Research article

The effect of intraoperative glycemic control on surgical site infections among diabetic patients undergoing coronary artery bypass graft (CABG) surgery

Issa M. Hweidi [a,*], Ala M. Zytoon [a], Audai A. Hayajneh [a], Salwa M. Al Obeisat [b], Aysam I. Hweidi [c]

[a] Faculty of Nursing, Adult Health Nursing Department, Jordan University of Science and Technology, P. O. Box 3030, Irbid 22110, Jordan
[b] Faculty of Nursing, Maternal-Child Health Nursing Department, Jordan University of Science and Technology, P. O. Box 3030, Irbid 22110, Jordan
[c] Faculty of Medicine, Jordan University of Science and Technology, PO Box 3030, Irbid 22110, Jordan

ARTICLE INFO

ABSTRACT

Objective: Perioperative poor glycemic control in diabetic patients undergoing Coronary Artery Bypass Graft (CABG) surgery has been associated with infectious complications, particularly surgical site infections that are linked with adverse health surgical outcomes. The purpose of this study was to investigate the effect of two different intraoperative glycemic control protocol, tight and conventional, on thirty-day postoperative surgical site infection (SSI) rates among diabetic patients undergoing CABG surgery.
Design: A randomized controlled trial (RCT) design was employed in the study, with a convenience sample of 144 adult patients who were scheduled to undergo coronary artery bypass grafting surgery.
Setting: A main referral heart institute in Amman, Jordan.
Participants: Subjects were randomly assigned to either the tight glycemic control group (n = 72), which maintained an intraoperative blood glucose level of 110–149 mg/dl via continuous intravenous insulin infusion, or the conventional glycemic control group (n = 72), which maintained an intraoperative blood glucose level of 150–180 mg/dl via continuous intravenous insulin infusion. The postoperative SSIs among both groups were evaluated and compared by independent blinded physicians.
Results: The primary findings of this study indicated no statistically significant difference between the two treatment groups in terms of SSI rates and their potential adverse surgical outcomes (p = 0.512).
Conclusion: Nurses should consider the glycemic stability and glycemic control approach to minimize adverse surgical outcomes post CABG surgery. Healthcare providers should also carefully consider diabetic patients who have undergone CABG surgery and are at risk of developing postoperative SSIs.
Clinicaltrials.gov identifier: NCT04451655 was retrospectively registered in 30/06/2020.

1. Introduction

Hyperglycemia is a condition that occurs when the blood glucose level is > 140 mg/dL in patients with Diabetes Mellitus (DM) [1]. Hyperglycemia is a common occurrence in Coronary Artery Bypass Graft (CABG) surgery patients, affecting approximately 93% of diabetic and 83% of nondiabetic CABG surgery patients [2]. Hyperglycemia has been shown to have negative impacts during the preoperative, intraoperative, and postoperative periods and to lead to increased incidence of postoperative infections, prolonged intensive care unit (ICU) and hospital lengths of stay, and increased rates of morbidity and mortality after CABG surgery [3, 4, 5, 6, 7, 8].

Diabetes Mellitus (DM) in patients undergoing cardiac surgery is identified as an independent risk factor associated with surgical site infections (SSIs) after cardiac surgery that has been operationally defined as an infection that arises after CABG surgery. It may only affect the superficial layers of an incision or may extend into deeper tissues that were handled during the CABG surgery [9, 10, 11, 12, 13, 14, 15]. Previous studies have suggested a link between poor glycemic control and adverse outcomes in diabetic patients undergoing CABG surgery, including increased SSI rates [16, 17, 18]. Some studies have shown the estimated prevalence of diabetes among patients undergoing CABG surgery to be 20.1–48% [19, 20, 21, 22]; meanwhile, in Jordan, higher rates of 53–57% have been reported [23, 24].

---

* Corresponding author.
  E-mail address: hweidi@just.edu.jo (I.M. Hweidi).

Glycemic control for diabetic patients undergoing cardiac surgery is essential for improving clinical outcomes, including infectious complications. Several studies have demonstrated the use of intravenous continuous insulin infusion (CII) to be useful as a standard of care for preventing hyperglycemia without causing hypoglycemia [25, 26, 27]. Multiple CII protocols have been published and many modifications have been made in line with the results of scientific research. Studies have provided significant evidence for the role of tight glycemic control in patients undergoing cardiac surgery in improving patients' clinical outcomes and reducing infections, morbidity, and mortality [26, 28, 29, 30, 31, 32].

However, other studies have challenged these findings and have shown tight glycemic control to lead to no improvement in clinical outcomes, or possibly even to worse outcomes, for patients undergoing cardiac surgery [33, 34, 35]. Recent studies have also reported similar results, indicating that tight glycemic control leads to no improvements in patients' clinical outcomes. Moreover, the conventional protocol has been shown to be more effective in controlling blood sugar and maintaining it within the normal range, therefore reducing the incidence of hypoglycemia [2, 36].

