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Associations Between Preoperative Glucose and Hemoglobin A1c Level and Myocardial Injury After Noncardiac Surgery: a Retrospective Cohort Study

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Abstract

Background

Perioperative blood glucose level has shown an association with postoperative outcomes. We compared the incidences of myocardial injury after noncardiac surgery (MINS) and 30-day mortality according to preoperative blood glucose and hemoglobin A1c (HbA1c) level.

methods

The patients were divided according to blood glucose level within one day before surgery. The poorly-controlled group was defined with fasting glucose > 140 mg/dl or random glucose > 180 mg/dl. Additionally, we compared the outcomes according to HbA1c > 6.5% among patients with available HbA1c within 3 months before surgery. The primary outcome was MINS, and 30-day mortality was also compared.

Results

A total of 12,304 patients was enrolled and divided into 8,324 (67.7%) in the well-controlled group and 3,980 (32.3%) in the poorly-controlled group. After adjustment with inverse probability of weighting, the poorly-controlled group exhibited significantly higher incidences of MINS and 30-day mortality (18.7% vs. 27.6%; odds ratio [OR], 1.29; 95% confidence interval [CI], 1.18–1.42; $P < 0.001$ and 2.0% vs. 5.1%; hazard ratio [HR], 2.00; 95% CI, 1.61–2.49; $P < 0.001$, respectively). In contrast to blood glucose, HbA1c was not associated with MINS or 30-day mortality.

Conclusion

Preoperative hyperglycemia was associated with MINS and 30-day mortality, while HbA1c was not. Immediate glucose control may be more crucial than long-term glucose control in patients undergoing noncardiac surgery.

Trial registration: KCT0004244

Background

Perioperative hyperglycemia is common, reported in 20–40% of patients undergoing noncardiac surgery and associated with poor postoperative outcomes [1]. Previous evidence has suggested that preoperative acute hyperglycemia is associated with poor postoperative outcomes [2–4] as well as chronic hyperglycemia accessed via hemoglobin A1c (HbA1c) [5]. Several guidelines recommend preoperative blood glucose control in diabetic patients [6–8], but 12–30% of patients with perioperative hyperglycemia do not have a history of diabetes [4]. Therefore, there remains a paucity of data for the best preoperative glucose management in the general population.

Cardiac complication is the leading cause of death after surgery, and hyperglycemia is a well-known major risk factor of ischemic heart disease [9]. Myocardial injury after noncardiac surgery (MINS) is the most common cardiac complication and is defined as any cardiac troponin (cTn) elevation above the 99th percentile upper reference limit within 30 days after surgery as a result of myocardial ischemia without requirement of ischemic symptoms [10–12]. In this regard, the occurrence of MINS may play a certain role in the association between preoperative hyperglycemia and postoperative outcomes, though this relationship has never been evaluated.

Therefore, in this study, we aimed to evaluate whether preoperative blood glucose level is associated with MINS and mortality. We also conducted analysis according to HbA1c level to evaluate the association with chronic hyperglycemia. Our findings may provide valuable information for preoperative glucose management in surgical patients.

Methods

The Institutional Review Board at Samsung Medical Center waived approval for this study and the requirement for written informed consent for access to the registry since the dataset was initially extracted in de-identified form (SMC 2019-08-048). This study is an observational cohort study using data from the SMC-TINCO registry (Samsung Medical Center Troponin in Noncardiac Operation, KCT0004244), a large single-center cohort containing de-identified data of 43,019 consecutive patients who had cTn I level measured before or within 30 days after noncardiac surgery between January 2010 and June 2019 at Samsung Medical Center, Seoul, Republic of Korea. Samsung Medical Center operates a paperless electronic archive system containing data of more than 4 million patients in more than 2 million surgeries, 900 million laboratory findings, and 200 million prescriptions. For mortalities that occur elsewhere and not at our institution, this system is consistently updated and confirmed with the National Population Registry of the Korea National Statistical Office using a unique personal identification number when available. The SMC-TINCO registry was generated using the “Clinical Data Warehouse Darwin-C,” which was built for investigators to search and retrieve de-identified medical records from this electronic archive system. After extracting the raw data of the preoperative evaluation sheets, the baseline characteristics of the patients were organized into a standardized form by independent investigators who were blinded to mortalities and cTn I level.

For this study, we excluded the following patients from the registry: 1) patients younger than 18 years at the time of surgery, 2) patients without postoperative cTn I level measurement, 3) patients who received cardiac massage before diagnosis of MINS, and 4) patients without available preoperative blood glucose measurement within 1 day before surgery. A total of 12,304 patients was enrolled in the final analysis.

