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Albumin Is A Better Predictor of Outcomes Than Body Mass Index Following Coronary Artery Bypass Grafting

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Abstract

Objective—Body Mass Index (BMI) influences risk in coronary artery bypass grafting (CABG) patients, while albumin, is not collected by the Society of Thoracic Surgeons database. We postulate that preoperative albumin is a better predictor of mortality than BMI following CABG.

Methods—BMI from patients with serum albumin level within 6 months of isolated CABG between 1995–2010 from our institutional databases were identified. Patients were stratified by National Heart, Lung and Blood Institute (NHLBI) BMI class, and by preoperative albumin. Regression models were used to assess predictors of morbidity and mortality.

Results—We analyzed 2,794 isolated CABG patients at our institution. Unadjusted mortality was highest with lowest BMI ($P \leq .05$), and in patients with 2–3g/dL albumin ($P = .02$). Ejection fraction (EF) and intra-aortic balloon pump (IABP) use were similar despite BMI; however, EF was lowest and IABP use highest in the 2–3g/dL albumin group ($P < .001$, respectively). Unlike BMI groups, increasing albumin was associated with lower major complication rates ($P = .001$). Similarly, adjusted mortality was not influenced by BMI (AOR 0.97, 95%CI 0.93–1.02), but increasing albumin levels reduced the adjusted odds of death (AOR 0.61, 95%CI 0.42–0.90).

Conclusions—Albumin, more than body mass index, is associated with mortality and morbidity in isolated CABG recipients and may be a better indicator for outcomes.

Keywords

Coronary Artery Bypass Grafting; Body Mass Index; Obesity; Albumin; Risk factors

Introduction

Elevated body mass index (BMI) has been considered to be a risk factor for poor outcomes in non-cardiac procedures. However, in patients undergoing cardiac surgery, there exists an

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obesity paradox, in that obese patients live longer than their normal-weight counterparts.¹⁻³ Despite better perioperative outcomes and 30-day mortality among higher BMI patients, obesity is an established risk factor for late mortality.⁴ The Society of Thoracic Surgeons (STS) national database, which represents more than 90% of cardiac surgical procedures performed in the United States (US), captures height and weight data allowing for BMI computations, however, preoperative serum albumin among patients undergoing cardiac surgical procedures is not collected.

Lower albumin levels may be a marker of persistent injury to arteries and progression of atherosclerosis and thrombosis.⁵ To this end, the British Regional Heart Study described an association between serum albumin and mortality among cardiovascular disease patients.⁶ Moreover, preoperative hypoalbuminemia is an established independent predictor of mortality following general surgical procedures.⁷ Furthermore, hypoalbuminemia is a common problem in elderly surgical patients that adversely affects outcome.⁸ Serum albumin is a reliable and reproducible predictor of general surgical risk and has a close correlation with the degree of malnutrition.^{8,9} Despite the strong literature in the general surgery population, the adoption of preoperative serum albumin as a risk factor for death has been slower among cardiovascular surgeons.¹⁰

Mortality and outcomes based upon contemporary BMI and preoperative serum albumin classification(s) have not been examined among patients undergoing isolated coronary artery bypass graft (CABG). Hence, we hypothesize that serum albumin may be an important and perhaps better prognosticator than BMI of short-term operative morbidity and mortality in patients undergoing isolated primary CABG.

Methods

Data Source

De-identified institutional data between 1995 and 2010 was obtained from the University of Virginia (UVA) Health System Clinical Data Repository (CDR). The CDR is maintained by the Division of Clinical Informatics, Department of Public Health Sciences, and contains patient level information that is managed through the UVA Health System. The CDR collects data and links cardiac surgery related information at our institution based on variables defined by the STS national database. Thus, all variables analyzed reflect STS criterion. Since the STS national database continually improves data accrual with every iteration of the data collection form, consistency in these analyzed data was maintained by utilizing only core variables reported across all versions of forms (latest version used v2.52). Even though data missing completely at random were not excluded from analysis, variables with systematic missing values underwent case-wise deletion. The current study along with appropriate patient consent waiver(s), were approved by the Human Investigation Committee at UVA (#15058).

Patient Selection

A total of 6,010 patients who underwent isolated primary CABG during this study period at our institution were identified. We excluded off-pump coronary revascularization recipients to maintain procedural homogeneity among the study population. Additionally, only patients with height, weight, and serum albumin collected within 6 months of isolated CABG were analyzed. Thus, from the original population, 2,794 patients were selected for analysis.

