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Effects of Hyperglycemia on the In-hospital and Long-term Prognosis of Patients with Acute ST-segment Elevation Myocardial Infarction

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Abstract

Objective: A large amount of acute ST-segment elevation myocardial infarction (STEMI) patients have stress hyperglycemia on admission, which is associated with poor in-hospital and long-term prognosis. This research aimed to find the effects of hyperglycemia on in-hospital mortality, adverse cardiovascular events and long-term prognosis in patients with STEMI.

Method: We conducted a prospective cohort study on 456 STEMI patients from January 2015 to December 2016 in Zhongda hospital affiliated to Southeast University. We recorded the baseline data, then used propensity matching (a ratio of 1:2) to balance the confounding variables and rule out the bias, according to the definition of stress hyperglycemia, admission random blood glucose >11.1 mmol/L, we divided patients into two groups: hyperglycemia group (71 cases) and non-hyperglycemia group (142 cases). We recorded and compared the baseline data, past history, auxiliary examination index, medication usage, coronary angiography data, and in-hospital outcome between two groups. One-year follow-up main adverse cardiovascular and cerebrovascular events (MACCE) were recorded by telephone and clinic, we use X^2 test to research the relationship between hyperglycemia and in-hospital outcome, we use ROC curve to assess the predictive value of hyperglycemia for in-hospital death both in diabetic and non-diabetic patients. Kaplan-Meier curve and Cox regression are used to evaluate the predictive value of stress hyperglycemia for the long-term prognosis.

Result: Stress hyperglycemia occurred in 86 patients (18.9%), of whom 65 had diabetes history. There were 10 patients (14.1%) died in hospital in hyperglycemia group, 6 for malignant arrhythmia, 3 for cardiogenic shock and 1 for cardiac rupture. In the non-hyperglycemia group, the in-hospital mortality is 3.5% (P=0.028). The incidence of malignant arrhythmia and cardiogenic shock were higher in hyperglycemia group than control group (P=0.023, P=0.030). The ROC curve of admission random blood glucose predicting in-hospital deaths for non-diabetic patients and diabetic patients showed the area under curve and 95% CI were 0.627, 0.438 ~ 0.837; 0.786, 0.586 ~ 0.913 respectively. The incidence of one-year follow-up MACCE was about 41.7% in hyperglycemia group, and the incidence in the control group was 27.8% (P=0.018). Gender, age, diabetes, hypertension, previous myocardial infarction, hyperglycemia, left ventricular ejection fraction were included in Cox regression model of one-year follow-up MACCE in STEMI patients. Stress hyperglycemia was an independent risk factor for one-year follow-up MACCE in STEMI patients (OR=4.398, 95% CI=2.869 ~ 7.483, P<0.001).

Conclusion: Hyperglycemia is a predictive factor for in-hospital death in STEMI patients, and it has good predictive value for the long-term prognosis.

Keywords Hyperglycemia; Acute myocardial infarction; In-hospital mortality; Prognosis

Abbreviations STEMI: ST-segment elevation myocardial infarction; T2DM: Type 2 Diabetes mellitus; MACCE: Main adverse cardiovascular and cerebrovascular events; ROC: Receiver operating characteristic; LVEF: Left ventricular ejection fraction; PCI: Percutaneous coronary intervention; TIMI: Thrombolysis in myocardial infarction.

Introduction

Research showed that no matter patients have diabetes or not, acute myocardial infarction patients often have stress hyperglycemia in admission, which can strengthen ischemic myocardial injury [1] and closely associated with mortality and complications in hospital [2,3]. Acute myocardial infarction patients with diabetes always have poor prognosis and increased mortality accordingly. Our research aimed to research the relationship between stress hyperglycemia, in-hospital death, in-hospital adverse cardiovascular events and one-year MACCE in patients with ST-segment elevation myocardial infarction, and assess the predictive value of stress hyperglycemia in hospital and in the long term.

Materials and Methods

General information

We did a single center prospective cohort study, enrolling 456 ST-segment elevation myocardial infarction patients in prospective randomized way from January 2015 to January 2016 at Zhongda Hospital affiliated to Southeast University, including 347 males and 109 females. The inclusion criteria were as followed: 1) willing to sign informed consent; 2) Aged more than 18; 3) Meet the diagnostic criteria of "2017 ESC guide: management of ST-segment elevation acute myocardial infarction patients" [4], the exclusion criteria were: 1) patients with severe cardiac insufficiency (require large vasoactive drugs to maintain blood pressure), severe valvular heart disease and hemodynamic instability; 2) severe liver dysfunction, malignancy, severe infectious disease and stroke patients; 3) information such as random admission blood glucose, follow-up, etc., was not complete.

