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Original Article

The Effects of Different BMI on Blood Loss and Transfusions in Chinese Patients Undergoing Coronary Artery Bypass Grafting

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Objective: Blood loss is a predictor of outcomes after coronary artery bypass grafting (CABG). This study investigated the effects of body mass index (BMI) on blood loss, blood transfusion rate, and the variations in coagulation parameters of Chinese patients undergoing CABG.
Methods: A total of 1007 Chinese patients who consecutively underwent isolated, primary CABG at Fuwai Hospital from January 1, 2013 to December 31, 2013 were included in this study. They were categorized by BMI into <24 kg/m² (low and normal weight group), 24≤ BMI <28 kg/m² (overweight group), and BMI ≥28 kg/m² (obese group). Following this BMI classification, the quantities of blood lost and recorded transfusions were analyzed.
Results: Blood loss and transfusion rates were significantly higher in the low and normal weight group compared with the obese group (p <0.01). Chest tube drainage over 24 h, duration of intensive care unit (ICU) stay, and postoperative mechanical ventilation were higher as well (p <0.01). Atrial fibrillation was closely related to blood transfusion (p <0.001).
Conclusions: Obesity is a predictor for protection against blood loss and transfusion in Chinese people. Patients with low and normal BMI lost more blood per kg of their weight and had higher total transfused volume during isolated primary CABG. Atrial fibrillation was associated with high blood transfusion.

Keywords: CABG, blood loss, BMI, obesity

Introduction

Improved socioeconomic conditions may be one reason for the overweight population which has expanded worldwide in recent decades. It is well known that obesity is a hazard for developing diabetes mellitus (DM), hypertension, and coronary artery disease.[1)] It also is believed to increase the perioperative morbidity and mortality from cardiovascular surgery, as evidenced by its inclusion into the Parsonnet system to stratify risk for perioperative death.[2)] An analysis of the National Cardiac Surgery Database of the Society of Thoracic Surgeons suggested that morbid obesity remains an independent predictor of increased operative mortality in patients who undergo coronary artery bypass grafting (CABG).[3)]

Most studies have evaluated the effect of body mass index (BMI) on early clinical outcomes after CABG between obese and non-obese patients.[4)] Grouping patients in this way means that each group includes patients with widely varying BMI that could mask the true impacts of varying BMI on outcomes.[5)]

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Bleeding remains a serious problem after cardiac surgery.[6,7] Up to 5% of surgery patients receive over 10 units of blood and approximately 4% require reoperation due to hemorrhage during cardiac surgery although many patients do not require perioperative blood transfusions. Ongoing hemorrhage not only increases the need for allogenic transfusions, but also complicates clinical management after surgery. Excessive bleeding that requires a transfusion is associated independently with severe perioperative events, such as sepsis, acute respiratory distress syndrome, and renal failure death. Understanding the intraoperative transfusion requirements will streamline the blood bank use and facilitate patient-specific interventions.

A number of preoperative parameters predict blood use. Clinical assessment tools already are in place to indicate blood use in some surgeries such as for trauma.[8] However, scheduled cardiac surgery routinely requires red cell transfusion. Research to predict which patients will require blood, and how much they will need, still is ongoing.[9,10] A tool to evaluate patients preoperatively for their estimated blood loss postoperatively would facilitate better patient-specific care.

This study investigated the effects of varied BMI on early clinical outcomes in patients undergoing CABG. We retrospectively evaluated the relation of BMI to bleeding, transfusions, and in-hospital outcomes among Chinese patients who underwent isolated, primary CABG.[11,12]

Subjects and Methods

Study population

The study was approved by the Ethics Committee of Fuwai Hospital, in compliance with the Declaration of Helsinki. Patient information was de-identified prior to analysis. From January 1, 2013 to December 30, 2013, 1007 patients who consecutively underwent isolated, primary CABG at Fuwai Hospital in Beijing, China were considered for inclusion. Isolated primary CABG was defined as isolated CABG surgery for the first time with or without cardiopulmonary bypass (CPB). Patients who underwent other concomitant cardiovascular surgical procedures were excluded.

