Aydin, Ebuzer; Ozkokeli, Mehmet
Does Homeostasis Model Assessment of Insulin Resistance have a predictive value for post-coronary artery bypass grafting surgery outcomes?
Revista Brasileira de Cirurgia Cardiovascular/Brazilian Journal of Cardiovascular Surgery, vol. 29, núm. 3, julio-septiembre, 2014, pp. 360-366
Sociedade Brasileira de Cirurgia Cardiovascular
São José do Rio Preto, Brasil

Available in: http://www.redalyc.org/articulo.oa?id=398941894011
Does Homeostasis Model Assessment of Insulin Resistance have a predictive value for post-coronary artery bypass grafting surgery outcomes?

O Modelo de Avaliação da Homeostase da Resistência à Insulina tem valor preditivo para os resultados após a cirurgia de revascularização miocárdica?

Ebuzer Aydin¹, MD; Mehmet Ozkokeli¹, MD

Abstract

Objective: This study aims to investigate whether pre-operative Homeostasis Model Assessment Insulin Resistance (HOMA-IR) value is a predictor in non-diabetic coronary artery bypass grafting patients in combination with hemoglobin A1c, fasting blood glucose and insulin levels.

Methods: Eighty one patients who were admitted to Cardiovascular Surgery Clinic at our hospital between August 2012 and January 2013 with a coronary artery bypass grafting indication were included. Patients were non-diabetic with <6.3% hemoglobin A1c and were divided into two groups including treatment and control groups according to normal insulin resistance (HOMA-IR<2.5, Group A; n=41) and high insulin resistance (HOMA-IR>2.5, Group B; n=40), respectively. Pre-operative fasting blood glucose and insulin were measured and serum chemistry tests were performed. The Homeostasis Model Assessment Insulin Resistance values were calculated. Statistical analysis was performed.

Results: There was a statistically significant difference in fasting blood glucose and HOMA-IR values between the groups. Cross-clamping time, and cardiopulmonary bypass time were longer in Group B, compared to Group A (P=0.043 and P=0.031, respectively). Logistic regression analysis revealed that hemoglobin A1c was not a reliable determinant factor alone for pre-operative glucometabolic evaluation of non-diabetic patients. The risk factors of fasting blood glucose and cardiopulmonary bypass time were more associated with high Homeostasis Model Assessment Insulin Resistance levels.

Conclusion: Our study results suggest that preoperative screening of non-diabetic patients with Homeostasis Model Assessment Insulin Resistance may improve both follow-up visit schedule and short-term outcomes, and may be useful in risk stratification of the high-risk population for impending health problems.

Descriptors: Atherosclerosis. Blood Glucose. Cardiopulmonary Bypass. Insulin Resistance. Perioperative Care. Prediabetic State.

¹Kartal Kosuyolu Training and Research Hospital Istanbul, Turkey.

Correspondence address:
Ebuzer Aydin
Denizer Caddesi no: 2 Cevizli Kavsagi Kartal, Istanbul, Turkey
E-mail: ebuzermd@gmail.com

This study was carried out at Kartal Kosuyolu Training and Research Hospital, Istanbul, Turkey.

No financial support.
INTRODUCTION

The cardiovascular risk is increased in individuals, who are non-diabetic, but have elevated insulin and glucose concentrations which are likely to be pro-atherogenic are likely to be associated with insulin resistance. Elevated insulin and glucose concentrations which are likely to be pro-atherogenic are directly associated with atherosclerosis. It promotes atherosclerosis and coronary artery diseases, while metabolic factors such as dyslipidemia, hypertension, and obesity may also contribute to the development of cardiac problems. Recently, some authors have suggested that diabetes mellitus (DM) is the measured tip of a much larger ‘dysglycemic iceberg’. There is growing evidence that dysglycemia, irrespective of DM history, is associated with adverse outcomes including prolonged hospitalization and higher mortality in coronary artery bypass grafting (CABG) patients.

