

# Electronic Glycemic Management System Improved Glycemic Control and Reduced Complications in Patients With Diabetes Undergoing Coronary Artery Bypass Surgery: A Randomized Controlled Trial

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Alexandre Barbosa Câmara de Souza, PhD<sup>1</sup> ,  
Marcos Tadashi Kakitani Toyoshima, PhD<sup>2</sup> , Priscilla Cukier, PhD<sup>1</sup>,  
Simão Augusto Lottenberg, PhD<sup>1</sup>, Paula Mathias Paulino Bolta, MSc<sup>3</sup>,  
Eduardo Gomes Lima, PhD<sup>3</sup>, Carlos Vicente Serrano Júnior, PhD<sup>3</sup>,  
and Marcia Nery, PhD<sup>1</sup> 

## Abstract

**Background:** In-hospital hyperglycemia poses significant risks for patients with diabetes mellitus undergoing coronary artery bypass graft (CABG) surgery. Electronic glycemic management systems (eGMSs) like InsulinAPP offer promise in standardizing and improving glycemic control (GC) in these settings. This study evaluated the efficacy of the InsulinAPP protocol in optimizing GC and reducing adverse outcomes post-CABG.

**Methods:** This prospective, randomized, open-label study was conducted with 100 adult type 2 diabetes mellitus (T2DM) patients post-CABG surgery, who were randomized into two groups: conventional care (gCONV) and eGMS protocol (gAPP). The gAPP used InsulinAPP for insulin therapy management, whereas the gCONV received standard clinical care. The primary outcome was a composite of hospital-acquired infections, renal function deterioration, and symptomatic atrial arrhythmia. Secondary outcomes included GC, hypoglycemia incidence, hospital stay length, and costs.

**Results:** The gAPP achieved lower mean glucose levels ( $167.2 \pm 42.5$  mg/dL vs  $188.7 \pm 54.4$  mg/dL;  $P = .040$ ) and fewer patients-day with BG above 180 mg/dL (51.3% vs 74.8%,  $P = .011$ ). The gAPP received an insulin regimen that included more prandial bolus and correction insulin (either bolus-correction or basal-bolus regimens) than the gCONV (90.3% vs 16.7%). The primary composite outcome occurred in 16% of gAPP patients compared with 58% in gCONV ( $P < .010$ ). Hypoglycemia incidence was lower in the gAPP (4% vs 16%,  $P = .046$ ). The gAPP protocol also resulted in shorter hospital stays and reduced costs.

**Conclusions:** The InsulinAPP protocol effectively optimizes GC and reduces adverse outcomes in T2DM patients' post-CABG surgery, offering a cost-effective solution for inpatient diabetes management.

## Keywords

type 2 diabetes mellitus, digital health protocol, in-hospital hyperglycemia, insulin therapy, medical informatics applications, non-critically ill inpatients

<sup>1</sup>Department of Endocrinology and Metabolism, Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, São Paulo, Brazil

<sup>2</sup>Oncendocrinology Service, Instituto do Câncer do Estado de São Paulo Octávio Frias de Oliveira, Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, São Paulo, Brazil

<sup>3</sup>Instituto do Coração, Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, São Paulo, Brazil

## Corresponding Author:

Marcia Nery, MD, PhD, Department of Endocrinology and Metabolism, Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo, Avenida Dr. Enéas Carvalho de Aguiar, 255,7o andar, sala 7037, São Paulo 05403-900, Brazil.

Email: marcia.nery@hc.fm.usp.br

## Introduction

Patients with diabetes mellitus (DM) face an elevated risk of hospitalization due to conditions such as coronary, cerebrovascular, peripheral vascular diseases, and infections.<sup>1,2</sup> In-hospital hyperglycemia (HH) is prevalent among this population, with estimates ranging from 22% to 46% in general hospitals.<sup>3,4</sup> Notably, rates soar to 70% to 80% among those hospitalized for acute coronary syndromes and cardiac surgeries, irrespective of prior diabetes diagnosis.<sup>5</sup>

Failure to promptly diagnose and manage HH poses significant risks, including a six-fold increase in nosocomial infections, hindered recovery post-acute myocardial infarction and stroke, heightened thrombotic event risks, and other adverse clinical outcomes.<sup>6,7</sup> Despite the critical role of insulin therapy in managing complications, achieving optimal glycemic control (GC) remains challenging.<sup>8</sup> Studies have highlighted shortcomings in guideline adherence globally, with up to 50% of patients in the United States<sup>9</sup> and 75% in Brazil receiving inadequate insulin therapy.<sup>10</sup> Barriers to adherence include limited understanding of complications, insufficient training, and fear of hypoglycemia.<sup>11,12</sup>

