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***Original Article** / Özgün Makale*

Effects of body mass index on the early surgical outcomes after coronary artery bypass grafting

Koroner arter baypas greftleme sonrasında beden kütle indeksinin erken cerrahi sonuçlar üzerindeki etkileri

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Background: This study aims to investigate the effects of body mass index (BMI) on early surgical outcomes of coronary artery bypass grafting (CABG).

Methods: Between August 2007 and March 2011, a total of 1,673 consecutive patients (1,209 males, 464 females; mean age 58.6±9.9 years; range 21 to 87 years) who underwent isolated CABG at Shariati Hospital, Tehran, Iran were retrospectively analyzed. The patients were classified into four groups based on the BMI values: underweight (BMI ≤19 kg/m^2, n=55), normal/overweight (BMI 20-29 kg/m^2, n=523), obese (BMI 30-39 kg/m^2, n=739) and morbidly obese (BMI ≥40 kg/m^2, n=356). Preoperative characteristics were compared among the four groups. Effects of BMI on postoperative mortality and morbidity were evaluated using the stepwise multivariate logistic regression analysis.

Results: There was no significant difference in the mortality rate among the groups. Intra-aortic balloon pump (IABP) was the only independent predictor of postoperative mortality in the multivariate logistic regression analysis (OR=20.5, 95% CI=8.6-50.5; p<0.001). Body mass index was independently associated with postoperative pulmonary complications (OR=1.6, 95% CI=1.2-2.1; p=0.001).

Conclusion: Our study results suggest that BMI is an independent predictor of post-CABG pulmonary complications, but not of post-CABG mortality.

Keywords: Body mass index; coronary artery bypass grafting; mortality.

Amaç: Bu çalışmada vücut kütle indeksinin (VKİ) koroner arter baypas greftlemenin (KABG) erken cerrahi sonuçları üzerindeki etkileri araştırıldı.

Çalışma planı: Ağustos 2007 - Mart 2011 tarihleri arasında, İran, Tahran Shariati Hastanesi'nde izole KABG yapılan toplam 1,673 ardışık hasta (1,209 erkek, 464 kadın; ort. yaş 58.6±9.9 yıl; dağılım 21-87 yıl) retrospektif olarak incelendi. Hastalar VKİ değerlerine göre dört gruba ayrıldı: zayıf (VKİ ≤19 kg/m^2, n=55), normal/aşırı kilolu (VKİ 20-29 kg/m^2, n=523), obez (VKİ 30-39 kg/m^2, n=739) ve morbid obez (VKİ ≥40 kg/m^2, n=356). Gruplar arasında ameliyat öncesi özellikler karşılaştırıldı. Beden kütle indeksinin ameliyat sonrası mortalite ve morbidite üzerindeki etkileri, basamaklı çok değişkenli lojistik regresyon analizi ile değerlendirildi.

Bulgular: Gruplar arasında mortalite oranı açısından anlamlı bir fark yoktu. İntraaortik balon pompası (İABP), çok değişkenli lojistik regresyon analizinde ameliyat sonrası mortalitenin tek bağımsız öngördürücüsü idi (OR=20.5, %95 CI=8.6-50.5; p<0.001). Beden kütle indeksi, ameliyat sonrası pulmoner komplikasyonlar ile bağımsız olarak ilişkilendirildi (OR=1.6, %95 CI=1.2-2.1; p=0.001).

Sonuç: Çalışma bulgularımız, VKİ'nin KABG sonrası mortalitenin değil, fakat KABG sonrası pulmoner komplikasyonların bağımsız bir öngördürücüsü olduğunu göstermektedir.

Anahtar sözcükler: Vücut kütle indeksi; koroner arter baypas greftleme; mortalite.

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Despite a worldwide epidemic of obesity and its associated comorbidities, which include diabetes mellitus (DM), hypertension (HT), coronary artery disease (CAD), and their consequences,[1-3] there is still a big debate regarding the adverse effects of obesity on the early and late outcomes of coronary artery bypass graft (CABG) surgery.[4-7] Although several studies have proposed obesity as a cause of increased mortality and morbidity after this procedure,[8,9] some authors believe that it plays no role.[10-13] In fact, some believe that the early mortality rate is higher in underweight patients compared with those who are overweight, obese, or morbidly obese after CABG.[14]

Obesity has emerged as an endemic concern in developing countries like Iran. Simultaneously the proportion of CAD patients who ultimately need CABG has increased. The outcomes of CABG are affected by multiple variables such as the personal characteristics of the patients and operative data, but having the ability to determine the postoperative prognosis of patients who undergo CABG would be beneficial. In this study, we conducted multivariate logistic regression analyses using an extensive database containing more than 200 different variables to investigate the effects of body mass index (BMI) on early surgical outcomes after CABG.