The evidence in the literature regarding the optimal range of blood glucose levels for improving clinical outcomes in diabetic patients undergoing cardiac surgery is contradictory. Therefore, there is a need for further scientific studies which implement robust designs to investigate the role of intraoperative tight and conventional glycemic control in improving postoperative clinical outcomes, particularly SSIs. Thus, the current study aimed to compare the effect of two different intraoperative glycemic control interventions, tight and conventional, on thirty-day postoperative SSI rates among Jordanian diabetic patients undergoing CABG surgery.

2. Methods

2.1. Design and sample

A randomized controlled trial (RCT) was implemented in the present study. The target population was all Jordanian patients with DM undergoing cardiac surgery. The accessible population of interest for this study included participants with intraoperative glycemic control conditions and was recruited from a main cardiac institute located in the Central Region in Jordan. The selected institute deals with most (around 50%) cardiac-related disorders, including cardiac surgery. The operating room where the study was conducted is staffed with a specialized operating cadre, including the cardiothoracic surgeons and one endocrinologist who supervised and monitored the implementation of the two interventional approaches of Portland protocol on behalf of all participants in both interventional groups. The sample size was calculated using G*Power analysis, with power = 0.80, level of significance of α = 0.05, and a medium effect size = 0.30. The minimum sample size required for each of the control groups was 64 patients, and an additional 10% of the total required sample was recruited to account for any possible dropouts. Thus, a total of 144 patients participated in the study. The participants were randomly assigned to the two treatment groups through computer-generated randomization. According to the Portland glycemic control protocol, two treatment groups were selected: a tight glycemic control group (maintaining blood glucose level from 110 to 149 mg/dl via CII throughout the intraoperative period) and a conventional glycemic control group (maintaining blood glucose level from 150 to 180 mg/dl via continuous intravenous insulin infusion throughout the intra-operative period). The Portland Protocol is a tight perioperative glucose control regimen using continuous insulin infusion in diabetic patients undergoing open heart surgery. In addition, researchers were very conservative in the implementation of the protocol parameters to control for confounding variables. The study had two groups of glycemic control interventions where two different levels of insulin infusion used as per to the strict guidelines of Portland Protocol for Continuous IV Insulin

Infusion that makes the study a clinical trial. Portland protocol is a widely used in acute care settings in western countries [26]. The eligibility criteria were Arabic-speaking adult Jordanian patients with DM who had undergone elective or urgent CABG surgery with or without cardiopulmonary bypass (CPB) as well as they were diagnosed with diabetes for at least 10 years. Subjects who were immunosuppressed were excluded from the study.

2.2. Data collection procedure

Data were collected from September 1 to November 30, 2018. Demographical data, including age, gender, height, weight, and body mass index (BMI), were collected at the baseline, during the preoperative phase. Historical medical data, including preoperative diabetic control, smoking status, comorbidities, and prior cardiac surgery, were collected during the preoperative phase. Further, surgical clinical data were collected on the day of the surgery and included number of previous CABG surgeries, number and type of harvest site grafts (anastomoses), CPB and CPB time, cross-clamp time, surgery time, the intra-aortic balloon pump (IABP) used, and IABP time. Finally, data on the clinical outcomes regarding the presence or absence of superficial and/or deep surgical site infections (SSIs) were collected throughout the 30-day period post-surgery. The SSI incidence rates among both groups were measured four times: during ICU stay time, at hospital discharge time, one-week post-hospital discharge, and 30 days post-hospital discharge.

On the day of surgery, the principal researcher collected data on routine lab diagnostic tests and lab diagnostic tests specific to the current study and documented the results in the study worksheet. Intraoperative blood glucose levels were measured every 30 min using the Accu-Chek Active glucometer with arterial line blood samples. The Accu-Chek Active glucometer was also used to measure blood glucose levels every 30 min after the patients were transferred to the ICU, and the results were documented by the ICU nurses in the ICU study worksheet. All members of the cardiac team were blinded to the intraoperative intervention that the patients received, and blinded cardiac surgeons, who were part of the cardiac surgical team, performed wound infection assessment.

The patient is given general anesthesia. This ensures that they will be asleep and pain free through the whole surgery. Prophylactic routine antibiotics were given to the participants.

The surgical technique begins with making around 10-inch cut in the chest by the surgeon. Then, a part or all the breastbone is cut to uncover the heart. Once the heart is exposed by the surgeon, a heart-lung bypass machine is connected to the patient to keep blood pass away and allow the surgeon to operate the CABG surgery. Then, a healthy vein or artery might be used to pass around the blocked artery. Eventually, the breastbone is closed by wire and the skin incision is stitched up by the surgeon.

2.3. Methods of data analysis

Means and standard deviations were used to describe the continuous variables, such as age and body mass index. Frequencies and percentages were used to describe the categorically measured variables, such as patient's sex and insulin treatment types. The independent groups t-test was used to assess the differences between the measured variables. Levene's test of equal variance and histograms were used to assess the continuous variables for homogeneity of variance and normality, respectively. The Mann-Whitney (U) non-parametric test was used to assess differences in the patients' levels of surgical site infections based on the mean measured continuous variables, as there were distributional differences in the measured metric variables across SSI levels. Point estimates were computed using the Statistical Package for the Social Sciences (SPSS) program, and Agresti-Coull adjusted 95% confidence interval was computed using the MedCalc software package, version 3.2.1. The SPSS software version 25 (SPSS, Inc, Chicago, Ill) was used for data analysis. The alpha significance level was set to 0.05 throughout the analysis.

