Impact of body mass index on outcome in patients undergoing coronary artery bypass grafting and/or valve replacement surgery

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Abstract
Objective: This study aimed to analyze the impact of body mass index on outcomes of 101 patients undergoing coronary artery bypass grafting, valve replacement, or combined valve/coronary artery bypass grafting surgery in a private hospital in Belo Horizonte, Brazil.

Methods: This was a prospective cross-sectional study of patients undergoing cardiac surgery from May 2009 to December 2012. All patients were followed up from the first day of admission until discharge or death. Patients were divided into three groups according to BMI: normal weight, overweight, and obese. The main outcome measure was the association between BMI and postoperative morbidities and mortality.

Results: Multivariate analysis identified obesity as an independent predictor of increased risk of surgical reintervention (odds ratio [OR] 13.6; 95%CI 1.1 - 162.9; \( P = 0.046 \)) and reduced risk of bleeding (OR 0.05; 95% CI 0.09 - 0.69; \( P = 0.025 \)). Univariate analysis showed that obesity was associated with increased frequency of wound dehiscence (\( P = 0.021 \)). There was no association between BMI and other complications or mortality in univariate analysis. There was also no association between body mass index and duration of cardiopulmonary bypass, aortic clamping, mechanical ventilation, and intensive care unit or hospital stay.

Conclusion: Obese individuals undergoing coronary artery bypass grafting, valve replacement, or combined surgery have a higher postoperative risk of surgical reintervention and lower chances of bleeding.


Resumo
Objetivos: Analisar o impacto do índice de massa corporal no desfecho de 101 pacientes submetidos à cirurgias de revascularização do miocárdio e/ou troca valvar.

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INTRODUCTION

The prevalence of obesity has been increasing in Brazil and developed countries[1,2]. Research by the Brazilian Institute of Geography and Statistics[3] has shown that almost half of Brazilians (48%) have excess weight. It is well known that obesity increases the risk of coronary artery disease (CAD)[4] and is associated with increased mortality in this population as well as in the general population[4,5]. In 2009, a total of 209,029 Brazilian patients were hospitalized due to CAD, with a mortality rate of 6.04%[6].

Given the endemic nature of obesity in the contemporary world, numerous patients with excess body weight are expected to require cardiac surgery[6-8]. Despite advances in clinical treatment and percutaneous procedures, coronary artery bypass grafting (CABG) is still considered a safe surgical method even in at-risk populations and is widely performed in Brazil and worldwide for treatment of obstructive CAD[8-10].

Conflicting data has been published on the influence of obesity on morbidity and mortality in cardiac surgery. Studies in different countries have documented an “obesity paradox”, suggesting a neutral or beneficial effect of excess weight on the outcome of patients undergoing coronary angioplasty, surgery for valve replacement, and CABG[11-20]. In a retrospective Brazilian study of 290 elderly patients who underwent CABG, obesity had a protective association with pulmonary dysfunction, risk of readmission, and mortality, although it was a risk factor for renal dysfunction during the postoperative period[21]. However, some authors have identified obesity, diabetes, and chronic obstructive pulmonary disease as independent risk factors of mediastinitis after cardiac surgery[22].

Data on the adverse or protective effects of body weight in Brazilian patients undergoing cardiac surgery remain scarce. The current study was designed to assess the preoperative impact of BMI on morbidity and mortality in the postoperative period in adult and elderly patients undergoing CABG, valve replacement, or combined cardiac surgery.

METHODS

Study Design and Sample

This was a prospective cross-sectional study conducted between May 2009 and December 2012 in a private hospital in Belo Horizonte, Minas Gerais, Brazil, with a residency training program in cardiovascular surgery. In all, 101 of 118 surgeries were assessed. The same team performed all surgical procedures. Adult and elderly patients (aged 60 years or over) were included. Patients younger than 18 years and those undergoing other surgical modalities such as excision of atrial myxoma and Bentall - De Bono surgery were excluded. All patients were followed up from the first day of hospitalization (pre-operative) until hospital discharge or death (when this occurred during hospitalization).

Ethical Aspects

The study participants were part of a wide-ranging study, entitled, “The use of nutritional assessment as a predictor of risk of complications in patients undergoing cardiac sur-
surgery⁴, which was approved by the Research Ethics Commit-
tee of Vera Cruz Hospital, Belo Horizonte, Minas Gerais, under number 097/09. All participants voluntarily signed an
informed consent form.

**Data Collection and Definitions**

Data were collected prospectively. The clinical vari-
ables included in the study were divided into pre-opera-
tive, peri-operative, and postoperative variables, as shown in Table 1.