The prevalence of prediabetes was estimated as 13.9% (4.1 million) among the population aged ≥35 years in 2007/2008 in Turkey. A large-scale study performed in Turkey revealed that impaired glucose tolerance (IGT) was increased from 6.7% to 13.9% (approximately 14 million patients) in the adult population over 20 years of age in a 12-year period. To overcome this impending health problem, guidelines and expert consensus documents for practicing physicians have been developed by the World Health Organization, American Diabetes Association (ADA), European Society of Cardiology (ESC), and European Association for the Study of Diabetes (EASD) guidelines and expert consensus documents for practicing physicians have been developed by the World Health Organization, American Diabetes Association (ADA), European Society of Cardiology (ESC), and European Association for the Study of Diabetes (EASD) guidelines and expert consensus documents for practicing physicians have been developed by the World Health Organization, American Diabetes Association (ADA), European Society of Cardiology (ESC), and European Association for the Study of Diabetes (EASD). However, there are several studies questioning the discriminative power of oral glucose tolerance test as accepted as the gold standard for DM today. It is costly, time-consuming, labor-intensive, and impractical for DM screening.
Homeostasis Model Assessment Insulin Resistance (HOMA-IR) is a validated and frequently used marker of insulin resistance. It incorporates both glucose and insulin concentrations to represent insulin resistance, which promotes atherosclerosis through endothelial dysfunction due to altered insulin signaling in endothelial cells\(^{[17]}\). As a result, it may be more strongly associated with cardiovascular disease than glucose or insulin concentrations, alone\(^{[3,6]}\).

In this study, we aimed to investigate whether pre-operative HOMA-IR value is a predictor in non-diabetic CABG patients when used in combination with HbA1c, fasting blood glucose (FBG) and fasting blood insulin (FBI) levels.

**METHODS**

**Study Population**

This randomized, prospective clinical study included 81 of 557 patients who were admitted to Cardiovascular Surgery Outpatient Clinic at Kartal Kosuyolu Training and Research Hospital between August 2012 and January 2013 with a CABG indication. Patients who neither were previously diagnosed with type 2 diabetes nor on any type of diabetes treatment were screened for HbA1c values. According to 2010 ADA guidelines for HbA1c identification, patients with an HbA1c value of <6.3% were included \(^{[14]}\). Diabetic patients were excluded due to the high mortality and morbidity rates in this population. Patients were divided into two groups: Group A consisted of 41 patients with normal insulin resistance (HOMA <2.5), while Group B consisted of 40 patients with high insulin resistance (HOMA-IR >2.5).

The study was performed in accordance with the principles of Declaration of Helsinki. The study protocol was approved by Institutional Review Board (IRB) of Kartal Kosuyolu Training and Research Hospital (IRB No: 538.38792-903/6010). Written informed consents, which were obtained from the patients, were confirmed by the IRB.

**Data Collection**

Blood glucose was measured after 12-hour fasting by using hexokinase method with Olympus AU-640e Chemistry Analyzer (Olympus America Inc., Melville, NY, USA), while FBI was measured by using chemiluminescence method with Siemens Advia Centaur XP Immunoassay System (Siemens Healthcare Diagnostics Inc., NY, USA). The HOMA values were calculated by using either the formula which was described by Matthews et al.\(^{[19]}\) (HOMA-IR = insulin (μU/mL) × fasting glucose (mmol/L)/22.5) or using the HOMA calculator website of Oxford University, Endocrinology and Metabolism Centre, Diabetes Trials Unit of Diabetes\(^{[19]}\). The cut-off value of HOMA-IR was considered 2.5\(^{[20]}\). The patients were divided into two groups including treatment and control groups, according to normal insulin resistance (HOMA-IR <2.5, Group A; n=41) and high insulin resistance (HOMA-IR >2.5, Group B; n=40), respectively.

Routine pre-operative laboratory tests including FBI and HOMA, and serum chemistry tests were performed. After an overnight fasting, venous blood samples were collected for the measurement of HbA1c level, plasma concentration of glucose, and insulin.