Table 1. The patients demographic and health characteristics. N = 144.

	Insulin Treatment		Test statistic	p-value
	Conventional n = 72	Tight n = 72		
Sex				
Male	64 (88.9%)	66 (91.7%)	$\chi2 (1) = 0.32$	0.574
Female	8 (11.1%)	6 (8.3%)		
Age (years), mean (SD)	60.1 (9.7)	59.2 (8.9)	$t (142) = 0.50$	0.589
43–54 Years	22 (30.6%)	24 (33.3%)	$\chi2 (2) = 0.34$	0.846
55–64 Years	29 (40.3%)	30 (41.7%)		
65–74 Years or older	21 (29.2%)	28 (25%)		
BMI Score, mean (SD)	28.30 (4.1)	28.6 (4.5)	$t (142) = 0.50$	0.616
Normal Weight: Height	16 (22.2%)	23 (31.9%)	$\chi2 (3) = 5.2$	0.16
Over-weight	35 (48.6%)	22 (30.6%)		
Class I obese	16 (22.2%)	19 (26.4%)		
Class II obese	5 (6.9%)	8 (11.1%)		
Preoperative Diabetes Management				
T2_Oral_Agent	46 (63.9%)	48 (66.7%)	$\chi2 (2) = 0.36$	0.834
T2_Insulin_Only	21 (29.2%)	18 (25%)		
T2_Oral_agent_&_Insulin	5 (6.9%)	6 (8.3%)		
Smoking				
No	30 (41.7%)	25 (34.7%)	$\chi2 (1) = 0.74$	0.391
Yes	42 (58.3%)	47 (65.3%)		
Previous MI				
No	48 (66.7%)	47 (65.3%)	$\chi2 (1) = 0.03$	0.56
Yes	24 (33.3%)	25 (34.7%)		
Previous PVD				
No	63 (87.5%)	64 (88. %)	$\chi2 (1) = 0.07$	0.796
Yes	9 (12.5%)	8 (11.1%)		
History of Hypertension				
No	23 (31.9%)	27 (37.5%)	$\chi2 (1) = 0.50$	0.484
Yes	49 (68.1%)	45 (62.5%)		
History of COPD				
No	64 (88.9%)	64 (88.9%)	$\chi2 (1) <0.001$	NS
Yes	8 (11.1%)	8 (11.1%)		
History of CVA				
No	67 (93.1%)	66 (91.7%)	$\chi2 (1) = 0.10$	0.745
Yes	5 (6.9%)	6 (8.3%)		
Preoperative HbA1c, mean (SD)	7.6 (0.9)	7.5 (0.9)	$t (142) = 0.50$	0.637
HbA1c > 7, n (%)	26 (36.1%)	31 (43.1%)	$\chi2 (1) = 0.73$	0.394
HbA1c =<7, n (%)	46 (63.9%)	41 (56.9%)		
Preoperative Parameters				
Preoperative BG (mg/dL)	192.7 (58.3)	186.6 (51.1)	$t (142) = 0.62$	0.534
Preoperative WBC (10*3/mm*3)	8 (1.4)	7.9 (1.4)	$t (142) = 0.10$	0.938
Preoperative Hematocrit (percent)	41.30 (5)	42.4 (4.7)	$t (142) = 1.50$	0.147
Preoperative Hemoglobin (g/dl)	13.74 (1.6)	14.10 (1.6)	$t (142) = 1.22$	0.222
Preoperative Platelets (10*3/mm*3)	271.6 (85.2)	237.3 (61.3)	$t (142) = 2.80$	0.147
Preoperative BUN (mg/dL)	16.7 (4.5)	15.9 (4.5)	$t (142) = 1.1$	0.288
Preoperative Creatinine (mg/dL)	0.87 (0.18)	0.89 (0.17)	$t (142) = 0.36$	0.732
Preoperative Sodium (mEq/L)	135.1 (3.15)	136.6 (3.2)	$t (142) = 2.66$	0.169
Preoperative Potassium (mEq/L)	4.23 (0.4)	4.4 (0.4)	$t (142) = 1.93$	0.156
Preoperative Calcium (mg/dL)	8.96 (0.6)	9.1 (0.6)	$t (142) = 0.42$	0.674
Harvested Grafts Sites for both conventional and tight glycemic control protocol (n, %)				
LIMA pedicled	(2, 1.4)			
Saphaneous open	(9, 6.3)			
Saphaneous endoscopy	(4, 3)			
Lima pedicle/saphaneous open	(80, 55.5)			
Lima pedicle/sapehnous endoscopic	(47, 32.6)			
LIMA pedicled/rdial	(1, 0.6)			
Lima pedicled/radia/saphenous endoscopic	(1, 0.6)			

Notes: SD= standard deviation; BMI= Body Mass Index; MI= myocardial infarction; PVD= peripheral vascular disease; COPD= chronic obstructive pulmonary disease; CVA= cerebral vascular accident.

