Severe Obesity Is Associated With Increased Risk of Early Complications and Extended Length of Stay Following Coronary Artery Bypass Grafting Surgery

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***Background*—**Better understanding of the relationship between obesity and postsurgical adverse outcomes is needed to provide quality and efficient care. We examined the relationship of obesity with the incidence of early adverse outcomes and in-hospital length of stay following coronary artery bypass grafting surgery.

***Methods and Results*—**We analyzed data from 7560 patients who underwent coronary artery bypass grafting. Using body mass index (BMI; in kg/m^2) of 18.5 to 24.9 as a reference, the associations of 4 BMI categories (25.0–29.9, 30.0–34.9, 35.0–39.9, and ≥40.0) with rates of operative mortality, overall early complications, subgroups of early complications (ie, infection, renal and pulmonary complications), and length of stay were assessed while adjusting for clinical covariates. There was no difference in operative mortality; however, higher risks of overall complications were observed for patients with BMI 35.0 to 39.9 (adjusted odds ratio 1.35, 95% CI 1.11–1.63) and ≥40.0 (adjusted odds ratio 1.56, 95% CI 1.21–2.01). Subgroup analyses identified obesity as an independent risk factor for infection (BMI 30.0–34.9: adjusted odds ratio 1.60, 95% CI 1.24–2.05; BMI 35.0–39.9: adjusted odds ratio 2.34, 95% CI 1.73–3.17; BMI ≥40.0: adjusted odds ratio 3.29, 95% CI 2.30–4.71). Median length of stay was longer with BMI ≥40.0 than with BMI 18.5 to 24.9 (median 7.0 days [interquartile range 5 to 10] versus 6.0 days [interquartile range 5 to 9], P=0.026).

***Conclusions*—**BMI ≥40.0 was an independent risk factor for longer length of stay, and infection was a potentially modifiable risk factor. Greater perioperative attention and intervention to control the risks associated with infection and length of stay in patients with BMI ≥40.0 may improve patient care quality and efficiency. **(*J Am Heart Assoc*. 2016;5:e003282 doi: 10.1161/JAHA.116.003282)**

Key Words: cardiovascular disease • diabetes mellitus • health outcomes • infection • surgery

The prevalence of obesity in Canada has increased across all obesity classes. Notably, a proportion of severe (class III) obesity has shown a concerning increase. In Canada, the prevalence of class III obesity increased from 0.4% to 1.3% between 1990 and 2003[1] and to 1.6% by 2011.[2] Greater body mass index (BMI) increases the risk of cardiovascular disease,[3] and referrals for coronary artery bypass grafting (CABG) surgery in patients with severe obesity have increased.[4] In Alberta, Canada, the cost of excess weight totaled 1.27 billion Canadian dollars, representing 5.6% of the total cost of all health conditions in the province, and coronary heart disease accounted for the greatest proportion of the total expenditure attributable to obesity.[5]

To devise strategies to provide quality and efficient care, determination of specific risk factors in patients undergoing CABG has become important. Interestingly, although severe obesity is commonly perceived as a risk factor for perioperative morbidity and increased resource utilization, current evidence remains controversial. Several studies showed that patients with severe obesity were at higher risk of acute operative mortality,[6] postoperative infections,[6–9] renal failure,[6,9,10] and prolonged hospital length of stay (LOS)[6,9–11] compared with patients with normal weight; however, several other studies failed to confirm these findings.[12–17] Consequently, it remains unclear whether patients with severe

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Received January 25, 2016; accepted April 15, 2016.

obesity undergoing CABG are at higher risk for acute complications and contribute to greater short-term resource utilization. Accordingly, using data from the Alberta Provincial Project for Outcome Assessment in Coronary Heart Disease (APPROACH) registry, we investigated whether obesity was associated with post-CABG adverse outcomes and played a role as a driver of elevated health care costs.

Methods

This study used data from the APPROACH registry in conjunction with postoperative mortality and early complications determined from the Vital Statistics Registry and the *International Classification of Diseases, Ninth Revision, Clinical Modification* codes, respectively. A description of the APPROACH database was published previously.[18,19] Briefly, the APPROACH registry is a population-based database that prospectively captures all patients referred for cardiac catheterization performed in the province of Alberta, Canada. Ethics approval was obtained from the University of Alberta Health Research Ethics Board. Because data were obtained from a clinical registry, the need for informed consent was waived.