PATIENTS AND METHODS

In this retrospective review of an existing data bank of patients with heart diseases, all of the consecutive patients who underwent isolated CABG at Shariati Hospital, Tehran, Iran between August 2007 and March 2011 were recruited to take part in this study. A total 2,333 patients were initially enrolled, but 659 patients were subsequently excluded due to having undergone valve surgery in conjunction with surgery for CAD. In addition, those with additional concomitant interventions, including valve operations and carotid endarterectomies, were also excluded as well as any patients with incomplete information regarding BMI. In the end, 1,673 patients (1,209 males and 464 females; BMI 32.5±5.3 kg/m^2) with a mean age of 58.6±9.9 (range 21-87) were included in the final analysis, and the participants were divided into four categories based on their BMI [underweight (BMI 16.5±1.1 kg/m^2; n=55), normal weight/overweight (BMI 24.1±2.4 kg/m^2; n=523), obese (BMI 35.3±3.1 kg/m^2; n=739), and morbidly obese (BMI 43.8±21.8 kg/m^2; n=336].

The surgical team was composed of four cardiac surgeons, all of whom used a similar technique. Blood cardioplegia was utilized for on-pump CABG and for single or two-vessel (2VD) CAD; however, off-pump CABG was preferred if the patient's anatomy was suitable. The four groups were compared with regard to various preoperative and postoperative characteristics such as age, gender, DM, HT, hypertriglyceridemia, hypercholesterolemia, a family history of CAD, cerebrovascular accidents (CVAs), renal function, intraoperative situations, postoperative mortality, and morbidities. Furthermore, the study protocol was approved by the ethics committee of the Tehran University of Medical Sciences (TUMS).

The preoperative data included age, gender, DM, HT, hypertriglyceridemia, hypercholesterolemia, a family history of CAD, cerebrovascular disease (CVD), and renal dysfunction. The primary outcome was defined as an early mortality rate in the first 30 days after surgery, whereas the secondary outcomes were morbidities that occurred during hospitalization.

We used the Cockcroft-Gault equation to estimate creatinine clearance.[15] Opium addiction was defined as inhaling opium smoke and/or eating opium in its crude form at least three times a week. In addition, infectious complications were defined as a deep or superficial sternal infection, leg infection, septicemia, or a urinary tract infection. The patients were considered to have neurological complications if they had suffered a stroke in the first 72 hours, had a transient ischemic attack, or been in a coma. Furthermore, those with a pulmonary embolism, pneumonia, pleural effusion, or a pneumothorax were classified as having pulmonary complications. The patients with ventricular arrhythmia had either ventricular tachycardia, fibrillation, premature ventricular contractions (PVCs), or atrioventricular junctional rhythm (AVJR), whereas those with supraventricular arrhythmia had atrial fibrillation (AF), flutter, or paroxysmal atrial tachycardia (PAT).

Additionally, our study included the following intraoperative findings: average units of transferred packed red blood cells (PRBCs), fresh frozen plasma (FFP) and platelet (PLT) transfusion, perfusion time, aortic cross-clamp time (ACCT), mechanical ventilation time, inotropic support, the need for an intra-aortic balloon pump (IABP) and a proportion of those who underwent on-pump cardiopulmonary bypass (CPB).

Statistical analysis

All of the statistical analyses were performed using the SPSS version 16.0 for Windows software program (SPSS Inc., Chicago, IL, USA). The results were reported using mean ± standard deviation (SD) for quantitative variables and percentages for categorical variables, and the groups were compared using a chi-square test (or Fisher's exact test, if needed) for categorical variables. A one-way analysis of variance (ANOVA) was also conducted to compare continuous variables between the four groups. Statistical significance was based on the evaluation of two-sided, design-based tests in which 0.05 represented the level of significance.

In the primary analyses, mortality and pulmonary complication rates differed significantly across the groups; thus, they were selected as dependent variables in order to compute a multivariate logistic regression model. First, the potential effects of the risk factors on surgical outcomes were tested using univariate analyses for postoperative mortality and pulmonary complications. When p<0.2, the variables were entered into the stepwise multivariable logistic regression analyses to construct the final model, and the body mass indices (BMIs) of the patients were also entered in this manner. Other covariates were female gender, age >65 years, DM, HT, smoking, hypertriglyceridemia, hypercholesterolemia, previous myocardial infarction (MI) >1, inotropic support, the use of an IABP, and off-pump CPB.

