Archives of Anesthesiology and Critical Care (In Press); x(x): xx-xx.

Available online at http://aacc.tums.ac.ir

Research Article

The Impact of Insulin Glargine on Blood Glucose Control during On-Pump Beating Coronary Artery Bypass Surgery in Diabetic Patients: A Single-Blind Randomized Controlled Trial

Raheleh Ganjali[1], Mahdi Kahrom[2], Fatemeh Bijari[3], Masoomeh Tabari[3], Ali Golchoobi Firoozjah[4], Shima Sheybani[3]*

[1]*Clinical Research Development Unit, Imam Reza Hospital, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran.*

[2]*Department of Cardiovascular Surgery, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran.*

[3]*Department of Anesthesiology, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran.*

[4]*Department of Cardiac Intensive Care, Ghaem Hospital, Mashhad University of Medical Sciences, Mashhad, Iran.*

ARTICLE INFO

Article history:
Received 14 July 2025
Revised 04 August 2025
Accepted 18 August 2025

Keywords:
Coronary artery bypass grafting;
Cardiopulmonary pump;
Type 2 diabetes;
Blood glucose level;
Regular insulin

ABSTRACT

Background: Diabetes mellitus in subjects of coronary artery bypass grafting (CABG) surgery is associated with increased morbidity and mortality. Therefore, in recent years, glycemic monitoring and control have been the focus of clinical research. This study aimed to determine the impact of insulin glargine on the management of blood glucose during the perioperative period of on-pump coronary artery bypass graft in diabetic patients.

Methods: In a randomized clinical trial, 80 patients with type 2 diabetes, candidates for elective CABG with a cardiopulmonary pump, were randomly separated into two groups. The intervention group received 0.2 units/kg of insulin glargine 2 hours before induction of anesthesia plus usual care. The control group received usual care. Usual care included injection of regular insulin before, during, and after surgery in accordance with a changed Van den Berghe code. Blood glucose (BG) level, ICU and hospital length of stay (LOS), creatinine, white blood cell count (WBC), and postoperative complications, including infection and dehiscence, were evaluated between two groups.

Results: The BG of patients upon entrance (p=0.04), 16 (p=0.01), 20 (p=0.01), and 24 (p=0.01) hours after admission to the ICU was significantly lower in the intervention than in the control group. There was a significant difference in the average BG levels at different times (p<0.001), so the highest and lowest BG levels were observed 4 and 20 hours after ICU administration in the intervention group and 4 hours and immediately after ICU admission in the control group. Average creatinine (p=0.01), regular insulin used until the end of the first day after surgery (p=0.01), ICU length of stay (LOS) (p=0.009), and hospital LOS (p=0.001) were significantly lower in the intervention group than the controls.

Conclusion: Insulin glargine plus regular insulin is able to maintain BG at a controlled level up to 24 hours after surgery. It also showed significant control over postoperative complications. This study revealed the therapeutic effectiveness of both insulin glargine and regular insulin in achieving adequate BG control for type 2 diabetes patients during the critical postoperative period of on-pump CABG.

The authors declare no conflicts of interest.

*Corresponding author.
E-mail address: sheybanish@mums.ac.ir

DOI:

Introduction

Diabetes is associated with a higher rates of death and disease from coronary artery disease (CAD) than individuals without diabetes [1-2]. WHO has announced a growing trend of diabetes rates and estimated it will be about 360 million by 2030, while 3/4 of cases will be in developing and undeveloped countries [3]. Evidence-based research has confirmed worse outcomes for diabetic patients under medical and invasive treatment strategies than for non-diabetics. Moreover, diabetes-associated metabolic disorders cause progressive and complex atherosclerotic coronary lesions [4-6]. Consequently, diabetes has been introduced as a major risk factor for CAD and is involved in decision-making for treatment approaches and has become a prominent concern for medical health systems.