Study Population

Patients in the study included adult residents of Alberta, Canada, who underwent CABG surgery at a single university hospital in Alberta between April 2003 and March 2014. Prior cardiac revascularization recipients (ie, percutaneous coronary intervention or CABG) who subsequently received another CABG were included. BMI, calculated as weight (in kg) over height squared (m^2), was identified for each patient. Based on BMI, patients were categorized as normal BMI (18.5–24.9), overweight (25.0–29.9), obese class I (30.0–34.9), obese class II (35.0–39.9), and obese class III (≥40.0).[20–22] Patients with BMI <18.5 (underweight) were excluded from the study.

Baseline Measures

Demographic and clinical variables collected at the time of cardiac catheterization included age, sex, BMI, concomitant diseases (ie, cerebrovascular disease, congestive heart failure, diabetes mellitus dialysis, hyperlipidemia, hypertension, liver disease, gastrointestinal disease, malignancy, peripheral vascular disease, pulmonary disease, and renal disease), smoking status, prior event and treatment (ie, prior CABG, myocardial infarction, and percutaneous coronary intervention), indication for catheterization (ie, stable and unstable angina, myocardial infarction, and others), ejection fraction (>50%, 35–50%, 20–34%, and <20%), and extent of coronary disease. The clinical diagnostic variables were updated at the time of the CABG procedure.[19] Concomitant diseases were collected as yes/no binary variables. Extent of coronary disease was divided into 6 categories: normal, lesion with <50% stenosis, low risk (ie, 1- or 2-vessel disease), high risk (ie, 2-vessel disease with proximal left anterior descending artery disease or 3-vessel disease), left main disease, and missing. Patients were identified as having diabetes mellitus based on their diagnosis or if they were receiving insulin or oral hypoglycemic agents.

Study Outcomes

Postoperative mortality, overall early complications, subgroups of early complications (ie, all-cause infection, renal and pulmonary complications), cardiovascular intensive care unit LOS, and total LOS in hospital were assessed as individual outcomes. Postoperative mortality, overall early complications, and subgroups of early complications were defined as incidences occurring within 30 days of CABG. Renal complication was defined as patients with a postoperative creatinine level >200 μmol/L.[18] Pulmonary complications included pulmonary edema and/or pulmonary embolism.

Statistical Analysis

Mean and standard deviation were used for continuous variables, whereas categorical variables were presented as counts and percentages. Baseline characteristics were compared across BMI categories with ANOVA for continuous variables and the chi-square test for categorical variables. If a significant difference was found, each group was compared against the normal BMI group by using post hoc pairwise comparisons with Bonferroni adjustment. For smoking history, indication of catheterization, ejection fraction, and extent of coronary disease, the distribution of the categories within each variable were compared using the chi-square test. If a significant difference was found, we performed post hoc pairwise comparisons between normal BMI and the other BMI groups using the chi-square test with Bonferroni adjustment.

Postoperative mortality and early complications were assessed using a Cox proportional hazards regression model and a multivariable logistic regression model, respectively. Because distributions were highly skewed, both intensive care unit and total LOS were assessed using the gamma generalized linear model with a log link. The analyses were adjusted for clinical covariates including age, sex, concomitant diseases, smoking status, prior cardiac events and treatment, indication of catheterization, ejection fraction, extent of coronary disease, and censoring due to death or transfer.

Table 1. Distribution of Demographic and Clinical Variables at the Time of Cardiac Catheterization by BMI Groups