Patient Groups

Records from selected patients were stratified by the National Heart, Lung and Blood Institute (NHLBI) BMI classification groups into Underweight ($\leq 18.4\text{kg/m}^2$), Normal (18.5

– 24.9kg/m²), Overweight (25.0 – 29.9kg/m²), Obese (30.0 – 39.9kg/m²) and Extremely Obese (≥ 40 kg/m²).¹¹ Additionally, patients were arbitrarily stratified into 4 preoperative serum albumin groups (<2, 2 – 3, 3 – 4, or >4g/dL) for analysis.

Statistical Analysis

The primary outcomes of interest were a composite of major complication, and operative mortality. A major complication was defined to include permanent stroke, renal failure as defined by an increase of serum creatinine to >2.0mg/dL, and twice the most recent preoperative creatinine level or a new requirement for dialysis post operatively, prolonged ventilation (>24 hours), deep sternal wound infection, or reoperation for any reason. Association between variables was measured by appropriate statistical hypothesis tests. Operative mortality was defined as 30-day and/or in-hospital mortality. The statistical significance of differences in proportions for categorical variables was evaluated by the Pearson χ^2 or Fisher's exact test where appropriate. The statistical significance of differences in mean values for continuous variables was assessed using single factor analysis of variance across groups. Results for the total series of hypothesis tests conducted in the study population were corrected for multiple comparison bias by adjusting each probability by the false discovery rate. Data are shown as number (n) and percentage by group (%), or mean $\pm$ standard deviation (SD), except where indicated otherwise.

Separate multivariable logistic regression models were developed to calculate the adjusted odds of major complications and mortality. Explanatory variables for models were selected a priori based on the established literature to control for differences in patient demographics, risk factors, operative features, BMI and serum albumin. The 95% confidence intervals (CI) for all covariates in the models were calculated. The models' predictive capacity to discriminate was measured using the area under the receiver operator characteristic curve (AUC). The Hosmer-Lemeshow χ^2 test for goodness-of-fit was performed to assess differences in model calibration for deciles of model probabilities, and large *p*-values were considered good-fit. Relative magnitude of the calculated Wald statistic was used to determine the contribution of each covariate to the regression model. Adjusted odds ratios are presented for each covariate along with their 95% CI. All data were analyzed using SPSSTM 18 (SPSS Inc., An IBM Company, Chicago, IL).

Results

Characteristics of isolated CABG stratified by BMI/serum albumin level

Isolated primary CABG was most commonly performed among the overweight (BMI 24.9 – 29.9 kg/m²) and those with serum albumin between 3–4g/dL (Tables 1 and 2, respectively). Risk factors across both groups were examined, and importantly, previous CABG, and New York Heart Association functional heart failure classifications were equivalent. Significantly, preoperative serum albumin and BMI categories were not linearly associated.

Diabetes as a risk factor was more common in the extremely obese and when albumin was between 2–3mg/dL (*P*<.05, respectively). Although intra-aortic balloon pump use (IABP) and left ventricular ejection fraction (LVEF) were not associated with any BMI group (*P*>.1, respectively), IABP use was lowest and LVEF was highest when albumin was >4g/dL (*P*<.001, respectively). Aortic cross-clamp times were equivalent among BMI and albumin groups.

Unadjusted Complications and Mortality by BMI/serum albumin level

The risk of any complication was no different across BMI groups. However, compared to patients with higher albumin levels, patients with serum albumin <2g/dL was associated

with the highest complication rate ($P < .001$). Deep sternal wound infection, postoperative stroke and dialysis dependent renal failure were also equivalent despite BMI or albumin level (Tables 3 and 4, respectively). Importantly, prolonged ventilation and gastrointestinal complications were not associated with any BMI group, but were lowest when albumin was $>4\text{g/dL}$ ($P \leq .01$, respectively). Postoperative atrial fibrillation was most common in the extremely obese ($\geq 40\text{ kg/m}^2$) and when serum albumin was $<2\text{g/dL}$ ($P = .01$ and $P = .03$, respectively).