The study was approved by the Ethics Committee of Zhongda Hospital affiliated to Southeast University (Nanjing, Jiangsu, China). Written informed consent was obtained from the patients or a legal representative.

Groups

There is no unified definition of stress hyperglycemia, the American Diabetes Association took fasting glucose >6.9 mmol/L or random blood glucose >11.1 mmol/L without diabetes history as the criteria of hyperglycemia in 2009 [5]. (2) Based on this, we recorded the baseline data, then used propensity matching (a ratio of 1:2) to balance the confounding variables and rule out the bias, we divided patients into two groups: hyperglycemia group (random admission glucose >11.1 mmol/L) 71 cases and non-hyperglycemia group (admission random glucose ≤ 11.1 mmol/L) 142 cases.

Data collection and follow-up

We recorded general information, past history, admission random glucose, troponin, blood routine, biochemical index, LVEF, platelet aggregation inhibitor, anticoagulant, beta blocker, statin, coronary angiography situation, the postoperative TIMI flow grade, hospital stay, hospital cost, in-hospital death, malignant arrhythmia, temporary pacemaker implantation, cardiogenic shock, congestive heart failure, one-year follow-up MACCE were implemented by telephone and outpatient clinic. MACCE mainly includes: all-cause death, target vessel revascularization, non-fatal myocardial infarction, unstable angina and heart failure that need hospital treatment, cerebral apoplexy, or transient cerebral hemorrhage.

Statistical analysis

SPSS 22.0 statistical software was used for data analysis. We used propensity matching (a ratio of 1:2) to balance the confounding variables and rule out the bias. The numerical data were expressed as X ± S, and compared using independent sample t test, non-normally distributed numerical data were expressed as median and 25-75 interquartile range, and compared using rank-sum test. Classification data were expressed as number and percentage and compared using X^2 test. ROC curve was to assess the correlation between hyperglycemia and in-hospital death. The predictive value of random blood glucose for prognosis of STEMI patients is evaluated by Kaplan-Meier curve and Cox regression. $P<0.05$ was considered statistically significant.

Results

Comparison of general data and past history between hyperglycemia group and non-hyperglycemia group

There were no statistical differences in gender, age, BMI, systolic blood pressure, diastolic blood pressure, heart rate, Killip classification, smoking, hypertension, diabetes, chronic kidney disfunction, cancer, previous myocardial infarction history, previous stent implantation history and atrial fibrillation history ($P \geq 0.05$) (Table 1).

Variables	Hyperglycemia group (n=71)	Non-hyperglycemia group (n=142)	P value
Male	40 (56.34%)	75 (52.82%)	0.627
Age	64.48 ± 13.47	64.86 ± 12.58	0.862
BMI (P_{25}-P_{75}) (kgm^{-2})	24.19 (21.22-26.77)	23.88 (20.55-26.39)	0.528
SBP (mm Hg)	125.66 ± 18.95	127.55 ± 22.01	0.568
DBP (mm Hg)	74.86 ± 15.05	75.48 ± 11.35	0.784
HR (bpm)	82.97 ± 18.49	77.94 ± 16.55	0.09
Killip classification	1.59 ± 0.98	1.44 ± 0.88	0.357
Smoking	21 (29.58%)	36 (25.35%)	0.511
Hypertension	47 (66.20%)	90 (63.38%)	0.686
Diabetes	34 (47.89%)	60 (42.25%)	0.435
Chronic kidney disfunction	5 (7.04%)	5 (3.52%)	0.307
Cancer	1 (1.41%)	2 (1.41%)	1

Previous myocardial infarction	3 (4.17%)	4 (2.82%)	0.429
Stent implantaion	3 (4.23%)	4 (2.82%)	0.429
Atrial fibrillation	3 (4.23%)	3 (2.11%)	0.318
BMI: Body Mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; HR: Heart rate.			

Table 1: Comparison of general data and past history between hyperglycemia group and non-hyperglycemia group.