Digital health applications have shown promise in aiding GC, especially for non-critically ill patients.<sup>13</sup> However, few randomized trials have evaluated specifically the impact of in-hospital insulin therapy in adverse nosocomial outcomes, beyond the intensive care unit (ICU) or perioperative settings.<sup>14</sup> In addition, existing tools often lack support for Portuguese language or fail to accommodate insulins provided by the Brazil's Unified Health System ("*Sistema Único de Saúde*").

Addressing this gap, InsulinAPP emerged in 2015 as an innovative digital solution, aimed at standardizing and facilitating insulin prescriptions for managing HH.<sup>15</sup> A prior study by Toyoshima et al<sup>15</sup> demonstrated its efficacy, reporting a 30% reduction in blood glucose levels with minimal hypoglycemia. Jones et al<sup>16</sup> further evaluated this electronic glycemic management system (eGMS), endorsing its quality, usability, and versatility as a user-friendly tool for physicians navigating hospital hyperglycemia complexities.

In this context, our prospective and randomized study aims to assess whether optimizing GC, as per the InsulinAPP protocol, significantly mitigates adverse clinical outcomes associated with HH.

## Methods

### Participants and Study Design

A prospective, open-label, randomized study was conducted at the Instituto do Coração (InCor) of *Hospital das Clínicas de São Paulo* University School of Medicine (HCFMUSP). From January 2018 to December 2021, we enrolled 100 adult individuals with type 2 diabetes mellitus (T2DM) aged between 18 and 80 years, discharged from the ICU to step-down wards for post-operative follow-up of coronary artery bypass graft (CABG) surgery.

The study adhered to the principles of the Declaration of Helsinki and the Guidelines for Good Pharmacoevidence Practices. Approval of the trial protocol was obtained from the Research Ethics Committee of HCFMUSP School of Medicine (Certificate of Presentation of Ethical Review: 82183417.3.0000.0068).

### Eligibility Criteria

Eligible participants were adult patients with T2DM, in the postoperative period following CABG surgery, discharged from the ICU to stepdown wards. Non-inclusion criteria included hyperglycemia without a known history of diabetes (stress hyperglycemia), planned hospital discharge within 48 hours of randomization, occurrence of any composite of primary outcome event within 24 hours, and laboratory evidence of diabetic ketoacidosis upon admission.

### Randomization

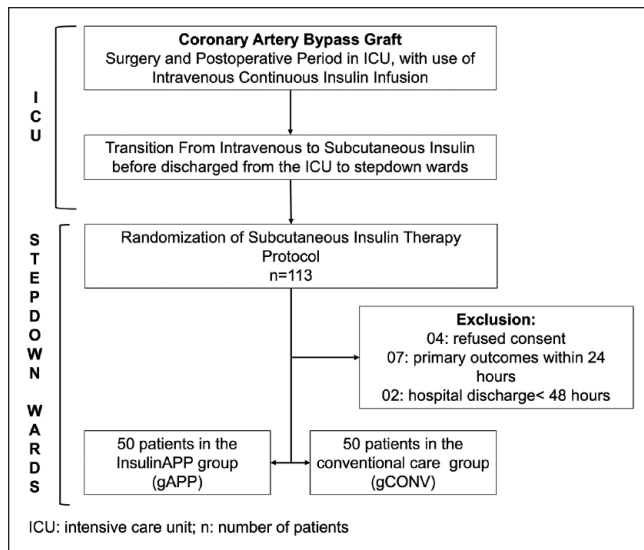
Resident and fellow physician teams (clusters) managing post-operative patients were randomly assigned to either conventional care group (gCONV) or the InsulinAPP protocol group (gAPP) using a computer-generated randomization process. The assignments were made at the beginning of the study period, and the intervention allocation was rotated bimonthly among the teams.

### Procedures

In the ICU, patients received continuous intravenous insulin infusion, with doses according to the computerized institutional protocol of InsulinAPP-ICU (<http://www.insulinapp-uti.com.br>). There was a transition from intravenous to subcutaneous insulin therapy before discharge from the ICU to the stepdown unit (Figure 1).

