previous reports [1, 5, 14]. One of the possibilities for this finding is that extreme obesity is associated with a lower degree of hemodilution caused by the relatively fixed size of the bypass circuit. This may also decrease cardiopulmonary bypass–generated coagulopathy that reduces the rate of postoperative bleeding [14]. In our study, another explanation might be the more frequent use of off-pump CABG surgery.

Table 6. Characteristics of Mortality in Patients With Body Mass Index of 50 or Greater

Characteristics	Operative Mortality (N = 5 of 57)	One-Year Mortality (N = 5 of 52)
Incidence	5 (8.7%)	5 (9.6%)
Female	5 (100%)	3 (60%)
Age (y)	55.4	61.8
Nonelective surgery (17)	3 (17.6%)	2
AVR/MVR (2 endocarditis)	2	0
CABG (15)	1 (6.7%)	2
Elective surgery (40)	2 (AVR/MVR + redo CABG)	3 (2 CABG + myxoma)
Cause of mortality		N/A
Infection	2	
Cardiac dysfunction	1	
Dysrhythmia	1	
Multiple organ failure	1	

AVR = aortic valve replacement; CABG = coronary artery bypass graft surgery; MVR = mitral valve replacement; N/A = not available.

A significant concern remains regarding the formidable surgical challenge of performing cardiac surgery on these extremely obese patients. In our hospital, an average of 50% of CABG surgery was performed by off-pump technique in the last 5 years. In this group of patients, 56% underwent off-pump CABG. The proportions of internal mammary artery (IMA) usage and grafts received per patient are highly comparable with other studies conducted on general isolated CABG patients, in which the use of the IMA graft was 83% and 93% in men, and 76% and 92% in women [19, 20]. The favorable result of CABG surgery in this group of patients is particularly noteworthy because of the dominant constitution of female patients (61%). Prior studies indicated that women have better outcomes with off-pump CABG than with on-pump CABG [16, 19, 20].

As regards the interpretation of our results, several study limitations need addressing. First, this study may include all the limitations inherent in any retrospective single-institution analysis, and underestimate the true effect of extreme obesity on combined outcomes from multiple centers. Second, the relatively small sample size limits powerful statistical conclusions. Additionally, extremely obese patients undergoing elective surgery were discretely selected, suggesting selection bias. With the exception of nonelective surgery, our current results are most likely attributable to improved diagnostics, case ascertainment, and intent references.

In summary, we found that extreme obesity promoted the need for surgical intervention 10 years earlier than normal weight. Cardiac surgery does not seem contraindicated among extremely obese patients. This group of patients could especially benefit from elective off-pump CABG surgery with lower operative mortality and other postoperative complications. Extreme obesity was not associated with increased risk of operative mortality in elective surgery.

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INVITED COMMENTARY

Major public health consequences have evolved from the obesity epidemic in the United States and worldwide. It has been estimated that approximately 30% of the adult population in the United States is classified as obese, defined as a body mass index (BMI) > 30 kg/m^2. Obesity is an independent risk factor for cardiovascular disease (CVD) and is related to a constellation of comorbidities, such as hypertension (HTN), dyslipidemia, type II diabetes mellitus (DM), inflammation, thrombosis, renal dysfunction, and the insulin resistant syndrome [1–4]. Statistically, there is a significant increase of younger obese men and women who die from CVD when compared with people who have a normal BMI. In fact, for every 1 kg/m^2 increase in BMI, there is a 4% increase in the percentage of myocardial infarct, a 3% increase in CVA, a 6% increase in HTN, an 8% increase in venous thrombotic emboli, and a 5% increase in atrial fibrillation [5].

Older, surgical literature reported increased BMI as a risk factor for new onset atrial fibrillation, wound infections, increased intensive care (ICU) unit days and 30-day mortality [6–8]. However, the association between obesity and increased morbidity and mortality after coronary artery bypass grafting (CABG) remains mixed in recent articles. Rockx and colleagues [9] and Villancencio and colleagues [10] reported that increased BMI was not a predictor for major perioperative complications, except for increased ICU days. In fact, lower BMI was a greater risk factor for increased risk of perioperative complications than obesity.

The majority of published articles report obesity (BMI $\geq$ 30) as a homogeneous group of patients with fixed risk factors, which is not a statistical reality. This article [11] reviewed a subset of patients with extreme obesity (BMI $\geq$ 50) to assess the effect of this BMI subset on surgical morbidity and mortality after open heart surgery (OHS). Sun and colleagues [11] reported a series of 57 extremely obese patients (BMI $\geq$ 50) with a mean age of 58 years; mean BMI $\geq$ 55; 63% women; 52% African American; and a significant incidence of HTN, DM, and short height. Elective CABG was done in 72% of the patients while the remainder were nonelective. Approximately 50% of all CABG was done off-pump. Using a multi-variant analysis, extreme obesity did not emerge as a significant risk factor for operative mortality and other adverse outcomes after elective surgery. Extreme obesity was associated with increased mortality and as a risk factor for longer ICU days in overall surgery. In the subset analysis, the mortality of patients with extreme obesity was also not significantly different from normal BMI patients undergoing elective CABG and isolated coronary bypass surgery. There were five mortalities (all women); only

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