Comparison of auxiliary inspection index between hyperglycemia group and non-hyperglycemia group

White blood cell count and random blood sugar were statistically significant in the two groups (P=0.043, P<0.001, respectively), none of troponin, red blood cell count, hemoglobin, platelet count, potassium ion, albumin, alanine aminotransferase, aspartate transaminase, lactate dehydrogenase, creatine kinase, creatinine, eGFR, uric acid, serum cystatin C, triglycerides, cholesterol, HDL-C, LDL-C, left ventricular ejection fraction was statistically significantly different (P ≥ 0.05) (Table 2).

Variables	Hyperglycemia group (n=71)	Non-hyperglycemia group (n=142)	P value
Troponin P_{50} (P_{25}-P_{75}) (ng/ml)	2.00 (0.57-12.25)	1.20 (0.12-8.30)	0.829
WBC P_{50}(P_{25}-P_{75}) (*10^9/L)	11.29 (7.92-12.62)	8.51 (7.13-10.15)	0.043
*RBC P_{50} (P_{25}-P_{75}) (*10^12/L)	4.65 (3.68-4.98)	4.27 (3.97-4.89)	0.58
Hb P_{50} (P_{25}-P_{75}) (g/L)	136 (111.25-152)	131 (118.50-147.50)	0.387
PLT P_{50} (P_{25}-P_{75}) (*10^9/L)	214 (172.75-214)	193 (171-247.50)	0.162
K+ P_{50} (P_{25}-P_{75}) (mmol/L)	3.91 (3.62-4.10)	3.81 (3.45-4.07)	0.412
ALB P_{50} (P_{25}-P_{75}) (g/L)	35.05 (31.25-39)	36 (34-38.80)	0.467
ALT P_{50} (P_{25}-P_{75}) (IU/L)	37.5 (22-74.25)	36 (25-57.50)	0.285
AST P_{50} (P_{25}-P_{75}) (IU/L)	94 (33.75-191.50)	90 (40-195.50)	0.249
LDH P_{50} (P_{25}-P_{75}) (IU/L)	480 (224-897.25)	367 (252.50-638.50)	0.551
Scr P_{50} (P_{25}-P_{75}) (μmol/L)	83 (72.25-111.75)	84 (68.75-100)	0.081
eGFR P_{50} (P_{25}-P_{75}) ml/1.73m2/min	70.51 (45.63-98.76)	80 (65-95.50)	0.366
UA P_{50} (P_{25}-P_{75}) (μmol/L)	319 (256.50-400.25)	306 (247.00-373.50)	0.843
Cys-C P_{50} (P_{25}-P_{75}) (mmol/L)	2.61 (1.94-3.08)	1.05 (0.79-2.35)	0.073
TG P_{50} (P_{25}-P_{75}) (mmol/L)	1.62 (1.30-2.41)	1.61 (1.11-2.05)	0.071
TC P_{50} (P_{25}-P_{75}) (mmol/L)	4.58 (3.77-5.50)	4.64 (3.82-5.47)	0.352
HDL-C P_{50} (P_{25}-P_{75}) (mmol/L)	1.12 (0.97-1.32)	1.15 (0.93-1.34)	0.325
LDL-C P_{50} (P_{25}-P_{75}) (mmol/L)	2.82 (2.22-3.40)	2.83 (2.37-3.42)	0.925
Admission random blood glucose P_{50} (P_{25}-P_{75}) (mmol/L)	15.67 ± 4.22	7.99 ± 1.56	<0.001*
LVEF P_{50} (P_{25}-P_{75})	0.37 ± 0.16	0.39 ± 0.79	0.79
WBC: White blood cell; RBC: Red blood cell; Hb: Hemoglobin; PLT: Platelet; ALB: Albumin; ALT: Alanine transaminase; AST: Aspartate transaminase; LDH: Lactic dehydrogenase; CK: Creatine kinase; Scr: Serum creatinine; Egfr: Estimated glomerular filtration rate; UA: Uric acid; Cys-c: Cystatin-c; TG: Triglyceride; TC: Total cholesterol; HDL-C: High density lipoprotein cholesterol; LDL-C: Low density lipoprotein cholesterol; LVEF: Left ventricular ejection fraction. *P<0.05			

Table 2: Comparison of auxiliary inspection index between hyperglycemia group and non-hyperglycemia group.

Comparison of medications, coronary angiography and hospitalization situation between hyperglycemia group and non-hyperglycemia

The number of coronary lesion vessels in hyperglycemia group is higher than the control group (P=0.038), hospital stay and hospital cost are also higher (P=0.036, 0.028, respectively). There were no significant difference between the two groups in aspirin, clopidogrel, low molecular heparin, statin, the proportion of thrombus aspiration, coronary stent implantation, and TIMI flow grades after coronary angiography (P ≥ 0.05) (Table 3).