Overall mortality was 3% (84/2794) in the analyzed population. Crude mortality was highest (11.8%) in the underweight BMI ($\leq 18.5\text{ kg/m}^2$) group and was lowest in the obese and extremely obese groups ($P = .05$). Moreover, higher mortality rates were noted in patients when serum albumin was $<3\text{g/dL}$, but was lowest with albumin $>4\text{g/dL}$ (2.0%, $P = .02$). Thirty-day readmission rate following isolated CABG was not influenced by preoperative BMI or serum albumin level. However, intensive care unit length of stay, total hospitalization and postoperative length of stay were all lowest when albumin was $>4\text{g/dL}$, while BMI class did not influence resource utilization.

Risk-adjusted major complications and mortality

Multivariable logistic regression models for postoperative major complications (Table 5) and mortality (Table 6) were developed, wherein greater than 93% of the records were analyzed. The area under the receiver operator characteristic curves (AUC) for models assessing major complications was 0.85. None of the BMI groups except the extremely obese ($\geq 40\text{ kg/m}^2$) were independent predictors of major complications. However, serum albumin independently reduced the adjusted odds of major complications by 40% (adjusted odds ratio [AOR] 0.60, 95% confidence interval [CI] 0.44 – 0.82). Moreover, albumin $<2\text{g/dL}$ increased the adjusted odds of major complications almost 5 fold (AOR 4.99, 95% CI 1.49 – 16.73), while albumin between 2–3g/dL increased the adjusted odds of prolonged ventilation more than 2 fold (AOR 2.78, 95% CI 1.75 – 4.41).

Risk-adjusted models for mortality (AUC 0.81) were not independently influenced by BMI level. Importantly, serum albumin independently reduced the adjusted odds of mortality by 39% (AOR 0.61, 95% CI 0.42 – 0.90). Increasing age, female gender and the need for preoperative dialysis also independently increased the adjusted odds of death ($P \leq .001$, respectively). All models were re-estimated using BMI and preoperative serum albumin as continuous variables, and no significant change or attenuation due to decrement in model performance was noted.

Discussion

Our study shows that preoperative serum albumin level, more so than body mass index, is an important independent predictor of major complications and mortality. As has been reported by others, we found that unadjusted mortality was lower in patients with higher BMI.^{2,3,12,13} Additionally, we demonstrate that increasing age, female gender, preoperative dialysis dependent renal failure and increased cardiopulmonary bypass time, all independently conferred additional risk of increased mortality. Furthermore, unit increases in left ventricular ejection fraction and albumin reduced the adjusted odds of death following isolated CABG at our institution. Interestingly, BMI classification did not influence major complications or mortality following case-mix adjustment. However, decreasing levels of preoperative serum albumin was inversely related to the adjusted odds of the likelihood of having an adverse outcome.

We note that 59% of cases reported in this series underwent urgent/emergent coronary revascularization, and only 7% of patients underwent isolated CABG when Albumin was

between 2–3g/dL. Most of the urgent/emergent cases were performed when patients had an Albumin between 3–4g/dL. As such, in the setting of an elective coronary revascularization, and when clinically feasible, preoperative optimization with nutritional supplementation could be advantageous, thereby reducing risk associated with low preoperative serum albumin. However, when delaying coronary surgery becomes detrimental, both patient and surgeon should be cautious of potential perioperative events.

Serum albumin level is a well-documented risk factor in general surgical operations. The National Veterans Affairs Surgical Risk Study from 54,215 major non-cardiac surgery cases examining morbidity and 30-day mortality, found that serum albumin concentration was the strongest predictor of morbidity and mortality.⁷ Similarly, hypoalbuminemia was found to be a predictor of poor surgical outcomes of colon cancer and was a poor indicator of long-term survival after curative resection in 2,529 patients.¹⁴

However, data regarding the influence of serum albumin in the cardiac surgery population is limited. Previous work has demonstrated that lower BMI and hypoalbuminemia independently predicted increased mortality and postoperative complications after CABG and/or valve surgery, at the Brigham and Women's Hospital between 1993 and 1997.¹⁰ Unlike the current study, all cardiac surgery recipients were analyzed, and no procedure specific risks were identified. Consistent with the current data, Christakis and co-workers have suggested that small body size did not increase the risk of operative mortality in 7,025 consecutive patients (5,694 men, 1,331 women) undergoing isolated CABG between 1990 and 1994.¹⁵ In contrast to the current work, obese BMI among 10,590 patients was not found to be an independent predictor of morbidity or mortality after CABG, though patients with underweight BMI ($\leq 19\text{kg/m}^2$) were at greater risk for adverse outcomes.¹⁶ In that particular study, albumin was not evaluated.