	Normal, 18.5–24.9	Overweight, 25.0–29.9	Obese Class I, 30.0–34.39	Obese Class II, 35.0–39.9	Obese Class III, ≥40.0	*P* Value
Participants, n (%)	1509 (20.0)	3080 (40.7)	1942 (25.7)	696 (9.2)	333 (4.3)	
Female, n (%)	342 (22.7)	482 (15.6)*	350 (18.0)*	152 (21.8)	81 (24.3)	<0.001
Age, y, mean (SD)	68.8 (10.6)	67.2 (10.4)*	65.8 (9.8)*	63.5 (9.6)*	62.0 (9.3)*	<0.001
Height, cm, mean (SD)	170.2 (12.1)	171.1 (11.0)*	171.0 (8.9)	169.5 (14.8)	167.6 (11.7)*	<0.001
Weight, kg, mean (SD)	67.2 (8.9)	80.8 (9.0)*	94.3 (10.5)*	107.7 12.4)*	125.4 (19.8)*	<0.001
BMI, kg/m^2, mean (SD)	23.0 (1.5)	27.4 (1.4)*	32.2 (1.4)*	37.0 (1.4)*	44.6 (5.0)*	<0.001
Concomitant disease, n (%)						
Cerebrovascular disease	141 (9.3)	229 (7.4)*	112 (5.8)*	45 (6.5)*	25 (7.5)	0.002
Congestive heart failure	151 (10.0)	268 (8.7)	166 (8.6)	63 (9.1)	37 (11.1)	0.350
Diabetes mellitus	383 (25.4)	1006 (32.7)*	795 (40.9)*	357 (51.3)*	208 (62.5)*	<0.001
Dialysis	35 (2.3)	37 (1.2)*	18 (0.9)*	8 (1.2)	8 (2.4)	0.003
Hyperlipidemia	1196 (79.3)	2535 (82.3)*	1678 (86.4)*	612 (87.9)*	287 (86.2)*	<0.001
Hypertension	1048 (69.5)	2334 (75.8)*	1597 (82.2)*	593 (85.2)*	285 (85.6)*	<0.001
Liver or gastrointestinal disease	49 (3.3)	115 (3.7)	62 (3.2)	26 (3.7)	8 (2.4)	0.629
Malignancy	29 (1.9)	64 (2.1)	51 (2.6)	14 (2.0)	5 (1.5)	0.515
Peripheral vascular disease	222 (14.7)	328 (10.7)*	205 (10.6)*	73 (10.5)*	29 (8.7)*	<0.001
Pulmonary disease	163 (10.8)	300 (9.7)	189 (9.7)	85 (12.2)	51 (15.3)*	0.008
Renal disease	105 (7.0)	200 (6.5)	120 (6.2)	60 (8.6)	26 (7.8)	0.208
Prior event and treatment						
Coronary artery bypass grafting	2 (0.1)	5 (0.2)	8 (0.4)	0 (0)	0 (0)	0.133
Myocardial infarction	312 (20.7)	651 (21.1)	462 (23.8)	143 (20.6)	80 (24.0)	0.090
Percutaneous coronary intervention	181 (12.0)	472 (15.3)*	321 (16.5)*	95 13.7)	57 (17.1)*	0.002
Smoking history		†	†	†		<0.001
Never or former	780 (51.7)	1786 (58.0)	1155 (59.5)	437 (62.8)	199 (59.8)	
Current smoker	433 (28.7)	717 (23.3)	477 (24.6)	140 (20.1)	72 (21.6)	
Unknown	296 (19.6)	577 (18.7)	310 (16.0)	119 (17.1)	62 (18.6)	
Indication of catheterization		†	†		†	<0.001
Stable angina	597 (39.6)	1365 (44.3)	935 (48.2)	313 (45.0)	158 (47.5)	
Unstable angina	205 (13.6)	435 (14.1)	247 (12.7)	90 (12.9)	49 (14.7)	
Myocardial infarction	564 (37.4)	1054 (34.2)	649 (33.4)	238 (34.2)	115 (34.5)	
Others	143 (9.5)	226 (7.3)	111 (5.7)	55 (7.9)	11 (3.3)	
Ejection fraction			†	†		0.039
>50%	523 (34.7)	1156 (37.5)	778 (40.1)	275 (39.5)	128 (38.4)	
35–50%	301 (20.0)	606 (19.7)	379 (19.5)	137 (19.7)	64 (19.2)	
20–34%	80 (5.3)	164 (5.3)	94 (4.8)	30 (4.3)	22 (6.6)	
<20%	28 (1.9)	37 (1.2)	23 (1.8)	5 (0.7)	8 (2.4)	
Missing	345 (22.9)	703 (22.8)	438 (22.6)	171 (24.6)	77 (23.1)	
Not performed	232 (15.4)	414 (13.4)	230 (11.8)	78 (11.2)	34 (10.2)	