Variables	Hyperglycemia group (n=71)	Non-hyperglycemia group (n=142)	P value
PCI	55 (77.46%)	92 (64.79%)	0.059
Aspirin	66 (92.96%)	133 (93.66%)	0.845
Low molecular heparin	65 (91.55%)	129 (90.85%)	0.865
Clopidogrel	63 (88.73%)	128 (90.14%)	0.75
Statin	64 (90.14%)	132 (92.96%)	0.475
Thrombus aspiration	40 (56.34%)	81 (57.04%)	0.922
Coronary lesion vessels	2.31 ± 0.93	2.02 ± 0.81	0.038*
Coronary stents	1.21 ± 0.81	1.15±0.69	0.456
Postoperative TIMI flow grade	2.84 ± 0.69	2.84 ± 0.61	0.993
Hospital stay $P_{50}(P_{25}$-$P_{75})$	10.76 (6.23-18.38)	8.32 (7.50-14.47)	0.036*
Hospital cost $P_{50}(P_{25}$-$P_{75})$	59365.45 (46703.54.15-81670.02)	55462.79 (43864.28-71826.59)	0.028*
PCI, percutaneous coronary intervention; TIMI, thrombolysis in myocardial infarction. *P<0.05.			

Table 3: Comparison of medications, coronary angiography and hospitalization situation between hyperglycemia group and non-hyperglycemia group.

Comparison of major adverse cardiovascular events between hyperglycemia group and non-hyperglycemia group

In hyperglycemia group, the incidence of hospital mortality, malignant arrhythmia and cardiogenic shock incidence were higher than control group (P=0.003, 0.023, 0.030, respectively), the incidence of temporary pacemaker implantation and congestive heart failure between the two groups had no significant difference (P ≥ 0.05) (Table 4).

Group	n	Hospital Mortality	Malignant arrhythmia	Temporary pacemaker implantation	cardiogenic shock	congestive heart failure
Hyperglycemia group	71	10	8	2	16	3
Non-hyperglycemia group	142	4	4	1	16	2
P value	-	0.003	0.023	0.26	0.03	0.201

Table 4: Comparison of major adverse cardiovascular events between hyperglycemia groups and non-hyperglycemia group.

The ROC curve of admission random blood glucose predicting in-hospital deaths for non-diabetic patients and diabetic patients

In non-diabetic patients, 8.1% of patients with hyperglycemia died in hospital, the ROC curve of admission random blood glucose predicting in-hospital deaths showed the area under curve and 95% CI were 0.627, 0.438 ~ 0.837 (P=0.043), in patients with diabetes, 9.6% of hyperglycemia patients died in hospital, the AUC and 95% CI were 0.786, 0.586 ~ 0.913 (P=0.013) , the cut-off value is 17.67 mmol/L, the sensitivity and specificity were 80.0% and 76.4% accordingly (Figures 1 and 2).

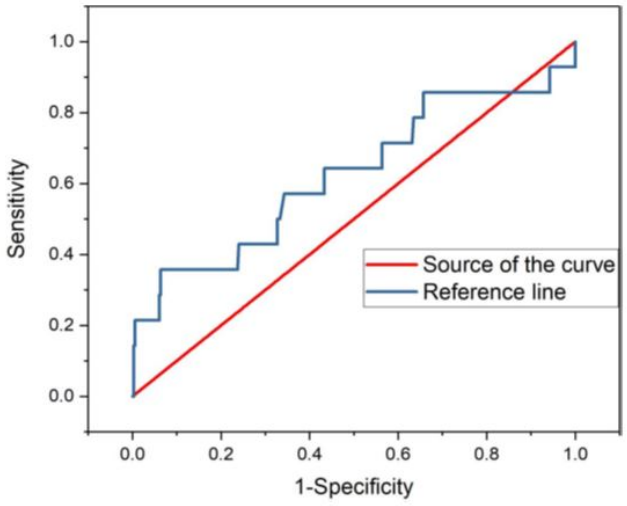

Figure 1: The ROC curve of admission random blood glucose predicting in-hospital deaths for non-diabetic patients.