There is no clear agreement on the association pattern of the influence of BMI on adverse outcomes. For example, important analyses have described a *U*-shaped BMI and body surface area relationship between obesity and perioperative mortality after CABG.^{17,18} While recent data from American College of Surgeons' National Surgical Quality Improvement Program (ACS-NSQIP) from 25,337 elderly (≥ 65 years) vascular surgery patients found that increased BMI alone was not a major factor predicting perioperative 30-day mortality.¹⁹ Significantly, there was a nonlinear reversed *J*-curve response showing poorest outcomes among the underweight and normal patients, with a slight increase in excessively obese patients.¹⁹ Our models were estimated following BMI probability plots confirming a Gaussian distribution with a marginal right skew. Our regression analyses were computed using BMI and preoperative serum albumin levels as continuous variables, and then re-estimated with their respective stratified groups. We found no notable change in performance between these two sets of models, providing further evidence for our findings.

On the cellular level, transport of serum albumin across capillary beds is facilitated by glycoprotein-60 during acute illness or stress response which leads to interstitial loss of albumin.²⁰ A vast majority of cardiovascular surgery patients receive statin therapy, which in addition to reducing HMG-CoA, have also been shown to stimulate albumin secretion from hepatocytes.²¹ Furthermore, albumin participates in cholesterol efflux from peripheral tissues and contributes to the overall cholesterol efflux along with contributions from high-density lipoproteins. Analyses from 14,571 cardiac surgery patients between 1992 and 2005 found that extremely obese patients ($\text{BMI} \geq 45\text{kg/m}^2$) have higher perioperative morbidity and mortality compared with a lower BMI group ($\text{BMI} 24 - 34.9\text{kg/m}^2$).⁴ Patients with elevated BMI can realize acceptable outcomes from cardiac procedures, but continue to suffer from the comorbidities of obesity. In contrast, similar analyses utilizing serum albumin have not been performed, making the current work novel and highly relevant in the

face of: (i) the discrepancy between analysis methodology, and (ii) lack of consensus regarding perioperative risk for morbidity and mortality among isolated CABG recipients. BMI might be a good marker for body habitus, but serum albumin is a better indicator of nutritional status. Review of preoperative albumin status in patients, especially before cardiac surgical procedures, given the degree of expectant tissue trauma from sternotomy, intraoperative challenge from the bypass circuit, and anticipated postoperative intensive care unit stay appears to be very important.

There are several limitations to consider when interpreting these results. First, this is an observational review of a retrospectively collected clinical database that captures cases for administrative analysis, where some groups had few patients. However, we linked our STS database against institutional data and could verify the raw dataset. Second, observational studies always have the potential of missing an unmeasured confounder, though model verification using different sets of variables attempts to address this issue. Next, body mass index may not accurately reflect adipose concentration among select populations.²² Finally, not using smoothing techniques to avoid categorization of BMI, might be analytically problematic.^{23,24} Our use of preoperative serum albumin levels within 6 months of isolated CABG, does not adjust for more acute nutritional changes among patients reflected by weight fluctuation and/or transient serum albumin levels. Despite these limitations, albumin was still identified as an independent risk factor for major complications and mortality.

In conclusion, obesity and elevated body mass index have long been considered to be independent risk factors for cardiac surgical operations. Within the general surgery literature, preoperative serum albumin is considered to be an important independent predictor of outcomes. The use of preoperative serum albumin to estimate perioperative risk for mortality awaits acceptance with the Society of Thoracic Surgeons national database. This study shows that within our single institution cohort of isolated CABG recipients, BMI <40kg/m² did not influence major complications or mortality, while decreasing serum albumin levels independently increased the adjusted odds of poor outcome. Taken together, the mechanisms through which increasing albumin levels confer greater protection following isolated CABG must be evaluated. Based on these data, the Society of Thoracic Surgeons national database should consider collecting serum albumin levels from cardiovascular surgery recipients, and adapt the annual risk predictor models to better estimate perioperative adverse events.

