Glycemic control in diabetic and non-diabetic cardiac surgical patients and length of hospital stay

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Abstract

Background: Maintaining blood glucose levels (BGL) within normoglycemic range has been shown to reduce morbidity and mortality in critically ill patients. However, there is little evidence that maintenance of normoglycemic BGL is beneficial for diabetic and non-diabetic patients who undergo cardiac surgery.

Purpose: To examine the relationship between BGL and length of stay (LOS) of cardiac surgical patients.

Methods: Data were obtained from the Safer Healthcare Now Project database in the cardiovascular intensive care unit (CVICU) at the Foothills Medical Centre, Calgary, Alberta, and included two BGL from cardiac surgery patients: BGL 1 was collected within four hours preoperatively, BGL 2 was collected postoperatively 24 hours after BGL 1. CVICU LOS and total hospital LOS were obtained from the Tracer database of the Department of Critical Care Medicine, Calgary Health Region. Demographic, clinical, and surgical data were collected from health records.

Results: For the 398 patients, no relationship was found between pre- and postoperative BGL and LOS. Although pre- and postoperative BGL were not different between diabetics and non-diabetics, diabetics had longer CVICU LOS and total hospital LOS. Age, preoperative HgbA1C, type of surgery, cross-clamp and cardiopulmonary bypass times, APACHE II scores, and postoperative complications also affected LOS.

Conclusion: In this cohort of cardiac surgical patients, pre- and postoperative BGL did not affect LOS.

The acute stress experienced by post surgical patients, whether or not they have a history of diabetes mellitus, often results in a hyperglycemic response (Van den Berghe & Mesotten, 2003). A hyperglycemic response is more often a pathological rather than a normal physiological response (Chittock, Henderson, Dhingra, & Ronco, 2003) adversely affecting immune function and wound healing, leading to increased postoperative infections and prolonged length of hospital stay (Furnary, Zerr, Grunkemeier, & Starr, 1999; Van den Berghe et al., 2001). Recent findings illustrate the importance of maintaining blood glucose levels (BGL) within normoglycemic range to reduce morbidity and mortality in critically ill patients (Chittock et al., 2003; Furnary, Wu, & Bookin, 2004; Golden, Peart-Vigilance, Kao, & Brancati, 1999; Pomposelli et al., 1998; Van den Berghe et al., 2001; Van den Berghe & Mesotten, 2003).

The Canadian Diabetes Association recommends a continuous intravenous insulin infusion to achieve BGL of 4.5 mmol/L to 6.0 mmol/L in postoperative patients with a random blood glucose level > 6.0 mmol/L and who require intensive care with mechanical ventilation (Cheng & Booth, 2003). They also recommend that a continuous insulin infusion be used to maintain intraoperative BGL between 5 mmol/L and 11 mmol/L for patients with diabetes undergoing cardiac surgery. However, there has been conflicting evidence that this is beneficial. Although the Canadian Diabetes Association (Cheng & Booth, 2003) recommends treatment for diabetics and non-diabetics with BGL ≥ 7.0 mmol/L, others suggest treatment when BGL are 11.1 mmol/L to 13.9 mmol/L (Fish, Weaver, Moore, & Steel, 2003; Furnary, Zerr, Grunkemeier, & Starr, 1999).

Recently, a protocol was implemented in the cardiovascular intensive care unit (CVICU) at the Foothills Medical Centre, Calgary, Alberta, to maintain BGL < 11.0 mmol/L in the first two postoperative days of cardiac surgical patients. Does maintenance of normoglycemic BGL in the cardiac surgical patient affect length of hospital stay?