In the stepdown unit, all patients received an insulin therapy using human insulins: Neutral Protamine Hagedorn (NPH) insulin as basal insulin and regular insulin as prandial and correctional insulin. The patients' non-insulin diabetes medications were discontinued during hospitalization. The gCONV group received conventional care based on clinical experience, whereas the gAPP group followed the eGMS protocol (<http://www.insulinapp.com.br>), which recommended basal-bolus insulin therapy or bolus-correction scheme based on predefined criteria (Figure 1).

The application recommends an initial basal-bolus insulin therapy regimen for individuals with T2DM whose previous total daily insulin dose (TDID) exceeded 0.2 units/kg/day or whose initial blood glucose (BG) levels were above 250 mg/dL. The basal-bolus insulin regime consisted of 50% of TDID allocated to basal insulin using NPH three times daily (before breakfast, before lunch, and at bedtime) and the remaining 50% for prandial insulin (regular insulin three times daily, prior to meals). If a TDID was less than 0.2 units/kg/day and BG levels were below 250 mg/dL, the recommendation of the



**Figure 1.** Organizational chart of patient flow in the study. ICU: intensive care unit; n: number of patients.

insulin prescription was with a bolus-correction scheme, which corresponds to a fixed pre-prandial dose (regular insulin three times daily, prior to meals), associated with a correction insulin dose. InsulinAPP also helps in deciding how to manage patients' GC throughout their hospitalization. If the patient remained hyperglycemic with glycemic averages above 180 mg/dL during reassessments and using the insulin bolus-correction scheme, it suggests switching to the basal-bolus insulin scheme. Our group detailed the protocol in a previously published article.<sup>17</sup>

Point-of-care BG levels were assessed four times a day (pre-breakfast, pre-lunch, pre-dinner, and at bedtime). The BG concentrations between 100 and 180 mg/dL were considered within the therapeutic range. Hypoglycemia was defined as a BG less than 70 mg/dL.

The patients underwent surgery according to the institutional standard protocol, performed by the same surgical team. Electronic prescriptions determined the insulin protocol, frequency of bedside glucose testing, and diet orders. Follow-up data were collected from the patient's electronic medical record.

## Outcomes

The primary outcome encompassed hospital-acquired infection, deterioration of renal function, and symptomatic atrial arrhythmia with a high ventricular response. Events were counted from the second day post-randomization until 30 days post-hospital discharge. The first day following randomization was excluded, as the intervention was expected to have a minimal impact on GC and, consequently, a minor effect on clinical outcomes.

The events of the primary composite outcome were defined as follows:

- Hospital-acquired infection: the need for a new course of antibiotic therapy (excluding prophylactic use).<sup>18</sup>
- Deterioration of renal function: an increase of 50% in creatinine or  $\geq 0.3$  mg/dL compared to the ICU discharge value.<sup>19</sup>
- Symptomatic atrial arrhythmia with a high ventricular response: newly diagnosed atrial fibrillation/flutter that required treatment, identified by electrocardiographic parameters along with symptoms of palpitation, embolism, or low flow.<sup>20</sup>

The BG measurements were taken starting from the first 24 hours of protocol inclusion until the primary outcome event. If the patient did not experience any of the events considered in the composite outcome during their hospital stay, glucose levels were analyzed until hospital discharge.

## Sample Size and Power Calculation

The power calculation was formulated based on the preceding RABBIT-2 Surgery study, which demonstrated a reduction in the composite outcome, including wound infection, pneumonia, bacteremia, respiratory failure, and acute renal failure in the basal-bolus group (8.6% vs 24.3% in the sliding scale insulin [SSI] group,  $P < .010$ ).<sup>21</sup> Furthermore, prior studies that specifically evaluated cardiac surgery showed a prevalence of nosocomial complications during the post-operative period in approximately 30% to 50% of individuals with diabetes.<sup>22</sup> Hence, presuming an incidence of adverse outcomes in 50% of individuals in the conservative group and 20% in the gAPP and assuming an alpha-error rate of 5%, we estimated that a sample of 50 subjects per group was necessary to achieve 90% statistical power.

## Statistical Analysis

Study results were scrutinized on an intention-to-treat basis. Study population data and clinical outcomes were described using proportions. Variables with a normal distribution are presented as the mean  $\pm$  standard deviation (SD), whereas variables with non-normal distributions are expressed as the median and interquartile range (p25; p75). For comparison of quantitative variables with a normal distribution, unpaired Student's *t*-test was employed. If data normalization was achieved only after logarithmic transformation, the transformed variable was used. Non-parametric data were analyzed using the Mann-Whitney test. Categorical variables were expressed as frequencies and percentages and compared using the chi-square test ( $\chi^2$ ).