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References

1. Watanabe A, Kohnoe S, Shimabukuro R, et al. Risk factors associated with surgical site infection in upper and lower gastrointestinal surgery. *Surg Today*. 2008; 38(5):404–412. [PubMed: 18560962]
2. van Straten AH, Bramer S, Soliman Hamad MA, et al. Effect of body mass index on early and late mortality after coronary artery bypass grafting. *Ann Thorac Surg*. Jan; 2010 89(1):30–37. [PubMed: 20103201]
3. Stamou SC, Nussbaum M, Stiegel RM, et al. Effect of body mass index on outcomes after cardiac surgery: is there an obesity paradox? *Ann Thorac Surg*. Jan; 2011 91(1):42–47. [PubMed: 21172483]

4. Tyson GH 3rd, Rodriguez E, Elci OC, et al. Cardiac procedures in patients with a body mass index exceeding 45: outcomes and long-term results. *Ann Thorac Surg.* Jul; 2007 84(1):3–9. discussion 9. [PubMed: 17588372]
5. Kuller LH, Eichner JE, Orchard TJ, Grandits GA, McCallum L, Tracy RP. The relation between serum albumin levels and risk of coronary heart disease in the Multiple Risk Factor Intervention Trial. *Am J Epidemiol.* Dec 1; 1991 134(11):1266–1277. [PubMed: 1755441]
6. Phillips A, Shaper AG, Whincup PH. Association between serum albumin and mortality from cardiovascular disease, cancer, and other causes. *Lancet.* Dec 16; 1989 2(8677):1434–1436. [PubMed: 2574367]
7. Gibbs J, Cull W, Henderson W, Daley J, Hur K, Khuri SF. Preoperative serum albumin level as a predictor of operative mortality and morbidity: results from the National VA Surgical Risk Study. *Arch Surg.* Jan; 1999 134(1):36–42. [PubMed: 9927128]
8. Arques S, Ambrosi P, Gelisse R, Luccioni R, Habib G. Hypoalbuminemia in elderly patients with acute diastolic heart failure. *J Am Coll Cardiol.* Aug 20; 2003 42(4):712–716. [PubMed: 12932607]
9. Haupt W, Holzheimer RG, Riese J, Klein P, Hohenberger W. Association of low preoperative serum albumin concentrations and the acute phase response. *Eur J Surg.* Apr; 1999 165(4):307–313. [PubMed: 10365830]
10. Engelman DT, Adams DH, Byrne JG, et al. Impact of body mass index and albumin on morbidity and mortality after cardiac surgery. *J Thorac Cardiovasc Surg.* Nov; 1999 118(5):866–873. [PubMed: 10534692]
11. Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The Evidence Report. National Heart, Lung, and Blood Institute; 1998.
12. Sun X, Hill PC, Bafi AS, et al. Is cardiac surgery safe in extremely obese patients (body mass index 50 or greater)? *Ann Thorac Surg.* Feb; 2009 87(2):540–546. [PubMed: 19161775]
13. Filardo G, Adams JP. Effect of body mass index on mortality in patients undergoing isolated coronary artery bypass grafting. *Ann Thorac Surg.* Sep.2010 90(3):1060. [PubMed: 20732558]
14. Lai CC, You JF, Yeh CY, et al. Low preoperative serum albumin in colon cancer: a risk factor for poor outcome. *Int J Colorectal Dis.* Dec 29.2010
15. Christakis GT, Weisel RD, Buth KJ, et al. Is body size the cause for poor outcomes of coronary artery bypass operations in women? *J Thorac Cardiovasc Surg.* Nov; 1995 110(5):1344–1356. discussion 1356–1348. [PubMed: 7475187]
16. Engel AM, McDonough S, Smith JM. Does an obese body mass index affect hospital outcomes after coronary artery bypass graft surgery? *Ann Thorac Surg.* Dec; 2009 88(6):1793–1800. [PubMed: 19932237]
17. Wagner BD, Grunwald GK, Rumsfeld JS, et al. Relationship of body mass index with outcomes after coronary artery bypass graft surgery. *Ann Thorac Surg.* Jul; 2007 84(1):10–16. [PubMed: 17588373]
18. Habib RH, Zacharias A, Schwann TA, Riordan CJ, Durham SJ, Shah A. Effects of obesity and small body size on operative and long-term outcomes of coronary artery bypass surgery: a propensity-matched analysis. *Ann Thorac Surg.* Jun; 2005 79(6):1976–1986. [PubMed: 15919295]
19. Nafiu OO, Kheterpal S, Moulding R, et al. The association of body mass index to postoperative outcomes in elderly vascular surgery patients: a reverse J-curve phenomenon. *Anesth Analg.* Jan; 2011 112(1):23–29. [PubMed: 21127285]
20. Tiruppathi C, Finnegan A, Malik AB. Isolation and characterization of a cell surface albumin-binding protein from vascular endothelial cells. *Proc Natl Acad Sci U S A.* Jan 9; 1996 93(1):250–254. [PubMed: 8552615]
21. Ha CE, Ha JS, Theriault AG, Bhagavan NV. Effects of statins on the secretion of human serum albumin in cultured HepG2 cells. *J Biomed Sci.* 2009; 16:32. [PubMed: 19291315]
22. Allison DB, Faith MS, Heo M, Kotler DP. Hypothesis concerning the U-shaped relation between body mass index and mortality. *Am J Epidemiol.* Aug 15; 1997 146(4):339–349. [PubMed: 9270413]