Plasma glucose level was measured by glucose-oxidase method. Hemoglobin A1c was measured by high-performance liquid chromatography, whereas plasma insulin was measured using radioimmunoassay. The patients underwent CABG by our surgical team and using a single technique. Patients were closely monitored intra- and post-operatively for mortality and morbidity.

**Statistical Analysis**

Statistical analysis was performed using SPSS for Windows v12.0 software (SPSS Inc., Chicago, IL, USA). At baseline, sample size was estimated by statistical analysis to achieve significant results. Power level was 90% to detect a difference between the group proportions (0.3000). The proportion in Group A (treatment group) was assumed to be 0.1000 under the null hypothesis and 0.4000 under the alternative hypothesis. The proportion in Group B (control group) was 0.1000. Two-sided Z test was used with pooled variance. The significance level of the test was targeted at 0.0500. The significance level actually achieved by this design was 0.0510.

Numerical parameters were expressed in mean, median, standard deviation, and maximum and minimum values. Categorical variables were expressed in numbers and percentages. The Mann-Whitney U test was performed to compare the binary groups in terms of abnormally distributed numerical variables. Cross-table statistics (Chi-square, Fisher, McNemar test) were used to compare categorical variables. Logistic regression analysis was also performed to define risk factors of the disease and to estimate disease probability, when individual characteristics of each patient were known or specific measurements were performed. Analysis of covariance (ANCOVA) was performed to compare the means of numerical variables between the groups. A P value of <0.05 was considered significant.

**RESULTS**

Of the patients, 70 were males and 11 were females. The mean age was 63.3±9.4 years (range, 34 to 81 years). Group A consisted of 41 patients with normal insulin resistance (HOMA <2.5), while Group B consisted of 40 patients with high insulin resistance (HOMA-IR >2.5). Demographic and clinical characteristics of the patients are summarized in Table 1. There was no statistically significant difference in demographic characteristics between the groups, except hypertension (Table 1). There was either no statistically sig-
A significant difference in the preoperative characteristics of the patients between the groups. Both groups had similar rates for smoking, preoperative stroke, and chronic pulmonary obstructive disease. The number of patients with hypertension was statistically significantly higher in Group B (P<0.049).

Glucosemetabolic evaluation demonstrated that fasting blood insulin and HOMA-IR values were statistically significant different between the treatment and control group (both P<0.001). However, no significant change in FBG and HbA1c values was observed between the groups. Cross-clamping time, Cardiopulmonary bypass (CPB) time, and length of hospitalization were longer in Group B compared to Group A, however, only cross-clamping and CPB time reached statistically significance (P=0.043 and P=0.031, respectively) (Table 1).

There was also a significant difference in the mean cross-clamping time, which was refined from covariant impact between the HOMA groups (P=0.009). It was observed that FBG and the number of revascularized vessels during CABG affected cross-clamping time (P=0.002, and P<0.001, respectively). In the logistic regression analysis, HbA1c risk factor was less frequently seen in Group B, compared to Group A. The risk factors of FBG and CPB time were highly associated with high HOMA levels (Table 2).

There was no statistically significant difference in the postoperative data including inotrope use, postoperative MI, rate of rhythm changes from baseline, the presence of infection, duration of ICU care and length of hospitalization between the groups. Two patients including one in Group A and one in Group B died after surgery due to the low cardiac output.