Definitions and Study Outcomes

We divided the patients according to blood glucose level: the poorly-controlled group was defined as fasting glucose > 140 mg/dl or random glucose > 180 mg/dl, while the well-controlled group comprised the rest of the patients according to ADA/AACE (American Diabetes Association and American Association of Clinical Endocrinologist) guidelines [6]. Glucose concentration was measured by the central laboratory at the time of the preoperative evaluation in patients who had a remarkable past medical history, diabetes, or a history of surgery greater than low risk. Among the study patients, those with available HbA1c measurement within 3 months before surgery were further divided into 2 groups according to HbA1c level of 6.5% [13]. Active cancer was defined as histologic diagnosis of cancer within the previous 6 months [14]. High-risk surgery was defined according to the 2014 European Society of Cardiology/Anesthesiology guidelines [15].

The primary outcome was MINS, defined as peak cTn I level above the 99th percentile upper reference limit within 30 days after surgery as a result of myocardial ischemia without requirement of ischemic symptoms. Therefore, an elevation with evidence of non-ischemic etiology such as sepsis, pulmonary embolus, atrial fibrillation, cardioversion, or chronic elevation was excluded [10–12]. The secondary outcome was 30-day mortality, which was classified into cardiovascular and non-cardiovascular mortalities. Cardiovascular mortality was death related

to myocardial infarction, cardiac arrhythmia, heart failure, stroke, or vascular causes, while non-cardiovascular mortality was defined as death from a cause other than cardiovascular conditions. All deaths without an undisputed non-cardiovascular cause were considered as cardiovascular death [16].

Perioperative cTn I Measurements & Management

According to the institutional protocol, perioperative cTn was measured for moderate- or high-risk surgeries or in patients with at least one of the major cardiovascular risk factors such as a history of ischemic heart disease, heart failure, stroke including transient ischemic attack, diabetes mellitus on insulin therapy, or chronic kidney disease based on current guidelines [15]. In patients with minor risk factors, perioperative cTn was measured at the discretion of the attending clinician with considerations for old age or recently suspected symptoms of ischemic disease. An automated analyzer (Advia Centaur XP, Siemens Healthcare Diagnostics, Erlangen, Germany) was used for cTn measurement. The lowest limit of detection was 6 ng/L, and the 99th percentile upper reference limit was 40 ng/L, as provided by the manufacturer. Patients with elevated cTn level were referred to cardiologists for further evaluation and proper management. Other perioperative management followed the institutional protocol based on current guidelines.

Statistical Analysis

For continuous data, the differences were compared by the t-test or the Mann-Whitney test as applicable and presented as mean ± standard deviation (SD) or median with interquartile range (IQR). Categorical data were presented as number (%) and compared using the chi-square or Fisher's exact test. Kaplan-Meier estimates were used to construct survival curves and compared with the log-rank test. MINS were compared using a logistic regression model and were reported as odds ratio (OR) with 95% confidence interval (CI). The mortality outcomes were compared using the Cox regression model and were reported as hazard ratio (HR). Variables with a standardized mean difference greater than 0.1 were retained in the multivariable model. To further reduce selection bias while maintaining balanced confounding variables between the two groups, we used weighted regression models with inverse probability weighting (IPW) [17] and conducted rigorous adjustment for differences in all baseline characteristics of the patients. According to this technique, weights for the poorly-controlled group were the inverse of the propensity score, and those for the well- controlled group were the inverse of the propensity score. To estimate an optimal cutoff point of fasting blood glucose associated with MINS, Pearson's correlation coefficient and receiver-operating characteristic (ROC) plots were constructed to estimate the threshold and compute the specificity and sensitivity. Regarding the sample size of this study, the power was estimated to be 0.99 when the OR of MINS occurrence was higher than 1.2 and the HR of 30-day mortality was higher than 1.6. To minimize the effects of the potential confounders and to investigate the robustness of our study, we conducted a sensitivity analysis separately for patients with fasting and random blood glucose levels, for patients with and without diabetes, and for patients with and without preoperative intensive care unit treatment. We also estimated the potential impact of unmeasured confounders [18]. Statistical analyses were performed with R 3.6.2 (Vienna, Austria; http://www.R-project.org/). All tests were 2-tailed, and $P < 0.05$ was considered statistically significant.

Results

Baseline Characteristics

We excluded 1,154 patients who were younger than 18 years, 6,596 patients without postoperative cTn measurement, and 46 patients who underwent cardiac massage before diagnosis of MINS. Among the 35,223

patients, preoperative blood glucose level was available in 12,304 patients. The patient flow of the study is shown in Fig. 1. The baseline characteristics of the entire population are summarized in Table 1. Patients in the poorly-controlled group were likely to be older and exhibited a higher incidence of diabetes, emergency operations, preoperative insulin and intensive care unit treatments, and use of intraoperative inotropics. The types of surgery in each group are summarized in Supplemental Table 1.