Table 2. The descriptive statistics for the patients surgical characteristics. N = 144.

	Insulin Treatment		Test statistic	p-value
	Conventional n = 72	Tight n = 72		
Surgical Priority Level				
Scheduled/elective	38 (52.8%)	40 (55.6%)	χ2 (1) = 0.11	0.734
Urgent	34 (47.2%)	32 (44.4%)		
Underwent CPB Bypass				
No	3 (4.2%)	3 (4.2%)	χ2 (1) <0.001	NS
Yes	69 (95.8%)	69 (95.8%)		
Received IABP Therapy				
No	66 (91.7%)	66 (91.7%)	χ2 (1) <0.001	NS
Yes	6 (8.3%)	6 (8.3%)		
Number of Grafts, mean (SD)	3.1 (0.7)	3.1 (0.8)	t (142) = 0.34	0.733
CPB Time (Minutes), mean (SD)	94.61 (41.2)	86.24 (31.2)	t (142) = 1.38	0.172
X-Clamp time (Minutes), mean (SD)	55.93 (23.5)	52.17 (21.3)	t (142) = 1.01	0.316
IABP Time (Hours), mean (SD)	1.13 (4.6)	0.75 (3.68)	t (142) = 0.53	0.598
OR Time (Hours), mean (SD)	4:30 (3:21)	4:55 (0:43)	t (142) = 1.1	0.274
Intraoperative BG (mg/dL), mean (SD)	178.7 (17.6)	142.8 (10.6)	t (116.8) = 14	0.001
MV Time (Hours), mean (SD)	8.22 (3.5)	7.6 (2.9)	t (142) = 1.23	0.667
Developed Post-Operative Complications				
None	51 (70.8%)	54 (75%)	χ2 (1) = 0.32	0.574
At least One	21 (29.2%)	18 (25%)		
Final Hospital Outcome				
Survived & Discharge	66 (91.7%)	67 (93.1%)	χ2 (1) = 0.10	0.754
Deceased	6 (8.3%)	5 (6.9%)		

Notes: SD= standard deviation; HbA1c= Glycated Hemoglobin; BG= Blood Glucose; WBCs= white blood cells; BUN= Blood Urea Nitrogen; CPB= cardiopulmonary bypass; IABP= intra-aortic balloon pump; X-Clamp= aortic cross clamp; OR= operating room; MV= Mechanical Ventilation; χ2 = Chi-square; t = t-test.

2.4. Ethical considerations

Ethical approval was obtained from the Institutional Review Board (IRB) at Jordan University of Science and Technology (Ref#: 20180441) prior to data collection. Signed informed consent was obtained from the participants, who were assured that their participation was voluntary, that all data would be kept confidential, and that they had the right to withdraw from the study at any time without consequences.

3. Results

Most of the participating patients (90.3%) were male. The mean age of the patients was 59.66 ± 9.3 years, with 31.9% of the participants aged below 54 years, 41% aged between 55-64 years, and 27.1% aged 64 years or over. The participants had a mean BMI of 28.46 ± 4.3. Based on World Health Organization (WHO) guidelines [37], the participants' BMI results indicated that 27.1% of the participating patients had normal weight-to-height, 39.6% were over-weight, 24.3% had class-I obesity, and 9% had class-II obesity. In addition, the analysis showed that the majority (61.8%) of the patients were active smokers, whilst 38.2% were non-smokers. As with regards to comorbidity, the results showed that 34% of the participants had previous myocardial infarction (MI), 11.8% had a history of peripheral vascular disease (PVD), 65.3% were diagnosed with hypertension (HTN), 11.1% were diagnosed with chronic obstructive pulmonary disease (COPD), and 7.6% had previous cerebrovascular accident (CVA) (See Table 1).

The analysis of the patients' surgical characteristics showed that more than half of the CABG surgeries performed (54.2%) had been elective pre-planned surgeries, whilst 45.8% had been urgent surgeries. Furthermore, the majority (95.8%) of the patients required CPB surgery, 6% did not require CPB surgery, and only 8.3% of the patients required intra-aortic balloon pump (IABP) therapy. The mean number of implanted cardiac grafts among the patients was 3.1 ± 1 grafts. The mean

CPB time in minutes among the patients was 90.42 min (SD = 36.7 min), and the mean aortic cross-clamp time in minutes was 54.1 min (SD = 22.5 min). Further, the mean IABP therapy time for participants who had needed it was 54.1 ± 22.5 h, whilst the mean total operative time among the participants was 4.61 ± 0.94 h.

Intra-operatively, fifty percent of the patients received tight insulin therapy, whilst the other half received conventional insulin therapy. The mean mechanical ventilation time in the ICU was 7.92 ± 3.3 h. Lastly but not least importantly, the final disposition of the patients at discharge time showed that (n = 133, 92.4%) of the total (144) participants had survived, with (n = 11, 7.6%) mortalities. However, after the application of the glycemic control protocol, no mortalities were reported among patients who developed postoperative SSIs (See Table 2).