Coronary artery bypass grafting (CABG) surgery is a CAD revascularization strategy, which is usually performed in two ways, using a cardiopulmonary pump or without a cardiopulmonary pump [7]. The outcome of patients has been compared in different studies to determine which surgical procedure is preferable. Although off-pump may reduce short-term effects such as renal failure and stroke, it may be related to decreased graft durability and a higher likelihood of cardiac re-intervention and mortality. However, on-pump procedures present very low rates of death and disease, yielding highly favorable outcomes [8-10]. CABG is regarded as the preferred revascularization procedure in diabetic cases of complex CAD [11]. Almost 30–50% of CABG patients have diabetes mellitus or metabolic syndrome, presenting worse outcomes following CABG [12-13], including a higher rate of recurrence, redo revascularization, readmission for cardiac and non-cardiac issues, mortality, renal failure, stroke, and sternal wound infections. These patients need more inotropic support and longer hospitalization, causing increased financial issues for the health system [14-16]. Therefore, managing blood glucose levels in diabetic patients receiving CABG surgery helps improve outcomes and reduces postoperative complications, causing better short-term and long-term survival and lowering recurrent events [17-19]. The guidelines of Society of Thoracic Surgeons (STS) suggest maintaining perioperative blood glucose (BG) below 180 mg/dl. Some centers consider sugar less than 150 mg/dl [20]. Insulin glargine (Lantus) is a recombinant human insulin analog, a long-acting insulin form used to treat type 1 and type 2 diabetes mellitus. Insulin glargine does not have a specific maximum effect, and this characteristic causes the risk of low BG to diminish. Following subcutaneous injection of Glargine insulin, its absorption is slower and longer than Isophane (Neutral Protamine Hagedorn) insulin, with an action onset of 1.5-3 hours and a time effect of 24 hours [21-22]. As a considerable proportion of patients undergoing CABG have diabetes and represent a considerably worse prognosis, considering treatment plans for BG control in these patients is a necessary component.

Objectives

This clinical trial was designed to investigate the impact of insulin glargine in combination with continued regular insulin for managing BG levels and complications around on-pump CABG surgery for patients with type 2 diabetes compared to using regular insulin as the routine method.

Methods

Study design

A randomized, single-blinded trial controlled with two parallel groups was designed between September 2019 and September 2020. The study was conducted in Ghaem Teaching Hospital of Mashhad University of Medical Sciences, Khorasan Razavi province, northeastern Iran. This randomized trial received approval from the Ethics Committee of Mashhad University of Medical Sciences, Mashhad, Iran (IR.MUMS.MEDICAL.REC.1399.076), and was recorded in the Iranian Registry of Clinical Trials.

Participants

Ninety-one patients with type 2 diabetes presented to Ghaem Teaching Hospital of Mashhad University of Medical Sciences who were candidates for elective coronary bypass surgery with a cardiopulmonary pump were screened for eligibility. Eligible patients signed up for the written informed consent after an oral explanation and studied it. The informed consent contained all information about the trial. Finally, eighty patients fulfilling the inclusion criteria participated in and completed the study.

The inclusion criteria included the following:

1. Patients with type 2 diabetes
2. Patients aged 35–75,
3. Patients who are candidates for on-pump CABG, and
4. Patients who are classified in ASA physical status II

The exclusion requirements were:

1. Patients with BG>300 mg/dl or <150 mg/dl on the surgery day
2. Patients with a past heart surgery, on-pump CABG, cardiac valve disorder, trauma, fever, or renal or thyroid or gastrointestinal disease or
3. Patients with allergic reactions to glargine

The flowchart of the patient's selection (CONSORT flow diagram) is illustrated in (Figure 1).

Randomization and Allocation

In this study, the eighty patients were separated into two parallel groups according to simple randomization. The allocation of patients to intervention and control groups was through the PASS-generated random allocation list by an independent researcher. The allocation ratio of intervention to control was 1:1. Allocation concealment was done by sealed envelope. The study was single-blind, as the patients were unaware of the intervention and control groups.

Intervention

At enrollment, patients were either randomized to receive a single dose of glargine or usual care. The intervention group was administered 0.2 units/kg of insulin glargine (Lantus SoloStar 100 units/ml, manufactured by Elixir Pharmaceutical Company, Iran) subcutaneously 2 hours prior to anesthesia induction, in addition to usual care. The control group received only usual care. Usual care included to provide regular insulin (LANSULIN R VIAL 100 IU/ml, Exir Pharma Co., Iran before, during, and after surgery (in accordance with a changed Van den Berghe code established in the Department of Heart Surgery, Ghaem Hospital). According to this protocol,

1. Before operation, if the patient's BG level was ≥150 mg/dl, 2 units of regular insulin were administered intravenously for every additional 50 mg/dl rise in BG.
2. During operation, the necessary dose of regular insulin was determined using the formula: (patient's BG / 150).
3. Post-operative in intensive care unit (ICU); at the first patient's BG minus 140, and then for each 40-unit increase in BG, 4 units of regular insulin were injected intravenously.