RESULTS

The patients` baseline characteristics are summarized in Table 1. When we compared the four groups, we found that a greater proportion of those with high BMIs had DM, HT, hypercholesterolemia, and hypertriglyceridemia.

A comparison between the four groups with regard to operative data is shown in Table 2, and there were significant differences in the average RBC units that were transfused as well as perfusion time. In addition, the mortality rate varied between 1.4% in the morbidly obese patients to 5.5% in the underweight patients, but the differences were not statistically significant between the four groups (p=0.229). We also compared the postoperative complications, and the results are given in Table 3. The between-group differences with respect to post-CABG pulmonary complications were statistically significant (p=0.001), but this was not the case for the surgical infection and neurological, renal, gastrointestinal, and vascular complications.

In the univariate analysis, we determined that postoperative mortality was significantly associated with female gender (OR=2.2; 95% CI=1.1-4.4; p=0.021), age >65 years (OR=2.5; 95% CI=1.3-5.2; p=0.007), HT (OR=2.6; 95% CI=1.2-5.6; p=0.011), IABP (OR=19.1; 95% CI=9.2-39.5; p<0.001), and off-pump CPB (OR=0.36; 95% CI=0.14-0.93; p=0.028). To offset the confounding variables, the effects of BMI on early surgical outcomes were measured using a multivariable logistic regression in the presence of other covariates, and we found that IABP continued to be an independent predictor of postoperative mortality (OR=20.5; 95% CI=8.6-50.5; p<0.001).

A higher BMI was independently associated with postoperative pulmonary complications (OR=1.6; 95%

Table 1. Baseline characteristics of the patients

Variables	Underweight (n=55)			Normal/overweight (n=523)			Obese (n=739)			Morbidly obese (n=356)			*Total* (n=1.673)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Female gender	9	16.4		109	20.8		195	26.4		151	42.4		464	27.9		<0.001
Mean age (years)			58.8±12.2			59.3±10.2			58.5±9.9			57.5±9.5			58.5±9.9	0.910
Age >65 years	17	30.9		161	30.8		212	28.7		83	23.3		473	28.3		0.093
Smokers	33	60.0		226	43.2		280	37.9		117	32.8		656	39.2		<0.001
Opium addiction	20	36.4		106	20.3		108	14.6		36	10.3		270	16.1		<0.001
Family history of CAD	2	3.6		33	6.3		58	7.8		30	8.4		123	7.4		0.421
Previous MI >1	22	40.0		193	36.9		276	37.4		114	32.0		605	36.2		0.302
Angina class IV and V	9	16.4		82	15.7		100	13.5		44	12.4		235	14.1		0.490
NYHA class III and IV	12	21.8		111	21.2		149	20.2		67	18.8		339	20.3		0.825
Ejection fraction			46.8±8.8			46.8±8.5			47.3±8.5			46.8±8.9			47.0±8.6	0.637
Diabetes mellitus	5	9.1		177	33.8		266	36.0		123	34.7		571	34.1		0.011
Hypertension	16	29.1		230	44.0		385	52.1		208	58.4		839	50.1		<0.001
Hypercholesterolemia	17	30.9		243	46.5		382	51.7		208	58.4		850	50.8		<0.001
Hypertriglyceridemia	14	25.5		241	46.1		381	51.6		213	59.8		849	50.7		<0.001
Cr clearance (ml/min)			1.16±0.55			1.14±0.39			1.22±0.48			1.11±0.42			1.17±0.59	0.300
CVA	1	1.8		5	1.0		7	0.9		3	0.8		16	1.0		0.688
COPD	3	5.5		6	1.0		15	2.0		8	2.2		32	1.9		0.122
Dialysis-dependent CRF	0	0.0		3	0.6		2	0.3		4	1.1		8	0.5		0.312

SD: Standard deviation; CAD: Coronary artery disease; MI: Myocardial infarction; NYHA: New York Heart Association; Cr: Creatinine; CVA: Cerebrovascular accident; COPD: Chronic obstructive pulmonary disease; CRF: Chronic renal failure.