BMI is a recognized measure of obesity that is defined as weight in kilograms divided by the square of the height in meters. This body size measurement best correlates with the body's fat content. Asians generally have lower BMI than Westerners. It has been suggested that applying BMI to define overweight or obesity for Chinese means something different from North American or European populations because obesity-associated metabolism is lower in Chinese individuals.[13] It also has been suggested that the BMI cutoff point for overweight or obesity in the Chinese population should be lower than WHO standards.[14] Therefore, we adopted the Chinese BMI cutoff values proposed by the Working Group on Obesity in China (WGOC)[15] and described in the Guidelines for Prevention and Control of Overweight and Obesity in Chinese Adults[16] to define overweight or obesity, as follows: BMI <18.5 kg/m^2 (underweight), $18.5\leq$ BMI <24 kg/m^2 (normal weight), $24\leq$ BMI <28 kg/m^2 (overweight), and BMI ≥ 28 kg/m^2 (obese). Because few patients were in the underweight group, we combined the underweight and normal weight groups (<24 kg/m^2). BMI for analysis were <24 kg/m^2 (low and normal weight group), $24\leq$ BMI <28 kg/m^2 (overweight), and BMI ≥ 28 kg/m^2 (obese).

All anesthesiologists involved in the study were experienced at cardiac anesthesia. Blood transfusion and fluid input were controlled by anesthesiologists according to an accepted fluid management guideline.[17] "Fluid" meant any fluid infused during operation except blood products. And blood products included plasma suspended red blood cells (RBCs), plasma, or recycled blood. Outcomes recorded included hospital death, renal failure, intensive care unit (ICU) stay duration, and mechanical ventilation time.

Data collection

Data were collected from hospital medical records. We obtained laboratory test results, perioperative condition, and postoperative recovery, especially to track fluid infusions, volume of chest tube drainage in the first 24 h after surgery, blood product transfusion, and reoperation. CPB time also was recorded. It was difficult to accurately assess blood loss during surgery because cell savers were used and various human factors. Although intraoperative blood loss was recorded, as this was a retrospective study we found that chest tube drainage in the first 24 h after surgery provided a better indication of blood loss. Transfused volume and chest tube drainage were divided by body weight, and the volume of chest tube drainage/weight and volume of transfusion/weight were obtained. The volume of chest tube drainage in the first 24 h after surgery was recorded by a nurse in the ICU. All nurses had been trained for accuracy record. Blood transfusion, ICU stay, and mechanical ventilation time also were recorded.

Table 1 Characteristics of the study cohort by body mass index category

Variable	BMI			p
BMI	<24 kg/m² (n = 323)	24–28 kg/m² (n = 493)	>28 kg/m² (n = 191)	
Age	62.4 ± 8.96	61 ± 8.78	58 ± 9.61	<0.01
Men (%)	75.5	79.9	82.7	0.12
Smoking (%)	39.0	43.0	46.6	0.23
Drinking (%)	13.0	17.4	20.9	0.054
Hypertension (%)	52.0	66.7	73.8	<0.01
Hyperlipidemia (%)	47.7	58.6	67.0	<0.01
Diabetes (%)	52.0	66.7	73.8	<0.018
History of renal failure (%)	2.2	1.4	1.6	0.71
History of liver disease (%)	1.2	1.0	2.0	0.53
Cerebrovascular events (%)	7.1	6.3	3.1	0.17
NYHA				
I	175	295	106	0.076
II	113	171	75	
III	29	22	9	
IV	6	5	1	
LVEF (%)	58.13 ± 10.9	58.96 ± 10.1	60.00 ± 8.8	<0.01
Myocardial infarction (%)	4.6	4.5	5.8	0.77
Peripheral artery disease (%)	2.1	1.6	3.1	0.46
Interventional stent (%)	8.0	10.8	8.9	0.42
Heart failure (%)	0.6	0.2	0.0	0.4
Atrial fibrillation (%)	9.0	3.4	5.2	<0.01
Surgery history (%)	17.6	20.3	18.8	0.64
CPB (%)	57.9	56.4	51.3	0.332
CPB primed RBC (%)	38.55	25.3	14.3	<0.01
Hematocrit	39.06 ± 4.97	39.68 ± 4.96	40.73 ± 4.68	0.01
RBC (10^{12}/L)	4.32 ± 0.55	4.40 ± 0.52	4.55 ± 0.51	<0.01
Hb	130.95 ± 16.87	134.95 ± 14.86	138.04 ± 15.66	<0.01
PLT (10^9/L)	197.48 ± 60.32	196.95 ± 63.53	209.77 ± 63.87	<0.01
Glucose (mmol/L)	5.76 ± 1.61	5.90 ± 1.81	6.23 ± 1.88	<0.01