Table 1. Demographic and clinical data of the study groups.

| Parameters                        | Group A: HOMA <2.5 n=41 (%) | Group B: HOMA >2.5 n=40 (%) | P value |
|----------------------------------|-----------------------------|-----------------------------|---------|
| Mean age (yrs, SD)               | 64.3±9.8                    | 62.3±8.9                    | 0.349   |
| Males                            | 37                          | 33                          |         |
| Smoker                           | 16 (39.0%)                  | 17 (42.5%)                  | 0.750   |
| Renal failure                    | 6 (14.6%)                   | 9 (22.5%)                   | 0.362   |
| Hypertension                     | 21 (51.2%)                  | 29 (72.5%)                  | 0.049   |
| PAD                              | 6 (14.6%)                   | 5 (12.5%)                   | 0.779   |
| COPD                             | 22 (53.7%)                  | 20 (50.0%)                  | 0.742   |
| CVA                              | 4 (9.8%)                    | 1 (2.5%)                    | 0.359   |
| Number of Revascularized Vessels | 2.4±1.0                     | 2.7±1.1                     | 0.127   |
| Pre-op MI                        | 22 (53.7%)                  | 21 (52.5%)                  | 0.917   |
| FBG (mg/dL)                      | 99.7±18.6                   | 107.5±25.3                  | 0.094   |
| FBI (µU/mL)                      | 5.3±3.0                     | 23.0±18.5                   | <0.001  |
| HbA1c (%)                        | 5.9±0.3                     | 5.8±0.4                     | 0.097   |
| HOMA-IR                          | 1.3±0.7                     | 6.0±5.1                     | <0.001  |
| Cross-clamping time (min)        | 45.5±18.2                   | 61.9±36.7                   | 0.043   |
| Pump time (min)                  | 75.6±25.3                   | 97.9±46.0                   | 0.031   |
| Hospitalization duration (days)  | 6.5±1.5                     | 7.2±1.7                     | 0.061   |

PAD=periarterial disease; COPD=chronic pulmonary obstructive disease; CVA=cerebrovascular event; MI=myocardial infarction; FBG=fasting blood glucose; FBI=fasting blood insulin

Table 2. Logistic regression model with dependent variable as HOMA (normal/high).

|                        | β*  | SE  | P  | Odds | %95 Confidence interval |
|------------------------|-----|-----|----|------|-------------------------|
|                        |     |     |    |      | Min. | Max.                    |
| FBG                    | 0.036 | 0.016 | 0.021 | 1.036 | 1.005 | 1.069 |
| HbA1c                  | -1.553 | 0.782 | 0.047 | 0.212 | 0.046 | 0.979 |
| PAD (Yes/No)           | -1.245 | 0.935 | 0.183 | 0.288 | 0.046 | 1.798 |
| HT (Yes/No)            | 0.785 | 0.598 | 0.189 | 2.193 | 0.679 | 7.075 |
| Pump time              | 0.023 | 0.011 | 0.026 | 1.024 | 1.003 | 1.045 |
| Post-op EF             | 0.022 | 0.024 | 0.363 | 1.022 | 0.975 | 1.072 |
| Hospitalization duration (day) | 0.159 | 0.207 | 0.443 | 1.172 | 0.781 | 1.757 |
| Smoking (Yes/No)       | 1.059 | 0.693 | 0.127 | 2.883 | 0.741 | 11.210 |

β=regression coefficient; SE=standard error; FBG=fasting blood glucose; PAD=periarterial disease; HT=hypertension; EF=ejection fraction
DISCUSSION

In this study, we investigated whether HOMA-IR value was a predictor in non-diabetic coronary CABG patients when used in combination with HbA1c, FBG and FBI levels. Our results showed that HOMA-IR might provide an insight to the glucometabolic states of non-diabetic individuals before CABG surgery, when used in combination with HbA1c, FBG and FBI levels.

With respect to diabetes and aging population of the world, it is certain that more powerful set of tools should be developed for prediabetic individuals to establish effective prevention, management, and treatment options in the following years. Velagali et al. performed a study in 1603 Framingham Heart Study Offspring participants to elucidate the potential relationship of increasing insulin resistance as well as high levels of insulin and glucose with cardiac structure by using cardiovascular magnetic resonance imaging (CMRI) modality. The authors observed that higher levels of HOMA-IR were related to increasing left ventricular mass indexed to height (LVM/ht²) and left ventricular end-diastolic volume (LVEDV) in both male and females.