A multivariate logistic regression analysis was performed to evaluate the factors associated with the primary composite outcome of acute kidney injury, atrial arrhythmias, and nosocomial infection. The analysis included confounding factors based on prior literature and clinical relevance.

**Table 1.** Demographic, Clinical, and Laboratory Characteristics of Participants at Hospital Admission.

Variable	Total (N = 100)	Conventional	InsulinAPP	P
Study population, N	100	50	50	-
Age (years) <sup>a</sup>	64.2 ± 9.1	64.4 ± 9.9	63.9 ± 8.3	.979
Female gender	36 (36%)	20 (40%)	16 (32%)	.405
Reported race (white/black and brown/others), N	82 /15/2	41/7/2	42/8/0	.148
Weight (kg) <sup>a</sup>	77.6 ± 14.9	79.2 ± 15.6	76.1 ± 14.2	.290
BMI (kg/m <sup>2</sup> ) <sup>a</sup>	28.6 ± 4.9	29.4 ± 5.2	27.8 ± 4.6	.132
HbA <sub>1c</sub> (%) <sup>b</sup>	7.4 (6.5; 8.6)	7.2 (6.5; 8.6)	7.5 (6.4; 8.5)	.570
FBG (mg/dL) <sup>a</sup>	166.7 ± 72.2	160.2 ± 78.1	173.1 ± 66.2	.184
Serum creatinine (mg/dL) <sup>b</sup>	1.04 (0.89; 1.27)	1.06 (0.90; 1.34)	1.02 (0.89; 1.19)	.390

Data are presented as <sup>a</sup>mean ± SD; <sup>b</sup>median (p25; p75) or n (%); unless otherwise noted.

BMI: body mass index; HbA<sub>1c</sub>: glycated hemoglobin; FBG: fasting blood glucose; N: number of patients; SD: standard deviation.

**Table 2.** Surgical Details and Clinical and Laboratory Parameters at Discharge From the ICU.

Variable	Total (N = 100)	Conventional (N = 50)	InsulinApp (N = 50)	P
Emergency admission	36 (36%)	19 (38%)	17 (34%)	.793
Surgical time (minutes) <sup>a</sup>	370 ± 112	383 ± 84	356 ± 134	.240
ECC use	80 (80%)	41 (82%)	39 (78%)	.617
ECC time (minutes) <sup>a</sup>	100 ± 31	101 ± 38	99 ± 22	.995
Anoxia time (minutes) <sup>a</sup>	81 ± 31	83 ± 38	80 ± 23	.835
Number of bridges <sup>b</sup>	3 (3; 4)	3 (3; 4)	3 (3; 4)	.820
ICU length of stay (days) <sup>b</sup>	4 (4; 6)	5 (4; 6)	4 (3; 5)	.210
Serum creatinine (mg/dL) <sup>c,a</sup>	1.32 ± 1.01	1.29 ± 0.48	1.35 ± 1.35	.122
Estimated glomerular filtration rate (mL/min per 1.73 m <sup>2</sup> ) <sup>a,c</sup>	65.32 ± 27.30	60.41 ± 26.93	70.44 ± 27.01	.244
Hematocrit (%) <sup>a,c</sup>	28.22 ± 4.02	28.66 ± 4.01	27.78 ± 4.03	.280
Leukocytes (×10 <sup>3</sup> /mm <sup>3</sup> ) <sup>a,c</sup>	10.00 ± 3.48	10.34 ± 4.14	9.64 ± 2.65	.580
C-reactive protein (mg/L) <sup>a,c</sup>	147.28 ± 76.83	147.74 ± 82.29	146.82 ± 71.79	.958
APACHE II score <sup>b,c</sup>	10 (9; 12)	11 (9; 13)	10 (8; 12)	.225
Duration of CII <sup>b,c</sup>	17.50 (11.00; 32.25)	20.50 (13.00; 33.00)	15.50 (9.25; 30.25)	.087
Total intravenous insulin therapy (units) <sup>b,c</sup>	262.50 (165.00; 483.75)	291.10 (184.60; 468.60)	230.95 (137.82; 450.72)	.123

Data are presented as <sup>a</sup>mean ± SD; <sup>b</sup>median (p25; p75) or n (%).

<sup>c</sup>Data obtained upon discharge from the ICU.