BG levels were recorded before, 2 hours after, and at the end of the operation.

After surgery, changes in BG levels in the ICU were assessed at 4-hour intervals for 24 hours. All patients received ICU care in two groups with up to 24 hours of monitoring. The goal was BS = 120-180 mg/dl at all times.

Outcomes

Baseline Characteristics of participants were collected that included sociodemographic data (age and gender) and data on diabetes (duration of use of oral hypoglycemic agents, hemoglobin A1C (HbA1c), diabetes duration, and diabetes complications), graft number, ejection fraction percentage, glomerular filtration rate (GFR), and duration of surgery. The primary outcome of the study was BG level during the first 24 hours after surgery between two groups. Secondary outcomes included differences between two groups in injection of regular insulin during surgery and first-day stay in ICU.

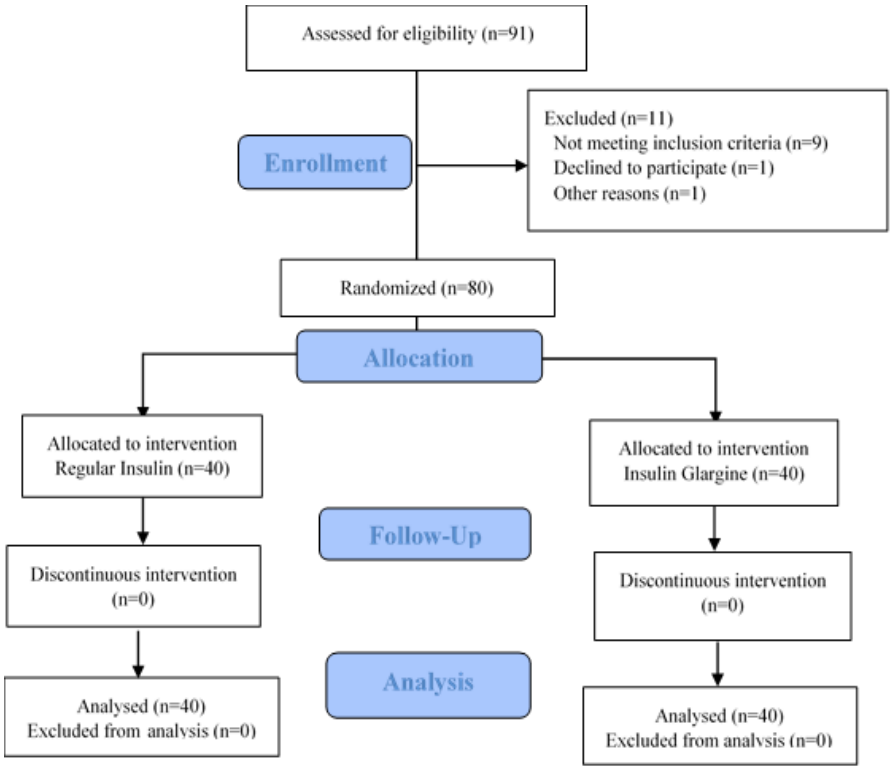

Figure 1- CONSORT diagram

In addition, information was collected on the total dose of regular insulin in the ICU on the first day, ICU and hospital length of stay (LOS), creatinine, and white blood cell count (WBC). In addition, information was collected on the total dose of regular insulin, white blood cell count (WBC), and creatinine in the ICU on the first day; hospital and ICU length of stay; and postoperative complications, including infection and dehiscence.

Sample size and statistical methods

Based on the prior research [23], the calculation of the sample size was determined with careful consideration to obtain a statistical power of 80% and using a significance level of 0.05 for a two-tailed test. The objective was to identify a meaningful difference in mean BG levels between the control and intervention groups. It was recommended that each group should consist of 35 patients to achieve this statistical power. Additionally, accounting for a 15% dropout rate anticipated during the course of the study, the decision was made to include a total of 40 patients for each group. Totally, eighty diabetic patients participated in this randomized clinical trial. The sample size was estimated using the commercial software package (PASS). The statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS), version 23, IBM. Data were displayed as means (±standard deviation) or counts (percentages). The Kolmogorov–Smirnov test was employed to evaluate the normal distribution of variables. For quantitative data, comparisons between the two groups were made using either the Mann–Whitney test or the independent t-test. We analyzed categorical variables with χ^2 tests or, when appropriate, Fisher's exact tests. The Friedman test was used for comparison of BG levels within each group. A $P<0.05$ was considered significant. A regression analysis was performed to adjust for potential confounding from variables that showed significant baseline differences between the groups.

