ORIGINAL ARTICLE

Morbidity and In-Hospital Mortality in Diabetic Patients Undergoing Cardiac Surgery: A Retrospective Cohort Study

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Objective: To evaluate the impact of diabetes mellitus (DM) in hospital mortality and morbidity after cardiac surgery.

Materials and Methods: The authors performed a retrospective cohort study in a tertiary medical center. One thousand two hundred fifteen patients had cardiac surgery between June 2015 and July 2021, divided into two groups, 824 non-diabetic, and 391 diabetic patients.

Results: In-hospital mortality rates were comparable in diabetic and non-diabetic patients at 7.2% versus 6.6% (p=0.786). However, chronic kidney disease, high American Society of Anesthesiologists physical status, preoperative arrhythmias, and non-valvular surgery were statistically significant predictors of in-hospital mortality. In-hospital morbidities were higher in diabetic patients compared with non-diabetic patients (p<0.001) with neurological complications at 11.3% versus 7% (p=0.018), pulmonary complications at 57.5% versus 37.9% (p<0.001), renal complications at 39.4% versus 17.2% (p<0.001), infectious complications at 15.9% versus 7.3% (p<0.001), and arrhythmias at 26.6% versus 17.6 (p<0.001). After risk adjustment, DM remained a risk factor for postoperative arrhythmias with an odds ratio of 1.63 (p=0.005), neurological complications with an odds ratio of 2.03 (p=0.007), pulmonary complications with an odds ratio of 1.96 (p<0.001), infectious complications with an odds ratio of 2.76 (p<0.001), and renal complications with an odds ratio of 2.78 (p<0.001).

Conclusion: Diabetic and non-diabetic patients have similar in-hospital mortality rates. DM was an independent predictor for postoperative complications.

Keywords: Diabetic mellitus; Cardiac surgery; Mortality; Postoperative complications

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An aging and obese population is contributing to an increase in the prevalence of diabetes mellitus (DM)[1]. Diabetes is still a major and well-known health disease associated with major adverse cardiac events, including myocardial infarction[2]. Diabetic patients had a 5-year mortality rate twice that of non-diabetic patients[3]. With improvements in both surgical and percutaneous revascularization procedures, diabetic patients with multivessel coronary artery disease frequently receive coronary artery bypass grafts (CABG) surgery. The prevalence of diabetic patients underwent CABG surgery ranges from 12% to 38%[3-5]. However, surgery including CABG, is not without risk. CABG surgery is considered a high-risk procedure, associated with a 30-day morbidity and mortality rate up of to 14.0% and 2.0%, respectively[6]. Diabetes, itself, is an established risk factor for significant morbidity after CABG surgery[7-11]. The adjusted risk for diabetes was approximately 35% higher morbidity than non-diabetics, especially in those using insulin[12]. Diabetes was shown to increase the risk of sternal wound infection, new dialysis requirement, multiorgan failure, and readmission with myocardial infarction following CABG surgery[13].

The results of short-term mortality in diabetic patients following CABG surgery have been less conclusive. Patients with type 2 diabetes who undergo CABG surgery experience significant higher total operative mortality compared to non-diabetic patients[5,7]. It was also a risk factor for early hospital death in Japanese patients, although it did not affect long-term survival[12]. In addition, it was reported in a recent systematic review and meta-analysis that the pooled relative risk (RR) for mortality following

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CABG surgery was significantly higher in patients with diabetes than in those without the disease at 30 days and one year, with RR of 1.64 and 1.83, respectively[14]. Nevertheless, some evidences suggest that hospital mortality was not significantly different[15,16]. The survival of CABG surgery patients with diabetes is also greatly affected by associated comorbidities such as renal failure[3,17] and peripheral vascular disease[9,17,18]. Moreover, previous studies examined the role of diabetes and outcomes in CABG surgery. It is noteworthy that the results in other cardiac surgery are lacking.

The present study aimed to explore the impact of DM on in-hospital mortality and morbidities compared with non-diabetic patients who underwent cardiac surgery.