Background

Hyperglycemia and postoperative complications. Hyperglycemia in critically ill patients is driven by increased release of counter-regulatory stress hormones and circulating concentrations of inflammatory cytokines (Douglas, Connery, & Ketzler, 2004; Mesotten & Van den Berghe, 2003). Until recently, maintaining BGL ≥ 12 mmol/L, regardless of a history of diabetes mellitus, was acceptable for critically ill patients (Mesotten & Van den Berghe). However, Umpierrez, Isaacs, Bazargan, You, Thaler, and Kitabchi (2002) suggested that non-diabetic patients with hyperglycemia had a 18.3-fold increased mortality rate, as compared with a 2.7-fold increase in diabetic patients. Additional findings suggest that hyperglycemia is more important in determining clinical outcomes rather than absolute hypoinsulinemia (Finney, Zekveld, Elia, & Evans, 2003). As Douglas et al. (2004) indicated, even though hyperglycemia commonly occurs in critically ill diabetic patients, it is also frequently found in non-diabetics.

Hyperglycemia post-cardiac surgery can have severe effects, including a predisposition to complications such as wound infections and polyneuropathy, often leading to lengthened hospital stays (Van den Berghe et al., 2001). Pomposelli et al.'s (1998) observational study of cardiac surgery patients with significant hyperglycemia (BGL > 12.2 mmol/L) reported increased rates of postoperative wound infections. A retrospective review of 20 cardiac surgery patients found that postoperative hyperglycemia (BGL > 11.1–13.9 mmol/L) placed patients at significantly higher risk (21%) for a variety of poor outcomes, including infections (Fish et al., 2003). As well, a prospective study of 2,467 diabetic patients undergoing cardiac surgery who were hyperglycemic (BGL > 11.1 mmol/L) in the immediate postoperative period were found to be at greater risk for deep sternal wound infections (Furnary et al., 1999). Post-cardiac surgical patients with diabetes who were in the higher quartiles of BGL were also found to have higher rates of leg and sternal wound infections, pneumonia, and urinary tract infections (Golden et al., 1999).

Maintaining BGL within normoglycemic range can also reduce mortality in critically ill patients. In a prospective cohort of 9,920 diabetics and 2,278 non-diabetics who had coronary artery bypass grafts, it was found that diabetics had a higher incidence (3.9%) of postoperative deaths than non-diabetics (1.6%) (Thourani et al., 1999). Krinsley (2003) also found from retrospective data of 1,826 patients (22% diabetics and 78% non-diabetics) in a medical-surgical intensive care unit (ICU), that even a "modest" degree of hyperglycemia (BGL > 15 mmol/L) occurring after ICU admission is associated with an increase in hospital mortality, independent of a diabetes mellitus diagnosis. Finney et al. (2003) also associated hyperglycemia (BGL > 11.1 mmol/L) with increased risk of mortality in critically ill patients.

Intensive insulin therapy and postoperative complications. Organs such as the heart, skeletal muscle, and adipose tissue are insulin-sensitive (Mesotten & Van den Berghe, 2003). Insulin stimulates glucose uptake for muscle catabolism in the heart and skeletal muscle. Adipose tissue in the presence of insulin increases serum fatty acids and triglycerides and, although the mechanisms are unknown, increased serum levels are thought to nourish critically ill patients (Mesotten & Van den Berghe). There is increasing evidence that aggressive blood glucose control in acute care settings offers significant benefits (Chittock et al., 2003; Van den Berghe et al., 2001). Furnary et al. (1999) noted that diabetic post-cardiac surgical patients with BGL maintained between 8.3 mmol/L and 11.1 mmol/L had a decreased incidence of deep sternal wound infections. BGL ≤ 8.0 mmol/L have been linked with decreased mortality rates (Finney et al., 2003). Van den Berghe et al. (2001) took tight glycemic control even further with intensive intravenous insulin therapy to maintain BGL at 4.4 mmol/L to 6.1 mmol/L, which resulted in decreased morbidity and mortality. As well, Krinsley (2003) determined that the lowest hospital mortality rate of 9.6% occurred with BGL between 4.4 mmol/L and 5.5 mmol/L; the highest mortality rate of 42.5% was with BGL ≥ 16.7 mmol/L. In comparison with maintaining BGL between 8.3 mmol/L and 14 mmol/L, Douglas et al. (2004) found that BGL < 6.7 mmol/L to 8.3 mmol/L reduced the incidence of wound and sternal infections and improved survival rates in postoperative cardiac patients.