Results

The study population's demographic and clinical characteristics are outlined in (Table 1). The average age among patients in the intervention group was 59± 4 years, and in the control group, it was 58± 7 years (p=0.8). The intervention group included 25 men (62.5%), while the control group included 23 men (57.5%) (p = 0.4). Most of the patients used metformin (97%) (p=0.18) and glibenclamide (53%) (p=0.37) as oral hypoglycemic agents. All of the patients, 30 (75%) in the control group and 32 (80%) in the intervention group, had hypertension (p=0.31). As shown in Table 1, HbA1c (p=0.45), creatinine before surgery (p=0.42), GFR (p=0.78), duration of use of oral hypoglycemic agents (p=0.69), duration of diabetes (p=0.20), graft number (p=0.37), and BMI (p = 0.09) did not differ significantly between the two groups. The duration of surgery was 183 (176.8, 225) minutes in the intervention group and 226.5 (183, 240) minutes in the control group, and a significant difference existed between the two groups (p = 0.01).

Since the main outcome of the study was the BG level, which was not a statistically significant difference in the baseline in the two groups (Table 2), further analysis rejected the confounding effect variables, ejection fraction percentage (p=0.01), and duration of surgery (p=0.05), which were significantly different in the baseline among two groups.

The randomization method is made to control other variables at baseline. Furthermore, when a special cardiac surgeon performed the surgery and similarly prescribed medications based on patient weight, the effects of confounding factors were reduced in both groups.

Between the groups

The average fasting blood sugar (FBS) on the day of surgery (p=0.1), before induction of anesthesia (p=0.4), and 2 hours after induction of anesthesia (p=0.4) was not significantly different between the two groups. During the operation, the intervention group received less regular insulin compared to the control group; however, this difference was not statistically significant (p = 0.5) (Table 2). (Table 3) showed that the BG level of the patients immediately after ICU admission (p=0.04) and 16 (p=0.01), 20 (p=0.01), and 24 (p=0.01) hours after ICU admission in two groups. Although BG levels were significantly reduced in the intervention group compared to the control group, no significant differences were observed at the remaining monitored times during ICU hospitalization($p>0.05$). The median of consumed regular insulin during the ICU's first day in the intervention and control groups was 11 (8, 11) and 24.5 (21, 41.8), respectively, which showed a significant difference among two groups (P=0.01). The median of creatinine (p=0.01), the ICU LOS (p=0.009), and the hospital LOS (p=0.001) in the intervention group was significantly lower than the control group (Table 4). The mean of white blood cells (WBC) was not significantly different between the two groups (P=0.1). Besides, no in-hospital mortality was observed in the studied groups. Post-operative complications, including infection (p=0.1) and dehiscence (p=0.3), in the patients of the studied groups had no statistically significant difference.

Within the groups

There was a significant difference between the average BG levels at different time points in the intervention group ($p<0.001$) and control group (p=0.002). The highest BG level was observed 4 hours after ICU admission in both groups. The lowest BG levels were observed immediately and 20 hours after ICU admission in the control and intervention groups, respectively (Figure 2).