BMI: body mass index; CPB: cardiopulmonary bypass; Hb: hemoglobin; LVEF: left ventricular ejection fraction; PLT: platelet; NYHA: New York Heart Association; RBC: red blood cell

Hemoglobin (Hb), RBC, platelet (PLT) from the last biochemical test before surgery, and the first biochemical tests in ICU were available. However, we did not know whether these patients had certain underlying diseases, such as hypertension, hyperlipidemia, diabetes, history of renal failure, history of liver disease, cerebrovascular events, heart failure, or atrial fibrillation.

Statistical analysis

All descriptive data are presented as mean (standard deviation [SD]) for normally distributed continuous variables, median (interquartile range) for abnormally distributed continuous data, or number (percent) for categorical data as appropriate. The Wilcoxon ranked sum test or analysis of variance (ANOVA), and chi-square test or Fisher exact tests were used for group comparisons, as appropriate.

A multiple linear regression model identified BMI groups that were independently associated with chest tube drainage in the first 24 h by weight and the intraoperative blood products used. Analysis of covariance was performed in the models with adjustment for covariates. We found significant differences among the three BMI groups in baseline characteristics from laboratory examination. Multi-categorical variables, such as BMI group, were included in the analysis in the form of dummy variables. For both models, covariates were selected and considered for entry into the multiple linear regression models by first performing univariate linear regression analysis of the possible association of each independent variable with $p \leq 0.1$.

All statistical analyses were performed with SPSS version 20.0 software (SPSS Inc., Chicago, IL, USA). A two-sided value of $p < 0.05$ was considered to indicate statistical significance.

Table 2 Postoperative outcome parameters by subgroup of body mass index (mean ± SD)

Variable	BMI			p
	<24 kg/m²	24–28 kg/m²	>28 kg/m²	
	(n = 323)	(n = 493)	(n = 191)	
Surgery time (min)	236. ± 87.5	233 ± 74.5	236 ± 55.6	0.257
Fluid input (mL/kg)	17.3 ± 8.01	14.1 ± 7.14*	12.8 ± 6.23*#	<0.01
Transfusion (mL/kg)	1.69 ± 6.99	0.55 ± 2.60*	0.24 ± 1.46*	<0.01
Bleeding (mL/kg)	5.04 ± 1.89	4.37 ± 1.28*	4.07 ± 1.13*#	<0.01
RBC (10^{12}/L)	3.43 ± 0.50	3.49 ± 0.46	3.59 ± 0.53	0.419
Hb (g/L)	103 ± 15.48	106 ± 13.65*	108 ± 15.2*	<0.01
PLT (10^9/L)	121 ± 48.5	127.69 ± 45.77*	140.45 ± 45.86*#	<0.01
Glucose (mmol/L)	7.19 ± 2.46	7.22 ± 2.12	7.60 ± 2.25	0.91
Chest tube drainage (ml/kg)	13.6 ± 7.92	10.42 ± 4.87*	8.43 ± 3.96*#	<0.01
ICU stay (min)	3932 ± 4330	3279 ± 2924*	3265 ± 3726*	0.025
Ventilation time (h)	25.6 ± 54.2	9.76 ± 22.5	18.7 ± 13.2	<0.01
Reoperation (%)	4 (1.2%)	3 (0.6%)	0	0.052
Total blood loss (mL)	298 ± 93.2	315 ± 87.3*	338 ± 103.7*#	<0.01