Continued

Table 1. Continued

	Normal, 18.5–24.9	Overweight, 25.0–29.9	Obese Class I, 30.0–34.39	Obese Class II, 35.0–39.9	Obese Class III, ≥40.0	*P* Value
Extent of coronary disease			†			0.067
Normal	6 (0.4)	13 (0.4)	6 (0.3)	3 (0.4)	2 (0.6)	
<50%	16 (1.1)	22 (0.7)	6 (0.3)	4 (0.6)	3 (0.9)	
Low risk	233 (15.4)	403 (13.1)	246 (12.7)	93 (13.4)	38 (11.4)	
High risk	753 (49.9)	1620 (52.6)	1106 (57.0)	367 (52.7)	185 (55.6)	
Left main disease	485 (32.1)	987 (32.1)	561 (28.9)	220 (31.6)	103 (30.9)	
Missing	16 (1.1)	35 (1.1)	17 (0.9)	9 (1.3)	2 (0.6)	

Low risk represented 1- or 2-vessel disease. High risk represented 2-vessel disease with proximal left anterior descending artery disease or 3-vessel disease. Continuous variables were tested by ANOVA with post hoc comparisons between normal BMI and the other BMI groups. Categorical variables were tested by the chi-square test with post hoc analysis comparing each BMI group against normal BMI using logistic regression. BMI indicates body mass index.
*Subgroups significantly different from the normal BMI ($P<0.05$). Pulmonary complication represents pulmonary edema and/or pulmonary embolism.
†Significant difference in the distribution of the categories compared with normal BMI.

All concomitant diseases were simultaneously included in the multivariable models as independent confounding variables to adjust for the regression analyses. In a sensitivity analysis, we also performed propensity analysis to account for potential confounders. Statistical analyses were performed with Stata statistical software, release 13 (StataCorp LP). $P<0.05$ was considered significant.

Results

Study Sample

During the 11-year period, 7560 patients underwent CABG, of which 1509 (20.0%) had a BMI classified as normal, 3080 (40.7%) were classified as overweight, 1942 (25.7%) were classified as obese class I, 696 (9.2%) were classified as obese class II, and 333 (4.4%) were classified as obese class III. Considerable differences in baseline characteristics among patient groups were found. Compared with patients with normal BMI, patients with class III obesity were characterized by younger age (62.0±9.3 versus 68.8±10.6, $P<0.001$) and lower prevalence of peripheral vascular disease (8.7% versus 14.7%, $P=0.011$). In contrast, patients with class III obesity had higher prevalence of diabetes mellitus (62.5% versus 25.4%, $P<0.001$), hyperlipidemia (86.2% versus 79.3%, $P=0.004$), hypertension (85.6% versus 69.5%, $P<0.001$), pulmonary disease (15.3% versus 10.8%, $P=0.02$), and prior percutaneous coronary intervention (17.1% versus 12.0%, $P=0.012$) compared with patients with normal BMI. There was no difference among the BMI groups in prevalence of congestive heart failure, liver or gastrointestinal disease, malignancy, or renal disease. Preoperative demographics and risk factors according to BMI categories are summarized in Table 1.

Postoperative Mortality and Early Complications

The unadjusted rates of postoperative mortality and early complications are shown in Table 2. When adjusted for covariates, there were no differences in postoperative mortality between the normal BMI group and the 4 other BMI categories (Table 3). Patients in the overweight and

Table 2. Incidence of Adverse Outcomes Following Cardiac Surgery by BMI Category

	Normal, 18.5–24.9 (n=1509)	Overweight, 25.0–29.9 (n=3080)	Obese Class I, 30.0–34.39 (n=1942)	Obese Class II, 35.0–39.9 (n=696)	Obese Class III, ≥40.0 (n=333)
Postoperative mortality, n (%)	32 (2.1)	51 (1.7)	31 (1.6)	6 (0.9)	7 (2.1)
Overall complications, n (%)	731 (48.4)	1482 (48.1)	881 (45.4)	338 (48.6)	170 (51.1)
Infection, n (%)	119 (7.9)	264 (8.6)	198 (10.2)	96 (13.8)	61 (18.3)
Pulmonary complications, n (%)	9 (0.6)	24 (0.8)	7 (0.4)	2 (0.3)	1 (0.3)
Renal complications, n (%)	107 (7.1)	189 (6.1)	109 (5.6)	58 (8.3)	28 (8.4)

Pulmonary complication represents pulmonary edema and/or pulmonary embolism. BMI indicates body mass index.