Table 1- The study population characteristics

Characteristics			Control	Intervention	P value
Age [Median (25-75 quartiles)]			60.0(58.0,63.8)	61.0(55.0,63.8)	0.82*
Sex [N(%)]		Male	23 (57.5%)	25 (62.5%)	0.42**
		Female	17 (42.5%)	15 (37.5%)	
BMI [Mean ±SD]			26.5 ±4	27.8 ±2.5	0.09***
Hypertension [N(%)]		Yes	30 (75%)	32 (80%)	0.31**
		No	10 (25%)	8 (20%)	
Anti-diabetic agents [N (%)]	Metformin	Yes	37 (94.9%)	40 (100%)	0.18**
		No	2 (5.1%)	0 (0.0%)	
	Glibenclamide	Yes	20 (51.3%)	23 (57.5%)	0.37**
		No	19 (48.7%)	17 (42.5%)	
	Empagliflozin/Metformin	Yes	1 (2.6%)	0 (0.0%)	0.39**
		No	38 (97.4%)	40 (100%)	
Graft number [Median (25-75 quartiles)]			3 (2,3)	3 (2,3)	0.37*
Ejection Fraction Percentage [Median (25-75 quartiles)]			45 (40,55)	40(35,45)	0.01*
Duration of surgery (minutes) [Median (25-75 quartiles)]			226.5(183,240)	183 (176.8,225)	0.04*
Duration of diabetes (years) [Median (25-75 quartiles)]			8 (5,11.5)	8 (4,10)	0.20*
Duration of use of oral hypoglycemic agents (years) [Median (25-75 quartiles)]			6.5(4.8,10)	8.0(4.0,10)	0.69*
Glomerular Filtration Rate (cc/min) [Median (25-75 quartiles)]			70.8(59.8,76.7)	62.2(53.5,92.0)	0.78*
Creatinine (mg/dl) (before surgery) [Median (25-75 quartiles)]			1.1(0.9,1.2)	1.0(1.0,1.4)	0.42*
HbA1c [Median (25-75 quartiles)]			8.2(6.8, 8.8)	8.1(6.7, 8.2)	0.45*

Notes: Values are represented as mean ±SD or N (%). ** Chi-Square Test * Mann-Whitney Test *** Independent T-Test. P<0.05 is statistically significant. BMI = Body Master Index. HbA1c = hemoglobin A1C

Table 2- BG levels before and after induction of anesthesia in intervention and control groups

Characteristics	Control [Median (25-75 quartiles)]	Intervention [Median (25-75 quartiles)]	P value
FBS on the day of operation (mg/dl)	165(150.3,202)	211(150.8,218)	0.14*
BG before induction of anesthesia (mg/dl)	168.5(150,248.5)	182(147.8,209)	0.47*
BG 2 hours after induction of anesthesia (mg/dl)	193.0(162,226.5)	203(164,253)	0.49*
Regular insulin consumed until the end of the operation (unit)	3.0(2.0,7.0)	3.0(2.0,4.0)	0.51 *

Notes: Values are represented as mean ±SD. * Mann-Whitney. P<0.05 statistically significant. FBS = fasting blood sugar; BG= blood glucose

Table 3- Changes in Blood Glucose (mg/dl) during ICU in intervention and control groups

Characteristics	Control [Median (25-75 quartiles)]	Intervention [Median (25-75 quartiles)]	P value
0 hour	203.5(185.8, 247)	196(184, 211)	0.041*
4 hour	250.5(227.5, 275.3)	237(220.3, 245)	0.21*
8 hour	222.5(199.3, 255)	259(213, 259)	0.06 *
12 hour	215.5(177.8, 252.5)	207(160.8, 219)	0.05 *
16 hour	214(185, 249.3)	186(160, 195)	<0.001 *
20 hour	203(189, 265.8)	167(167, 189.8)	<0.001 *
24 hour	207(183, 260)	182(177, 182)	<0.001 *

Notes: Values are represented as mean ±SD. * Mann-Whitney Test. P<0.05 statistically significant. ICU = Intensive Care Unit

Table 4- Comparison of the investigated variables on the first postoperative day in the ICU

Characteristics	Control [Median (25-75 quartiles)]	Intervention [Median (25-75 quartiles)]	P value
Regular insulin at the end of the first day in ICU	24.5(21, 41.8)	11(8, 11)	0.01*

LOS in ICU (hours)	51.5(46.0,72.0)	47.0(47.0,47.0)	0.009*
LOS in Hospital (days)	9(7,9.8)	6(6,9)	0.001*
WBC	13400(11400,17275)	12500(12200,13900)	0.13 *
Creatinine	1.1(0.8,1.3)	0.8(0.8,1.1)	0.01*

Notes: Values are represented as mean±SD. * Mann-Whitney Test. P<0.05 statistically significant. ICU = Intensive Care Unit; LOS =Length of Stay; WBC = White Blood Cell Count