23. Filardo G, Hamilton C, Hamman B, Grayburn P. Obesity and stroke after cardiac surgery: the impact of grouping body mass index. *Ann Thorac Surg.* Sep; 2007 84(3):720–722. [PubMed: 17720366]
24. Filardo G, Hamilton C, Hamman B, Ng HK, Grayburn P. Categorizing BMI may lead to biased results in studies investigating in-hospital mortality after isolated CABG. *J Clin Epidemiol.* Nov; 2007 60(11):1132–1139. [PubMed: 17938055]

Table 1

Unadjusted perioperative characteristics by NHLBI body mass index groups

Perioperative feature	NHLBI BMI Classification				P
	Underweight ≤18.4 kg/m ² N = 17	Normal 18.5–24.9 kg/m ² N = 652	Overweight 24.9–29.9 kg/m ² N = 1,075	Obese 30–39.9 kg/m ² N = 908	Extremely Obese ≥40 kg/m ² N = 142
Age, years	64.6 (12.9)	66.6 (10.5)	64.9 (10.5)	61.9 (10.5)	57.9 (9.9)
Weight, kg	51.5 (7.7)	68.4 (8.9)	82.3 (9.4)	99.0 (13.7)	124.6 (19.3)
Gender, Female	4 (23.5)	184 (28.2)	239 (22.2)	265 (29.2)	54 (26.7)
Race, Caucasian	13 (76.5)	595 (91.3)	982 (91.3)	828 (91.2)	126 (88.7)
Risk Factor,					
Stroke	-	47 (7.2)	78 (7.3)	63 (6.9)	5 (3.5)
Diabetes	3 (17.6)	160 (24.5)	370 (34.4)	441 (48.6)	86 (60.6)
Renal Failure	1 (5.9)	55 (8.4)	99 (9.2)	103 (11.3)	13 (9.2)
Dialysis	1 (5.9)	14 (2.1)	26 (2.4)	33 (3.6)	2 (1.4)
Previous CABG	-	27 (4.1)	40 (3.7)	28 (3.1)	-
NYHA, Class III	5 (29.4)	164 (25.2)	275 (25.6)	245 (27.0)	43 (30.3)
Class IV	5 (29.4)	178 (27.3)	284 (26.2)	204 (22.5)	41 (28.9)
Albumin, g/dL	3.7 (0.7)	3.9 (0.1)	3.9 (0.6)	3.9 (0.5)	3.9 (0.5)
IABP use	5 (29.4)	95 (14.6)	141 (13.1)	106 (11.7)	16 (11.3)
Left Ventricular EF, %	44.4 (13.2)	49.5 (12.9)	50.2 (12.4)	50.1 (12.1)	50.9 (12.6)
Cross Clamp time, minutes	49.4 (46.0)	62.6 (33.9)	65.4 (37.9)	64.6 (37.5)	62.3 (33.1)