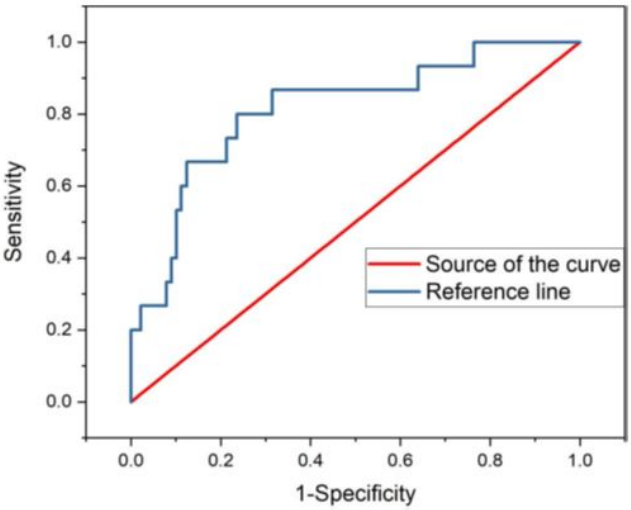

Figure 2: The ROC curve of admission random blood glucose predicting in-hospital deaths for diabetic patients.

Kaplan-Meier curve and Cox regression model

The incidence of one-year follow-up MACCE in hyperglycemia group was 41.7%, compared with 27.8% in the control group (P=0.018). Gender, age, diabetes, hypertension, past history of myocardial infarction, hyperglycemia, left ventricular ejection fraction were included in Cox regression model. Stress hyperglycemia is an independent predictor of MACCE (OR=4.398, 95% CI=2.869 ~ 7.483, P<0.001) (Table 5 and Figure 3).

Variables	OR	95% CI	P value
Male	2.137	1.305 ~ 4.072	0.039*
Age	1.864	1.057 ~ 2.378	0.027*
Diabetes	1.488	1.033 ~ 2.856	0.041*
Hypertension	1.899	1.124 ~ 2.742	0.028*
Previous myocardial infarction	7.759	2.657 ~ 22.655	<0.001*
Hyperglycemia	4.398	2.869 ~ 7.483	<0.001*
LVEF	0.639	0.557 ~ 0.874	0.041*
Postoperative TIMI flow grade	1.003	0.656 ~ 2.894	0.78

LVEF, left ventricular ejection fraction; TIMI, thrombolysis in myocardial infarction. * P<0.05.

Table 5: Cox regression model for one-year follow-up MACCE.

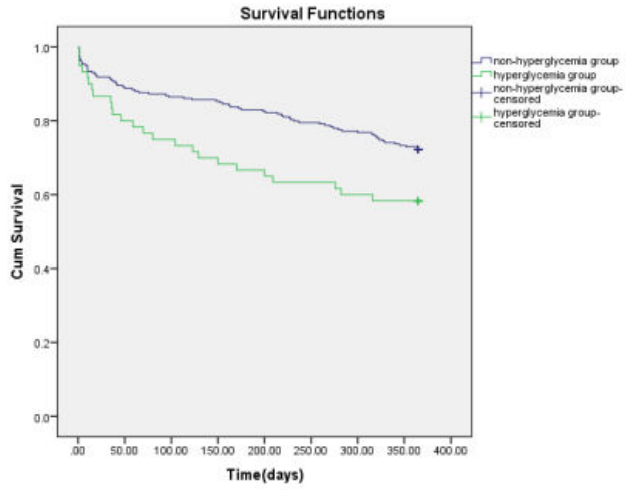

Figure 3: The incidence of one-year follow-up MACCE in hyperglycemia group and non-hyperglycemia group.

Discussion

AMI patients with diabetes have higher mortality than those with normal blood glucose [6], several large sample cohort studies showed a significant increased cardiovascular risk in patients with impaired glucose tolerance [7,8]. A 20-year follow-up in Whitehall Study, Paris Prospective Study and Helsinki Policemen Study that enrolled over 20,000 non-diabetic patients showed that hyperglycemia significantly increased the risk of cardiovascular events, all-cause mortality and cancer incidence [9]. Oswald et al. [10,11] found that in acute myocardial infarction patients with or without diabetes, admission random blood glucose levels were closely associated with mortality [10,11]. In patients with acute myocardial infarction, the incidence of stress hyperglycemia is high, and the elevated level of admission random blood glucose is often associated with poor long-term prognosis [12].