Table 1
Baseline characteristics according to preoperative blood glucose level

	Well-Controlled	Poorly-controlled	Before IPW		After IPW	
	(*N* = 8,324)	(*N* = 3,980)	*P*-value	SMD	*P*-value	SMD
*Preoperative HbA1c	6.7 (± 1.3)	7.5 (± 1.7)	< 0.001	52.2		
Days to peak cardiac troponin	0.50 (0.08–1.73)	0.54 (0.08–1.81)	0.06	2.8	0.49	1.4
Male	4710 (56.6)	1562 (62.2)	0.03	5.8	0.87	0.3
Age	62.9 (± 13.8)	64.7 (± 12.4)	< 0.001	14.3	0.55	1.2
Diabetes	6116 (73.5)	3324 (83.5)	< 0.001	24.6	0.76	0.7
Hypertension	5524 (66.4)	2756 (69.2)	0.002	6.2	0.96	0.1
Chronic kidney disease	869 (10.4)	409 (10.3)	0.81	0.5	0.96	0.1
Current smoking	915 (11.0)	461 (11.6)	0.35	1.9	0.95	0.1
Current alcohol	1531 (18.4)	797 (20.0)	0.03	4.1	0.95	0.1
Previous disease						
Coronary artery disease	1516 (18.2)	781 (19.6)	0.06	3.6	0.87	0.3
Heart failure	203 (2.4)	80 (2.0)	0.16	2.9	0.94	0.2
Stroke	685 (8.2)	442 (11.1)	< 0.001	9.7	0.84	0.4
Arrhythmia	603 (7.2)	287 (7.2)	0.98	0.1	0.98	0.1
Heart valve disease	108 (1.3)	44 (1.1)	0.42	1.8	0.95	0.1
Active cancer	3124 (37.5)	1506 (37.8)	0.76	0.6	0.96	0.1
Preoperative inhospital care						
Insulin use	1734 (20.8)	825 (20.7)	0.91	0.3	0.76	0.6
Intensive care unit	516 (6.2)	446 (11.2)	< 0.001	17.8	0.89	0.3
ECMO	0	0				

Data are presented as n (%), mean (± standard deviation) or median (interquertile range)

*Preoperative HbA1c was not retained in multivariable or IPW adjustments.

IPW, inverse probability weighting; SMD, standardized mean difference; HbA1c, hemoglobin A1c; ECMO, extracorporeal membranous oxygenation; ESC, European Society of Cardiology; ESA, European Society of Anaesthesiology;

	Well-Controlled	Poorly-controlled	Before IPW		After IPW	
	(*N* = 8,324)	(*N* = 3,980)	*P*-value	SMD	*P*-value	SMD
Continuous renal replacement therapy	42 (0.5)	25 (0.6)	0.46	1.6	0.89	0.3
Ventilator	96 (1.2)	93 (2.3)	< 0.001	9	0.9	0.2
Operative variables						
ESC/ESA surgical high risk	1519 (18.2)	859 (21.6)	< 0.001	8.4	0.93	0.2
Emergency operation	1917 (23.0)	1456 (36.6)	< 0.001	30	0.87	0.3
General anesthesia	7220 (86.7)	3482 (87.5)	0.26	2.2	0.87	0.3
Operation duration, hours	3.06 (± 2.19)	3.03 (± 2.14)	0.5	1.3	0.89	0.3
Packed red blood cell transfusion	812 (9.8)	396 (9.9)	0.76	0.7	0.96	0.1
Continuous infusion of inotropics	2483 (29.8)	1388 (34.9)	< 0.001	10.8	0.87	0.3
Data are presented as n (%), mean (± standard deviation) or median (interquertile range)						
*Preoperative HbA1c was not retained in multivariable or IPW adjustments.						
IPW, inverse probability weighting; SMD, standardized mean difference; HbA1c, hemoglobin A1c; ECMO, extracorporeal membranous oxygenation; ESC, European Society of Cardiology; ESA, European Society of Anaesthesiology;						

Acute Glucose Control and Clinical Outcomes

Postoperative cTn was elevated in 2,755 patients, and 103 of them had non-ischemic causes. Therefore, the overall incidence of MINS was 21.6% (2652/12304). In multivariable analysis, the occurrence of MINS was significantly higher in the poorly-controlled group (18.7% vs. 27.6%; OR, 1.31; 95% CI, 1.19–1.44; $P < 0.001$) (Table 2). The 30-day mortality was also higher in the poorly-controlled group (2.0% vs. 5.1%; HR, 1.77; 95% CI, 1.43–2.19; $P < 0.001$) (Table 2) (Fig. 2). After an IPW adjustment, MINS (OR, 1.29; CI 95%, 1.18–1.42, $P < 0.001$) and 30-mortality (HR, 2.0; CI 95%, 1.61–2.49; $P < 0.001$) were consistently increased. Sensitivity of the effect of an unmeasured confounder on the observed association was evaluated assuming a 40% prevalence of the measured confounder, and that the association was significant under any circumstances (Supplemental Tables 2 and 3). In ROC analysis, the optimal cutoff point of fasting blood glucose for MINS was 141 mg/dl with an area under the ROC curve of 0.561 and 174 mg/dl with an area under the ROC curve of 0.521 for random blood glucose. The sensitivity and specificity were 45.6% and 67.2% for fasting blood glucose and 23.6% and 84.0% for random blood glucose, respectively (Fig. 3).