Materials and Methods

The present study was conducted in a retrospective cohort design. Patients who had cardiac surgery at Songklanagarind Hospital between June 2015 and July 2021 were included in the database if they met the following criteria: patients aged 18 years or older who had CABG, valvular, combined CABG and valvular, and/or aortic surgery. Patients with congenital heart disease were not included. Subsequently, the patients were divided into two groups, 1) the DM group, which included all patients with preoperative diabetes diagnosis regardless of the duration of DM, and 2) the non-DM group, which included all patients without such diagnosis. All types of preoperative arrhythmias noted in the anesthetic record were included. Intraoperative dexamethasone was administered regularly in the patients to ameliorate the inflammatory response to cardiopulmonary bypass (CPB) during cardiac surgery. Nevertheless, this practice was discontinued years ago. Therefore, some of the patients did not receive intraoperative dexamethasone. Furthermore, the authors' institute did not have perioperative blood glucose management protocol. Therefore, the decision depended on the attending anesthesiologist. All data were reviewed in the electronic hospital information system until the patients were discharged. Post-operative complications after cardiac surgery that occurred during the hospital stay were recorded (Table 1).

The present study was approved by the Human Research Ethics Committee, Faculty of Medicine, Prince of Songkla University, Thailand (REC 63-430-8-1). Informed consent forms were not required because it was a retrospective database survey. Furthermore, the research center treats all hospital databases with the strictest confidentiality.

Sample size calculation

The sample size for the present study was determined using the formula for case control study to compare proportions of exposure between two groups. The proportion of exposure between DM and non-DM groups was determined by the mortality rates following heart valve surgery that differed between diabetic and non-diabetic patients, which was 8% versus 4%, respectively[11], and the rates of postoperative complications following CABG surgery, which included pneumonia, mediastinitis, and acute renal failure, that were double in diabetic patients[12]. The ratio between patients with DM and non-DM in Songklanagarind Hospital was 1 to 2 (r=2), with the alpha (α)=0.05 and beta (β)=0.2. Thus, the numbers of patients in diabetes and non-diabetic groups were 396 and 796, respectively.

Statistical analysis

The data were managed and analyzed using the R program, version 3.14. All variables were descriptively analyzed. The quantitative variables were calculated by observing minimum and maximum values and the median value as interquartile range (IQR) for non-normal distribution variables including age, gender, body weight, body height, body mass index, pre-operative ejection fraction, hemoglobin A1c (HbA1c), CPB time, aortic cross-clamp time (XCT), circulatory arrest time, fasting blood sugar on the day of surgery, blood glucose level, insulin use, intensive care unit (ICU) stays, hospital length of stay, duration of mechanical ventilator, and timing of death after surgery. For qualitative variables, absolute and relative frequencies were calculated.

The student's t-test was used to compare the averages of the two groups, and the non-parametric Mann-Whitney U test was performed when the assumption of data normality was rejected. In addition, the chi-square Fisher's exact tests or as appropriate to evaluate the homogeneity between proportions. Statistical significance was set at p-value less than 0.05.

A univariate analysis was applied to examine the significant parameters associated with in-hospital mortality. A multivariable logistic regression model was constructed to evaluate whether the following variable, age, body mass index, preoperative underlying disease such as hypertension, dyslipidemia, chronic kidney disease, on dialysis, cerebrovascular

Table 1. Definition of postoperative complications in the study

Post-operative complications after cardiac surgery during the hospital stays
1. Neurological complications - Stroke: defined as a central neurologic deficit lasting ≥72 hours (i.e., weakness of the extremity or loss of consciousness, loss of speech, blindness) - Transient ischemic attack (TIA): defined as loss of the neurological function that occurred abruptly but return to normal within 24 hours - Coma lasting ≥ 24 hours due to anoxic/ischemic, and/or metabolic encephalopathy, thromboembolic event or cerebral bleeding.
2. Myocardial infarction: defined as (i) prolonged typical chest pain that was not relieved by nitrates, or elevated cardiac enzymes (CK-MB or troponin >0.2 micrograms/mL) (ii) (at least two) electrocardiogram series showing new changes in the ST/T segment (iii) a new Q wave of ≥ 0.03 seconds, or (iv) more than one-third of the QRS complex in at least two contiguous leads
3. Cardiac arrest: defined as acute cardiac arrest as documented by one of the following - Ventricular fibrillation - Rapid ventricular tachycardia with hemodynamic instability - Asystole
4. Cardiac arrhythmias that required intervention - Atrial fibrillation - Atrial flutter - Paroxysmal supraventricular tachycardia - Bradyarrhythmia
5. Pulmonary complications - Prolonged mechanical ventilation (need of ventilation for ≥48 hours in the postoperative period) - Acute respiratory distress syndrome - Pulmonary embolism - Pneumonia (diagnosed by the following criteria: positive cultures of sputum, blood, or pleural fluid; empyema; or chest radiograph with new infiltrates)
6. Renal complications - Acute renal failure: defined as a serum creatinine level more than double that of the preoperative level, or the need for new-onset renal replacement therapy
7. Low cardiac output syndrome (LCOS) necessitates the use of either an intra-aortic balloon pump (IABP) or an extracorporeal membrane-oxygenator (ECMO)
8. Infectious complications - Mediastinitis (defined as a deep infection involving a muscle, bone, and/or the mediastinum) - Thoracotomy wound infection (infection involving the thorax and parasternal region) - Superficial leg incision infection (infection involving the site of saphenous vein dissection) All infectious complications must fulfill the following conditions: 1) be an open wound with tissue excision, 2) have samples that produced positive cultures, and 3) be treated with antibiotics. Infections related to venous catheters and the urinary tract were also included.
9. Multiple organ failure: defined as the malfunctioning of two or more organ systems