Sung et al. performed one of the largest-sized clinical trials in 49,076 normoglycemic healthy Korean subjects to define the possible correlation between insulin resistance and high blood pressure. Based on anthropometric measurements, metabolic variables including FBI and HOMA, and serum chemistry tests, a significant and independent correlation among the level of IR, BMI, waist circumference and systolic BP, diastolic BP, and the prevalence of high BP was reported in normoglycemic subjects. Although the correlation between insulin resistance and hypertension has been a subject of long lasting debate in many studies in the literature, the results of large-sample sized study performed on rather young, non-obese, normoglycemic individuals were quite supportive in favor of the existence of a correlation, as the study revealed increased atherogenic risk factors related to insulin resistance in the study population.

Furthermore, prolonged fasting, which is a physiological condition characterized by muscular insulin resistance in the presence of increased free fatty acid levels, increased fat oxidation and low glucose and insulin levels, is likely to be associated with insulin resistance. The prolonged preoperative fasting also increases the metabolic stress of the surgery and thereby increases insulin resistance and hyperglycemia. Although the exact underlying mechanism remains to be elucidated, defects in transmembrane proteins appear to play an important role.

In addition, cross-clamping time, and CPB time were statistically significantly longer in patients with high HOMA-IR values in our study, despite similar data including preoperative demographic characteristics, number of previous bypass surgery, and number of additional cardiac procedures during surgery between the two groups. Although the mean age was not statistically significant between the groups, it was observed that patients who required undergoing CABG with high HOMA levels were 3.3 years younger than those with normal HOMA levels.

We considered that it was clinically significant in the clinical practice. Moreover, the surgical team reported worse quality in the vascular structures in Group B, and the incidence of hypertension was statistically significantly higher in this group. In the light of literature, we concluded that insulin resistance levels might be closely related to coronary vascular pathologies leading to CAD development in our study population. Also, we considered that clinical outcomes of the vascular damage presented itself as hypertension disease, poor vascular quality during operation, and longer cross-clamping and CPB pump time in the operation as well as high HOMA levels, and that, thereby, HOMA might be a reliable variable indicating the underlying problem in patients who were progressing to a more complicated stage of pathogenesis.

Tekumit et al. conducted a prospective study including a total of 166 patients undergoing CABG. Among them, 60% patients without diabetes history were diagnosed with dysglycemia using the OGTT. The authors concluded that fasting blood glucose alone was not sufficient to diagnose nearly half of the patients with dysglycemia. They recommended, thus, addition of HbA1c to the preoperative examination schedule. In another study from Korea investigating the relationship between insulin resistance and post-interventional complications in patients undergoing percutaneous coronary intervention, major adverse cardiac events (MACE) were observed within 30 days after the procedure.

It was reported that high HOMA-IR value was related to high incidence of complications and short-term MACE even in non-diabetic patients. Furthermore, in another cross-sectional study including 61 patients with DM undergoing coronary angiogram for the evaluation of CAD, Srinivasan et al. found a statistically significant correlation between HOMA-IR value and severity of CAD, as assessed by Gensini score. The authors concluded that HOMA-IR measurement might be helpful in predicting the severity of CAD. In this present study, HbA1c values were increased more in Group A, whereas FBI (P<0.001), and glucose (P=0.094) levels were higher in Group B, as evidenced by the logistic regression analysis.

Review of the literature revealed that insulin resistance was not only a component of glucose metabolism for DM, however, it could also be another missing element in atherosclerosis. We suggested that HOMA-IR might be a reasonable and reliable test for metabolic examination among prediabetic individuals who were referred to a tertiary healthcare center for further diagnosis and treatment of CAD. In our study, it was striking that HbA1c levels were within normal limits in patients with longer cross-clamping time, despite in-
increased HOMA levels. In the light of literature data regarding the possible factors affecting the results of HbA1c levels, we concluded that HOMA-IR might be used during prediabetic patient screening in combination with HbA1c thanks to its promising predictive potential, cost-effectiveness, and easy-to-use handling.