Table 2
The incidence of myocardial after noncardiac surgery and mortality according to preoperative blood glucose level

	Well-Controlled (*N* = 8,324)	Poorly-controlled (*N* = 3,980)	Unadjusted OR/HR (95% CI)	*P*-value	Adjusted OR/HR (95% CI)	*P*-value	IPW OR/HR (95% CI)	IPW *P*-value
MINS	1553 (18.7)	1099 (27.6)	1.66 (1.52–1.82)	< 0.001	1.31 (1.19–1.44)	< 0.001	1.29 (1.18–1.42)	< 0.001
30-day mortality	166 (2.0)	204 (5.1)	2.63 (2.14–3.23)	< 0.001	1.77 (1.43–2.19)	< 0.001	2.00 (1.61–2.49)	< 0.001
Cardiovascular death	40 (0.5)	55 (1.4)	2.93 (1.95–4.40)	< 0.001	1.81 (1.19–2.76)	0.01	2.15 (1.39–3.33)	< 0.001
Noncardiovascular death	126 (18.7)	149 (3.7)	2.53 (2.00-3.21)	< 0.001	1.76 (1.37–2.25)	< 0.001	1.95 (1.51–2.51)	< 0.001
Data are presented as n (%)								
Multivariable analysis included age, diabetes, emergency operation, preoperative intensive care unit treatment, and intraoperative inotropics use.								
MINS was presented with OR, and mortalities were presented as HR								
MINS, myocardial injury after noncardiac surgery; OR, odds ratio; HR, hazard ratio; CI, confidence interval; IPW, inverse probability weighting								

Chronic Glucose Control and Clinical Outcomes

In a total of 12,304 patients, 4,373 had HbA1c test findings available within 3 months prior to surgery. The poorly-controlled group was older and exhibited higher incidences of diabetes, chronic kidney disease, coronary artery disease, ESC/ESA high-risk operation, emergency operation, active cancer, preoperative insulin and intensive care unit treatments, and use of intraoperative inotropics (Table 3). The incidence of MINS did not significantly differ between the two groups in the multivariable and IPW adjusted analyses (25.4% vs. 21.3%; OR, 1.01; 95% CI, 0.86–1.20; $P = 0.89$; OR, 0.98; 95% CI, 0.85–1.14; $P = 0.80$; respectively) (Table 4). The 30-day mortality also did not differ between the two groups (Fig. 4, Table 4). The optimal cutoff point of HbA1c for MINS was 6.4%, and the area under the ROC curve was 0.519. Using this value, the sensitivity and specificity were 37.3% and 67.2%, respectively (Fig. 3).

Table 3
Baseline characteristics according to HbA1c level

	HbA1c ≤ 6.5%	HbA1c > 6.5%.	Before IPW		After IPW	
	(*N* = 1,849)	(*N* = 2,524)	*P*-value	SMD	*P*-value	SMD
*Preoperative HbA1c	5.8 (± 0.5)	7.8 (± 1.4)	< 0.001	> 99		
Days to peak cardciac troponin	0.66 (0.10–2.19)	0.66 (0.10–1.85)	0.4	3.6	0.28	3.4
Male	1113 (60.2)	1484 (58.8)	0.37	2.9	0.95	0.2
Age	64.3 (± 13.4)	67.0 (± 10.5)	< 0.001	22.3	0.38	2.8
Diabetes	1535 (83.0)	2524 (100.0)	< 0.001	64	< 0.001	39.2
Hypertension	1472 (79.6)	2043 (80.9)	0.29	3.3	0.52	2
Chronic kidney disease	428 (23.1)	366 (14.5)	< 0.001	22.3	0.97	0.1
Current smoking	168 (9.1)	248 (9.8)	0.44	2.5	0.82	0.7
Current alcohol	304 (16.4)	404 (16.0)	0.73	1.2	0.6	1.7
Previous disease						
Coronary artery disease	430 (23.3)	718 (28.4)	< 0.001	11.9	0.68	1.3
Heart failure	69 (3.7)	88 (3.5)	0.73	1.3	> 0.99	< 0.1
Stroke	222 (12.0)	231 (9.2)	0.003	9.3	0.64	1.5
Arrhythmia	176 (9.5)	228 (9.0)	0.62	1.7	0.96	0.25
Heart valve disease	31 (1.7)	30 (1.2)	0.22	4.1	0.7	1.2
Active cancer	478 (25.9)	932 (36.9)	< 0.001	24	0.38	2.9
Preoperative inhospital care						
Insulin use	370 (20.0)	513 (20.3)	0.83	0.8	0.89	0.5
Intensive care unit	175 (9.5)	131 (5.2)	< 0.001	16.5	0.65	1.4
ECMO	0	0				

Data are presented as n (%), mean (± standard deviation) or median (interquartile range)

*Preoperative HbA1c was not retained in multivariable or IPW adjustments.