Controversy exists regarding intensive insulin therapy. Finney et al. (2003) in a prospective, observational study of 531 ICU patients (cardiac surgery and medical), found that BGL of 6.1 mmol/L to 8.0 mmol/L maintained by a daily infusion of 35 IU to 40 IU insulin was associated with increased mortality. Hypoglycemia, according to the Canadian Diabetes Association (Cheng & Booth, 2003), is a plasma glucose level < 4.0 mmol/L, severe hypoglycemia is < 2.8 mmol/L and the development of autonomic (e.g., trembling, palpitations, diaphoresis, hunger) or neuroglycopenic symptoms (e.g., difficulty concentrating and speaking, weakness, drowsiness), or symptoms responding to administration of a carbohydrate. Severe hypoglycemia is associated with mild intellectual impairment and may lead to permanent neurologic sequelae such as hemiparesis. However, prospective studies such as the Diabetes Control and Complications Trial (DCCT) (Diabetes Control and Complications Trial Research Group, 1996) and the Stockholm Diabetes Intervention Study (Reichard & Pihl, 1994) did not find an association between intensive insulin therapy and neuropsychological impairment.

Specifically, in the cardiac population, hypoglycemia induced by tight glycemic control may increase the risk of cardiovascular events. According to Landstedt-Hallin, England, Adamson, and Lins (1999), Marques et al. (1997), and Heller (2000), hypoglycemia in type 1 diabetics caused prolonged QT intervals, increasing the risk of ventricular tachycardia and sudden death. In addition, Desouza, Salazar, Cheong, Murgo, and Fonseca (2003) demonstrated that out of 54 patients who experienced hypoglycemia (BGL< 3.89mmol/L), 26 experienced symptoms of hypoglycemia and 10 reported chest pain and, of these 10, four had ECG abnormalities. In one case report by Bhatia, Pandey, Rodriguez, Mehta, and Joshi (2003), the use of an intensive insulin infusion (2u/hr) resulted in hypoglycemia (2.8 mmol/L) in a non-diabetic patient, which required a rapid infusion of dextrose solution. This treatment may have been associated with hyperkalemia, and the cardiac arrest of this 77-year-old female. Recently, Gunjan et al. (2007) concluded in a randomized, open-label, controlled trial of 400 diabetic and non-diabetic cardiac surgery patients, that intensive insulin therapy did not reduce peri-operative death or morbidity.

Purpose of the study

Hyperglycemia has been associated with many cardiac complications. However, there is a lack of evidence showing that maintenance of normoglycemic BGL is beneficial for diabetic and non-diabetic patients who undergo cardiac surgery. The aim of the Safer Healthcare Now Project was to determine whether maintaining BGL < 11mmol/L in the first 48 hours would result in decreased rates of wound and sternal infections. In this study, the aim was to further determine if BGL < 11.0 mmol/L would result in decreased CVICU length of stay (LOS) and total hospital LOS. The relationship between preoperative and postoperative BGL and LOS of cardiac surgical patients was examined comparing diagnosed diabetics versus non-diabetics. The specific questions addressed were:

1. Is there a difference in LOS by maintaining preoperative and postoperative BGL <11.0 mmol/L between diabetic and non-diabetic cardiac surgical patients?
2. What postoperative complications result from the maintenance of preoperative and postoperative BGL <11.0 mmol/L in diabetic and non-diabetic cardiac surgical patients?
3. What factors affect preoperative and postoperative BGL and LOS in diabetic and non-diabetic cardiac surgical patients?

Methods

Design. A retrospective, cohort design was used to examine the relationship between BGL and LOS in diabetic and non-diabetic cardiac surgical patients. Blood glucose levels were obtained from the Safer Healthcare Now Project database (CVICU, Foothills Medical Centre) and length of hospital stay was accessed via the Tracer database from the Department of Critical Care Medicine, Calgary Health Region. Demographic, clinical, and surgical data were collected from health records.