**Limitations**

The major limitation of this study was the small sample size. A larger sample size from multiple tertiary healthcare centers would provide higher statistical power for the outcomes.

**CONCLUSION**

In conclusion, our study results suggest that HOMA-IR is a predictor in non-diabetic CABG patients. We believe that pre-operative screening of non-diabetic patients with HOMA-IR in combination with HbA1c may improve both follow-up visit schedule and short-term outcomes, and may be useful in risk stratification of the high-risk population regarding impending health problems which may likely to be originated from two main chronic diseases: coronary artery disease and diabetes mellitus. However, we believe further studies are required to confirm these findings.

**Disclosure**

No conflict of interest.

---

**Authors’ roles & responsibilities**

|        |         |
|--------|---------|
| EA     | Main author |
| MO     | Coauthor   |

**REFERENCES**

1. Emerging Risk Factors Collaboration, Sarwar N, Gao P, Seshasai SR, Gobin R, Kaptoge S, Di Angelantonio E, et al. Diabetes mellitus, fasting blood glucose concentration, and risk of vascular disease: a collaborative meta-analysis of 102 prospective studies. Lancet. 2010;375(9733):2215-22.

2. Sarwar N, Sattar N, Gudnason V, Danesh J. Circulating concentrations of insulin markers and coronary heart disease: a quantitative review of 19 Western prospective studies. Eur Heart J. 2007;28(20):2491-7.

3. Giacco F, Brownlee M. Oxidative stress and diabetic complications. Circ Res. 2010;107(9):1058-70.

4. Yu Q, Gao F, Ma XL. Insulin says NO to cardiovascular disease. Cardiovasc Res. 2011;89(3):516-24.

5. Kanan L, Chernoff A. Insulin Resistance and Atherosclerosis: Is it Time to Measure HOMA-IR to Predict Coronary Artery Disease? N Am J Med Sci. 2013;5(10):615-6.

6. Bornfeldt KE, Tabas I. Insulin resistance, hyperglycemia, and atherosclerosis. Cell Metab. 2011;14(5):575-85.

7. Gerstein HC. Glycosylated hemoglobin: finally ready for prime time as a cardiovascular risk factor. Ann Intern Med. 2004;141(6):475-6.

8. Halkos ME, Lattouf OM, Puskas JD, Kilgo P, Cooper WA, Morris CD, et al. Elevated preoperative hemoglobin A1c level is associated with reduced long-term survival after coronary artery bypass surgery. Ann Thorac Surg. 2008;86(5):1431-7.

9. Alserius T, Anderson RE, Hammar N, Nordqvist T, Ivert T. Elevated glycosylated haemoglobin (HbA1c) is a risk marker in coronary artery bypass surgery. Scand Cardiovasc J. 2008;42(6):392-8.

10. Ceyhan K, Altunkas F. [Prediabetes, becoming the equivalent of coronary artery disease]. Turk Kardiyol Dern Ars. 2012;40(5):458-65.

11. Satman I, Yilmaz T, Sengül A, Salman S, Salman F, Uygur S, et al. Population-based study of diabetes and risk characteristics in Turkey: results of the Turkish diabetes epidemiology study (TURDEP). Diabetes Care. 2002;25(9):1551-6.

12. Satman I, Omer B, Tutuncu Y, Karaca S, Gedik S, Dincceag N, et al.; TURDEP-II Study Group. Twelve-year trends in the prevalence and risk factors of diabetes and prediabetes in Turkish adults. Eur J Epidemiol. 2013;28(2):169-80.

13. World Health Organization. Definition and diagnosis of diabetes mellitus and intermediate hyperglycemia: report of a WHO/IDF consultation. 2006; (NLM classification: WK 810) [Accessed Sep 3, 2013]. Available at: http://whqlibdoc.who.int/publications/2006/9241594934_eng.pdf

14. Rydén L, Standl E, Bartnik M, Van den Berghe G, Betteridge J, de Boer MJ, et al; Task Force on Diabetes and Cardiovascular Diseases of the European Society of Cardiology (ESC); European Association for the Study of Diabetes (EASD). Guidelines on diabetes, pre-diabetes, and cardiovascular diseases: executive summary. The Task Force on Diabetes and Cardiovascular Diseases of the European Society of Cardiology (ESC) and of the European Association for the Study of Diabetes (EASD). Eur Heart J. 2007;28(1):88-136.