CII: continuous insulin infusion; ECC: extracorporeal circulation; ICU: intensive care unit; N: number of patients; SD: standard deviation; APACHE: Acute Physiology and Chronic Health Evaluation.

For statistical analysis and the construction of graphs, Stata 15.1 software (College Station, Texas) was used. A two-tailed *P*-value less than .050 was deemed statistically significant throughout the analysis.

## Results

### Participants Characteristics

The study included 100 individuals, with 64% male and 82% identifying as white people, with a mean age of 64.2 ± 9.1

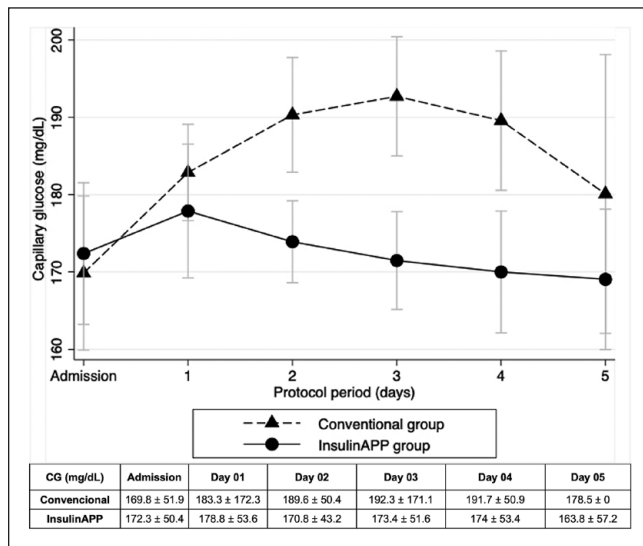
years. There were no significant demographic differences between the gAPP and gCONV groups at hospital admission (Table 1).

### Surgical Details

The mean surgical duration was 370 ± 112 minutes, with 80% of procedures using extracorporeal circulation (ECC) (Table 2). Internal mammary artery grafting was universal, with 9% undergoing bilateral grafting. Saphenous vein graft was used in 90% of procedures.

## Post-operative Management

The median ICU stay was 4 days (4; 6 days) for all individuals, which intravenous insulin administered to maintain serum glucose levels between 140 and 180 mg/dL. Ventilatory and hemodynamic parameters did not significantly differ between groups (Table 2).



**Figure 2.** Average daily blood glucose throughout the study.

## Glycemic Control and Insulin Therapy

The median preoperative HbA<sub>1c</sub> was 7.4%, with no statistical difference between groups (Table 1). Initial post-randomization BG levels were comparable between the groups. However, subsequent mean glucose levels were lower in the gAPP compared with the gCONV ( $167.2 \pm 42.5$  vs  $188.7 \pm 54.4$  mg/dL;  $P = .040$ ) (Figure 2), with lower glycemic dispersion ( $20.2 \pm 11.0$  vs  $26.4 \pm 12.2\%$ ,  $P = .020$ ) and fewer percentage of patients-day with BG above 180 mg/dL (51.3% vs 74.8%, respectively,  $P = .011$ ) (Table 3). In the gAPP group, 90.3% of individuals on oral diets received an insulin regimen that included prandial bolus and correction insulin (either bolus-correction or basal-bolus regimens) compared with 16.7% in the gCONV ( $P = .001$ ) (Figure 3). Adherence to the app-guided treatment in the gAPP was 94%.

## Clinical Outcomes

The primary composite outcome was significantly lower in the gAPP group (16%) compared with the gCONV group (58%) ( $P < .001$ ) (Table 4). Hospital stays and costs were significantly reduced in gAPP (Table 4). The readmission rate was higher in gCONV, but not significantly different (Table 4). Post-pericardiotomy syndrome incidence did not differ between groups (11% vs 13%,  $P = .640$ ). No deaths occurred until hospital discharge or within 30 days after the procedure.