*Indicating a difference on comparison with BMI: <24 kg/m² with p <0.05; #Indicating a difference on comparison with BMI: 24–28 kg/m² with p <0.05. RBC: red blood cell; Hb: hemoglobin; PLT: platelet; BMI: body mass index; ICU: intensive care unit

Results

Demographic and clinical data of the patients are presented in **Table 1**. There was an imbalance of age, hypertension, hyperlipidemia, atrial fibrillation and other parameters of which the p value is smaller than 0.05 among the three study groups. During further statistical analysis with multivariable linear regression, we excluded this as a bias on study results. Although CPB time was not different among the three groups, the low and normal group showed a significantly higher CPB primed RBC during the preoperative period (p <0.01, **Table 1**). They also had lower Hb, RBC, PLT, and glucose (p <0.01, **Table 1**) than the obese group.

The infused fluid and blood volume, chest tube drainage, and transfusion rate in the low and normal group were markedly higher than in the obese group immediately after the patients were transferred to the ICU (**Table 2**, p <0.01). ICU stay (p = 0.025) and ventilation time (p <0.01) in the low and normal group also were substantially higher than the obese group (**Table 2**). After surgery, Hb and PLT were lower in the low and normal groups than in the obese group (**Table 2**, p <0.01). Reoperation rates in the low and normal group and overweight groups were higher than in the obese group (**Table 2**, 1.2% and 0.6% vs 0, respectively). Compared with the obese group, low and normal weight patients had more blood transfused (1.69 ± 6.99, 0.24 ± 1.46 mL/kg, p <0.01, **Table 2**) and lost more blood ([5.04 ± 1.89, 4.07 ± 1.13 mL/kg], p <0.01, **Table 2**).

As detailed in **Tables 3** and **4**, it is clear that age influenced chest tube drainage/weight (0.089 [0.056, 0.123], p <0.001, **Table 3**) and intraoperative fluid input/weight (0.114 [0.075, 0.153], p <0.001, **Table 4**). Atrial fibrillation was associated closely with blood transfusion (–1.4 [–2.7, –0.17], p = 0.026, **Table 5**).

Discussion

Our study had two primary novel findings. First, BMI had an inverse relationship with blood loss among low and normal, overweight, and obese ethnic Chinese patients after CABG. Low and normal weight patients had more chest tube drainage per kilogram. Meanwhile, ICU stay and ventilation durations were longer in the low and normal group than in the obese group. In contrast, a very low BMI is known to predict further blood loss after surgery. Unfortunately, there were too few patients with the lowest BMI (<18.5 kg/m²) for us to confirm this finding. Still, there was dramatically higher blood loss and blood product administration after combining low and normal weight patients compared to obese patients.

Our results were that low or normal weight was a significant preoperative indicator of increased chest tube drainage and perioperative bleeding. It is important to note that chest tube drainage is only a partial surrogate for surgical site bleeding. Several studies that evaluated reoperations for bleeding had similar results, including decreased reoperation among obese populations.[4,18–20) It has been demonstrated that adipocytes produce

Table 3 Linear regression analysis for chest drainage

Chest tube drainage in the first 24 h/weight	Simple linear regression				Multiple linear regression			
	B	p	95% CI		B	P	95% CI	
			Lower	Upper			Lower	Upper
BMI group								
BMI <24 kg/m²	5.157	<0.001	4.102	6.212	4.840	<0.001	3.696	5.989
24≤ BMI <28 kg/m²	1.987	<0.001	1.002	2.972	1.682	0.002	0.644	2.720
BMI ≥28 kg/m²*								
Age	0.092	<0.001	0.051	0.134	0.089	<0.001	0.056	0.123
Diabetes mellitus	1.221	0.004	0.402	2.040				
Hyperlipidemia	1.436	<0.001	0.669	2.202				
Hypertension	0.797	0.048	0.005	1.589				
Atrial fibrillation	−1.602	0.059	−3.267	0.064				
Glucose	<0.001	0.214	<0.001	0.001				
RBC	−0.890	0.021	−1.645	−0.134				
Hb	−0.022	0.069	−0.046	0.002				
PLT	−0.008	0.013	−0.014	0.002				
Hematocrit	−0.046	0.241	−0.124	0.031				