HbA1c, hemoglobin A1c; IPW, inverse probability weighting; SMD, standardized mean difference; ECMO, extracorporeal membranous oxygenation; ESC, European Society of Cardiology; ESA, European Society of Anaesthesiology;

	HbA1c ≤ 6.5%	HbA1c > 6.5%.	Before IPW		After IPW	
	(*N* = 1,849)	(*N* = 2,524)	*P*-value	SMD	*P*-value	SMD
Continuous renal replacement therapy	17 (0.9)	5 (0.2)	0.002	9.7	> 0.99	< 0.1
Ventilator	38 (2.1)	29 (1.1)	0.02	7.2	0.95	0.2
Operative variables						
ESC/ESA surgical high risk	309 (16.7)	564 (22.3)	< 0.001	14.2	0.58	1.9
Emergency operation	513 (27.7)	413 (16.4)	< 0.001	27.7	0.07	5.7
General anesthesia	1510 (81.7)	2054 (81.4)	0.84	0.7	0.93	0.3
Operation duration, hours	2.99 (± 2.22)	2.92 (± 2.10)	0.24	3.6	0.62	1.6
Packed red blood cell transfusion	276 (14.9)	220 (8.7)	< 0.001	19.3	0.97	0.1
Continuous infusion of inotropics	603 (32.6)	638 (25.3)	< 0.001	16.2	0.85	0.6
Data are presented as n (%), mean (± standard deviation) or median (interquartile range)						
*Preoperative HbA1c was not retained in multivariable or IPW adjustments.						
HbA1c, hemoglobin A1c; IPW, inverse probability weighting; SMD, standardized mean difference; ECMO, extracorporeal membranous oxygenation; ESC, European Society of Cardiology; ESA, European Society of Anaesthesiology;						

Table 4
The incidence of myocardial after noncardiac surgery and mortality according to HbA1c level

	HbA1c ≤ 6.5% (*N*= 1,849)	HbA1c > 6.5%. (*N*= 2,524)	Unadjusted OR/HR (95% CI)	*P*-value	Adjusted OR/HR (95% CI)	*P*-value	IPW OR/HR (95% CI)	IPW *P*-value
MINS	470 (25.4)	537 (21.3)	0.79 (0.69–0.91)	< 0.001	1.01 (0.86–1.20)	0.89	0.98 (0.85–1.14)	0.8
30-day mortality	57 (3.1)	64 (2.5)	0.82 (0.57–1.17)	0.28	1.19 (0.81–1.76)	0.38	1.13 (0.78–1.65)	0.52
Cardiovascular death	14 (0.8)	17 (0.7)	0.89 (0.44–1.80)	0.74	1.49 (0.65–3.38)	0.34	1.56 (0.71–3.45)	0.27
Noncardiovascular death	43 (2.3)	47 (1.9)	0.80 (0.53–1.21)	0.29	1.11 (0.91–1.73)	0.66	1.02 (0.66–1.58)	0.92
Data are presented as n (%).								
Multivariable analysis included age, diabetes, chronic kidney disease, history of coronary artery disease, active cancer, high surgical risk, emergency operation, preoperative intensive care unit treatment, intraoperative packed red blood cell transfusion, and intraoperative inotropics use.								
Diabetes was retained into multivariable analysis after IPW adjustment.								
MINS was presented with OR, and mortalities were presented as HR.								
HbA1c, hemoglobin A1c; MINS, myocardial injury after noncardiac surgery; OR, odds ratio; HR, hazard ratio; CI, confidence interval; IPW, inverse probability weighting.								

Discussion

The main findings of this study are as follows: 1) the incidence of MINS was significantly higher in the patients with high preoperative blood glucose level, and 2) 30-day mortality was also higher in these patients regardless of cause of death, but 3) higher preoperative HbA1c was not associated with occurrence of MINS or 30-day mortality. Together, these findings suggest that control of acute hyperglycemia in the preoperative period may be helpful in preventing MINS occurrence and 30-day mortality regardless of the presence of chronic hyperglycemia.

Glucose control is one of the cornerstones in perioperative management, and preoperative hyperglycemia has shown association with in-hospital mortality and postoperative complications [3]. Several guidelines recommend preoperative glucose control for diabetic patients [6–8]; however, owing to the lack of large randomized trials, the ideal treatment agent and glucose target level are widely debated [1]. Surgical patients often encounter a state described as “stress hyperglycemia,” comprising hyperglycemia without a history of diabetes [19], and perioperative blood glucose control appeared to be important in patients either with or without diabetes [2]. In this study, we enrolled noncardiac surgical patients regardless of diabetes and evaluated the association between blood glucose level within one day before surgery and MINS, a major cause of postoperative mortality. The

incidence of MINS with increased 30-day mortality was significantly higher in patients with poorly-controlled blood glucose level.

Several explanations could be considered regarding the observed association between hyperglycemic patients and MINS. First, hyperglycemia induces coronary microvascular dysfunction [20]. Given that type 2 myocardial infarction plays a role as the main mechanism in MINS, we can assume that coronary microvascular dysfunction may have had an influence in the higher incidence of MINS in surgical patients with hyperglycemia [10]. Second, oxidative stress arises directly or indirectly from hyperglycemia. This imbalance between free radial generation and elimination or detoxification is a principle mediator of myocardial injury during ischemia–reperfusion, which frequently occurs during the perioperative period [21]. Finally, endothelial dysfunction in diabetic patients may explain the results. The aforementioned oxidative stress also contributes to endothelial dysfunction, one of the causes of type 2 myocardial infarction [12].