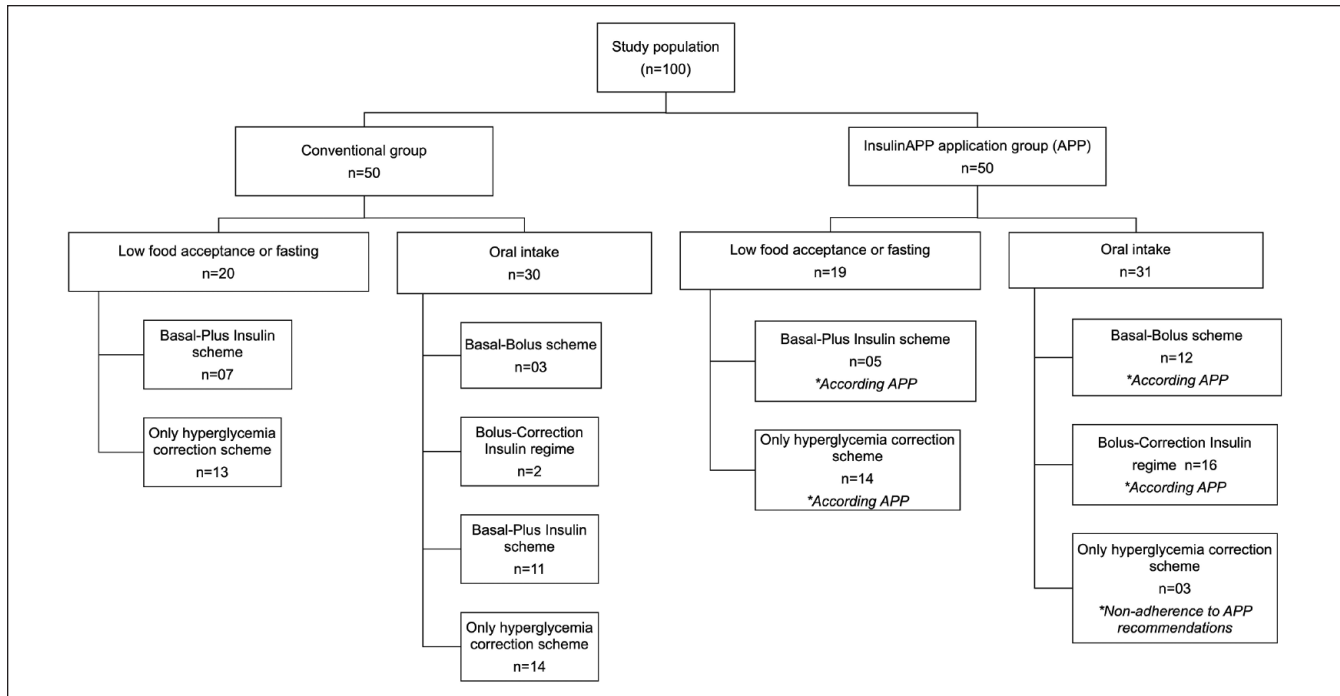
**Table 3.** Details of Glycemic Control And Insulin Therapy After Randomization.

Variable	Total (N = 100)	Conventional (N = 50)	InsulinAPP (N = 50)	P
BG prior to randomization (mg/dL)	171 ± 51	170 ± 52	172 ± 50	.839
Initial prescription				
Only correction scheme	44 (44%)	27 (54%)	17 (34%)	.001
Bolus-correction	18 (18%)	2 (4%)	16 (32%)	-
Basal-plus	23 (23%)	18 (36%)	5 (10%)	-
Basal-bolus	15 (15%)	3 (6%)	12 (24%)	-
Total daily insulin dose (unit/day)	25.8 ± 23.9	23.5 ± 25.4	28.1 ± 22.3	.207
Insulin to body weight ratio (unit/kg/day)	0.34 ± 0.32	0.31 ± 0.33	0.38 ± 0.31	.250
NPH insulin dose (unit/day)	24.8 ± 10.4	27.0 ± 12.2	22.1 ± 7.1	.160
Regular insulin dose (unit/day)	16.4 ± 17.4	12.1 ± 16.6	20.6 ± 17.3	.002
Capillary glucose (mg/dL)	177.9 ± 49.7	188.7 ± 54.4	167.2 ± 42.5	.040
Glycemic dispersion (%)	23.3 ± 12.0	26.4 ± 12.2	20.2 ± 11.0	.020
Proportion of days with average GC on target (100-180 mg/dL)	53 (53%)	23 (46%)	30 (60%)	.161
Percentage of patient-days with any glucose > 180 mg/dL (%)	63.1	74.8	51.3	.011
Number of patients with hypoglycemia (<70 mg/dL)	10 (10%)	8 (16%)	2 (4%)	.046
Low food acceptance or fasting	39 (39%)	20 (40%)	19 (38%)	.838
Use of prandial insulin in patients with oral intake	33/61 (54.1%)	5/30 (16.7%)	28/31 (90.3%)	.001

Data are presented as mean ± SD; or n (%); unless otherwise noted.