accident, chronic obstructive pulmonary disease, peripheral arterial disease, smoking, American Society of Anesthesiologists (ASA) physical status classification, history of congestive heart failure (CHF), myocardial infarction, and type of cardiac surgery, were independent predictors of in-hospital mortality. For each covariate, adjusted odds ratios (OR) and 95% confidence intervals (CI) were analyzed. The propensity matching score had been used in matched postoperative complications in which the distribution of measured baseline variables was similar between patient with DM and non-DM.

Results

Baseline characteristics

The present study included 1,215 patients with and without diabetes who underwent cardiac surgery. The patients were at an average age of 60.3 years. Patients with DM accounted for 32.2% of the total population. Most of the patients in the DM group who underwent CABG surgery were significantly older and more overweight. Fifty-seven out of 391 patients (14.6%) in the DM group were treated with insulin therapy. The DM group had significantly more comorbidities than the non-DM group, such as hypertension, dyslipidemia, and chronic renal disease. Furthermore, more patients in the DM group required dialysis and/or suffered from peripheral vascular disease.

Patients in the DM group were also more likely to present with CHF and unstable angina. On the other hand, the non-DM group more often had arrhythmias such as atrial fibrillation and atrial flutter, and higher preoperative left ventricular ejection fraction (LVEF) (Table 2). Patients with DM had significantly higher rates of previous therapy with ischemic heart or hypertensive medications than those without DM. In contrast, patients without DM had significantly

Table 2. Demographic and preoperative variables according to the study group

	Diabetes (n=391)	Non-diabetes (n=824)	p-value
Age (years); median (IQR)	64 (58, 70.5)	60 (51, 68)	<0.001
Sex: male/female; n (%)	247 (63.2)/144 (36.8)	506 (81.4)/318 (38.6)	0.631
BMI; median (IQR)	24.6 (22.3, 27.4)	22.9 (20.6, 25.8)	<0.001
Comorbid disease; n (%)	377 (96.7)	577 (70.0)	<0.001
Hypertension	325 (83.1)	391 (47.5)	<0.001
Dyslipidemia	234 (59.8)	247 (30.0)	<0.001
Chronic kidney disease	116 (29.7)	125 (15.2)	<0.001
On dialysis	25 (6.4)	13 (1.6)	<0.001
TIA/CVA	36 (9.2)	77 (9.3)	1
COPD	10 (2.6)	31 (3.8)	0.36
Peripheral arterial disease	9 (2.3)	4 (0.5)	0.01
Smoking	79 (20.2)	151 (18.3)	0.482
On mechanical ventilation	25 (6.6)	48 (8.3)	0.402
ASA physical status classification; n (%)			0.107
3	319 (81.6)	710 (86.2)	
4	64 (16.4)	99 (12.0)	
5	8 (2.0)	15 (1.8)	
Type of surgery; n (%)			0.442
Elective	343 (87.7)	708 (85.9)	
Emergency	48 (12.3)	116 (14.1)	
Preoperative EF; n, median (IQR)	278, 49 (35,62)	589, 60 (48,70)	<0.001
Arrhythmia; n (%)	44 (11.3)	213 (25.8)	<0.001
Left ventricular hypertrophy; n (%)	275 (70.3)	569 (69.1)	0.7
Congestive heart failure; n (%)	108 (27.6)	161 (19.5)	0.002
Myocardial infarction/unstable angina; n (%)	157 (40.2)	183 (22.2)	<0.001
Preoperative use of inotropic agents; n (%)	39 (10.0)	76 (9.2)	0.754
HbA1c; n, median (IQR)	174, 7.1 (6.3, 8.3)	53, 5.6 (5.4, 6)	<0.001

BMI=body mass index; TIA=transient ischemic attack; CVA=cerebrovascular accident; COPD=chronic obstructive pulmonary disease; ASA=American Society of Anesthesiologists; EF=ejection fraction; HbA1c=hemoglobin A1c; IQR=interquartile range

higher rate of digoxin and anticoagulant medication therapy. In addition, the median HbA1c level was significantly higher in patients with DM than in those without DM.