Stress hyperglycemia is transient hyperglycemia occurred during disease, the American diabetes association (ADA) defined stress hyperglycemia in 2009 as, for patients without diabetes, fasting glucose

>6.9 mmol/L or random blood glucose >11.1 mmol/L [5]. Norhammar A et al. [13] did a research published in Lancet, claiming that in the early stages of acute myocardial infarction, increased blood glucose can be a marker for early risk assessment [13]. Stress hyperglycemia can be seen as a compensatory response to ischemic myocardial cells when acute myocardial infarction occurred, the rise in blood sugar can increase the availability of glucose, reduce the apoptosis, and meanwhile, metabolic disorders can lead to extensive myocardial injury. Hyperglycemia has direct adverse effects on ischemic myocardium, including oxidative stress, inflammation, apoptosis, endothelial dysfunction, hypercoagulability, and platelet aggregation [1]. Stubbs PJ found serum insulin is weakly correlated with glucose levels after AMI [14], Oliver EF put forward hyperglycemia is related with the hormone that raises blood sugar rather than decreased insulin level [15].

Lonborg et al. [16] found STEMI patients with hyperglycemia have significantly greater myocardial infarction size than control group, stress hyperglycemia can be used as a marker to assess myocardial injury severity [16]. A multi-center, prospective cohort study [17] enrolled 816 AMI patients with cardiogenic shock confirmed admission blood glucose is an independent risk factor for mortality in non-diabetic patients, Deckers JW [18] included 11324 patients from 1985 to 2005 with AMI, the conclusion is that the incidence of hyperglycemia and that in non-diabetic patients are increasing, the 30-day mortality in stress hyperglycemia group was 3.6 times compared with control group (95% CI=2.9 ~ 2.9).

In this study, 18.9% of patients with STEMI are consolidated with hyperglycemia on admission, statistically significant differences can be seen in gender, Killip classification, smoking, diabetes, history of previous myocardial infarction, white blood cell count, albumin, alanine transaminase, triglycerides, admission random blood glucose, LVEF, hospital days, hospital cost, in-hospital deaths, malignant arrhythmia, temporary pacemaker implantation, cardiogenic shock between hyperglycemia group and non-hyperglycemia group. Binary analysis showed that stress hyperglycemia is an independent risk factor for in-hospital death. There were 86 patients with hyperglycemia, of which 65 were diabetic. In non-diabetic patients, the ROC of admission random blood glucose predicting in-hospital deaths showed the area under curve is 0.670, while the area is 0.746 in patients with diabetes, which has higher predictive value. One-year follow-up MACCE showed that the incidence of main adverse cardiovascular and cerebrovascular events was significantly higher in hyperglycemia group, stress hyperglycemia is included in Cox regression model for one-year follow-up MACCE, in other word, hyperglycemia is an independent discriminator of MACCE.

Stress hyperglycemia is closely associated with poor outcome in patients with acute myocardial infarction, therefore, we need to pay high attention to the admission random blood glucose to help evaluate both in-hospital and long-term prognosis in STEMI patients. GONG SU et al. [19] found that elevated blood glucose variability was more predictive for MACCE in AMI patients. Teraguchi I also put forward the blood glucose changes from the peak to valley may be a potential therapeutic targets [20]. More clinical researches need to be carried out to confirm intervention measures and their curative effects.

Conclusion

A large amount of STEMI patients have hyperglycemia on admission, our research showed that hyperglycemia is closely related to poor prognosis both in hospital and in the long term in STEMI patients. Admission blood glucose can be regarded as a good discriminator for predicting in-hospital and long-term prognosis, and we should pay more attention to it in clinical practice.

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Competing Interests

The authors have declared that no competing interest exists.

Authors' Contributions

Yuhan Qin and Gaoliang Yan contributed equally to this work.