Clinical and demographic data including the presence of
associated comorbidities and risk factors were obtained from
medical history collected during the pre-operative evaluation. Nutritional parameters including body mass index (BMI) and albumin concentration were measured during the pre-oper-
ative period. The BMI was calculated using the Quetelet's
index[23]. BMI was classified according to criteria from the
World Health Organization (WHO)[24]. The study population
was divided into three groups: normal weight (BMI between
18.5 and 24.9 kg/m²), overweight (BMI ≥ 25 kg/m² and < 30
kg/m²), and obese (BMI ≥ 30 kg/m²).

All surgical procedures were performed under balanced
intravenous general anesthesia. Median sternotomy was per-
formed in all patients. After systemic heparinization, cardio-
pulmonary bypass was instituted between the ascending aorta
and the right atrium using a 2-stage cannula or cannulation of
both venae cavae. Cardiac protection was instituted by means
of intermittent clamping of the aorta and crystalloid cardio-
dioplegia with blood dilution during CABG and valve replace-
ment surgery, respectively. The duration of cardiopulmonary
bypass (CPB) and aorta clamping were measured during the
perioperative period.

The Acute Physiology and Chronic Health Evaluation
(APACHE II) score was calculated on patient admis-
sion to the intensive care unit (ICU) during the immediate
post-operative period, and the duration of mechanical venti-
lation (MV), time of stay in the ICU, total length of hospital
stay, complications, and postoperative mortality (when this
occurred up to 30 days after the surgical procedure) were also
recorded.

Complications were categorized as: 1) infectious; 2) cardiovascular; 3) requiring surgical reintervention for sternal
wound dehiscence; 4) increased bleeding; 5) acute kid-
ney injury; and 6) minor complications. Infectious compli-
cations were defined as pneumonia, urinary tract infection,
sepsis, septic shock, mediastinitis, infections of the lower
limbs, or endocarditis. Cardiovascular complications were
defined as acute myocardial infarction, cardiogenic shock,
atrial fibrillation, stroke, heart failure, transient ischemic at-
tack, or lower limb ischemia. Increased bleeding was char-
acterized as the need for blood transfusion or surgical rein-
tervention. Acute kidney injury in the postoperative period
was defined as serum creatinine levels greater than or equal
to 2.0 or requiring hemodialysis. The following were con-
sidered minor complications: pericardiotomy syndrome,
pleural effusion, pressure ulcers, lowers limb wounds, and
sinusitis.

The main outcome assessed in this study was the associa-
tion between BMI and complications during the CABG or
valve replacement postoperative period.

**Statistical Analysis**

Descriptive analysis of the data was performed; propor-
tions were calculated for categorical variables and minimum,
median, maximum, average and standard deviation were
calculated for continuous variables. Chi-square and Krus-
kal-Wallis tests were used to assess independence between
groups and for comparison of medians, respectively[25].

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**Table 1. Clinical variables in the study.**

<table>
<thead>
<tr>
<th>Preoperative variables</th>
<th>Perioperative variables</th>
<th>Postoperative variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Surgical procedure</td>
<td>APACHE II Score</td>
</tr>
<tr>
<td>Gender</td>
<td>CPB time (min)</td>
<td>Infectious complications</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>Aorta clamping time (min)</td>
<td>Cardiovascular complications</td>
</tr>
<tr>
<td>Albumin (g/dL; normal ≥3.5g/dL)</td>
<td></td>
<td>Surgical reintervention</td>
</tr>
<tr>
<td>Smoking (current)</td>
<td></td>
<td>Acute kidney injury</td>
</tr>
<tr>
<td>Heart failure (LVEF &lt; 45%)</td>
<td></td>
<td>Minor complications</td>
</tr>
<tr>
<td>CKD (Cr ≥2.5mg/dL or dialysis)</td>
<td></td>
<td>Mortality (up to 30 DAS)</td>
</tr>
<tr>
<td>COPD (drug therapy)</td>
<td></td>
<td>MV duration (days)</td>
</tr>
<tr>
<td>Glucose intolerance/DM (plasma glucose ≥100mg/dL/ drug therapy)</td>
<td></td>
<td>ICU stay (days)</td>
</tr>
<tr>
<td>HBP (≥130/85 mmHg/ drug therapy)</td>
<td></td>
<td>Total length of hospital stay (days)</td>
</tr>
<tr>
<td>Dyslipidemia (HDL&lt;40mg/dL in men and &lt;50mg/dL in women and/or TG ≥150mg/dL/ drug therapy)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CPB=cardiopulmonary bypass; DM=diabetes mellitus; DAS= days after surgery; COPD=chronic obstructive pulmonary disease; APACHE II score=Acute Physiology and Chronic Health Evaluation; HBP=high blood pressure; LVEF=left ventricle ejection fraction; HDL=high density lipoprotein cholesterol; BMI=body mass index CKD=chronic kidney disease; TG=triglycerides; ICU=intensive care unit; MV=mechanical ventilation.
The multivariate analysis used an adjusted multinomial regression model that considered the overweight group as the reference. The model was adjusted for postoperative complications; those without significant $P$ values were retained due to clinical significance\cite{25}.