Operative characteristics

The proportion of the DM group that underwent CABG and CABG combined with valvular surgery, which was 67.8% and 10.5%, respectively, was significantly higher than the non-DM group at 30.3% and 8.9%, respectively. In contrast, the non-DM group underwent more valvular and aortic surgeries than the DM group (Table 3). CPB time and XCT were longer in the DM group than in the non-DM group, however, this difference was not statistically significant (Table 3). Simultaneously, the non-DM group had a higher incidence of shockable rhythm such as ventricular fibrillation or ventricular tachycardia, after releasing an aortic cross-clamp than the DM group. In addition, patients in the non-DM group were administered dexamethasone more frequently than those in the DM group at 95.3% versus 29.9% ($p<0.001$). Furthermore, intraoperative dopamine, norepinephrine, and nitroglycerine were administered more frequently to the DM group, and this difference was significant (Table 3).

Blood glucose management

The average median blood glucose level of patients in the DM group was significantly higher than that of those in the non-DM group. In addition, patients in the DM group showed higher hyperglycemia rates, greater than 180 mg/dL, than those in the non-DM group. In contrast, patients in the non-DM group had higher hypoglycemia rates, at less than 70 mg/dL, than those in the DM group (Table 4). Furthermore, 41.7% and 19.1% of diabetic and non-diabetic patients respectively required intraoperative

Table 3. Intraoperative variables in diabetic and non-diabetic patients

	Diabetes (n=391)	Non-diabetes (n=824)	p-value
Type of cardiac surgery; n (%)			<0.001
CABG	265 (67.8)	250 (30.3)	
Valvular	71 (18.2)	410 (49.8)	
Combined CABG & valvular	41 (10.5)	73 (8.9)	
Aortic	14 (3.6)	91 (11.0)	
Lowest temperature during CPB; n (%)			0.004
Mild (>32 Celsius)	372 (95.1)	741 (89.9)	
Moderate (28 to 32 Celsius)	9 (2.3)	24 (2.9)	
Deep hypothermia (<28 Celsius)	10 (2.6)	59 (7.2)	
CPB time (minutes); median (IQR)	118 (93, 148.5)	115 (83.8, 158)	0.51
Aortic cross-clamp time (minutes); median (IQR)	82 (60, 105.5)	81 (57, 114)	0.597
Circulatory arrest time (minutes); n, median (IQR)	8, 0 (0, 0)	69, 0 (0, 0)	<0.001
Dexamethasone use; n (%)	117 (29.9)	785 (95.3)	<0.001
Arrhythmia during on CPB; n (%)	50 (12.8)	161 (19.5)	0.005
Electrical heart defibrillation; n (%)	49 (12.5)	161 (19.5)	0.003
Intraoperative inotropic drug; n (%)	390 (99.7)	823 (99.9)	1
Epinephrine	240 (61.5)	474 (57.6)	0.214
Norepinephrine	276 (70.8)	519 (63.1)	0.01
Dopamine	68 (17.4)	95 (11.5)	0.007
Dobutamine	164 (42.1)	371 (45.1)	0.352
Levosimendan	0 (0)	2 (0.2)	0.828
Milrinone	65 (16.7)	105 (12.8)	0.081
Nitroglycerin	89 (22.8)	129 (15.7)	0.003

CABG=coronary artery bypass graft; CPB=cardiopulmonary bypass; IQR=interquartile range

insulin. The average median dose of insulin in both groups was 10 IU.

Postoperative glucose levels were high in both groups, however, the DM group had significantly higher average median blood glucose levels on the first, second, and third postoperative days than those in the non-DM group (Figure 1). In the first 24 hours postoperatively, 243 (63%) and 107 (13.1%) of the patients in the DM and non-DM groups required insulin. The average median insulin dose administered within 24 hours postoperatively to patients in the DM group was significantly higher than that for those in the non-DM group (Table 4).