In total, six (8.3%) of the 72 patients in the conventional group experienced some form of SSIs. Therefore, we can be 95% confident that the true point estimate for SSIs among the patients who had received conventional insulin therapy could be between 3.7% and 17.3% for that proportion, according to an Agresti-Coull adjusted 95% confidence interval. Meanwhile, only four (5.6%) of the 72 patients in the tight group developed various SSIs. Thus, we can be 95% confident that the true incidence of SSIs among patients who received tight insulin therapy could be anywhere between (Agresti-Coull 95% C.I: 1.7%–13.8%). However, two out of the four (2/4) patients developed two site infections each, resulting in a total of six infections among the group. Hence, the true point estimate of SSIs rises to (8.3%, 95% C.I-Agresti-Coull: 3.9%–17%) SSIs in the tight group.

The distribution of SSIs in the conventional group was as follows: 1.4% of the participating patients developed superficial sternal wound infection (SSWI), 4.2% developed deep sternal wound infection (DSWI), 2.8% developed superficial harvesting wound infection (SHWI), and no patients developed deep harvesting wound infection (DHWI). As for the tight group, no patients developed SSWI, 5.6% developed DSWI, 1.4% developed SHWI, and 1.4% developed DHWI (See Table 3).

Table 3. Bivariate analysis for the statistical differences between the two treatment groups on the surgical site infections. N= 144.

	Insulin Treatment		Test	p-value
	Conventional n = 72	Tight n = 72	Statistic (The chi-square test or Fisher's test)	
Developed SSIs				
No	66 (91.7%)	68 (94.4%)	χ2 (1) = 0.43	0.512
Yes	6 (8.3%)	4 (5.6%)		
SSWI	1 (1.4%)	0 (0%)	χ2 (1) <0.01	0.999
DSWI	3 (4.2%)	4 (5.6%)	χ2 (1) <0.01	0.999
SHWI	2 (2.8%)	1 (1.4%)*	χ2 (1) <0.01	0.999
DHWI	0 (0%)	1 (1.4%)*	χ2 (1) <0.01	0.999

Notes: SSIs= surgical site infections; SSWI= superficial sternal wound infection; DSWI= deep sternal wound infection; SHWI= superficial harvesting wound infection; DHWI= deep harvesting wound infection.

* Subjects developed DSWI and additional types of either SHWI or DHWI.

4. Discussion

The current study found no statistically significant differences in postoperative SSIs between the two treatment groups, which is consistent with some studies that have investigated glycemic control and postoperative SSIs [2, 33, 34, 35, 36] and contradictory to others [26, 28, 29, 30, 32]. The contradictory evidence in the literature may be attributed to differences in the timing of interventions, in the operational definitions adopted for the treatment groups, or in the acceptable level of hyperglycemia permitted in the conventional groups. For example, four previous studies used 200 mg/dl as the mean Blood Glucose (BG) level for the conventional group [26, 28, 29, 30]. Meanwhile, one study used 200 mg/dl or below as the mean BG level prior to the subcutaneous insulin (SQI) intervention every 4 h for the first group of patients, and the same BG level prior to the CII intervention [26]. However, this interventional approach led to significant increases in BG level (>200 mg/dl), irrespective of the type of insulin intervention employed.

Similarly, Lazar and colleagues allowed BG levels of up to 250 mg/dl in patients in the conventional group before intervention with intermittent SQI. As such, intraoperative BG levels were consistently close to 250 mg/dl and never less than 200 mg/dl [30]. While the researchers did attempt to maintain perioperative BG levels below 250 mg/dl, their protocol of intermittent SQI was inadequate for achieving this. The mean BG levels during the intraoperative period and the first 12 h of the postoperative period were consistently greater than 200 mg/dl. Allowing BG levels to exceed severe hyperglycemia (>200 mg/dl) and utilizing the intermittent SQI method of insulin delivery may have contributed to the significant difference in postoperative SSIs between the two treatment groups.

In the meta-analysis of Hua and colleagues [29], three of the five randomized clinical Trial (RCT) studies included were found to have allowed for BG levels of greater than 200 mg/dl prior to the insulin intervention for patients in the control group. Also, a recent meta-analysis by De Vries and colleagues [28] indicated that eleven of the fifteen RCT studies included had allowed for BG levels of greater than 200 mg/dl prior to the insulin intervention for patients in the control group. This resulted in a mean BG level during the perioperative period of higher than 200 mg/dl and BG levels which exceeded severe hyperglycemia levels (>200 mg/dl), which could lead to increased occurrence of postoperative SSIs and prolonged ICU [3, 4, 5, 6, 7, 8].