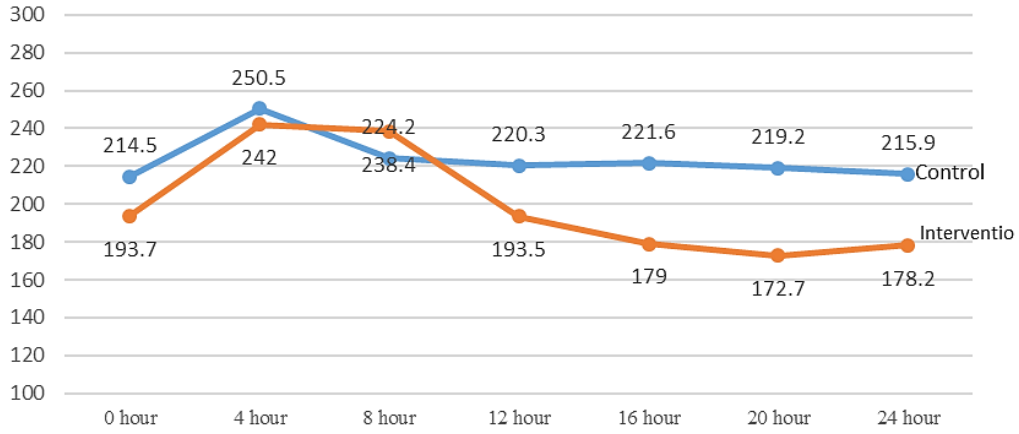

Figure 2- The trend of changes in BG during ICU

Discussion

The difference that after 8 hours of ICU admission, the intervention group showed a more downward course of BG up to 24 hours. Insulin glargine, a human insulin analog, is formulated for high solubility at pH 4 but low solubility at neutral pH. Upon subcutaneous injection, the acidic solution is neutralized, resulting in the formation of insulin micro-deposits. These deposits provide a slow, continuous release, yielding a peak less, steady concentration-time profile over 24 hours, thus enabling basal glucose control with a single daily dose [24].

In this study, the regular insulin units injected at the end of the first day after surgery, the ICU LOS, and the in-hospital LOS were significantly lower in the intervention group than the control group. In this regard, a study investigated the effect of insulin glargine on BG control in patients hospitalized in intensive care units and showed that the average BG level in the glargine group was significantly lower than in the control group. Although the mortality rate was similar in the two groups, the ICU LOS was two days shorter in the Glargine group [25]. These data support that the addition of insulin glargine to routine protocols is a more effective strategy for lowering circulating BG concentrations.

This approach not only reduces the frequency of hyperglycemic events but also minimizes the patient requirement for corrective doses of regular insulin. This setting is associated with reducing ICU LOS but may increase hypoglycemic events. Critically, the study demonstrated a favorable safety profile, as severe hypoglycemic events were not observed among the participants.

The present study showed that better BG control was associated with very few postoperative complications. In line with this finding, a study with subcutaneous injection of Glargine 2 hours before surgery (1 unit/kg) compared to normal saline showed that Glargine effectively controls BG levels in diabetic patients, and its control significantly affects postoperative complications [23]. Elevated postoperative blood glucose (BG) significantly increases the risk of infection across both diabetic and non-diabetic patients, with a higher BG concentration correlating directly to greater infection potential [26]. Notably, continuous intravenous insulin infusion following cardiac surgery in diabetic patients has been demonstrated to mitigate the risk of deep sternal wound infection and decrease patient mortality [27]. In line with these reports, the results of the present study revealed no complications in any of the intervention group patients. In the control group, only two patients had an infection, and one had a dehiscence. However, contrary to these results, in another study, a combination of regular insulin injection and insulin glargine improved BG control in patients with diabetes undergoing CABG but did not significantly reduce postoperative complications [28].

The present study can pave the way for further studies regarding the knowledge of the effects of insulin glargine on controlling hyperglycemia in patients with type 2 diabetes undergoing coronary artery bypass grafting with a cardiopulmonary pump.

Also, these findings can be used to find a suitable method and provide better instruction for glycemic control and complication reduction in diabetic cases who underwent coronary bypass surgery. Although this study was novel and unique, it also had limitations. Since there

were few studies in this field, it was impossible to compare this study's results with other similar studies accurately. In this investigation, the rationality of the sample size is demonstrated to bolster the confidence level of the findings; nevertheless, it is imperative to carry out a multicenter study with an expanded sample size prior to extrapolating the outcomes.

Conclusion

This clinical trial showed the greater effectiveness of the insulin glargine treatment method compared to regular insulin in controlling BG in patients with type 2 diabetes undergoing CABG with a cardiopulmonary pump.