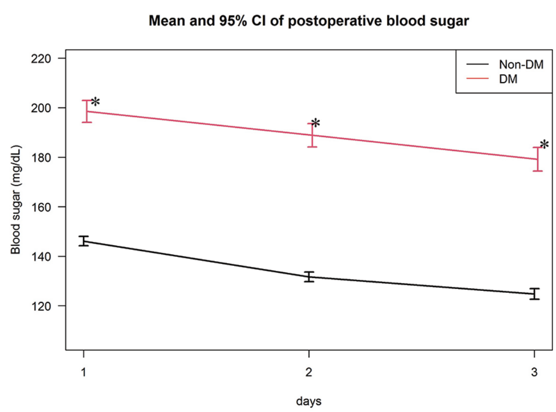

Figure 1. Postoperative blood sugar in non-diabetic and diabetic patients who undergoing cardiac surgery, * p<0.001.

HbA1c

HbA1c levels were measured in 227 of the 1,215 patients (18.6%), with 44.5% of the DM group and 6.4% of the non-DM group. Patients in the DM group had a higher median level of HbA1c than those in the non-DM group, at 7.1% versus 5.6% (p<0.001). HbA1c levels were not associated with postoperative death (p=0.143). Even after adjusting by using logistic regression analysis, HbA1c level was not an independent predictor for in-hospital mortality (OR 0.89, 95% CI 0.59 to 1.34, p=0.573).

Postoperative complications

The DM group had significantly higher rates of complications such as arrhythmias, and neurological, pulmonary, renal, and infectious complications, while the non-DM group had higher re-operation rates (Table 5). Patients in the DM group developed

Table 4. Perioperative blood glucose and insulin requirement in diabetic and non-diabetic patients

Blood glucose level	Diabetes (n=391)	Non-diabetes (n=824)	p-value
Intra-operative blood sugar; n (%)	386 (98.7)	183 (22.2)	<0.001
Fasting blood sugar (mg.dL^{-1}), median (IQR)	137 (115.2, 170)	113 (98.5, 150)	<0.001
Average blood glucose (mg.dL^{-1}), median (IQR)	174.2 (144.6, 203.6)	143 (107, 184.8)	<0.001
Highest value of blood glucose (mg.dL^{-1}), median (IQR)	213.5 (173.5, 258.8)	157 (108, 218.5)	<0.001
Lowest value of blood glucose (mg.dL^{-1}), median (IQR)	132.5 (114, 159.5)	128 (102.5, 164.5)	0.388
Hyperglycemia (blood sugar more than 180 mg.dL^{-1})	270 (69.9)	65 (35.5)	<0.001
Hypoglycemia (blood sugar less than 70 mg.dL^{-1})	2 (0.5)	6 (3.3)	0.026
Intra-operative insulin; n (%)	161 (41.7)	35 (19.1)	<0.001
Bolus	149 (92.5)	33 (94.3)	1
Continuous infusion	12 (7.5)	2 (5.7)	1
Frequency use of insulin; median (IQR)	1 (1, 2)	1 (1, 2)	0.814
Average dose of insulin (unit); median (IQR)	10 (10, 20)	10 (5, 15)	0.318
Post-operative blood glucose			
First 24 hours after surgery; n (%)	386 (98.7)	819 (99.4)	0.384
Initial glucose at ICU (mg.dL^{-1}); median (IQR)	201 (169, 240)	189 (157.5, 226)	<0.001
Median glucose (mg.dL^{-1}); median (IQR)	204.9 (183.4, 230.7)	176.7 (159.9, 196)	<0.001
Highest glucose (mg.dL^{-1}); median (IQR)	263.5 (228, 298.8)	218 (189, 251)	<0.001
Lowest glucose (mg.dL^{-1}); median (IQR)	150 (130, 177)	143 (128, 157)	<0.001
Post-operative insulin; n (%)			
Insulin infusion	243 (63.0)	107 (13.1)	<0.001
Average dose in first 24 hours (IU), median (IQR)	19 (4, 33.5)	0 (0, 6)	<0.001

ICU=intensive care unit; IQR=interquartile range

Table 5. Postoperative complications and mortality rate between the non-diabetic and diabetic patients