Sample. The Safer Healthcare Now Project database consisted of patients admitted to the CVICU from October to December 2005, and March to April 2006. Patients excluded were those who had existing comorbidities such as end stage renal failure, end stage pulmonary diseases, or terminal cancer. End stage was defined as the need for technical life support, such as continuous renal replacement therapy, intra-aortic counterpulsation balloon pump, or extracorporeal oxygenation.

Definition of variables. *Blood glucose level* (BGL) is the amount of glucose measured in mmol/L by the use of Lifescan glucometers (Johnson & Johnson, Co.). Samples were drawn from a capillary source or from an arterial line. BGL 1 was collected within four hours prior to surgery. BGL 2 was collected postoperatively 24 hours after BGL 1.

Hyperglycemia is a BGL > 7.0 mmol/L (Cheng & Booth, 2003).

Total hospital LOS was the amount of time (in days) from when patients were admitted to the CVICU post-cardiac surgery to when they were discharged from the hospital telemetry ward.

CVICU LOS included time spent immediately post surgery in the CVICU to when the patient was transferred to the hospital telemetry ward.

Demographic characteristics included gender (male or female) and age in years.

Clinical characteristics included previous diagnosis of diabetes mellitus (diabetic or non-diabetic)—diabetics were further categorized into insulin-dependent diabetes mellitus (type 1) or non-insulin-dependent diabetes mellitus (type 2). Pre-existing comorbidities (presence or absence) included ischemic heart disease, previous myocardial infarction, vascular disease, cerebrovascular accident, dysrhythmias, chronic obstructive pulmonary disease, and/or acute/chronic renal failure; preoperative HgbA1C is the amount of glycosylated hemoglobin present in the body recorded as a percentage (normal HgbA1C = 4.3% to 6.1%); body mass index (BMI) is a ratio of weight-to-height (weight [kg] ÷ height [m^2]).

Surgical characteristics included type of surgery (coronary artery bypass grafts [CAB]), valve replacement/repair, CAB and valve replacement/repair, ascending aortic aneurysm [AAA] repair, AAA and valve replacement/repair, and other); aortic cross-clamp time (in minutes); cardiopulmonary bypass (CPB) time (in minutes); and Acute Physiology and Chronic Health Evaluation II (APACHE II) disease severity score from 0 to 71 (Knaus, Draper, Wagner, & Zimmerman, 1985).

Postoperative complications (presence or absence) included arrhythmias, cardiac arrest, hemorrhage, valvular leak, cardiac tamponade, delirium, cerebral vascular accident, infection, re-operations, or inability to be weaned off the ventilator.

Data collection protocol. Ethical approval was received from the Health Research Ethics Board. Data were then obtained from the Safer Healthcare Now Project database. Health record reviews provided the gender, age, diagnosis of diabetes mellitus, pre-existing comorbidities, preoperative HgbA1C, BMI, type of surgery, cross-clamp and CPB times, pre- and postoperative APACHE II scores, and postoperative complications.

Data analysis. To determine whether there was a relationship between BGL and LOS in post-cardiac patients, variables were analyzed using the Statistical Package for Social Sciences (SPSS) version 15. T-tests were used to determine differences between BGL and LOS in diabetic and non-diabetic post-cardiac surgical patients. Demographic, clinical, and surgical characteristics of the cohort were then examined using t-test, Pearson's r, or Chi-square to explore factors affecting BGL and LOS.

Results

Sample. Of the 433 cardiac surgical patients in the Safer Healthcare Now Project database, there were 398 patients with health records available from the time period of October to December 2005, and of March to April 2006. There were 35 health records unavailable due to various reasons such as involved in another study or involved in an internal audit. Of the 398 patients, the average age was 64.8 ± 11.5 years (range = 23 to 89 years). There were more males (77.9%) than females (22.1%), and in this cohort, 74.1% did not have diabetes mellitus. Among the male patients, there were 24.2% who were diabetic; among the female patients, there were 31.8% who were diabetic. There was no difference between diabetic and non-diabetic patients in age ($p = 0.92$) or gender ($p = 0.17$). Of the 25.9% who had diabetes mellitus, 3.3% were insulin dependent and 22.6% were non-insulin dependent (Table One).