For chronic hyperglycemia, conflicting results have been reported in previous studies [5, 22]. Therefore, we also assessed the effect of chronic high glucose level by evaluating only patients with available HbA1c level, and demonstrated that higher preoperative HbA1c was not significantly associated MINS or 30-day mortality. Some of previous reports correspond to our result. One study from a database of 38,989 patients showed that the risk of surgical complications was increased in diabetic patients, but no significant correlation was found for HbA1c level [22]. Another study showed that chronic hyperglycemia was associated with a longer length of hospital stay but not 30-day mortality [6]. Regarding myocardial injury, one study showed an inverse relationship with HbA1c in patients undergoing percutaneous coronary intervention [23].

According to our results, acute glycemic control in the preoperative period appeared to be more effective in preventing MINS than chronic control, also leading to a difference in 30-day mortality. These findings suggest that the occurrence of MINS may be involved in the increased mortality of hyperglycemic patients and the importance of acute preoperative blood glucose control regardless of the presence chronic hyperglycemia. Furthermore, we estimated the optimal cutoff values for fasting blood glucose and random blood glucose using ROC curve analysis. Despite the low area under the curve, the estimated values were relatively well-matched with ADA/AACE guidelines [6].

Our study has several limitations. First, with the nature of a single-center, observational study, the results may have been affected by selection bias or unmeasured confounding factors. Since our institutional patients were mostly Asian, ethnic differences could not be considered. Second, perioperative cTn I measurement was not included as a routine clinical practice at our institution. Given that patients with a certain cardiovascular risk usually underwent the test, our results may have been exaggerated. In addition, preoperative blood sugar and HbA1c tests were also not performed in all patients. Third, a detailed preoperative cardiac evaluation such as left ventricular ejection fraction or coronary artery angiogram was not available for all patients. Despite these limitations, this is the first study to compare the incidence and relevant outcomes of MINS in patients according to glucose and HbA1c levels. The results of the present study may reinforce evidence for future guidelines of glucose control in patients undergoing noncardiac surgery.

Conclusion

Preoperative hyperglycemia was associated with increased MINS and 30-day mortality, while HbA1c was not. Immediate glucose control may be more crucial than long-term glucose control in patients undergoing noncardiac

surgery.

Abbreviations

MINS
Myocardial Injury After Noncardiac Surgery; cTn, High cardiac Troponin; OR:Odds Ratio; HR:hazard ratio; CI:Confidence Interval; IQR:Interquartile Range.

Declarations

Acknowledgements

Not applicable

Author Contributions

J.P. and AR.O. researched thedata, designed the analysis, and wrote the manuscript. JH.L., JJ.M., JH.K., J.K., and K.Y. conducted the research. AR.O., JH.C., SC.L., and HC.G. analyzeddata. SH.L. supervised and managed the research and critically reviewed and edited the manuscript. K.K. and J.P. performed statistical analysis and critically reviewed and edited the manuscript. J.A., and S.M.L helped with data curation and interpretation.SH.L. take full responsibility for the work as a whole, the study design,access to data, and the decision to submit and publish the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

This study was approved by theInstitutional Review Board at Samsung Medical Center(SMC 2019-08-048). Owing to the retrospective nature of the study, informed consent was waived.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

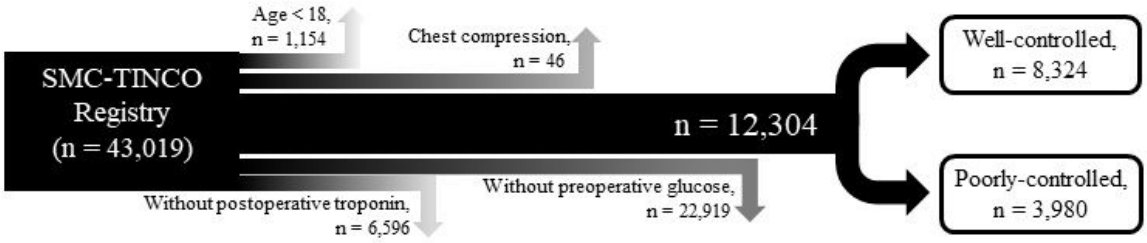


Figure 1

Patient flowchart.