obese class I groups had similar risks of overall early complications compared with patients in the normal BMI group. Patients in the obese class II and III groups, however, were at higher risk of overall early complications compared with patients in the normal BMI group (obese class II: adjusted odds ratio [aOR] 1.35; 95% CI 1.11–1.63; obese class III: aOR 1.56, 95% CI 1.21–2.01; both P=0.001). Subgroup analyses identified obese classes I, II, and III as independent risk factors for infection (class I: aOR 1.60, 95% CI 1.24–2.05; class II: aOR 2.34, 95% CI 1.73–3.17; class III: aOR 3.29, 95% CI: 2.30–4.71). The risks of renal and pulmonary complications were not different between the 4 BMI groups and the normal BMI group. The adjusted risk factors relative to normal BMI are summarized in Table 4. The risk factors used in the risk adjustment for overall early complications and infection and their associations with the dependent variables are also summarized in Table 5.

Propensity analysis also showed consistent results, with the obese class II and III groups showing higher risks of early complications (class II: aOR 1.33, 95% CI 1.10–1.60; class III: aOR 1.53, 95% CI 1.20–1.96). The same analysis identified obese classes I, II, and III as independent risk factors for infection (class I: aOR 1.59, 95% CI 1.24–2.03; class II: aOR 2.24, 95% CI 1.66–3.01; class III: aOR 3.13, 95% CI 2.20–4.46).

There were no differences in post-CABG intensive care unit LOS between the 4 BMI groups and the normal BMI group (Table 6). Similarly, no differences were observed for total LOS between the normal BMI group and the overweight, obese class I, and obese class II groups; however, total LOS was significantly longer in the obese class III group (Table 6). Median total LOS of patients with class III obesity was 7.0 days (interquartile range [IQR] 5 to 10 days), which was 1.14 (95% CI 1.02–1.28) times longer than patients with normal BMI (median 6.0 days, IQR 5 to 9 days).

Table 3. Estimated Hazard Ratios and 95% CIs of Postoperative Mortality Relative to the Normal BMI Group

	Adjusted Hazard Ratio	95% CI	*P* Value
Postoperative mortality			
Normal	1.00		
Overweight	1.00	0.64–1.58	0.971
Obese class I	1.06	0.64–1.77	0.833
Obese class II	0.56	0.23–1.37	0.192
Obese class III	1.30	0.55–3.07	0.591

Hazard ratios for different body mass index groups were computed after adjusting for clinical covariates. BMI indicates body mass index.

Factors Associated With Prolonged LOS in Obese Class III

With obese class III shown as an independent risk factor for prolonged LOS, we performed post hoc analyses assessing associations between potential risk factors and LOS on the isolated obese class III group. Stepwise regression analysis revealed that infection (r=11.2, P=0.029), dialysis (r=28.1, P<0.001), renal complication (r=14.1, P=0.002), ejection fraction <20% (r=47.3, P<0.001), and female sex (r=8.9, P=0.004) were positively associated with LOS. In addition, because both infection[23] and diabetes mellitus[24] are considered independent risk factors for prolonged LOS following CABG, we included their interaction in the model. Although diabetes mellitus alone was not associated with prolonged LOS

Table 4. Estimated Odds Ratios and 95% CIs of Adverse Outcomes Relative to the Normal BMI Group

	Adjusted Odds Ratio	95% CI	*P* Value
Complications			
Normal	1.00	—	—
Overweight	1.11	0.97–1.26	0.117
Obese class I	1.08	0.94–1.25	0.293
Obese class II	1.35*	1.11–1.63	0.002
Obese class III	1.56*	1.21–2.01	0.001
Infection			
Normal	1.00	—	—
Overweight	1.24	0.98–1.57	0.068
Obese class I	1.60*	1.24–2.05	<0.001
Obese class II	2.34*	1.73–3.17	<0.001
Obese class III	3.29*	2.30–4.71	<0.001
Pulmonary			
Normal	1.00	—	—
Overweight	1.45	0.66–3.17	0.351
Obese class I	0.68	0.25–1.88	0.462
Obese class II	0.56	0.12–2.71	0.474
Obese class III	0.59	0.07–4.84	0.622
Renal			
Normal	1.00	—	—
Overweight	0.90	0.69–1.16	0.411
Obese class I	0.90	0.67–1.21	0.479
Obese class II	1.38	0.95–2.00	0.086
Obese class III	1.56	0.97–2.51	0.068

Odds ratios for different body mass index groups were computed after adjusting for clinical covariates. Pulmonary complication represents pulmonary edema and/or pulmonary embolism. BMI indicates body mass index
*Significant adjusted odds ratio (P<0.05).