BG: blood glucose; GC: glycemic control; NPH: Neutral Protamine Hagedorn.





**Figure 3.** Flowchart of the insulin protocol used in study subjects.

**Table 4.** Composite Clinical Outcomes and Hospital Acquired Events.

Variable	Total (N = 100)	Conventional (N = 50)	InsulinAPP (N = 50)	P
Primary composite outcome	37 (37%)	29 (58%)	8 (16%)	<.001
Hospital stays duration post-randomization (days) <sup>a</sup>	14.2 ± 16.0	18.6 ± 17.7	9.8 ± 12.8	<.001
Average cost per hospital stays (US\$) <sup>a</sup>	2947.31 ± 1536.64	3231.00 ± 1937.93	2663.63 ± 922.46	.012
Re-hospitalization rate	14 (14%)	9 (18%)	5 (10%)	.249

Data are presented as <sup>a</sup>mean ± SD or n (%).

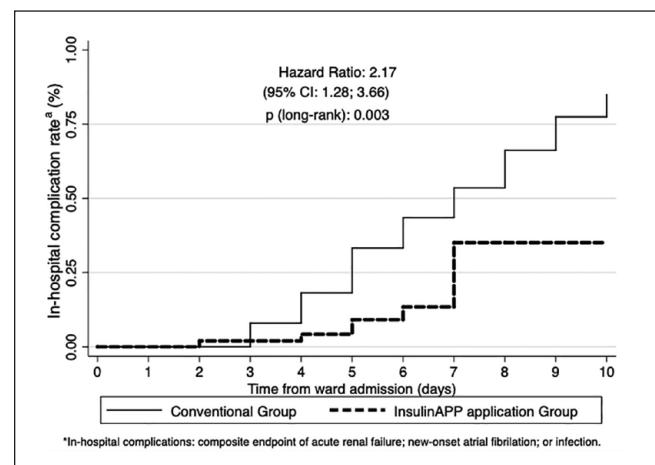
Primary composite outcome: acute kidney injury, atrial arrhythmias, and nosocomial infection.

N: number of patients; SD: standard deviation.

### Risk Factors for Primary Outcomes

The first outcome occurred in the gCONV after a median of 5 (4-10) days, whereas in the gAPP, it was 7 (4; 18) days, with no significant difference ( $P = .740$ ). However, the Kaplan-Meier curve for the cumulative risk of hospital complications showed a greater chance of events in the gCONV than in the gAPP, with a hazard ratio of 2.17 (95% confidence interval [CI] = 1.28-3.66,  $P = .003$ ) (Figure 4).

In the logistic regression analysis, four confounding factors were defined based on clinical relevance and prior literature: intervention group (eGMS vs conventional),  $HbA_{1c} > 8.5\%$ ,<sup>23</sup> extracorporeal circulation,<sup>24</sup> and female gender.<sup>25</sup> These parameters were significant predictors in the univariate analysis. The multivariate analysis confirmed that the intervention group, extracorporeal circulation, and gender remained significant predictors, with adjusted odds ratio (OR) indicating the strength and



**Figure 4.** Kaplan-Meier curve for cumulative risk of hospital complications.

<sup>a</sup>In-hospital complications: composite endpoint of acute renal failure, new-onset atrial fibrillation, or infection.

**Table 5.** Univariate and Multivariate Logistic Regression Analysis of Factors Associated With the Primary Composite Outcome.

Variable	Univariate analysis			Multivariate analysis		
	Odds ratio (95% CI)	Coefficient	P	Odds ratio (95% CI)	Coefficient	P
InsulinAPP group	0.14 (0.05-0.35)	-1.981	<.001	0.10 (0.03-0.32)	-2.276	<.001
HbA <sub>1c</sub> >8.5% at admission	2.30 (0.92-5.79)	0.834	.076	2.06 (0.63-6.73)	0.722	.232
Extracorporeal circulation	4.19 (1.14-15.45)	1.432	.031	5.61 (1.19-26.55)	1.724	.030
Female gender	5.13 (2.12-12.44)	1.636	<.001	6.63 (2.19-20.09)	1.891	.001

direction of these associations. The detailed ORs, confidence intervals, coefficients, and *P*-values for each variable are presented in Table 5.

### Hypoglycemia and Safety

Hypoglycemia was less prevalent in the gAPP (4%) compared with the gCONV group (16%) (*P* = .046) (Table 3). In the gCONV group, 75% of hypoglycemia cases occurred in individuals on an insulin correction regimen, and 25% occurred in those on a basal-plus regimen. In the gAPP group, half of hypoglycemic events occurred in individuals on a bolus-correction regimen, and the other half occurred in those on a basal-bolus insulin regimen.