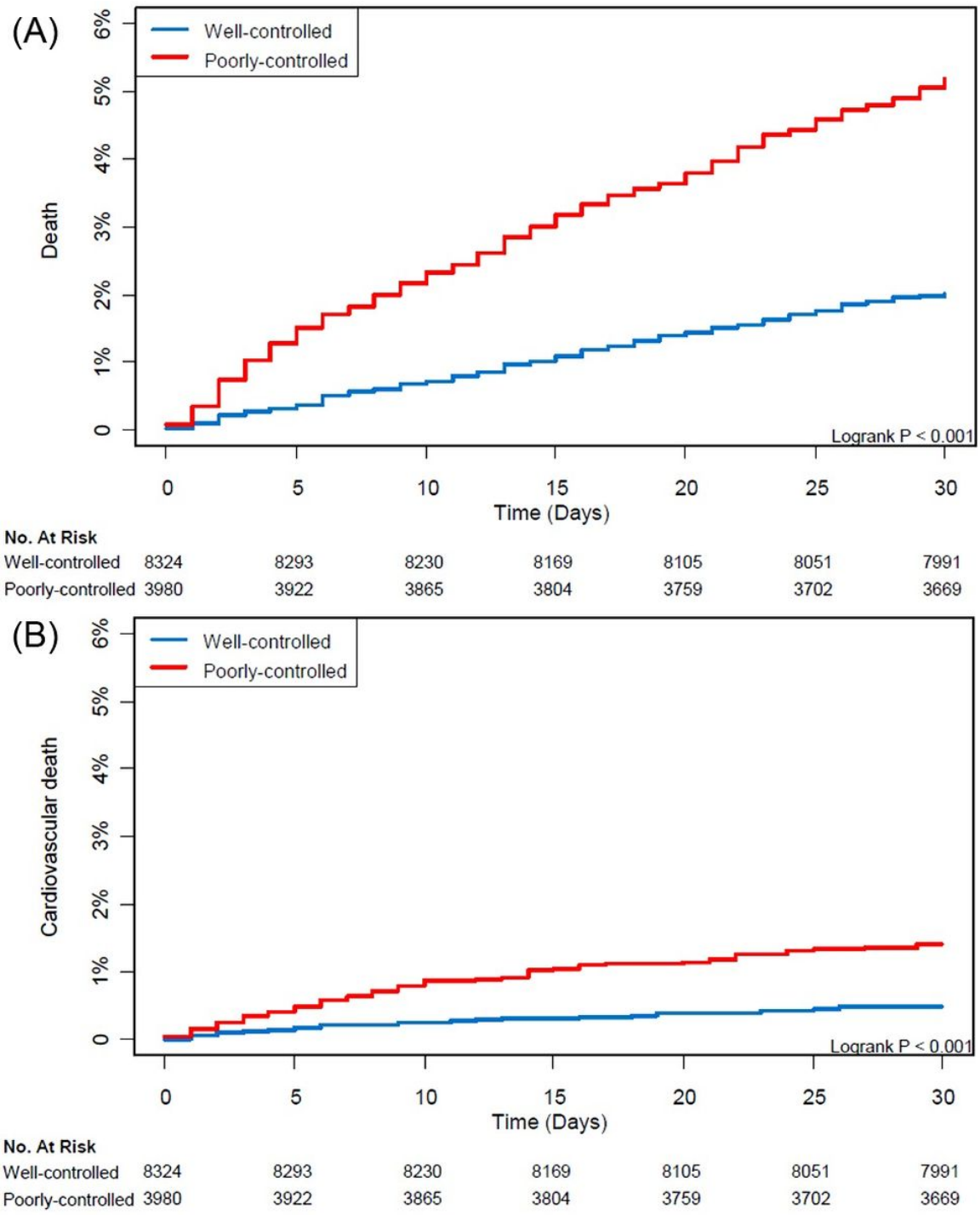


Figure 2

Kaplan-Meiercurves of 30-day mortality according to acute glucose control.