Post-operative complications	Diabetes (n=391)	Non-diabetes (n=824)	p-value
Post-operative complications; n (%)	302 (77.2)	465 (56.4)	<0.001
Myocardial infarction	8 (2.0)	8 (1.0)	0.205
Cardiac arrest	24 (6.1)	36 (4.4)	0.235
Cardiac arrhythmia	104 (26.6)	145 (17.6)	<0.001
Low cardiac output syndrome required IABP/ECMO	36 (9.2)	36 (4.4)	0.001
Neurological complications	44 (11.3)	58 (7.0)	0.018
Pulmonary complications	225 (57.5)	312 (37.9)	<0.001
Renal complications	154 (39.4)	142 (17.2)	<0.001
Infectious complications	62 (15.9)	60 (7.3)	<0.001
Reoperation	12 (3.1)	58 (7.0)	0.008
Multiorgan failure	4 (1.0)	9 (1.1)	1
Reintubation	33 (8.4)	25 (3.0)	<0.001
In-hospital death; n (%)	28 (7.2)	54 (6.6)	0.786
Timing of death after surgery (hours); median (IQR)	84.2 (36.5, 215.8)	79.3 (27, 201.1)	0.989
ICU stay (days); median (IQR)	3 (2, 6)	3 (2, 5)	<0.001
Hospital stay (days); median (IQR)	12 (9, 20)	11 (9, 17)	<0.001
Duration of mechanical ventilator (hours); median (IQR)	18.5 (14.1, 43.1)	18 (13.6, 22.8)	0.034
Need of non-invasive ventilation after extubation; n (%)	66 (16.9)	68 (8.3)	<0.001

IABP=intra-aortic balloon pump; ECMO=extracorporeal membrane oxygenation; ICU=intensive care unit; IQR=interquartile range

LCOS and required an intra-aortic balloon pump (IABP) or extracorporeal membrane oxygenation (ECMO) more often than in the non-DM group (Table 5). After adjusting using logistic regression analysis, DM was significantly associated with an increased rate of arrhythmias, infection, reintubation,

Table 6. Logistic regression analysis and propensity score matching of predicting post-operative complications in diabetic patients after cardiac surgery

Postoperative complications	Logistic regression		Propensity match	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Myocardial infarction	2.13 (0.79 to 5.72)	0.133	2.02 (0.6 to 6.77)	0.24
Cardiac arrest with ROSC	1.43 (0.84 to 2.43)	0.186	1.44 (0.76 to 2.72)	0.26
Arrhythmias	1.7 (1.27 to 2.26)	<0.001	1.63 (1.16 to 2.3)	0.005
LCOS	2.22 (1.38 to 3.58)	0.001	1.22 (0.74 to 2.02)	0.44
Neurologic complications	1.67 (1.11 to 2.53)	0.015	2.03 (1.2 to 3.43)	0.007
Pulmonary complications	2.22 (1.74 to 2.84)	<0.001	1.96 (1.47 to 2.6)	<0.001
Renal complications	3.12 (2.38 to 4.1)	<0.001	2.78 (2.01 to 3.85)	<0.001
Infection	2.4 (1.64 to 3.5)	<0.001	2.76 (1.69 to 4.49)	<0.001
Reoperation	0.42 (0.22 to 0.79)	0.007	0.59 (0.28 to 1.22)	0.15
Multiorgan failure	0.94 (0.29 to 3.06)	0.913	1.34 (0.3 to 6.01)	0.70
Reintubation	2.95 (1.73 to 5.03)	<0.001	1.91 (1.06 to 3.45)	0.029

ROSC=return of spontaneous circulation; LCOS=low cardiac output syndrome; OR=odds ratio; CI=confidence interval

neurologic, pulmonary, and renal complications (Table 6). Both logistic regression and propensity score match analysis did not significantly reveal any difference in postoperative myocardial infarction (OR 2.13, 95% CI 0.79 to 5.72, p=0.133 and OR 2.02, 95% CI 0.6 to 6.77, p=0.24, respectively). Despite that the low cardiac output syndrome increased significantly with OR 2.22 (95% CI 1.38 to 3.58, p=0.001) as determined by logistic regression analysis, propensity score matching did not show a significant difference (OR 1.22, 95% CI 0.74 to 2.02, p=0.44) (Table 6). The length of ICU stays, duration of mechanical ventilation, and total hospital stays were also significantly higher in the DM group than in non-DM group. Patients in the DM group required higher levels of non-invasive ventilation after extubation and reintubation than those in the non-DM group at 16.9% versus 8.3% (p<0.001) (Table 5).

In-hospital mortality

Eighty-two patients or 6.7% died in the hospital. Patients in the DM group had higher in-hospital mortality rates during admission, with a death rate of 28 out of 391 patients or 7.2% versus 6.6% (p=0.786) but without statistical significance (Table 5). After adjusting using logistic regression analysis, diabetes was not identified as an independent predictor for in-hospital mortality (OR 0.65, 95% CI 0.37 to 1.16, p=0.146) (Table 7). Chronic kidney disease, ASA physical status 4 and 5, preoperative arrhythmias, and non-valvular surgery were statistically significant predictors of in-hospital mortality from logistic regression analysis (Table 7).