Furthermore, five studies showed the use of tight glycemic control (≤150 mg/dl) during the perioperative period to lead to a significant decrease in postoperative SSIs [26, 28, 29, 30, 32]. Continuous glycemic control during surgery and the ICU period helps to maintain BG levels in the target range for a longer period for the treatment groups. In turn, this helps maintain the mean BG levels within the preset target ranges during the intraoperative and postoperative periods. Further, not maintaining

BG levels within the target ranges could lead to perioperative hyperglycemia, which may impact patients' clinical outcomes and increase the incidence of SSIs. Previous studies have clearly evidenced that avoiding the incidence of severe hyperglycemia is vital not only during the intraoperative period but also during the preoperative and late postoperative periods. Severe hyperglycemia may predispose patients to increased infectious complications, and higher morbidity and mortality rates [3, 4, 5, 6, 7, 8].

On the other hand, studies [26, 28, 29, 30, 32] targeted a higher level of BG in the tight glycemic control (≤150 mg/dl) to reduce the risks of hypoglycemia that include operative mortality, re-exploration, bleeding, reintubation, prolonged ventilation, and pneumonia [38]. In turn, these potential complications may increase the risk of postoperative infectious complications, particularly SSIs [10, 11, 12, 14, 39].

4.1. Limitations of the study

This study was conducted in a single center, which may impact the clinical validity of the findings. Further, the study is also limited in its use of convenience sampling, as this may impact the external validity and limit the generalizability of the results. Another limitation of this study could be the inter-observer variability which may have occurred because of differences in personal opinions between the physicians as they were assessing the SSIs. Finally, whilst previous studies have defined tight glycemic control more conservatively, the present study was limited in its use of the American Diabetes Association (ADA) guidelines to define tight glycemic control. This may have led to the significant differences between the tight and conventional glycemic control interventions and thereby lower statistical power used in the data management protocol. In addition, identifying the microbiological profile of SSIs was beyond the scope of this study, however, authors are considering this aspect to be taken into consideration in near future research endeavors. Furthermore, further studies with different methodologies are recommended to clinically validate the results of the current study.

5. Conclusion

There was a small portion of the study participants in the tight glycemic control group had SSIs compared to conventional glycemic control group. As for the tight group, the highest percentage among the infection types was DSWI followed by SHWI, and DHWI among the study participants. Moreover, no SSWI reported among participants within this group of glycemic control intervention. However, there was no statistically significant difference between the two glycemic control interventions among study groups. Intraoperative tight glycemic control did not reduce thirty-day postoperative SSIs among the participants. The current study has shown that the use of tight glycemic control during the intraoperative period can be safely achieved through the judicious implementation of the protocol. Identifying patients who are most likely to develop postoperative SSIs is of paramount importance. Therefore, when providing care for at-risk patients, nurses should consider the glycemic stability and glycemic control approach to minimize the occurrence of adverse surgical outcomes post CABG surgery, more specifically surgical wound site infections.

Declarations

Author contribution statement

Issa Hweidi: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Alaa Zaytoon: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Audai Hayajneh: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Salwa Al Obeisat: Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Aysam Hweidi: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

The clinical trial described in this paper was registered at Clinical-Trials.gov under the registration number NCT04451655.

References

[1] P.H. Marathe, H.X. Gao, K.L. Close, American diabetes association standards of medical care in diabetes 2017, J. Diabetes 9.4 (2017) 320–324. Print.

[2] G. Umpierrez, S. Cardona, F. Pasquel, et al., Randomized controlled trial of intensive versus conservative glucose control in patients undergoing coronary artery bypass graft surgery: GLUCO-CABG trial, Diabetes Care (2015). http://care.diabetesjournals.org/content/38/9/1665. (Accessed 17 July 2019).

[3] ÜMit Arslan, Mehmet Erdem MemetogLu, Rasim Kutlu, Ozan Erbasan, Mehmet Tort, EyüP Serhat CAlik, Ziya Yildiz, M. Ali Kaygin, Ozan Erdem, Ali IHsan Tekin, Preoperative Hba1c level in prediction of short-term morbidity and mortality outcomes following coronary artery bypass grafting surgery, Russ. Open Med. J. 4 (2015).

[4] Z. Faritous, M. Ardeshiri, F. Yazdanian, A. Jalali, Z. Totonchi, R. Azarfarin, Hyperglycemia or high Hemoglobin A1c: which one is more associated with morbidity and mortality after coronary artery bypass graft surgery? Ann. Thorac. Cardiovasc. Surg. Off. J. Assoc. Thorac. Cardiovasc. Surg. Asia 20 (3) (2014) 223–228. Print.

[5] K.M. Järvelä, N.K. Khan, E.L. Loisa, J.A. Sutinen, J.O. Laurikka, J.A. Khan, Hyperglycemic Episodes Are Associated with Postoperative Infections after Cardiac Surgery, 2010. Internet resource.

[6] Mavra Mannan, ShahanTemoor Farooq, Rubab Munir, Muhammad Farhan Habib, Original article coronary artery bypass grafting (CABG) –complications in diabetics. Third year medical students, Rawalpindi medical college. Rawalpindi institute of cardiology, Rawalpindi, hamad medical corporation, J. Rawalpindi Med. Coll. Students Suppl. 19 (S-1) (2015) 9–12.