Also, the results showed that despite the injection of more insulin in the control group, the BG level was significantly lower in the intervention group than in the control group, which probably indicates the synergistic effect of regular insulin and glargine in the body. However, more extensive studies are necessary to generalize the results.

Abbreviations

CAD = Coronary Artery Disease
CABG = Coronary Artery Bypass Grafting
STS= Society of Thoracic Surgeons
BG= Blood Glucose
ICU = Intensive Care Unit
HbA1c =Hemoglobin A1c
GFR= Glomerular Filtration Rate
LOS =Length of Stay
WBC = White Blood Cell Count
SPSS = Statistical Package for The Social Sciences
FBS = Fasting Blood Sugar
pH = Power of Hydrogen

Acknowledgment

The authors gratefully acknowledge the support and assistance provided by the Clinical Research Development Unit at Imam Reza Hospital, Faculty of Medicine, Mashhad University of Medical Sciences (Mashhad, Iran) during the execution and preparation of this project.

Funding

This study was supported by Research Council of Mashhad University of Medical Sciences, Mashhad, Iran (Code: 980566), and this body took full responsibility for the financing of the project. The results of the present study are part of thesis of Fatemeh Bijari.

Ethical Approval

This research was approved by the ethics committee of Mashhad University of Medical Sciences with the ethical code IR.MUMS.MEDICAL.REC.1399.076, all the study steps were carried out according to ethical protocols.

Informed consent

Written informed consent was obtained from all individual participants included in the study.

References

[1] Norhammar A, Malmberg K, Diderholm E, Lagerqvist B, Lindahl B, Rydén L, et al. Diabetes mellitus: the major risk factor in unstable coronary artery disease even after consideration of the extent of coronary artery disease and benefits of revascularization. J Am Coll Cardiol. 2004;43(4):585-91.

[2] Bax JJ, Young LH, Frye RL, Bonow RO, Steinberg HO, Barrett EJ. Screening for coronary artery disease in patients with diabetes. Diabetes care. 2007;30(10):2729-36.

[3] Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. Diabetes care. 2004;27(5):1047-53.

[4] Glovaci D, Fan W, Wong ND. Epidemiology of diabetes mellitus and cardiovascular disease. Curr Cardiol Rep. 2019;21(4):1-8.

[5] Ouattara A, Lecomte P, Le Manach Y, Landi M, Jacqueminet S, Platonov I, et al. Poor intraoperative blood glucose control is associated with a worsened hospital outcome after cardiac surgery in diabetic patients. Anesthesiology. 2005;103(4):687-94.

[6] Zhang X, Wu Z, Peng X, Wu A, Yue Y, Martin J, et al. Prognosis of Diabetic Patients Undergoing Coronary Artery Bypass Surgery Compared With Nondiabetics: A Systematic Review and Meta–analysis. Journal Cardiothorac Vasc Anesth. 2011;25(2):288-98.

[7] Shroyer AL, Grover FL, Hattler B, Collins JF, McDonald GO, Kozora E, et al. On-pump versus off-pump coronary-artery bypass surgery. N Engl J Med. 2009;361(19):1827-37.

[8] Lamy A, Devereaux P, Prabhakaran D, Taggart DP, Hu S, Paolasso E, et al. Off-pump or on-pump coronary-artery bypass grafting at 30 days. N Engl J Med. 2012;366(16):1489-97.

[9] Lamy A, Devereaux P, Prabhakaran D, Taggart DP, Hu S, Straka Z, et al. Five-year outcomes after off-pump or on-pump coronary-artery bypass grafting. N Engl J Med. 2016;375(24):2359-68.

[10] Huang K-C, Wu I-H, Chou N-K, Yang Y-Y, Lin L-C, Yu H-Y, et al. Late outcomes of off-pump versus on-pump coronary bypass in patients with diabetes:

a nationwide study from Taiwan. J Thorac Cardiovasc Surg. 2019;157(3):960-9. e2.
[11] Godoy LC, Ko DT, Rao V, Farkouh ME. The role of coronary artery bypass surgery versus percutaneous intervention in patients with diabetes and coronary artery disease. Prog Cardiovasc Dis. 2019;62(4):358-63.
[12] Raza S, Sabik JF 3rd, Ainkaran P, Blackstone EH. Coronary artery bypass grafting in diabetics: A growing health care cost crisis. J Thorac Cardiovasc Surg. 2015;150(2):304-2.e2.
[13] Santos KAQ, Berto B, Sousa AG, Costa FAAd. Prognosis and complications of diabetic patients undergoing isolated coronary artery bypass surgery. Braz J CardiovascSurg. 2016; 31:07-14.
[14] Kogan A, Ram E, Levin S, Fisman EZ, Tenenbaum A, Raanani E, et al. Impact of type 2 diabetes mellitus on short-and long-term mortality after coronary artery bypass surgery. Cardiovasc Diabetol. 2018;17(1):1-8.
[15] Jones KW, Cain AS, Mitchell JH, Millar RC, Rimmasch HL, French TK, et al. Hyperglycemia predicts mortality after CABG: postoperative hyperglycemia predicts dramatic increases in mortality after coronary artery bypass graft surgery. J Diabetes Complicat. 2008;22(6):365-70.
[16] Szabó Z, Håkanson E, Svedjeholm R. Early postoperative outcome and medium-term survival in 540 diabetic and 2239 nondiabetic patients undergoing coronary artery bypass grafting. Ann Thorac Surg. 2002;74(3):712-9.
[17] Lazar HL, Chipkin SR, Fitzgerald CA, Bao Y, Cabral H, Apstein CS. Tight glycemic control in diabetic coronary artery bypass graft patients improves perioperative outcomes and decreases recurrent ischemic events. Circulation. 2004;109(12):1497-502.
[18] Robich MP, Iribarne A, Leavitt BJ, Malenka DJ, Quinn RD, Olmstead EM, et al. Intensity of glycemic control affects long-term survival after coronary artery bypass graft surgery. Ann Thorac Surg. 2019;107(2):477-84.
[19] Strahan S, Harvey RM, Campbell-Lloyd A, Beller E, Mundy J, Shah P. Diabetic control and coronary artery bypass: effect on short-term outcomes. Asian Cardiovasc Thorac Ann. 2013;21(3):281-7.
[20] Lazar HL, McDonnell M, Chipkin SR, Furnary AP, Engelman RM, Sadhu AR, et al. The Society of Thoracic Surgeons practice guideline series: blood glucose management during adult cardiac surgery. Ann Thorac Surg. 2009;87(2):663-9.
[21] Hirsch IB. Insulin analogues. N Engl J Med. 2005;352(2):174-83.
[22] Heinemann L, Linkeschova R, Rave K, Hompesch B, Sedlak M, Heise T. Time-action profile of the long-acting insulin analog insulin glargine (HOE901) in comparison with those of NPH insulin and placebo. Diabetes Care. 2000;23(5):644-9.
[23] Gandhi H, Sarvaia A, Malhotra A, Acharya H, Shah K, Rajavat J. Effects of glargine insulin on glycemic control in patients with diabetes mellitus type II undergoing off-pump coronary artery bypass graft. Ann Card Anaesth. 2018;21(2):167.
[24] Yeldandi RR, Lurie A, Baldwin D. Comparison of once-daily glargine insulin with twice-daily NPH/regular insulin for control of hyperglycemia in inpatients after cardiovascular surgery. Diabetes Technol Ther. 2006;8(6):609-16.
[25] Nader ND, Hamishehkar H, Naghizadeh A, Shadvar K, Iranpour A, Sanaie S, et al. Effect of adding insulin glargine on glycemic control in critically Ill patients admitted to intensive care units: a prospective randomized controlled study. Diabetes, Metab Syndr.2020;13:671.
[26] Latham R, Lancaster AD, Covington JF, Pirolo JS, Thomas CS. The association of diabetes and glucose control with surgical-site infections among cardiothoracic surgery patients. Infect Control Hosp Epidemiol. 2001;22(10):607-12.
[27] Furnary AP, Zerr KJ, Grunkemeier GL, Starr A. Continuous intravenous insulin infusion reduces the incidence of deep sternal wound infection in diabetic patients after cardiac surgical procedures. Ann Thorac Surg. 1999;67(2):352-60.
[28] Seyed Khalil F, Seyed Mohammad M, Seyed Jalil M, Seyed Hossain M, Habibbolla H, Seyed Ali B, et al. Comparing effects of continuous insulin infusion with or without subcutaneous glargine insulin on glycemic control in diabetic patients undergoing coronary artery bypass graft [CABG]. 2010.