Discussion

The proportion of patients with diabetes in the present study that underwent CABG surgery was found to be as high as 32.2%. The patients with DM were significantly older and more overweight when compared to those without diabetes. They also had significantly more comorbidities than those without diabetes. Similarly, a study that included 1,109 diabetic patients compared to 2,748 non-diabetic patients who underwent primary isolated on-pump CABG found that diabetic patients were more likely to be diagnosed preoperatively with hypertension, hyperlipidemia, renal failure, peripheral vascular disease, and chronic obstructive pulmonary disease[19].

Mortality

Data regarding the early mortality after CABG showed conflicting results[20-22]. Thourani et al. demonstrated that diabetic patients had a significantly higher incidence of postoperative death[23]. Carson et al. found that patients with diabetes had a 23% to 37% increase in 30-day mortality[12]. In addition, Rajakaruna et al. found that diabetic patients had mortality outcomes comparable to those of non-diabetic patients[1]. On the contrary, the impact of diabetes on short-term mortality after cardiac surgery in the present study was not significant. Moreover, in other reports, early mortality in patients with diabetes was not significantly different from that of those without diabetes[15,24-26].

Morbidity

Cardiac surgery in DM patients is associated with greater perioperative morbidity than in patients

Table 7. Univariate and multivariable Odds ratio Estimates for in-hospital mortality during admission

Predicting factors associated with mortality	Univariate		Multivariate	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Diabetes mellitus	1.1 (0.69 to 1 to 77)	0.693	0.65 (0.37 to 1.16)	0.146
Age	1.03 (1.01 to 1.05)	0.01	1.02 (0.99 to 1.04)	0.172
BMI	0.96 (0.91 to 1.02)	0.188		
Underlying diseases				
Hypertension	1.3 (0.81 to 2.07)	0.278		
Dyslipidemia	0.92 (0.58 to 1.46)	0.732		
CKD	3.17 (1.99 to 5.04)	<0.001	2.21 (1.28 to 3.83)	0.004
CVA	1.39 (0.7 to 2.77)	0.352		
COPD	0.7 (0.17 to 2.96)	0.629		
Peripheral arterial disease	2.55 (0.56 to 11.7)	0.229		
Smoking	0.8 (0.43 to 1.46)	0.462		
ASA physical status class (ref. ASA class 3)				
Class 4	9.45 (5.67 to 15.77)	<0.001	7.25 (4.2 to 12.53)	<0.001
Class 5	50.08 (20.15 to 124.47)	<0.001	51.62 (19.26 to 138.34)	<0.001
Arrhythmia	1.6 (0.97 to 2.63)	0.064	3.03 (1.58 to 5.83)	<0.001
Congestive heart failure	3.19 (2.02 to 5.05)	<0.001		
Unstable angina/myocardial ischemia	2.64 (1.68 to 4.16)	<0.001	1.46 (0.82 to 2.59)	0.198
Type of cardiac surgery				
Valvular & non-valvular	0.55 (0.34 to 0.87)	0.012	0.48 (0.25 to 0.9)	0.023

BMI=body mass index; CKD=chronic kidney disease; CVA=cerebrovascular accident; COPD=chronic obstructive pulmonary disease; ASA=American Society of Anesthesiologists

without DM[27-29]. This was related in part to a high incidence of comorbid conditions as well as the adverse effects of hyperglycemia and hypoglycemia on clinical outcomes[20,23,27,30]. Halkos et al, also found that patients with diabetes had an increased incidence of postoperative morbidity after valve operations[31]. In the present study, DM was an independent factor of postoperative complications after adjusting for logistic regression analysis.

Stroke

A higher incidence of postoperative stroke has been reported among diabetics[3,23]. However, the present study contradicts the finding of Kubal et al., which revealed no link between diabetes and postoperative stroke[32].

Acute renal failure

Acute renal failure was more common in diabetic patients who underwent CABG and other open-heart surgery[32-34]. In the present study, DM was also associated with an increased risk of renal problems. Nonetheless, according to the findings, there was no significant increase in the incidence of postoperative renal failure in diabetic individuals[4,35]. A complicated interplay between renal hemodynamics, tubular, endothelial cell damage, and the inflammatory process is involved in the pathogenesis of ischemic acute renal failure[36]. Hypoglycemia-induced endothelial dysfunction leads to tubular injury at the microvascular level, initiating and subsequently extending the tubular damage[37]. A tubuloglomerular feedback mechanism may be involved in the impairment of renal blood flow and glomerular filtration rate[38].