References

1. Moriyama N, Ishihara M, Noguchi T, Nakanishi M, Arakawa T, et al. (2014) Admission Hyperglycemia Is an Independent Predictor of Acute Kidney Injury in Patients With Acute Myocardial Infarction. Circ J 78: 1475-1480.
2. Naruse H, Ishii J, Hashimoto T, Kawai T, Hattori K, et al. (2012) Pre-Procedural Glucose Levels and the Risk for Contrast-Induced Acute Kidney Injury in Patients Undergoing Emergency Coronary Intervention. Circ J 76: 1848-1855.
3. Allison SP, Tomlin PJ, Chamberlain MJ (1969) Some Effects of Anaesthesia and Surgery on Carbohydrate and Fat Metabolism. Brit J Anaesth 41: 588-593.
4. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, et al. (2018) 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). Eur Heart J 39: 119-177.
5. Dungan KM, Braithwaite SS, Preiser JC (2009) Stress hyperglycaemia. Lancet 373: 1798-1807.
6. Abbott RD, Donahue RP, Kannel WB, Wilson PWF (1988) The Impact of Diabetes on Survival Following Myocardial-Infarction in Men Vs. Women. Jama 260: 3456-3460.
7. Fuller JH, Shipley MJ, Rose G, Jarrett RJ, Keen H (1980) Coronary-Heart-Disease Risk and Impaired Glucose-Tolerance - The Whitehall Study. Lancet 1: 1373-1376.
8. Borch-Johnsen K, Neil A, Balkau B, Larsen S, Borch-Johnsen K, et al. (1999) Glucose tolerance and mortality: comparison of WHO and American Diabetes Association diagnostic criteria. Lancet 354: 617-621.
9. Balkau B, Shipley M, Jarrett RJ, Pyorala K, Pyorala M, et al. (1998) High blood glucose concentration is a risk factor for mortality in middle-aged nondiabetic men - 20-year follow-up in the Whitehall Study, the Paris Prospective Study, and the Helsinki Policemen Study. Diabetes Care 21: 360-367.
10. Oswald GA, Smith CCT, Betteridge DJ, Yudkin JS (1986) Determinants and Importance of Stress Hyperglycemia in Nondiabetic Patients with Myocardial-Infarction. Br Med J 293: 917-922.
11. Fava S, Aquilina O, Azzopardi J, Muscat HA, Fenech FF (1996) The prognostic value of blood glucose in diabetic patients with acute myocardial infarction. Diabet Med 13: 80-83.
12. Malmberg K, Norhammar A, Wedel H, Ryden L (1999) Glycometabolic state at admission: Important risk marker of mortality in conventionally treated patients with diabetes mellitus and acute myocardial infarction - Long-term results from the Diabetes and Insulin-Glucose Infusion in Acute Myocardial Infarction (DIGAMI) study. Circulation 99: 2626-2632.

13. Norhammar A, Tenerz A, Nilsson G, Hamsten A, Efendic S, et al. (2002) Glucose metabolism in patients with acute myocardial infarction and no previous diagnosis of diabetes mellitus: a prospective study. Lancet 359: 2140-2144.
14. Trifunovic D, Stankovic S, Sobic-Saranovic D, Marinkovic J, Petrovic M, et al. (2014) Acute insulin resistance in ST-segment elevation myocardial infarction in non-diabetic patients is associated with incomplete myocardial reperfusion and impaired coronary microcirculatory function. Cardiovasc Diabetol 13.
15. Oliver MF, Opie LH (1994) Effects of Glucose and Fatty-Acids on Myocardial-Ischemia and Arrhythmias. Lancet 343: 155-158.
16. Lonborg J, Vejlstrup N, Kelbk H, Nepper-Christensen L, Jorgensen E, et al. (2014) Impact of Acute Hyperglycemia on Myocardial Infarct Size, Area at Risk, and Salvage in Patients with STEMI and the Association With Exenatide Treatment: Results From a Randomized Study. Diabetes 63: 2474-2485.
17. Yang JH, Song PS, Song YB, Hahn JY, Choi SH, et al. (2013) Prognostic value of admission blood glucose level in patients with and without diabetes mellitus who sustain ST segment elevation myocardial infarction complicated by cardiogenic shock. Critical Care 17.
18. Deckers JW, van Domburg RT, Akkerhuis M, Nauta ST (2013) Relation of Admission Glucose Levels, Short- and Long-Term (20-Year) Mortality After Acute Myocardial Infarction. Am J Cardiol 112: 1306-1310.
19. Su G, Mi SH, Tao H, Li Z, Yang HX, et al. (2013) Impact of Admission Glycemic Variability, Glucose, and Glycosylated Hemoglobin on Major Adverse Cardiac Events After Acute Myocardial Infarction. Diabetes Care 36: 1026-1032.
20. Teraguchi I, Imanishi T, Ozaki Y, Tanimoto T, Ueyama M, et al. (2014) Acute-Phase Glucose Fluctuation Is Negatively Correlated With Myocardial Salvage After Acute Myocardial Infarction - Involvement of Monocyte Subsets. Circ J 78: 170-179.