Approximately half of the patients had a preoperative HgbA1C of 6.4 ± 1.4% (range = 4.6% to 4.1%). Preoperative HgbA1C was significantly higher in diabetics than in non-diabetics ($p< 0.001$). The average BMI was 28.4 ± 5.2 kg/m^2, with a range of 15.0 to 52.8 kg/m^2. Patients in this cohort who had an increased BMI were more likely to have diabetes mellitus ($p = 0.008$). The majority (93.2%) of this cohort had some form of pre-existing comorbidity, such as ischemic heart disease, previous myocardial infarction, cerebrovascular accident, dysrhythmias, chronic obstructive pulmonary disease, and/or acute/chronic renal failure. Diabetics had more pre-existing comorbidities than non-diabetics ($p = 0.005$).

The majority of surgeries (94%) were coronary artery bypass grafts, valve replacements/repairs, or a combination, with more non-diabetics (n=295) than diabetics (n=103) having any type of surgery ($p < 0.001$) during the study time period. The mean cross-clamp time was 61.0 ± 34.7 min. (range = 0 to 210 min.) and the mean cardiopulmonary bypass (CPB) time was 83.0 ± 43.5 min. (range = 0 to 308 min.). There was one coronary artery bypass graft surgery done off-pump. Cross-clamp and CPB times were not different between diabetics and non-diabetics ($p = 0.87$). As well, pre- and postoperative APACHE II scores, 27.5 ± 4.9 and 16.3 ± 4.8, respectively, were not different for diabetic or non-diabetic patients ($p = 0.1$ and $p = 0.12$, respectively). Furthermore, 61.3% of the patients had some form of postoperative complication such as arrhythmias, cardiac arrest, hemorrhage, valvular leak, cardiac tamponade, delirium, cerebral vascular accident, infection, and/or the inability to be weaned off the ventilator. Other serious complications included the requirement of life support measures (e.g., intra-aortic balloon counterpulsation, continuous renal replacement therapy, and extracorporeal oxygenation). However, these postoperative complications were not statistically different between the diabetic and non-diabetic patients ($p = 0.16$).

BGL and LOS for diabetic and non-diabetic patients. The mean pre-operative BGL for the total cohort was 7.8 ± 2.1 mmol/L (range = 3.6 to 3.8 mmol/L), slightly higher than the mean postoperative BGL of 7.4 ± 1.9 mmol/L (range = 2.5 to 12.1 mmol/L) ($p < 0.001$). In the Safer Healthcare Now Project for the CVICU, the goal was to maintain BGL < 11.0 mmol/L. The preoperative and postoperative BGL were not significantly different between diabetics and non-diabetics (Table Two). The median CVICU LOS was 1.8 days (range = 0.24 to 51.4 days) for the total cohort, and the median total hospital LOS was 11.0 days (range = 2 to 121 days). Diabetics had a longer CVICU LOS than non-diabetics (M = 3.6 ± 6.4 days versus M = 2.2 ± 2.0 days, $p = 0.03$). Similarly, diabetics had a longer total hospital LOS than non-diabetics (m = 18.0 ± 18.9 days versus m = 12.8 ± 9.5 days, $p = 0.01$). However, preoperative and postoperative BGL did not correlate with CVICU LOS ($r = 0.05$, $p = 0.29$