Table 5. The Risk Factors Used in the Risk Adjustment for Overall Early Complications and Infection

	Overall Early Complication		Infection	
	Odds Ratio	95% CI	Odds Ratio	95% CI
Age	1.04*	1.04–1.05	1.03*	1.02–1.01
Sex	1.08	0.95–1.22	0.72	0.60–0.86
Cerebrovascular disease	1.01	0.84–1.22	1.14	0.87–1.50
Congestive heart failure	1.30*	1.08–1.55	1.48*	1.17–1.87
Diabetes mellitis	1.05	0.94–1.16	1.32*	1.11–1.56
Dialysis	0.98	0.63–1.50	1.72*	1.02–2.92
Hyperlipidemia	0.93	0.82–1.07	0.90	0.73–1.12
Hypertension	0.89	0.79–1.01	0.81	0.66–0.99
Liver or gastrointestinal disease	1.17	0.90–1.53	1.37	0.95–1.98
Malignancy	1.17	0.85–1.63	1.38	0.88–2.19
Peripheral vascular disease	1.14	0.98–1.32	1.23	0.98–1.54
Pulmonary disease	1.25*	1.07–1.47	1.24	0.99–1.56
Renal disease	1.80*	1.46–2.23	1.25	0.95–1.65
Current smoker	1.16*	1.02–1.31	1.17	0.95–1.43
Prior coronary artery bypass grafting	0.47	0.16–1.40		
Prior myocardial infarction	1.04	0.92–1.19	1.22	1.00–1.49
Prior percutaneous coronary intervention	1.08	0.93–1.25	0.92	0.73–1.18
Indication of catheterization				
Myocardial infarction	1.11	1.00–1.25	1.27*	1.06–1.53
Unstable angina	1.01	0.87–1.17	1.14	0.88–1.47
Others	1.06	0.87–1.30	1.35	0.99–1.83
Ejection fraction				
35–50%	1.17*	1.03–1.34	1.35*	1.07–1.71
20–34%	1.96*	1.56–2.47	1.96*	1.42–2.73
<20%	2.38*	1.53–3.70	2.45*	1.42–4.21
Not performed	1.56*	1.34–1.83	1.49*	1.16–1.92
Missing	1.39*	1.22–1.58	1.45*	1.16–1.80
Extent of coronary disease				
<50%	0.46	0.17–1.23	0.28	0.08–1.02
Low risk	0.43	0.19–0.96	0.32	0.13–0.78
High risk	0.31	0.14–0.69	0.38	0.15–0.91
Left main disease	0.33	0.14–0.73	0.34	0.14–0.84
Missing	0.28	0.10–0.73	0.32	0.09–1.10

Low risk represented single or 2-vessel disease. High risk represented 2-vessel disease with proximal left anterior descending artery disease or 3-vessel disease. Pulmonary disease represents pulmonary edema and/or pulmonary embolism.
*Significant odds ratio ($P<0.05$). Prior coronary artery bypass grafting was excluded from a covariate list for infection due to insufficient cases.

($r=-0.9$, $P=0.721$), the coefficient for infection–diabetes mellitis interaction was relatively large and similar to that of infection and female sex ($R=9.9$, $P=0.123$). Accordingly, we further explored the impact of diabetes mellitis in relation to infection within the obese class III group by stratifying the patients into 4 groups: (1) no infection or diabetes mellitis, (2) infection alone, (3) diabetes mellitis alone, and (4) diabetes mellitis and infection. The gamma generalized linear model with a log link using no infection or diabetes mellitis as a reference group showed that adjusted relative total LOS was 3.2 (95% CI 2.6–4.1) times longer in patients with diabetes mellitis and infection (median 19.0 days [IQR 23.0 days] versus 6.0 days

Table 6. Length of Hospital Stay After Coronary Artery Bypass Grafting Relative to Normal BMI

	Adjusted exp(β)	95% CI	*P* Value
Intensive care unit length of stay			
Overweight	0.95	0.88–1.03	0.254
Obese class I	0.95	0.87–1.04	0.277
Obese class II	1.06	0.94–1.19	0.355
Obese class III	1.05	0.90–1.23	0.516
Total length of stay			
Overweight	0.98	0.92–1.04	0.423
Obese class I	0.97	0.91–1.03	0.297
Obese class II	1.06	0.98–1.16	0.162
Obese class III	1.14*	1.02–1.28	0.021

*Significant adjusted exp(β) ($P<0.05$). BMI indicates body mass index , exp(β); exponentiated regression coefficient.