Data shown as n (%) or mean (SD), as appropriate

NHLBI, National Heart, Lung, and Blood Institute

BMI, Body mass index

CABG, Coronary Artery Bypass Graft

MI, Myocardial Infarction

LAD, Left anterior descending artery

NYHA, New York Heart Association heart failure functional classification

IABP, Intra-aortic balloon pump

Table 2

Unadjusted perioperative characteristics by preoperative serum albumin group

Perioperative feature	Preoperative Serum Albumin				P
	≤2 g/dL N = 20	2-3 g/dL N = 204	3-4 g/dL N = 1,361	>4 g/dL N = 1,209	
Age, years	61.7 (10.6)	63.4 (10.9)	65.2 (10.9)	62.7 (10.4)	<0.001
Weight, kg	79.7 (15.8)	83.3 (19.9)	85.5 (18.8)	88.3 (18.2)	<0.001
Gender, Female	2 (10.0)	71 (34.8)	409 (30.1)	264 (21.8)	<0.001
Race, Caucasian	18 (90.0)	179 (87.7)	1,248 (91.7)	1,099 (90.9)	0.32
Risk Factor,					
Stroke	3 (15.0)	17 (8.3)	107 (7.9)	66 (5.5)	0.04
Diabetes	4 (20.0)	93 (45.6)	522 (38.4)	441 (36.5)	0.03
Renal Failure	2 (10.0)	39 (19.1)	151 (11.1)	79 (6.5)	<0.001
Dialysis	1 (5.0)	7 (3.4)	42 (3.1)	26 (2.2)	0.40
Previous CABG	1 (5.0)	7 (3.4)	51 (3.7)	36 (3.0)	0.73
NYHA, Class III	2 (10.0)	61 (29.9)	343 (25.2)	326 (27.0)	0.16
Class IV	4 (20.0)	55 (27.0)	370 (27.2)	283 (23.4)	0.15
IABP use	4 (20.0)	44 (21.6)	192 (14.1)	123 (10.2)	<0.001
Left Ventricular EF, %	50.4 (12.2)	46.4 (12.0)	48.9 (12.6)	51.9 (12.1)	<0.001
Cross Clamp time, minutes	70.9 (33.3)	63.7 (33.1)	64.2 (36.6)	64.3 (37.5)	0.87

Data shown as n (%) or mean (SD), as appropriate

CABG, Coronary Artery Bypass Graft

MI, Myocardial Infarction

LAD, Left anterior descending artery

NYHA, New York Heart Association heart failure functional classification

IABP, Intra-aortic balloon pump

EF, Ejection Fraction

Table 3
Complications, Resource use, and Mortality by NHLBI body mass index groups

Outcome Variable	NHLBI BMI Classification				P
	Underweight ≤18.4 kg/m ² N = 17	Normal 18.5–24.9 kg/m ² N = 652	Overweight 24.9–29.9 kg/m ² N = 1,075	Extremely Obese ≥40 kg/m ² N = 142	
Any Complication	9 (52.9)	260 (39.9)	448 (41.7)	354 (39.0)	0.13
Deep Sternal Wound	-	2 (0.3)	5 (0.5)	10 (1.1)	0.31
Stroke/Neurocognitive	2 (11.8)	21 (3.2)	43 (4.0)	22 (4.0)	0.10
Reoperation	1 (5.9)	8 (1.2)	17 (1.6)	13 (1.4)	0.51
Atrial Fibrillation	1 (5.9)	117 (17.9)	208 (19.3)	174 (19.2)	0.01
GI Complication	1 (5.9)	10 (1.5)	21 (2.0)	22 (2.4)	0.53
Pneumonia	4 (23.5)	19 (2.9)	23 (2.1)	25 (2.8)	<0.001
Prolonged Ventilation	1 (5.9)	50 (7.7)	87 (8.1)	66 (7.3)	0.96
Dialysis	-	5 (0.8)	11 (1.0)	11 (1.2)	0.31
Renal Failure	-	32 (4.9)	48 (4.5)	59 (6.5)	0.02
Total ICU stay, hours	59.2 (52.9)	53.5 (109.1)	47.2 (76.6)	48.8 (90.2)	0.52
Length of stay, days	8.9 (2.7)	8.8 (7.2)	8.7 (8.0)	9.2 (9.7)	0.50
Surgery to Discharge, days	5.9 (2.1)	6.5 (6.6)	6.4 (7.4)	7.0 (9.3)	0.35
30D Readmission	1 (5.9)	53 (8.1)	85 (7.9)	88 (9.7)	0.46
Major Complications	2 (11.8)	93 (14.3)	158 (14.7)	129 (14.2)	0.65
Mortality	2 (11.8)	20 (3.1)	40 (3.7)	19 (2.1)	0.05

Data shown as n (%) or mean (SD), as appropriate

NHLBI, National Heart, Lung, and Blood Institute

BMI, Body mass index

TIA, Transient ischemic attack

MI, Myocardial infarction

GI, Gastrointestinal

MODS, Multi-organ dysfunction syndrome

ICU, Intensive care unit

30D, Thirty-day

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Table 4
Complications, Resource use, and Mortality by preoperative serum albumin groups