*BMI ≥28 kg/m² as the control group; $R^2 = 0.784$. RBC: red blood cell; Hb: hemoglobin; PLT: platelet; BMI: body mass index; CI: confidence interval

Table 4 Linear regression analysis for intraoperative fluid input/weight

Fluid input/weight	Simple linear regression				Multiple linear regression			
	B	p value	95% CI		B	p value	95% CI	
BMI group								
BMI <24 kg/m²	4.493	<0.001	3.199	5.787	4.870	<0.001	3.496	6.245
24≤ BMI <28 kg/m²	1.349	0.029	0.141	2.557	1.755	0.007	0.482	3.028
BMI ≥28 kg/m²*								
Age	0.073	0.004	0.023	0.124	0.114	<0.001	0.075	0.153
Diabetes mellitus	−0.724	0.150	−0.171	0.262				
Hyperlipidemia	−0.672	0.155	−1.597	0.254				
Hypertension	0.087	0.857	−0.865	1.040				
Atrial fibrillation	1.068	0.295	−0.934	3.070				
Glucose	<0.001	0.808	−0.001	0.001				
RBC	−1.342	0.004	−2.242	−0.441				
Hb	−0.050	0.001	−0.078	−0.021				
PLT	0.003	0.466	−0.005	0.010				
Hematocrit	−0.098	0.039	−0.191	−0.005				

*BMI ≥28 kg/m² as the control group; $R^2 = 0.807$. RBC: red blood cell; Hb: hemoglobin; PLT: platelet; BMI: body mass index; CI: confidence interval

plasminogen activator inhibitor-1, possibly explaining why obese people have less perioperative bleeding.[21] Our study shown that overweight and obese patients had less chest tube drainage in the 24-h period after surgery. Nevertheless, these characteristics of obesity could explain both the decreased incidence of bleeding complications and the decreased need for reoperation from bleeding complications in obese patients.

Our study demonstrated that it is important at the clinical level to take a patient's BMI into account when preparing for the perioperative sequelae of CABG surgery. Furthermore, we need to understand the etiologies relating BMI to coagulation. The literature on postoperative bleeding blood loss by BMI category is equivocal. A few authors have reported that the risk of postoperative bleeding complications does not differ between obese and non-obese patients.[14] Others have reported a decreased incidence of bleeding complications and a decreased need for reoperation due to bleeding in obese individuals that we observed.[18,19] However, the causes largely remain unexplored. The link may be related to the procoagulant state seen in metabolic

Table 5 Linear regression analysis for blood transfusion/weight

Blood transfusion/ weight	Simple linear regression				Multiple linear regression			
	B	p value	95% CI		B	p value	95% CI	
BMI group								
BMI <24 kg/m^2	1.451	<0.001	0.663	2.239	1.033	0.018	0.174	1.893
24 ≤BMI <28 kg/m^2	0.312	0.406	−0.425	1.048	0.061	0.879	−0.719	0.839
BMI ≥28 kg/m^2*								
Age	0.055	<0.001	0.025	0.085				
Diabetes mellitus	0.387	0.198	−0.202	0.977				
Hyperlipidemia	0.690	0.014	0.137	1.242				
Hypertension	0.503	0.083	−0.066	1.071				
Atrial fibrillation	−1.799	0.003	−2.991	−0.607	−1.429	−0.026	−2.689	−0.169
Glucose	0.001	<0.001	<0.001	0.001				
RBC	−0.930	0.001	−1.474	−0.385				
Hb	−0.026	0.003	−0.044	−0.009				
PLT	−0.005	0.036	−0.009	<0.001				
Hematocrit	−0.058	0.040	−0.114	−0.003				