Table 2. Operative clinical characteristics of the patients

Variables	Underweight (n=55)			Normal/overweight (n=523)			Obese (n=739)			Morbidly obese (n=356)			*Total* (n=1.673)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
PRBC units transfused			2.5±1.3			2.6±2.1			2.2±1.6			2.3±2.0			2.4±1.8	0.033
ACCT (minutes)			59.3±22.3			46.3±24.9			49.2±41.5			48.8±19.4			48.3±32.4	0.129
Mechanical ventilation (minutes)			170±56			175±61			182±72			181±67			179±66	0.787
Inotropic support	15	27.3		94	18.0		148	20.0		77	21.6		334	20.6		0.292
IABP	4	7.3		39	7.5		49	6.6		25	7.0		117	7.0		0.955
Off-pump CPB	15	27.3		159	30.4		234	31.6		122	34.3		530	31.7		0.575
FFP units transfused			4.4±2.1			5.8±4.0			4.8±2.8			5.3±3.6			5.2±3.5	0.056
PLT units transfused			8.2±4.3			6.3±2.9			6.4±5.1			7.9±3.9			6.8±4.2	0.519
Mean distal venous anastomosis			2.2±0.86			2.1±0.84			2.1±0.83			2.1±0.85			2.1±0.84	0.914
Venous distal anastomosis >2	12	21.8		143	27.3		118	16.0		101	28.4		374	22.4		0.910
IMA grafts >1	1	1.8		24	4.6		41	5.5		22	6.2		89	5.3		0.468

SD: Standard deviation; PRBC: Packed red blood cells; ACCT: Aortic cross-clamp time; IABP: Intraaortic balloon pump; CPB: cardiopulmonary bypass; FFP: Fresh frozen plasma; PLT: Platelet; RBC units= 250 cc; PLT unit= 50 cc

CI=1.2-2.1; p=0.001). Furthermore, age >65 years (OR=1.6; 95% CI=1.04-2.5; p=0.031), inotropic support (OR=1.9; 95% CI=1.2-2.9; p=0.007), IABP (OR=6.1; 95% CI=3.6-10.4; p<0.001), and coronary distal anastomosis >2 (OR=1.6; 95% CI=1.03-2.5; p=0.034) were also identified as independent predictors of postoperative pulmonary complications in the multivariate analyses.

DISCUSSION

The so-called “obesity paradox” (also known as the “overweight paradox”) has been recently alluded to by several researchers as a way of explaining the incongruent outcomes of CAD in obese patients,[16-18] but it seems that the same holds true for patients who undergo CABG. Similar to the results of the study by Ömeroğlu et al.,[19] the obese and morbidly obese patients in our survey were more likely to have DM, HT, and hypertriglyceridemia, which are some of the known risk factors for cardiac diseases. In contrast to what might have been expected based on these preexisting risk factors, we found that the mortality rate was higher in the underweight patients than in those who were morbidly obese. However, this difference was not statistically significant. Some studies have found no significant association between a patient’s BMI and mortality after CABG,[12-14,20,21] but others have proposed that being underweight is an

Table 3. Comparison of the patients with different BMIs with respect to early mortality and morbidities after coronary artery bypass surgery

Variables	Underweight (n=55)		Normal/overweight (n=523)		Obese (n=739)		Morbidly obese (n=356)		*Total* (n=1.673)		
	n	%	n	%	n	%	n	%	n	%	*p*
Mortality	3	5.4	9	1.7	15	2.0	5	1.4	32	1.9	0.229
Ventricular arrhythmia	8	14.5	107	20.5	131	17.7	58	18.3	304	18.2	0.351
Ventricular tachycardia	0	0.0	8	1.5	10	1.4	4	1.1	22	1.3	0.781
Ventricular fibrillation	1	1.8	7	1.3	2	0.3	0	0.0	10	0.8	0.021
Supraventricular arrhythmia	8	14.5	69	13.2	75	10.1	39	10.9	191	11.4	0.333
Atrial fibrillation	7	12.7	62	11.9	72	9.7	37	10.4	178	10.6	0.638
Postoperative MI	0	0.0	1	0.2	2	0.3	4	1.1	9	0.5	0.311
Renal complications	0	0.0	7	1.3	10	1.4	1	0.3	18	1.1	0.311
Dialysis	0	0.0	5	1.0	7	0.9	1	0.3	13	0.8	0.560
Pulmonary complications	6	10.9	32	6.1	52	7.6	40	12.9	136	8.1	<0.001
Neurological complications	0	0.0	5	1.6	10	1.4	5	1.4	20	1.2	0.752
Vascular complications	0	0.0	1	0.2	0	0.0	1	0.3	2	0.1	0.583
Gastrointestinal complications	0	0.0	3	0.6	6	0.8	3	0.8	12	0.7	0.869
Infection complications	0	0.0	3	0.6	2	0.3	3	0.8	8	0.5	0.311
Leg infection	0	0.0	0	0.0	0	0.0	1	0.1	1	0.1	0.296
Deep sternal infection	0	0.0	3	0.6	2	0.3	3	0.8	8	0.5	0.567
Septicemia	0	0.0	0	0.0	0	0.0	1	0.3	1	0.1	0.296
Prolonged mechanical ventilation	1	1.9	12	2.3	18	2.5	18	5.1	49	3.0	0.066
Need for reoperation for bleeding	4	7.3	21	4.0	12	3.4	12	3.4	60	3.6	0.397