[7] Robert H. Thiele, Christoph Hucklenbruch, Jennie Z. Ma, Colquhoun Douglas, Zhiyi Zuo, Edward C. Nemergut, Jacob Raphael, Admission hyperglycemia is associated with poor outcome after emergent coronary bypass grafting surgery, J. Crit. Care 30.6 (2015) 1210–1216. Print.

[8] Jia Zheng, Cheng, et al., Does HbA1c level have clinical implications in diabetic patients undergoing coronary artery bypass grafting? A systematic review and meta-analysis, Int. J. Endocrinol. (2017). https://www.hindawi.com/journals/ije/2017/1537213/. (Accessed 17 July 2019).

[9] Martin Priyadharshanan, Mahmoud Loubani, Risk Factors and Mortality Associated with Deep Sternal Wound Infections Following Coronary Bypass Surgery with or without Concomitant Procedures in a UK Population: a Basis for a New Risk Model? OUP Academic, 2010. https://academic.oup.com/icvts/article/11/5/543/655751. (Accessed 17 July 2019).

[10] Sulakshana Balachandran, Annemarie Lee, Linda Denehy, Kuan-Yin Lin, Alistair Royse, Colin Royse, Doa El-Ansary, Risk factors for sternal complications after cardiac operations: a systematic review, Ann. Thorac. Surg. 102 (6) (2016) 2109–2117. Print.

[11] Farzan Filsoufi, Javier G. Castillo, Parwis B. Rahmanian, Stafford R. Broumand, Silvay George, Alain Carpentier, David H. Adams, Epidemiology of deep sternal wound infection in cardiac surgery, J. Cardiothorac. Vasc. Anesth. 23.4 (2009) 488–494. Print.

[12] Heilmann, Claudia, Stahl, et al., Wound Complications after Median Sternotomy: a Single-centre Study, OUP Academic, 2013. https://academic.oup.com/icvts/article/16/5/643/682505. (Accessed 17 July 2019).

[13] H. Kubota, H. Miyata, N. Motomura, et al., Deep sternal wound infection after cardiac surgery, J. Cardiothorac. Surg. (2013). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3663691/. (Accessed 17 July 2019).

[14] I. Lola, S. Levidiotou, A. Petrou, H. Arnaoutoglou, E. Apostolakis, G.S. Papadopoulos, Are there independent predisposing factors for postoperative infections following open heart surgery? J. Cardiothorac. Surg. (2011). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3223138/. (Accessed 17 July 2019).

[15] M.S. Siddiqi, Saphenous Vein Harvest Wound Complications: Risk Factors, Identificati: CWCMR. Chronic Wound Care Management and Research, 2016. https://www.dovepress.com/saphenous-vein-harvest-wound-complications-risk-factors-identification-peer-reviewed-fulltext-article-CWCMR. (Accessed 17 July 2019).

[16] FaroghA, M.U.A. Shah, S. Afshan, Impact of Preoperative Diabetes Mellitus on Morbidity in Patients Undergoing Coronary, 2019 https://www.researchgate.net/publication/296195894_FaroghA_Shah_MUA_Afshan_S_Impact_of_preoperative_diabetes_mellitus_on_morbidity_in_patients_undergoing_coronary_artery_bypass_graft_surgery_Pak_Heart_J_2015483143-146.

[17] Ramin Shiraly, Zahra Shayan, Vahid Keshtkar, Mehdi Hamed, Self-reported factors associated with engagement in moderate to vigorous physical activity among elderly people: a population-based study, Int. J. Prev. Med. 8 (2017) 26.

[18] K.A.Q. Santos, B. Berto, A.G. Sousa, FAAda Costa, Prognosis and complications of diabetic patients undergoing isolated coronary artery bypass surgery, Braz. J. Cardiovasc. Surg. (2016). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5062695/. (Accessed 17 July 2019).

[19] L.D. Cornwell, S. Omer, T. Rosengart, F.G. Bakaeen, L. D Cornwell, S. Omer, T. Rosengart, F.G. Bakaeen, T. Rosengart, F.G. Bakaeen, W.L. Holman, Changes over time in risk profiles of patients who undergo coronary artery bypass graft surgery: the veterans affairs surgical quality improvement program (vasqip), JAMA Surg. 150.4 (2015) 308–315. Print.

[20] M.J. Holzmann, B. Rathsman, B. Eliasson, et al., Long-term prognosis in patients with type 1 and 2 diabetes mellitus after coronary artery bypass grafting, J. Am. Coll. Cardiol. (2015). https://www.ncbi.nlm.nih.gov/pubmed/25908069. (Accessed 17 July 2019).

[21] Michel Kindo, H. Minh, et al., Trends in Isolated Coronary Artery Bypass Grafting over the Last Decade, OUP Academic, 2016. https://academic.oup.com/icvts/article/24/1/71/2835936. (Accessed 17 July 2019).

[22] T. Shimizu, S. Miura, K. Takeuchi, T. Tashiro, K. Saku, Effects of gender and aging in patients who undergo coronary artery bypass grafting: from the Fu-registry, Cardiol. J. 19.6 (2012) 618–624. Print.