Table One: Characteristics of the cohort

Characteristic	Total Cohort	Diabetics	Non-Diabetics	p Value*
Demographic Characteristics:				
Gender				
Male (N/%)	310/77.9	75/24.2	235/75.8	0.17
Female (N/%)	88/22.1	28/31.8	60/68.2	
Age (mean ± S.D.), yr. old	64.8 ± 11.5	64.7 ± 9.3	64.8 ± 12.2	0.92
Clinical Characteristics:				
Diabetes Mellitus (N/%)				
Type 1—insulin dependent		13/3.3		
Type 2—non-insulin dependent		90/22.6		
Non-Diabetes Mellitus (N/%)			295/74.1	
Pre-existing Comorbidities (N/%)	371/93.2	102/27.5	269/72.5	0.005
Pre-op HgbA1C** (mean ± S.D.), %	6.4 ± 1.4	7.5 ± 1.7	5.8 ± 0.5	<0.001
BMI** (mean ± S.D.), kg/m^2	28.4 ± 5.2	29.5 ± 5.2	27.9 ± 5.1	0.01
Surgical Characteristics:				
Type of Surgery (N/%)				<0.001
Coronary Artery Bypass Grafts (CAB)	239/60.1	79/33.1	160/66.9	
Valve Replacement/Repair	83/20.9	9/10.8	74/89.2	
CAB & Valve Replacement/Repair	52/13.1	12/23.1	40/76.9	
Ascending Aortic Aneurysm (AAA)	6/1.5	0/0	6/100	
AAA & Valve Replacement/Repair	7/1.8	2/28.6	5/71.4	
Other	11/2.8	1/9.0	10/91.0	
Cross-clamp Time (mean ± S.D.), min.	65.8 ± 34.7	66.3 ± 33.7	65.6 ± 35.2	0.87
CPB Time (mean ± S.D.), min	90.3 ± 43.5	90.8 ± 42.3	90.0 ± 43.9	0.87
Pre-op APACHE II score*** (mean ± S.D.)	27.5 ± 4.9	28.2 ± 5.3	27.3 ± 4.8	0.13
Post-op APACHE II score*** (mean ± S.D.)	16.3 ± 4.8	16.9 ± 4.9	16.0 ± 4.8	0.12
Postoperative Complications (N/%)	244/61.3	70/28.7	174/71.3	0.16

Note. BMI—Body Mass Index, APACHE—Acute Physiology and Chronic Health Evaluation
*Based on Fisher's exact 2-sided test or 2-tailed T-test for Equality of Means comparing patients with and without diabetes mellitus, statistical significance of $p<0.05$
**Health Canada normal BMI range = 18.5–24.9 kg/m^2 ; Calgary Health Region normal value for HgbA1C = 4.3–6.1%
***APACHE II scores range from 0–71

and r = -0.03, $p = 0.61$, respectively). As well, there was no association between pre- and post- BGL and total hospital LOS (r = 0.03, $p = 0.63$ and r = -0.07, $p = 0.20$, respectively).

Factors affecting blood glucose levels. Among the demographic, clinical, and surgical characteristics analyzed, higher preoperative and postoperative BGL were associated with an elevated BMI ($p < 0.001$ and $p = 0.001$, respectively). The remaining characteristics did not significantly affect BGL (Table Three).

Factors affecting length of stay. Demographic, clinical, and surgical characteristics were also examined that may affect LOS (Table Four). Increased age was related to a longer total hospital LOS ($p = 0.01$), but not CVICU LOS ($p = 0.57$). Longer cross-clamp and CPB times were also associated with increased CVICU LOS ($p = 0.01$ and $p = 0.001$, respectively), but did not affect total hospital LOS ($p = 0.55$ and $p = 0.45$, respectively). Higher preoperative HgbA1C only affected CVICU LOS ($p < 0.001$). Type of surgery, pre- and post-APACHE II scores, and postoperative complications were associated with significantly longer CVICU and total hospital LOS. Patients having combination CAB and valve replacement/repair surgery had the longest CVICU LOS (M = 4.30 ± 7.38 days) and total hospital LOS (M = 20.14 ± 18.67 days) in comparison to other types of cardiac surgery ($p = 0.004$). Although having postoperative complications was not specifically related to BGL in this cohort, for those patients with postoperative complications in contrast to those without, mean CVICU LOS was 3.21 ± 4.56 days and 1.49 ± 0.78 days, respectively, and total hospital LOS was 16.93 ± 15.36 days and 10.03 ± 5.05 days, respectively.