[IQR 3.0 days]) and 1.9 (95% CI 1.4–2.6) times longer in infection alone (10.0 days, IQR 7.0 days). Diabetes mellitus alone was not significantly associated with LOS (median 7.0 days, IQR 3.0 days).

Discussion

With a steady increase in the total number of bypass operations, cardiac operation has become a major contributor to overall medical resource utilization.[25] Consequently, attempts to identify and control risks associated with cardiac operation have become important to provide quality and cost-efficient care. To date, studies examining the impact of severe obesity on post-CABG adverse outcomes have shown conflicting results. Possible explanations for the inconsistent outcomes include the use of heterogeneous reference categories and BMI criteria for the definition of severe obesity. Indeed, although wide ranges of BMI increase within-group variations,[26] several studies used lower BMI cutoffs than current Canadian national[22] or international[20,21] guidelines (ie, BMI ≥40) to define severe obesity. It is of importance to note, however, that contradicting findings still existed among the studies defining severe obesity as BMI ≥40.[6,17,27,28]

Using the APPROACH database, we found a differential impact of BMI groups on acute post-CABG clinical outcomes. Consistent with previous reports,[6,17,27,28] patients with severe obesity in our study were characterized by younger age with more comorbidities compared with patients with normal BMI, except for peripheral vascular disease. The lower prevalence of peripheral vascular disease in patients with class III obesity may seem counterintuitive considering higher cases of atherogenic risk factors, such as diabetes mellitus, hyperlipidemia, and hypertension in this group. We speculate that significantly younger age and thus shorter exposure to these risk factors contributed to the lower prevalence of peripheral vascular disease. After adjusting for such baseline discrepancies, we found that obese classes II and III were independent risk factors for overall early complications. The increased risk of all-cause infections but not pulmonary or renal complications indicated that, among available measures, infection was primarily responsible for the increased complication rates. A previous study demonstrated that wound infections delay healing and increase LOS[23]; however, although complication rates were increased in both obese classes II and III, only the obese class III group was associated with longer total LOS compared with normal BMI. We speculate that higher rates of infection in the obese class III group contributed to prolonged LOS.

Our results showing no differences between the normal BMI group and the other 4 BMI groups in operative mortality or intensive care unit LOS are consistent with previous findings.[10,29–31] The lack of association between BMI and the incidence of pulmonary complication, however, needs to be interpreted with caution because only 43 patients (0.6%) experienced pulmonary complications. Our database captured only pulmonary edema and pulmonary embolism as pulmonary complications. This may explain the limited occurrence of pulmonary complications and implies a high chance of a type II error. Similarly, relatively high ORs but no statistically significant differences for renal complications in patients categorized as obese class II (OR 1.38, P=0.086) and class III (OR 1.56, P=0.068) could also be related to insufficient power.

The incidence of complications is associated with increased hospital costs.[32,33] Moreover, longer LOS as a result of complications demands greater resource use.[25] Consequently, it is likely that patients classified as obese class III consumed more health care resources than the normal BMI group by increasing LOS and treatment costs. Considering our results and those of several other studies showing the longest LOS in patients with severe obesity,[6,7,34] class III obesity is an important contributor to prolonged LOS following CABG. With a continuous increase in the prevalence of class III obesity,[1,2] better strategies to reduce the LOS of this group would play an important role in reducing overall LOS and its associated costs.