[23] Hayel Al Adwan, et al., Prevalence of Co-morbidities among adult patients presented for open heart surgery and the implication on convalescence period, Int. J. Adv. Med. 4 (1) (2017) 1.

[24] Al-Zaru, M. Ibtisam, et al., Economical and clinical impact of surgical site infection following coronary artery bypass graft surgery in north Jordan, Int. J. Nurs. Pract. 17 (2) (2011) 117–125.

[25] L. Boreland, M. Scott-Hudson, K. Hetherington, A. Frussinetty, J.T. Slyer, The effectiveness of tight glycemic control on decreasing surgical site infections and readmission rates in adult patients with diabetes undergoing cardiac surgery: a systematic review, Heart Lung 44 (5) (2015) 430–440.

[26] A.P. Furnary, Y. Wu, S.O. Bookin, Effect of hyperglycemia and continuous intravenous insulin infusions on outcomes of cardiac surgical procedures: the Portland diabetic project, Endocr. Pract.: Off. J. Am. Coll. Endocrinol. Am. Assoc.Clin. Endocrinol. 10 (2004). Print.

[27] Ogawa, Shinji, Okawa, et al., Continuous Postoperative Insulin Infusion Reduces Deep Sternal Wound Infection in Patients with Diabetes Undergoing Coronary Artery Bypass Grafting Using Bilateral Internal Mammary Artery Grafts: a Propensity-Matched Analysis, OUP Academic, 2015. https://academic.oup.com/ejcts/article/49/2/420/2465117. (Accessed 17 July 2019).

[28] F.E.E.D. Vries, S.L. Gans, J.S. Solomkin, et al., Meta-analysis of lower perioperative blood glucose target levels for reduction of surgical-site infection, Br. J. Surg. 104 (2) (2016).

[29] J. Hua, G. Chen, H. Li, et al., Intensive intraoperative insulin therapy versus conventional insulin therapy during cardiac surgery: a meta-analysis, J. Cardiothorac. Vasc. Anesth. 26 (5) (2012) 829–834.

[30] H. Lazar, S. Chipkin, C. Fitzgerald, Y. Bao, H. Cabral, C. Asptein, Tight glycemic control in diabetic coronary artery bypass graft patients improves perioperative outcomes and decreases recurrent ischemic events, ACC Curr. J. Rev. 13 (6) (2004) 57.

[31] G. Van Den Berghe, P. Wouters, F. Weekers, et al., Intensive insulin therapy in critically Ill patients G, N. Engl. J. Med. 345 (19) (2001) 1359–1367.

[32] Ehab A. Wahby, M. Elnasr, M. Abo, Michael I. Eissa, Sahbaa M. Mahmoud, Perioperative Glycemic Control in Diabetic Patients Undergoing Coronary Artery Bypass Graft Surgery 24.2, 2016. Print.

[33] C.M. Bhamidipati, D.J. LaPar, G.J. Stukenborg, C.C. Morrison, J.A. Kern, I.L. Kron, G. Ailawadi, Superiority of moderate control of hyperglycemia to tight control in patients undergoing coronary artery bypass grafting, J. Thorac. Cardiovasc. Surg. 141.2 (2011) 543–551. Print.

[34] S. Finfer, D.R. Chittock, S.Y. Su, D. Blair, D. Foster, V. Dhingra, R. Bellomo, D. Cook, P. Dodek, W.R. Henderson, P.C. Hébert, S. Heritier, D.K. Heyland, C. McArthur, E. McDonald, I. Mitchell, J.A. Myburgh, R. Norton, J. Potter, B.G. Robinson, J.J. Ronco, Intensive versus conventional glucose control in critically Ill patients, N. Engl. J. Med. 360.13 (2009) 1283–1297. Print.

[35] Y.G. Gunjan, A.N. Gregory, D.A. Martin, J.M. Charles, V.S. Hartzell, C.O.B. Peter, G.J. Matthew, R.W. Arthur, M.C. Susanne, M.M. Lisa, A.R. Robert, M.M.M. Molly, Intensive intraoperative insulin therapy versus conventional glucose management during cardiac surgery: a randomized trial, Ann. Intern. Med. 146.4 (2007) 233–243. Print.

[36] H.L. Lazar, C. Fitzgerald, M. M McDonnell, S. Chipkin, C. Bliss, H. Cabral, Effects of aggressive versus moderate glycemic control on clinical outcomes in diabetic coronary artery bypass graft patients, Ann. Surg. 254.3 (2011) 458–464. Print.

[37] Q. Nuttall Frank, Body mass index: obesity, BMI, and health: a critical review, Nutr. Today 50 (3) (2015) 117–128.

[38] S.C. Stamou, M. Nussbaum, J.D. Carew, et al., Hypoglycemia with intensive insulin therapy after cardiac surgery: predisposing factors and association with mortality, J. Thorac. Cardiovasc. Surg. 142 (1) (2011) 166–173.

[39] Q.C.G.D. Silva, M.H. Barbosa, Risk factors for surgical site infection in cardiac surgery, Acta Paul. Enferm. 25 (spe2) (2012) 89–95.