15. Bennett CM, Guo M, Dharmage SC. HbA(1c) as a screening tool for detection of Type 2 diabetes: a systematic review. Diabet Med. 2007;24(4):333-43.

16. Wang W, Lee ET, Fabsitz RW, Welty TK, Howard BV. Using HbA1c to improve efficacy of the American Diabetes Association fasting plasma glucose criterion in screening for new type 2 diabetes in American Indians: the strong heart study. Diabetes Care. 2002;25(8):1365-70.
Aydin E & Ozkokeli M - Does Homeostasis Model Assessment of Insulin Resistance have a predictive value for post-coronary artery bypass grafting surgery outcomes?

17. Aziz A, Wheatcroft S. Insulin resistance in Type 2 diabetes and obesity: implications for endothelial function. Expert Rev Cardiovasc Ther. 2011;9(4):403-7.

18. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia. 1985;28(7):412-9.

19. HOMA calculator web site for Diabetes Trials Unit of Diabetes, Endocrinology and Metabolism. Centre at Oxford University [Accessed Mar 7, 2013]. Available at: http://www.dtu.ox.ac.uk/homacalculator/

20. Sharma S, Fleming SE. Use of Hba(1C) testing to diagnose pre-diabetes in high risk African American children: a comparison with fasting glucose and HOMA-IR. Diabetes Metab Syndr. 2012;6(3):157-62.

21. Velagaleti RS, Gona P, Chuang ML, Salton CJ, Fox CS, Blease SJ, et al. Relations of insulin resistance and glycemic abnormalities to cardiovascular magnetic resonance measures of cardiac structure and function: the Framingham Heart Study. Circ Cardiovasc Imaging. 2010;3(3):257-63.

22. Sung KC, Kim BJ, Kim BS, Kang JH, Lee MH, Park JR, et al. In normoglycemic Koreans, insulin resistance and adiposity are independently correlated with high blood pressure. Circ J. 2004;68(10):898-902.

23. Hoeks J, van Herpen NA, Mensink M, Moonen-Kornips E, van Beurden D, Hesselink MK, et al. Prolonged fasting identifies skeletal muscle mitochondrial dysfunction as consequence rather than cause of human insulin resistance. Diabetes. 2010;59(9):2117-25.

24. Feguri GR, Lima PR, Lopes AM, Roledo A, Marchese M, Trevisan M, et al. Clinical and metabolic results of fasting abbreviation with carbohydrates in coronary artery bypass graft surgery. Rev Bras Cir Cardiovasc. 2012;27(1):7-17.

25. Zecchin HG, Carvalheiro JBC, Saad MJA. Molecular mechanisms for insulin resistance in the metabolic syndrome. Rev Soc Cardiol Estado de São Paulo. 2004;(4):574-89.

26. Tekumit H, Cenal AR, Polat A, Uzun K, Tataroglu C, Akinci E. Diagnostic value of hemoglobin A1c and fasting plasma glucose levels in coronary artery bypass grafting patients with undiagnosed diabetes mellitus. Ann Thorac Surg. 2010;89(5):1482-7.

27. Yun KH, Jeong MH, Kim KH, Hong YJ, Park HW, Kim JH, et al. The effect of insulin resistance on prognosis of non-diabetic patients who underwent percutaneous coronary intervention. J Korean Med Sci. 2006;21(2):212-6.

28. Srinivasan MP, Kamath PK, Manjrekar PA, Unnikrishnan B, Ullal A, Kotekar MF, et al. Correlation of severity of coronary artery disease with insulin resistance. N Am J Med Sci. 2013;5(10):611-4.