Discussion

Hyperglycemia has been linked to postoperative complications and, in turn, has prolonged LOS (Finney et al., 2003; Krinsley, 2003; Thourani et al., 1999). However, maintaining normoglycemic levels by the use of intensive insulin therapy may result in an increased postoperative hypoglycemia (Heller, 2000; Landstedt-Hallin et al., 1999; Marques et al., 1997). BGL between 2.0 mmol/L and 4.0 mmol/L have been associated with an increased risk of developing life-threatening cardiac dysrhythmias, resulting in increased length of hospital stay and/or death (Krinsley). Adverse events from BGL < 11.0 due to increased levels of catecholamines and hypokalemia

Table Two: BGL and LOS in diabetic and non-diabetic patients

Variable	Total Cohort	Diabetics	Non-Diabetics	p Value*
Pre-BGL (mean ± SD)	7.8 ± 2.1	7.7 ± 2.1	7.8 ± 2.2	0.70
Post-BGL (mean ± SD)	7.4 ± 1.9	7.6 ± 2.5	7.3 ± 1.6	0.33
CVICU LOS (mean ± SD)	2.6 ± 3.7	3.6 ± 6.4	2.2 ± 2.0	0.03*
Total Hospital LOS (mean ± SD)	14.2 ± 12.8	18.0 ± 18.9	12.8 ± 9.5	0.01*

Note. *Based on 2-tailed T-test for Equality of Means comparing patients with and without diabetes, statistical significance of $p<0.05$

Table Three: Relationship between BGL and cohort characteristics

	Pre-BGL	Post-BGL
Demographic Characteristics:		
Gender	t = 0.67 (p = 0.50)	t = -0.37 (p = 0.71)
Age	r = 0.02 (p = 0.77)	r = -0.06 (p = 0.22)
Clinical Characteristics:		
Pre-existing Comorbidities	t = -0.21 (p = 0.83)	t = 0.10 (p = 0.92)
Pre-operative HgbA1C	r = -0.09 (p = 0.21)	r = 0.01 (p = 0.90)
BMI	r = 0.19 (p < 0.001)*	r = 0.16 (p = 0.001)*
Surgical Characteristics:		
Type of Surgery	F = 0.24 (p = 0.95)	F = 0.88 (p = 0.50)
Cross-clamp Time	r = 0.03 (p = 0.63)	r = 0.09 (p = 0.09)
Cardiopulmonary Bypass Time	r = 0.05 (p = 0.31)	r = 0.10 (p = 0.06)
Preoperative APACHE II	r = 0.08 (p = 0.11)	r = -0.04 (p = 0.44)
Postoperative APACHE II	r = 0.05 (p = 0.30)	r = -0.08 (p = 0.13)
Postoperative Complications	t =-1.86 (p = 0.05)	t = 0.60 (p = 0.55)

Note. *Association is statistically significant at $p < 0.05$ (2-tailed) can prolong QT intervals, thereby inducing cardiac arrest. Hypoglycemia and increased secretion of counter-regulatory hormones, such as epinephrine and norepinephrine, have also been demonstrated to cause vasoconstriction and platelet aggregation leading to cardiac ischemia (Desouza et al., 2003), which can result in prolonged CVICU and total hospital LOS.

In this study cohort, patients' BGL were maintained below 11.0 mmol/L (median pre-BGL = 7.6 mmol/L; median post-BGL = 7.3 mmol/L) due to the Safer Healthcare Now Project in the CVICU. Also, BGL < 11.0 mmol/L pre- and post-cardiac surgery were not found to be related to CVICU and total hospital LOS, nor was a difference found between diabetic and non-diabetic BGL. However, diabetic patients did have a longer CVICU and total hospital LOS. This may have been due to an unavailability of beds on the ward and, so, they stayed in the CVICU longer, and specific patients who had undergone more complex surgeries were included in the study and, thus, may have skewed the data to indicate longer-than-average LOS.