Analyses were performed using STATA version 12.0 (Stata Corporation, College Station, Texas), with a 5% significance level.

RESULTS

A total of 101 patients were included in this study and most were male (73.3%). Sixty-one percent were elderly, with a mean age of 61.8±10.1 years. The mean BMI was 27.3±4.3 kg/m$^2$ (Figure 1). Approximately 32.0% of patients had a healthy weight, 47.5% were overweight, and 20.8% were obese. The mean serum albumin level in the preoperative period was 4.1±0.6 g/dL. None of the participants was malnourished in the pre-operative period according to BMI classification. A minority (9.0%) had serum albumin less than 3.5 g/dL. When the study population was stratified according to BMI classification, there was no significant difference in the frequency of elderly individuals between the groups (Table 2).

Analysis of comorbidities and risk factors identified in the pre-operative period for the entire sample population revealed that the majority of patients were hypertensive (83.2%), dyslipidemic (76.2%), and glucose intolerant or diabetic (68.3%). Approximately 15% had previous history of cardiac surgery and around 17% were smokers. When classified by BMI, the only comorbidities and/or risk factors that showed statistical differences between the groups were diabetes and hypertension that were more prevalent among overweight individuals (Table 2).

CABG was the most common surgical procedure in this population (71% of cases), followed by valve replacement (23%) and combined surgery (6%). There was no difference in the frequency of CABG or valve replacement between the normal, overweight, and obese groups ($P=0.241$).

On average, patients remained in CPB for 79.3±24.9 minutes in the peri-operative period, and the average aortic clamping time was 37.6±16.9 minutes. The median CPB times in healthy, overweight, and obese individuals were 73 (interquartile range [IQR]: 58-97 min), 80.5 (IQR: 67-93 min), and 71 min (IQR: 62-81 min), respectively. The median aorta clamping times were 35 (IQR: 28-52 min), 37.5 (IQR: 29-43 min), and 31 min (IQR: 25-35min), respectively.

Table 2. Demographic characteristics, comorbidities, and risk factors during preoperative evaluation of patients undergoing heart surgery.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal weight n=32</th>
<th>Overweight n=48</th>
<th>Obesity n=21</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender</td>
<td>55.6%</td>
<td>30.0%</td>
<td>21.6%</td>
<td>0.939</td>
</tr>
<tr>
<td>Elderly</td>
<td>37.7%</td>
<td>37.7%</td>
<td>24.6%</td>
<td>0.015*</td>
</tr>
<tr>
<td>GI/ DM</td>
<td>25.0%</td>
<td>25.0%</td>
<td>0.0%</td>
<td>0.151</td>
</tr>
<tr>
<td>HBP</td>
<td>33.3%</td>
<td>33.3%</td>
<td>11.1%</td>
<td>0.267</td>
</tr>
<tr>
<td>COPD</td>
<td>100.0%</td>
<td>100.0%</td>
<td>0.0%</td>
<td>0.100</td>
</tr>
<tr>
<td>CKD</td>
<td>3.2%</td>
<td>3.2%</td>
<td>23.4%</td>
<td>0.507</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>47.1%</td>
<td>29.4%</td>
<td>23.5%</td>
<td>0.222</td>
</tr>
<tr>
<td>Smoking</td>
<td>40.0%</td>
<td>60%</td>
<td>0.0%</td>
<td>0.099</td>
</tr>
</tbody>
</table>

*BMI=body mass index; CKD=chronic kidney disease; COPD=chronic obstructive pulmonary disease; DM=diabetes mellitus; HBP=high blood pressure; GI=glucose intolerance; HF=heart failure; PHS=previous heart surgery.*
for the same patient groups. There were no significant differences in median CPB time ($P=0.215$) and aortic clamping ($P=0.064$) between groups stratified by BMI.