Outcome Variable	Preoperative Serum Albumin				P
	≤2 g/dL N = 20	2-3 g/dL N = 204	3-4 g/dL N = 1,361	>4 g/dL N = 1,209	
Any Complication	15 (75.0)	114 (55.9)	615 (45.2)	397 (32.8)	<0.001
Deep Sternal Wound	-	-	12 (0.9)	6 (0.5)	0.38
Stroke/Neurocognitive	-	12 (5.9)	52 (3.8)	28 (2.3)	0.02
Reoperation	1 (5.0)	9 (4.4)	15 (1.1)	15 (1.2)	0.001
Atrial Fibrillation	6 (30.0)	44 (21.6)	288 (21.2)	205 (17.0)	0.03
GI Complication	-	9 (4.4)	35 (2.6)	14 (1.2)	0.01
Pneumonia	2 (10.0)	9 (4.4)	40 (2.9)	25 (2.1)	0.04
Prolonged Ventilation	6 (30.0)	32 (15.7)	108 (7.9)	70 (5.8)	<0.001
Dialysis	-	2 (1.0)	16 (1.2)	13 (1.1)	0.96
Renal Failure	1 (5.0)	32 (15.7)	77 (5.7)	44 (3.6)	<0.001
Total ICU stay, hours	77.3 (91.9)	64.3 (100.9)	50.8 (105.6)	45.7 (64.4)	0.02
Length of stay, days	11.8 (8.8)	11.8 (12.0)	9.5 (9.8)	7.8 (5.2)	<0.001
Surgery to Discharge, days	9.8 (8.3)	8.6 (10.8)	7.0 (9.4)	5.9 (4.7)	<0.001
30D Readmission	-	12 (5.9)	117 (8.6)	114 (9.4)	0.19
Major Complications	8 (40.0)	58 (28.4)	204 (15.0)	139 (11.5)	<0.001
Mortality	1 (5.0)	11 (5.4)	48 (3.5)	24 (2.0)	0.02

Data shown as n (%) or mean (SD), as appropriate

TIA, Transient ischemic attack

MI, Myocardial infarction

GI, Gastrointestinal

MODS, Multi-organ dysfunction syndrome

ICU, Intensive care unit

30D, Thirty-day

Table 5

Multivariable logistic regression models for major complications

Predictor Variable	Adjusted OR	P
<i>Model evaluating body mass index</i>		
Body Mass Index, Normal	Reference	
Underweight	0.24 (0.04 – 1.61)	0.14
Overweight	1.34 (0.90 – 2.00)	0.15
Obese	1.51 (0.86 – 2.66)	0.15
Extremely Obese	2.87 (1.07 – 7.67)	0.04
<i>Model examining preoperative serum albumin</i>		
Albumin >4 g/dL	Reference	
<2 g/dL	4.99 (1.49 – 16.73)	0.009
2–3 g/dL	2.78 (1.75 – 4.41)	<0.001
3–4 g/dL	1.28 (0.95 – 1.73)	0.10

Area under receiver operator characteristic curve 0.85, Data analyzed >93%, Nagelkerke $R^2 \geq 0.38$

OR, Odds Ratio

CI, Confidence Interval

Models adjusted for age, female gender, weight, race, preoperative diabetes, preoperative dialysis dependent renal failure, preoperative smoking, preoperative stroke, New York Heart Association functional heart failure class IV, left ventricular ejection fraction, left anterior descending disease 50% or greater, elective status, aortic cross-clamp time, intensive care unit length of stay

Table 6

Multivariable logistic regression model for mortality

Predictor Variable	AOR (95% CI)	P
Body Mass Index, kg/m ²	0.97 (0.93 – 1.02)	0.21
Albumin, g/dL	0.61 (0.42 – 0.90)	0.01

Area under receiver operator characteristic curve 0.81, Data analyzed 100%, Nagelkerke $R^2 \geq 0.20$

AOR, Adjusted Odds Ratio

CI, Confidence Interval

Models adjusted for age, female gender, preoperative diabetes, preoperative dialysis dependent renal failure, New York Heart Association functional heart failure class IV, elective status, left ventricular ejection fraction, perfusion time