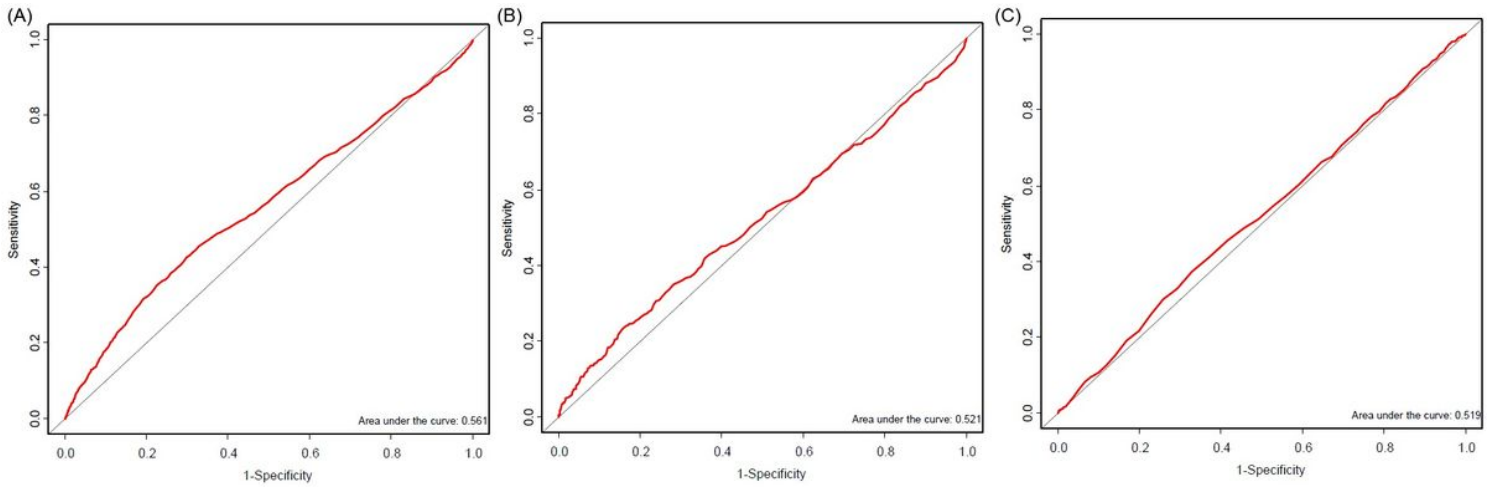


Figure 3

Receiver-operating characteristic curves for preoperative (A) fasting blood glucose level, (B) random blood glucose level, and (C) HbA1c level associated with myocardial injury after noncardiac surgery.

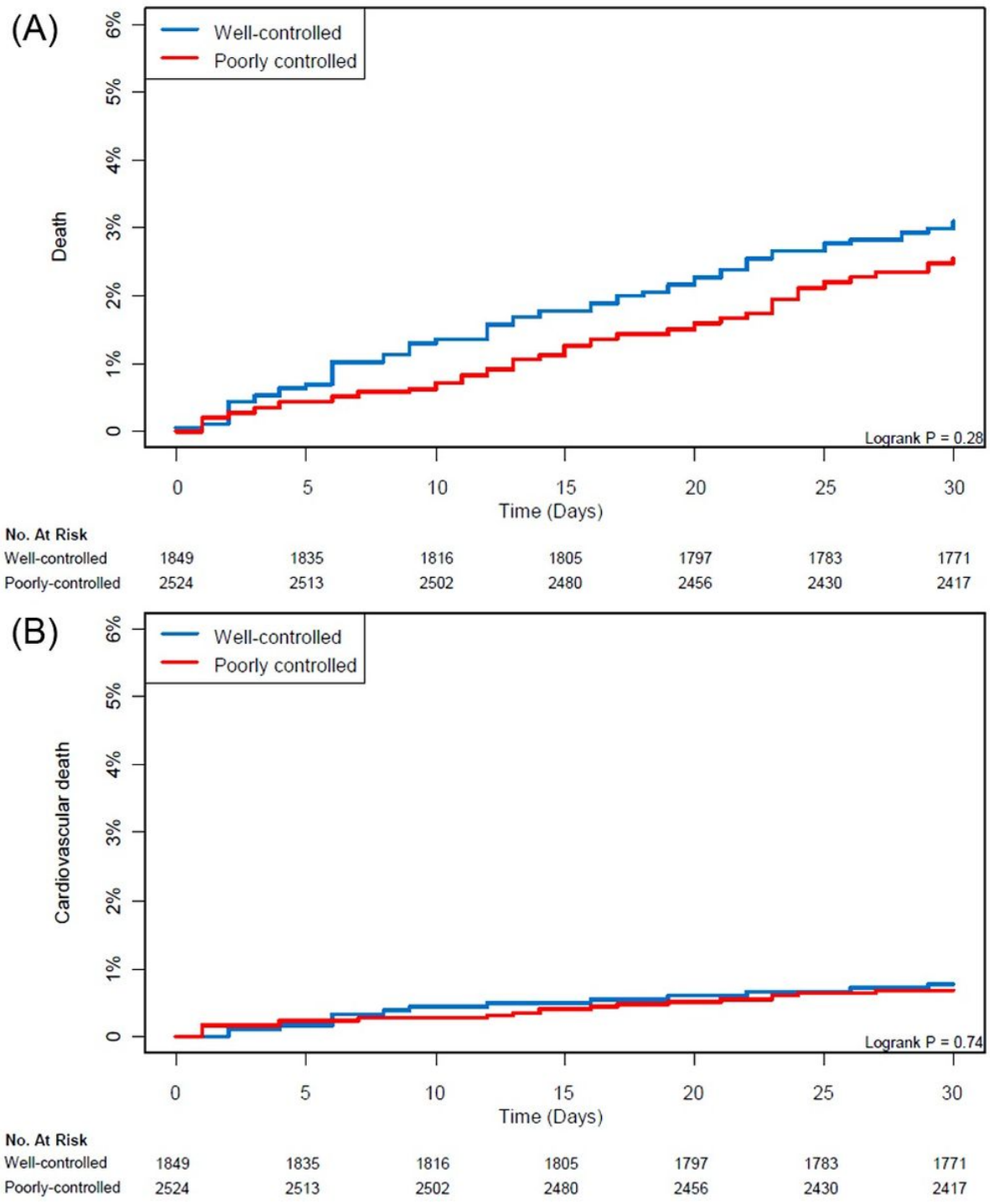


Figure 4

Kaplan-Meiercurves of 30-day mortality according to chronic glucose control.

Supplementary Files

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