In the immediate postoperative period, 44% of patients had APACHE II scores higher than 8.0. This score was also not different among normal BMI, overweight, and obese patients ($P=0.458$).

The median post-surgical ICU and MV durations were 5 days (min: 3; max: 102) and 1 day (min: 1; max: 35), respectively. The median hospital stay was 16 days (min: 4; max: 117). There was no difference between MV, ICU, and hospitalization duration between patient groups (Table 3). Most patients were discharged from hospital (94.1%), while postoperative mortality occurred in 6 of 101 patients (5.9%).

Slightly more than half of the patients (50.5%) had no postoperative complications. The univariate analysis revealed an association between obesity and surgical reintervention due to sternal wound dehiscence ($P=0.021$). All patients with sternal wound dehiscence were obese (Table 4). Univariate analysis revealed no association between BMI and postoperative mortality ($P=0.15$).

The multivariate analysis was adjusted for classes of complications (cardiovascular, infectious, requirement for surgical reintervention due to sternal wound dehiscence, bleeding, acute kidney injury, and minor complications) using the overweight group as a reference. Obesity was an independent predictor for surgical reintervention due to sternal wound dehiscence (odds ratio [OR]: 13.6; 95% confidence interval [95%CI]: 1.1-162.9; $P=0.046$) and a protective factor for bleeding (OR: 0.05; 95%CI: 0.09-0.69; $P=0.025$), as shown in Table 5. Mortality was not entered in the multivariate model due to the low number of deaths.

Table 3. Comparison of MV, ICU, and hospital stay postoperative times from patients undergoing heart surgery.

<table>
<thead>
<tr>
<th>Days</th>
<th>Normal weight</th>
<th>BMI</th>
<th>Obesity</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>Median</td>
<td>Q1-Q3</td>
<td>n</td>
</tr>
<tr>
<td>MV</td>
<td>32</td>
<td>1</td>
<td>1-2.5</td>
</tr>
<tr>
<td>ICU</td>
<td>32</td>
<td>5</td>
<td>4-9</td>
</tr>
<tr>
<td>Hospital stay</td>
<td>32</td>
<td>17</td>
<td>10-23</td>
</tr>
</tbody>
</table>

BMI=body mass index; CABG=coronary artery bypass grafting; MV=mechanical ventilation

Table 4. Association between BMI and postoperative complications from CABG and/or valve replacement (univariate analysis).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal</th>
<th>Overweight</th>
<th>Obesity</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular complications</td>
<td>32.1</td>
<td>46.2</td>
<td>21.8</td>
<td>0.854</td>
</tr>
<tr>
<td>Infectious complications</td>
<td>28.4</td>
<td>48.7</td>
<td>23.0</td>
<td>0.436</td>
</tr>
<tr>
<td>Sternal wound dehiscence</td>
<td>0.0</td>
<td>0.0</td>
<td>10.0</td>
<td>0.021*</td>
</tr>
<tr>
<td>Bleeding</td>
<td>32.4</td>
<td>43.2</td>
<td>24.3</td>
<td>0.249</td>
</tr>
<tr>
<td>Acute kidney failure</td>
<td>31.5</td>
<td>47.8</td>
<td>20.7</td>
<td>0.981</td>
</tr>
<tr>
<td>Minor complications</td>
<td>32.1</td>
<td>45.2</td>
<td>22.6</td>
<td>0.501</td>
</tr>
</tbody>
</table>

BMI=body mass index; CABG=coronary artery bypass grafting

Table 5. Obesity and postoperative complications risk at CABG and/or valve replacement (multivariate analysis).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal weight</th>
<th>BMI</th>
<th>Obesity</th>
<th>P value</th>
<th>95% IC</th>
<th>95% IC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular complications</td>
<td>0.83</td>
<td>0.22-3.13</td>
<td>0.784</td>
<td>0.83</td>
<td>0.22-3.13</td>
<td>0.784</td>
</tr>
<tr>
<td>Infectious complications</td>
<td>2.27</td>
<td>0.65-7.98</td>
<td>0.200</td>
<td>2.27</td>
<td>0.65-7.98</td>
<td>0.200</td>
</tr>
<tr>
<td>Sternal wound dehiscence</td>
<td>2.18</td>
<td>0.42-11.43</td>
<td>0.357</td>
<td>2.18</td>
<td>0.42-11.43</td>
<td>0.357</td>
</tr>
<tr>
<td>Bleeding</td>
<td>0.37</td>
<td>0.08-1.65</td>
<td>0.194</td>
<td>0.37</td>
<td>0.08-1.65</td>
<td>0.194</td>
</tr>
<tr>
<td>Acute kidney injury</td>
<td>0.74</td>
<td>0.11-5.18</td>
<td>0.761</td>
<td>0.74</td>
<td>0.11-5.18</td>
<td>0.761</td>
</tr>
<tr>
<td>Minor complications</td>
<td>0.73</td>
<td>0.18-3.01</td>
<td>0.661</td>
<td>0.73</td>
<td>0.18-3.01</td>
<td>0.661</td>
</tr>
</tbody>
</table>