A subsequent stepwise multiple regression analysis conducted for the obese class III group showed that infection, dialysis, renal failure, indication of catheterization, and female sex were the predictors of prolonged LOS. In addition, although diabetes mellitus per se did not increase total LOS, we found significantly increased total LOS when patients with diabetes mellitus experienced infection (3.2 times longer compared with patients with no diabetes mellitus or infection). Greater perioperative attention and consideration for patients with class III obesity that possess the identified risks have the potential to improve patient outcomes and reduce health care costs. Nonetheless, although closer attention is warranted for at-risk patients for better prognosis, factors such as dialysis, renal failure, decreased ejection fraction, and sex do not allow preoperative manipulation. Consequently, subsequent discussion focuses primarily on infection, which is widely seen in patients with class III obesity and can be a potential treatment target to reduce LOS and its associated costs. Infection has been reported as one of the most costly complications, with incremental costs exceeding 30 000 US dollars per episode.[35,36]

The increased risk of infection in patients with class III obesity has been reported previously. Studies have shown that class III obesity is associated with increased risks of superficial wound,[8,9,26,29,37–39] deep sternal wound,[8,9,26,29,37–39] and harvest site[29,38] infections. Our data did not allow us to distinguish specific sites of infection; however, our results corresponded to a general consensus that obese class III is associated with higher postsurgical infection risk. A potential explanation for the increased infection risk in class III obesity includes trauma and necrosis,[40] possibly owing to poor healing of underperfused adipose chest wall tissues,[9,39] and increased technical difficulty. Large amounts of adipose tissue limit the exposure of the heart and mammary artery and require operation at greater depth within the chest.[41] Naturally, the technical difficulty increases in patients with class III obesity. The longer surgical duration prolongs surgical site exposure, resulting in a higher chance of contamination.[32,42]

In patients with class III obesity, we also found that diabetes mellitus alone did not contribute to longer LOS but significantly increased LOS in patients who experienced postsurgical infection. The incidence of postsurgical infections is high in patients with diabetes mellitus.[43,44] Furthermore, the prevalence of diabetes mellitus is high for obese class III. This may explain the highest infection rates that we observed in patients with class III obesity and corroborates the importance of properly treating infection, particularly in patients with class III obesity. Intensive perioperative glucose control may be effective in reducing the incidence of postsurgical infection and LOS.[45] In addition, more aggressive use of antibiotic prophylaxis appears to be a rational approach to reducing LOS[46] and accompanying resource utilization.[47] Concerted efforts to reduce the incidence of infection and perioperative blood glucose are likely to be effective in reducing prolonged LOS and associated costs. Given that patients with higher BMI have a reduced response to prophylaxis, adjustments of drug doses may also be considered.[48]

Our study has several limitations. First, the major limitation of the study is the lack of actual health care cost data. The primary purpose of the present study was to identify post-CABG adverse outcomes that would be associated with increased health care costs, perhaps through extended LOS. The actual cost associated with the adverse outcomes was beyond the scope of this study. Second, we used BMI, which may not accurately reflect the degree of obesity.[49] Third, although we controlled for available confounding variables, residual confounding not included in our analysis cannot be neglected; for example, although there have been ongoing improvements in the medical management and care of patients,[50] such changes over time were not taken into account in our analyses. Similarly, although we adjusted for ejection fraction and extent of coronary disease that could have affected surgical factors (ie, surgical duration, cross-clamp duration, and number of vessels bypassed), failing to adjust for actual surgical details that play an important role as a modulator of LOS may have increased the chance of residual confounding. In addition, inclusion of "missing" and "not completed" as separate categories for analysis may have influenced our estimates.[51] Nonetheless, although some patients had missing data in a few covariate categories, the main predictor (ie, BMI category), outcomes (ie, mortality, complications, and LOS), and the other covariates were available for these patients. Considering that removing patients with a missing covariate from the statistical models would result in the exclusion of 2725 patients (≈36%) with the aforementioned information available, we felt it was important to include these patients to avoid data waste and to maintain statistical power. Last, as discussed earlier, relatively small number of patients with class III obesity might have limited our ability to detect independent and significant associations between class III obesity and some adverse outcomes.

In conclusion, patients with class III obesity undergoing CABG surgery have a higher risk of perioperative complications. In addition, class III obesity is associated with increased hospital LOS compared with patients with normal BMI. We also identified infection as a primary treatment opportunity to reduce LOS and its associated medical costs. With increases in the demand for cardiac surgical interventions among patients with severe obesity,[50] this information should be useful to caregivers, surgeons, and their patients to assess the risks and clinical outcomes and to better prepare for possible adverse outcomes, perhaps leading to better resource use.

Sources of Funding

The program of research is supported by a Partnerships for Research and Innovation in the Health System (PRIHS) award from Alberta Innovates – Health Solutions (AIHS).

Disclosures

None.

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