MI: Myocardial infarction.

independent predictor for post-CABG morbidity and mortality.[17,22,23] Rahmanian et al.[9] determined that the highest mortality rate (4.6%) occurred in patients with a BMI <20 kg/m^2, and this was true even though their study included those with a BMI >30 kg/m^2. In our study, the underweight subjects smoked more and also had more pulmonary complications and longer perfusion times, all of which could be responsible for the higher mortality rate in this group. Moreover, the prevalence of opium addiction was higher in these patients, and continued use of opium has been reported to be a predictor of rehospitalization after CABG surgery. Furthermore, the low rate of compliance in these patients may also have been a contributing factor.[24] However, some authors believe that opium usage is not related to post-CABG outcomes.[25] Another explanation for the poor results of the underweight patients in our study might have been the presence of smaller coronary arteries. On the other hand, some authors believe that obesity is associated with mortality after CABG surgery.[5,26] Interestingly, there is another group of studies which supports a U-shaped pattern for mortality after CABG,[27,28] These authors indicated that extreme BMIs, in both very low and very high ranges, are associated with the increased rates of mortality after CABG.

In both the univariate and multivariate analyses in our study, extreme BMIs were associated with postoperative pulmonary complications; thus, obesity seems to be an independent predictor for pulmonary complications after CABG. In addition, Jenkins and Moxham[29] also reported that obesity has adverse effects on pulmonary function through increased functional residual capacity, decreased vital capacity, and maximum voluntary ventilation; our findings are in consistence with previous reports.[11,13] Likewise, other authors have reported greater respiratory problems and subsequent longer mechanical ventilation times after CABG among underweight patients.[4,9] Based on our findings, it seems that the association between post-CABG pulmonary complications and preoperative BMI also follows a U-shaped pattern, with both very high and very low ranges. Additionally, the CPB times were longer in the underweight group in our study, but the pulmonary complications were higher in the underweight and morbidly obese patients. In the underweight group, the longer CPB time might have been responsible for the higher pulmonary complications, but in the morbidly obese group, obesity may have played a greater role.

Older age has been reported to be an independent factor of pulmonary dysfunction after CABG.[30] Some severe, restrictive pulmonary changes may occur after CABG, and, lung function seems to be more severely affected by CABG in elderly patients compared with those who are younger.[30] Therefore, older patients might be at a greater risk for post-CABG pulmonary complications than would be expected from their preoperative lung function.[31] As Goyal et al.[32] reported, venous grafting is associated with less severe pulmonary complications than arterial grafting. Contrary to our expectations, our results showed that the increased number of venous grafts was correlated with a higher incidence of post-CABG pulmonary complications. The main underlying reason for this is still unclear; therefore, further studies are needed to evaluate this finding. However, the study results of Faritous et al.[33] agreed with our findings which determined that preoperative inotropic agents were predictive factors of pulmonary involvement after CABG. We also found that IABP was another independent factor that affected the post-CABG pulmonary complications. However, the reason for this is also not certain, so further research is needed on this topic as well.

Similar to our findings, Kuduvalli et al.[13] surveyed 4,713 patients who underwent isolated CABG and confirmed that obese patients were more likely to have prolonged mechanical ventilation. However, they found no association between BMI and mortality, stroke, MI, bleeding, or re-exploration, but they did find a significant association between obesity and sternal infection, which was inconsistent with our findings. Several studies have also reported that obese patients can develop sternal wound infections due to poor healing of the adipose chest wall tissue.[9,27,34] Furthermore, the operation time might also play a role in wound healing and subsequent infections.

It was interesting that 21.3% of our patients were classified as morbidly obese based on their BMI. As expected, one reason for this might be that many of the patients with CAD were treated medically, with a considerable number undergoing percutaneous coronary intervention (PCI). In contrast, the patients with a more comorbid disease and risk factors such as obesity were referred for surgery.

The retrospective nature of our study limits the interpretation of our findings; however we applied a multivariable logistic regression analysis to offset any confounding effects. It is possible that BMI might not be an appropriate tool to measure the distribution of body fat, which could have limited our outcomes. However, a systematic review by Coutinho et al.[35] showed that for CAD patients, including those with normal and high BMI, central obesity was related to mortality, which was not true for BMI.

Conclusion

We determined that BMI is an independent predictor of post-CABG pulmonary complications but not post-CABG mortality. Furthermore, the BMIs of both the underweight and morbidly obese patients in our study were associated with post-CABG pulmonary complications.

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