BMI=body mass index; CABG=coronary artery bypass grafting
DISCUSSION

To our knowledge, this was the first prospective Brazilian study designed to examine the impact of BMI on the outcome of patients undergoing CABG or valve replacement. The main finding of this study was that obesity in the preoperative period could be considered a predictor of risk for surgical reintervention by wound dehiscence and may reduce the risk of bleeding in the postoperative period of cardiac surgery. Although obesity appears to increase the frequency and risk of sternal wound dehiscence, it was not associated with other complications in the postoperative period or with increased mortality.

Univariate and multivariate analyses revealed an association between obesity and increased frequency or risk of reoperation for sternal wound dehiscence in this study. We believe that the increased subcutaneous tissue thickness in individuals with excessive body weight may contribute to this complication. In support of our findings, a cohort study published in 2014 involving 5,815 patients who underwent CABG also noted that obesity was a predictive factor for sternal wound dehiscence, along with diabetes and female sex\(^{29}\).

In multivariate analysis, obesity was a protective factor for increased bleeding in the CABG or valve replacement postoperative period. The observation that obesity is a protective factor for bleeding in the postoperative period of cardiac surgery was expected, since obese individuals have abundant mediastinal fat and large abdominal pressure, which leads to increased intrathoracic pressure that compresses sites of minor bleeding. In addition, reduced administered volume after CPB and less hemodilution in obese patients may also contribute to lower risk of postoperative bleeding. Thus, obese patients have significantly lower risks of surgical reintervention due to bleeding than non-obese or underweight patients\(^{27,28}\).

We found no association between obesity and the presence of infectious or cardiovascular complications, acute kidney injury, or minor complications. Gurin et al. analyzed data from 1,526 patients during the CABG postoperative period and also reported no difference in the incidence or risk of major complications (death, myocardial infarction, stroke), cardiopulmonary events (heart failure, cardiogenic shock, reintubation), and wound infection among obese patients\(^{29}\).

In the present study, there was no association between obesity and increased risk of mortality. However, two recent meta-analyses have noted that obese individuals have reduced risk of mortality after coronary revascularization\(^{18,30}\). In other studies, obese patients undergoing valve replacement surgery also showed superior survival time\(^{19,20}\).

Our results showed lower average durations of CPB and aortic clamping than those described by other authors (79.3±24.9 min vs. 103.4±35.1 min and 37.6±16.8 min vs. 74.8±24.2 min, respectively)\(^{19}\). In our population, BMI was not associated with changes in CPB duration and aortic clamping, possibly due to little intrathoracic anatomical variation in non-obese and obese patients. In addition, the duration of MV, ICU stay, and total length of hospital stay also did not differ according to BMI in the present study. These findings are consistent with data of other publications\(^{19,31-33}\).

This study has some methodological limitations, especially with regard to the sample size. It was not possible to evaluate the usefulness of BMI as a predictor of mortality in the multivariate analysis. However, this is perhaps the only prospective study that provides data about the influence of BMI outcomes of adult and elderly patients undergoing myocardial revascularization or prosthetic valve replacement in Brazil. In addition, our results contribute to knowledge about the obesity paradox in cardiovascular surgery.

CONCLUSION

Obese patients undergoing CABG or valve replacement may be at increased risk of surgical reintervention by wound dehiscence and seem to be more protected from the risk of increased postoperative bleeding. Obesity does not appear to be related to increased incidence of other complications or postoperative mortality. However, larger studies are needed to establish definitive conclusions about the impact of obesity on mortality in the CABG and valve replacement postoperative period.

<table>
<thead>
<tr>
<th>Authors’ roles &amp; responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>VEAC</td>
</tr>
<tr>
<td>SMF</td>
</tr>
<tr>
<td>TOR</td>
</tr>
<tr>
<td>RRR</td>
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<tr>
<td>EAVR</td>
</tr>
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<td>CMFC</td>
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<td>JCFC</td>
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REFERENCES