### Discussion

Our study presents a paradigm shift in in-hospital insulin therapy for non-critically ill patients, showcasing the efficacy and safety of the digital protocol over conventional care. Notably, eGMS not only improved GC but also mitigated adverse clinical outcomes, including infection, acute kidney injury, and new atrial arrhythmias. Remarkably, our study fills a crucial gap in the literature by providing prospective evidence of a digital tool's efficacy in enhancing glycemic parameters and reducing hospital complications.

Consensus and guidelines have recommended using an alternative insulin regimen to the basal-bolus regimen for patients with less severe hyperglycemia.<sup>26,27</sup> The app's emphasis on bolus-correction regimen as an alternative insulin therapy regimen is based on the fact that post-prandial hyperglycemia generally occurs earlier in the pathophysiology of diabetes.<sup>28</sup> This may explain why the contribution of post-prandial glucose predominates in patients with fairly good control, whereas the contribution of fasting hyperglycemia increases as GC worsens.<sup>29</sup> A retrospective study with the use of InsulinAPP in patients in a hospitalist ward showed that 93% of blood glucose measurements were within the target range of 70 to 180 mg/dL with the use of the insulin bolus-correction scheme and without episodes of hypoglycemia.<sup>15</sup> In addition, this scheme allows the use of only one type of insulin, making it easier to prescribe insulin. Our findings highlight the superiority of a protocol incorporating prandial insulin over correction insulin alone, aligning with previous literature demonstrating the therapeutic success of

basal-bolus and basal-plus regimens over SSI regimen.<sup>21,30</sup> This strategic balance not only resulted in a lower average glycemia but also exhibited a reduction in the glucose variation coefficient, few instances of significant hyperglycemia, and decreased prevalence of hypoglycemia.

Furthermore, InsulinAPP's adaptive nature challenges conventional guidelines, offering alternative regimens tailored to individual patient needs. The safety profile of our digital tool is noteworthy, with a significantly lower incidence of hypoglycemia compared with conventional care. Moreover, our intervention exhibits tangible benefits, translating into reduced post-operative complications and costs. The financial implications are compelling, with better GC correlating with reduced costs and hospital stays.

Our study does have various limitations, including reflecting the activities of a single academic cardiology center and limited statistical power for severe hypoglycemia detection. Future multicenter studies across diverse medical settings and ethnic groups are necessary to confirm the generalizability of our findings. Despite limitations, our study provides valuable insights into the utility of InsulinAPP. The broader applicability of our findings reinforces the safety and efficacy of human insulin use, particularly in resource-constrained settings like public hospitals in Brazil and other developing countries.

### Conclusions

In conclusion, our study demonstrates that GC guided by the InsulinAPP digital protocol significantly improves glycemic profiles and reduces unfavorable clinical outcomes in non-critical post-operative cardiac surgery patients discharged from the ICU. The protocol's effectiveness in reducing hyperglycemia rates translates into shorter hospital stays and reduced resource utilization compared with conventional treatment. These findings underscore the potential of eGMS as a cost-effective and accessible solution for optimizing in-hospital insulin therapy in similar patient populations.

### Abbreviations

AKI, acute kidney injury; BG, blood glucose; BMI, body mass index; CABG, coronary artery bypass grafting; CI, confidence interval; DM, diabetes mellitus; ECC, extracorporeal circulation; eGMS, electronic glycemic management system; gAPP, InsulinAPP application group; GC, glycemic control; gCONV, conventional

protocol group; HbA<sub>1c</sub>, glycated hemoglobin; HH, in-hospital hyperglycemia; HR, hazard ratio; ICU, intensive care unit; InCor, Instituto do Coração; n, number of individuals; NPH, Neutral Protamine Hagedorn; p25; p75, interquartile range; SD, standard deviation; SSI, sliding scale insulin; T2DM, type 2 diabetes mellitus; TDID, total daily insulin dose.


### Declaration of Conflicting Interests


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### ORCID iDs

Alexandre Barbosa Câmara de Souza  <https://orcid.org/0000-0002-4029-3667>

Marcos Tadashi Kakitani Toyoshima  <https://orcid.org/0000-0002-9146-4606>

Marcia Nery  <https://orcid.org/0000-0003-2415-9668>

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