Other factors, such as postoperative wound and sternal infections, are often prevalent in diabetic patients, and have been associated with longer hospital stays, increased use of health care resources, and greater peri-operative mortality than non-diabetic patients undergoing cardiac surgery (Bhatia, Pandey, Rodriguez, Mehta, & Joshi, 2003; Rehman & Mohammed, 2003). As well, Fowler, O'Brien, Muhlbaier, Corey, Ferguson, and Peterson (2005) found that diabetes mellitus was an independent risk factor that contributed to higher rates of major infections post-cardiac surgery, resulting in significantly higher mortality and postoperative LOS > 14 days. In this cohort, other characteristics of age, pre-operative HgbAIC, type of surgery, cross-clamp and CPB times, pre- and post-APACHE II scores, and postoperative complications were also found to be associated with longer CVICU and/or total hospital LOS. Hospitalized diabetics are usually older, less active, and have higher HgbA1C levels at the time of admission (Umpierrez, Isaacs, Bazargan, You, Thaler, & Kitabchi, 2002). Furthermore, Krinsley (2003) determined that higher APACHE II scores, specifically in the cardiac, pulmonary, and general surgical patients, are associated with increased ICU LOS and mortality. Finally, postoperative complications such as wound and sternal infections have been shown to increase mortality and LOS (Rehman & Mohammed).

Limitations of the study. Various limitations to this study included re-admission to the CVICU and to the hospital ward that could not be accounted for, and LOS also included patients who may have been eligible for transfer to a rural hospital or in need of home support, but were waiting for these to be established. Other variables not accounted for were initiation of anticoagulant therapy due to a new onset of dysrhythmias, whether the cardiac surgery was scheduled, urgent, or emergent, and whether some patients were awaiting diagnostic results prior to approval for discharge, which may have prolonged patients' LOS. Also, cardioplegia solution (glucose content based on how much solution given during cardiac surgery) may have influenced postoperative BGL, Parsonnet Scores (calculated preoperative risk score) were not available, and APACHE II scores are based on trauma patients and do not translate precisely to postoperative cardiac patients. Finally, some data, such as postoperative HgbA1C values and length of surgery, were not available.

Conclusion

In this cohort of cardiac surgical patients, there was no correlation between preoperative and postoperative BGL and CVICU LOS and total hospital LOS. However, age, preoperative

Table Four: Relationship between LOS and cohort characteristics

	CVICU LOS	Total Hospital LOS
Demographic Characteristics:		
Gender	t = 0.80 (p = 0.42)	t = 1.34 (p = 0.18)
Age	r = 0.03(p = 0.57)	r = 0.13 (p = 0.01)*
Clinical Characteristics:		
Pre-existing Comorbidities	t = -1.17 (p = 0.24)	t = -1.62 (p = 0.11)
Pre-operative HgbA1C	r = 0.31 (p < 0.001)*	r = 0.14 (p = 0.06)
BMI	r = -0.02 (p = 0.73)	r = 0.01 (p = 0.80)
Surgical Characteristics:		
Type of Surgery	F = 3.04 (p = 0.01)*	F = 3.19 (p = 0.008)*
Cross-clamp Time	r = 0.13 (p = 0.01)*	r = 0.03 (p = 0.55)
Cardiopulmonary Bypass Time	r = 0.17 (p = 0.001)*	r = 0.04 (p = 0.45)
Pre-operative APACHE II	r = 0.19 (p < 0.001)*	r = 0.26 (p < 0.001)*
Postoperative APACHE II	r = 0.23 (p < 0.00)*	r = 0.33 (p < 0.00)*
Postoperative Complications	t = -5.77 (p < 0.001)*	t = -6.20 (p < 0.001)*

Note. *Association is statistically significant at $p < 0.05$ (2-tailed)

HgbAIC, type of surgery, cross-clamp and CPB times, pre- and postoperative APACHE II scores, and postoperative complications were found to be associated with an increased LOS. The findings suggest that there may be other variables, such as preoperative HgbA1C, and pre- and post-APACHE II scores, also affecting postoperative cardiac patients' LOS. As well, patients' comorbidities may possibly be a greater predictor of increased LOS, as these patients preoperatively are more acutely ill and are at higher risk of postoperative complications.

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