Arrhythmias

Arrhythmias following cardiac surgery commonly affect 20% to 30% of patients[39]. A higher incidence of shockable rhythms after removing the aortic cross-clamp was found in patients with diabetes compared to those without diabetes. Furthermore, with adjusted logistic analysis, DM was an independent predictor of postoperative arrhythmias in the present study. Nevertheless, the incidence rates of cardiac arrests in the ICU were not different between groups. DM was, somehow, shown to reduce the incidence of arrhythmia when compared with non-diabetic patients with 23% versus 26% in CABG surgery[19]. This is similar to the finding of Halkos et al[40]. Previous studies have indicated that tight glycemic control results in better arrhythmia[41,42].

Infection

The predisposition of patients with DM to infectious complications after cardiac surgery has frequently been suggested, however, there are some exceptions[34,43-45]. The present study showed that the incidence of infectious complications in diabetic patients was higher than in non-diabetic patients, and with adjusted logistic regression, DM was the independent factor of infectious complications. The predisposition to infections is due to angiopathy, neuropathy, and hyperglycemia[33]. Furthermore, diabetic patients have deteriorated host defense systems, such as wound healing and granulocyte function[1,20,33,46,47]. Acute hyperglycemia has several effects on innate immunity. It reduces neutrophil and complement activity while increasing proinflammatory cytokines such as tumor necrosis factor-α and interleukin-6[48]. Previous studies have suggested a relation between improved glucose control during the perioperative period and lower rates of wound infection and dehiscence[32,49-51].

Myocardial infarction

A recent study reported no increased risk of perioperative myocardial infarction, or LCOS in diabetic patients compared to patients without diabetes[21]. Similarly, in the present study, diabetic patients also had no increased risk of perioperative myocardial infarction. However, patients with diabetes had a significantly increased risk of LCOS requiring IABP or ECMO. However, Ascione et al, suggested that inadequate blood glucose control, regardless of diabetic status, was an independent predictor of postoperative myocardial infarction in patients undergoing cardiac surgery[52]. In contrast to the finding of the present study, the risk of postoperative myocardial infarction and low cardiac output syndrome did not significantly differ between patients with and without DM.

Limitation

This study has important limitations. First, it was a retrospective cohort study, hence, missing database records could compromise the analysis. Some information was unavailable in the facility's registry, such as HbA1c measurements, which were not routine practice and information about the main causes of death, which was not always available. In addition, obtaining intraoperative fasting glucose and glucose level results was not feasible for patients without diabetes, which accounted for 77.8% of the patients. Second, the present study did not assess DM subtypes, because DM type 1 (DM1) may have had a higher severity with a two-fold increase in the risk of death compared to that in non-diabetic patients, as demonstrated in another study[53]. Third, the duration of diabetes, particularly in patients with DM duration longer than 10 years affected the risk of in-hospital mortality, was not assessed in the present trial. Finally, another explanation for the null association between DM and mortality may be the small number of patients used in the comparison.

Conclusion

In conclusion, the present study demonstrated that patients with diabetes were an independent predictor of postoperative complications after cardiac surgery. In addition, DM was an independent predictor of postoperative arrhythmias, and infectious, neurologic, pulmonary, and renal complications following cardiac surgery. These led to significantly longer ICU stays, duration of mechanical ventilation, and total hospital stays. However, it was not associated with mortality.

What is already known on this topic?

DM is reported as a common comorbidity in patients undergoing cardiovascular surgery. It has also been associated with increased morbidity in cardiac surgery. However, there are conflicting reports on the mortality and early outcomes of patients with diabetes who undergo cardiac surgery.

What does this study add?

Diabetic and non-diabetic patients have similar in-hospital mortality rates. DM was an independent predictor for postoperative arrhythmias, and infectious, neurologic, pulmonary, and renal complications following cardiac surgery. Patients with diabetes showed higher hyperglycemia rates, thus greater than 180 mg/dL, and required higher doses of insulin than those in the non-diabetic patients both during and after surgery. However, HbA1c level was not an independent predictor for in-hospital mortality.

Authors' contributions

MS participated in the design of the study, analysis, and interpretation of the data, and drafting of the manuscript. WW participated in the supervision of the study, the manuscript writing and the final approval of the manuscript for publication. Finally, AC and DY participated in the data collection.

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Conflicts of interest

The authors declare no conflict of interest.

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