*BMI ≥28 kg/m^2 as the control group; $R^2 = 0.105$. RBC: red blood cell; Hb: hemoglobin; PLT: platelet; BMI: body mass index; CI: confidence interval

syndrome and obesity, which is characterized by higher levels of tissue factor and Factor VIII, fibrinogen, inhibition of fibrinolytic pathways (decreased tissue plasminogen activator activity and increased plasminogen activator inhibitor-1), and greater PLT aggregability due to the presence of hyperlipidemia and endothelial dysfunction that is frequently encountered in obese patients.[20,22]

Considering the varying risks of adverse outcomes for different BMI groups, it is clear that ours was not the first study to contradict the prevailing view that obesity is a risk factor for operative mortality and morbidity following CABG[23] or to infer that obesity may protect against some adverse outcomes.[24] Several previous studies have suggested that underweight is related to low cardiac output syndrome, strokes, bleeding, and prolonged ventilator therapy.[8,18,25] In our patient population, low and normal body weight was an independent risk factor for increased rates of postoperative bleeding and transfusion, prolonged ICU stay, and ventilation time. Similarly, Engelman et al.[12] showed a significant association between low BMI and reoperation for bleeding (11.5% in underweight patients compared with 5% in normal weight patients, odds ration (OR): 2.1, p <0.001). By analyzing re-operated patients, Kristensen, et al. found that survivors had a lower EuroSCORE, less time on CPB and briefer re-exploration. They differentiated hemorrhages into coagulopathic and surgical. In total, 56.4% of the patients had surgical bleeding. They recommended that surgeries be planned carefully in patients with a high EuroSCORE, low ejection fraction (EF), low BMI, DM, preoperative s-creatinine >134 µmol/l or for procedures other than CABG.[26] In our study, a few cases required reoperation (low and normal weight, 1.2%; overweight patients, 0.6%; none among obese) and no significant differences were found between groups. Other studies have investigated the effect of obesity on surgical outcomes.[18,27,28] Two studies on general surgery patients showed no increase in morbidity related to obesity. Studies of cardiovascular surgery that focused largely on CABG produced mixed results. Jin et al. postulated that this ambiguity was due to differing BMI classifications and sample sizes. Similarly, Romero-Corral, in a meta-analytical review, found that overweight coronary artery disease (CAD) patients had the lowest risk of cardiovascular complications and overall mortality. Our findings of reduced ICU stays and mechanical ventilation times in obese patients support the above reports although no mechanism was evident.

Several well-designed, randomized controlled trials have been conducted recently on transfusions in critically ill or CABG patients.[14] Other short-term adverse effects of blood transfusions in cardiac surgical patients have been documented well, but few studies have assessed long-term survival.[15,16] Despite all available evidence, transfusion practices vary substantially.[18,24] Deciding when a patient requires transfusion varies significantly among intensivists, anesthetists, and cardiac surgeons.[18,25,26] The use of blood and other blood product transfusions in cardiac surgical patients remains very high.[29]

This large-scale study after primary CABG was conducted among exclusively ethnic Chinese and found lower blood loss and transfusion with elevated BMI. Atrial fibrillation was associated with high blood transfusion. Obesity helped to predict protection against blood loss, transfusion, and shortened ICU stay and ventilation times among CABG surgery patients in China.

Limitations

First, this was a retrospective study conducted in single center among ethnic Chinese patients. We applied the Chinese definitions of obesity based on BMI, which has lower cutoffs than for Western populations. Our results are most appropriate for Chinese people, and further study likely is warranted among other populations. Second, because this was a retrospective study, we could not make a definitive evaluation of fluid management during surgery. However, as the anesthesiologists who controlled fluids were experienced on cardiac anesthesia, bias between patients may be minimal. Third, surgical manipulation may have influenced intra-operative bleeding. However, Fuwai Hospital is the largest and most experienced heart center in China where most surgeons have more than 20 years of experience. So, the surgical time and procedure should have been consistent.

Disclosure Statement

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