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Research Article

Clinical Outcomes of Different Insulin Regimens for Acute Coronary Syndrome-Related Hyperglycemia: A Multimodal Comparative Study

Abdullah Abu Lamzi[1]*, Sulaiman Alzerei[2], Aseel Abu Nada[3] and Yara Abu Lamzi[4]

[1]*Internal Medicine Department, An-Najah National University Hospital, Nabuls, Palestine*

[2]*Internal Medicine Department, Nasser Medical Complex, Ministry of Health, Khan Younis, Palestine*

[3]*Anesthesia and ICU Department, Shifa Medical Complex, Ministry of Health, Gaza, Palestine*

[4]*Faculty of Medicine, Islamic University of Gaza, Gaza, Palestine*

***Corresponding Author:** Abdullah Abu Lamzi, Internal Medicine Department, An-Najah National University Hospital, Nabuls, Palestine. E-mail ID: abd.m.lamzi3@gmail.com.

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Abstract

Background: Hyperglycemia is a common and serious complication among patients admitted with acute coronary syndrome (ACS) and is associated with increased mortality, prolonged hospitalization, and adverse cardiovascular outcomes. Several insulin regimens exist for inpatient glycemic control, yet comparative evidence specific to ACS remains limited. This study evaluated the effectiveness and safety of four commonly used insulin strategies-Sliding Scale (SS), Basal-Bolus (BB), Carbohydrate Index-based dosing (CI), and Premixed insulin (PM)-in managing hyperglycemia among ACS patients in Gaza hospitals.

Methods: A multimodal comparative study was conducted at Shifa Medical Complex and European Gaza Hospital from January 2023 to January 2024. A total of 350 ACS patients with hyperglycemia were included and allocated into four insulin-regimen groups based on clinical practice: SS (n = 110), BB (n = 95), CI (n = 75), and PM (n = 70). Data were collected from medical records and bedside glucose monitoring. Outcomes included glycemic control metrics (mean glucose, variability, hypoglycemia), clinical outcomes (mortality, major complications, reinfarction), and length of stay. Multivariate logistic regression was performed to identify independent predictors of mortality.

Results: Basal-Bolus therapy resulted in significantly better glycemic control, with the lowest mean glucose (156 ± 33 mg/dL), lowest glucose variability, and highest time-in-range (72%) ($p < 0.001$). The Sliding-Scale group showed the poorest control and highest variability. In-hospital mortality differed significantly among the groups: SS (14.5%), BB (6.3%), CI (8.0%), PM (12.8%) ($p = 0.03$). Basal-Bolus therapy also achieved the shortest mean length of stay (5.1 ± 2.4 days), while Sliding Scale had the longest (7.8 ± 3.1 days) ($p < 0.001$). In multivariate analysis, Sliding-Scale therapy was independently associated with higher mortality (Adjusted OR 2.90, 95% CI 1.21-6.96, $p = 0.016$), along with higher admission glucose and increased glycemic variability.

Conclusion: Among insulin regimens used for ACS-related hyperglycemia, Basal-Bolus therapy provided superior glycemic stability and was associated with lower mortality and shorter hospitalization. Sliding-Scale insulin was linked to poor glycemic control, greater glucose variability, and independently increased mortality risk. Implementing physiologic insulin strategies-particularly Basal-Bolus-may improve outcomes in ACS patients with hyperglycemia, especially in resource-limited settings.

Keywords: *Basal-Bolus Insulin; Sliding Scale; Acute Coronary Syndrome; Hyperglycemia Management; In-Hospital Mortality*

Introduction

Hyperglycemia commonly complicates acute coronary syndrome (ACS) and is associated with worse short-term and long-term outcomes. Stress hyperglycemia during ACS results from a cascade of neurohormonal activation - catecholamines, cortisol, and inflammatory cytokines - that produce increased hepatic glucose output and peripheral insulin resistance [1]. Large observational studies and meta-analyses have repeatedly shown that higher admission glucose and greater in-hospital glycemic excursions correlate with increased infarct size, higher rates of heart failure, recurrent ischemia, arrhythmias, and both in-hospital and 30-day mortality, in patients with and without preexisting diabetes mellitus [2-5]. Consequently, controlling hyperglycemia in the setting of ACS is a therapeutic priority, but the optimal method to deliver insulin and achieve safe, physiologic glycemic control remains debated [6-8].

Insulin provides metabolic benefits beyond glucose lowering: it reduces circulating free fatty acids, improves myocardial glucose uptake, favorably alters substrate utilization during ischemia, and attenuates inflammatory and pro-thrombotic pathways [9]. Evidence from randomized and observational studies suggests that improved glycemic control may reduce infarct expansion and adverse remodeling; however, intensive glucose-lowering strategies carry the risk of hypoglycemia, which itself is tied to arrhythmogenic events and worse outcomes [10-12]. Thus, achieving a therapeutic window of tight but safe control is the clinical challenge.

Multiple inpatient insulin strategies exist. Sliding Scale Insulin (SSI) is reactive - short-acting insulin is given in response to measured hyperglycemia - and is often criticized because it lacks basal insulin and may permit prolonged hyperglycemia or glucose variability between doses [13,14]. Basal-Bolus regimens combine long-acting basal insulin to control fasting glucose with short-acting boluses at meals or prandial times, and represent a physiological replacement model associated with stable glycemia in multiple inpatient settings [15,16]. Carbohydrate Insulin Index-based regimens (which tailor insulin dose to carbohydrate intake and glycemic index/insulin index concepts) seek individualized prandial coverage and can reduce prandial excursions but require nutritional assessment and staff training [17,18]. Premixed insulin formulations (fixed ratios of intermediate and rapid/short-acting insulin) can simplify administration but limit flexibility and dosing precision - potentially causing mismatch between insulin action and metabolic needs in the acute setting [19].

Although some ICU and perioperative trials favor physiologic basal-bolus approaches over sliding-scale regimens in reducing glucose variability and preventing complications [20-22], specific comparative data among ACS patients are sparse. Differences in patient physiology during myocardial ischemia (increased catecholamines, variable oral intake, hemodynamic instability) mean that ambulatory-derived approaches may not translate directly to the ACS inpatient context. Moreover, resource-limited hospitals may rely more on sliding-scale or premixed insulin for simplicity, while more intensive/individualized approaches may be logistically challenging [23]. This contextual reality makes locally generated comparative evidence important for clinical policy.

The present multimodal comparative study evaluates four commonly used insulin methods - Sliding Scale, Basal-Bolus, Carbohydrate Insulin Index, and Premix - among patients admitted with ACS and hyperglycemia at two major Gaza hospitals (Shifa Medical Complex and European Gaza Hospital) during January 2023-January 2024. We compared glycemic control metrics (admission glucose, mean in-hospital glucose, glucose variability, hypoglycemia frequency), clinical endpoints (in-hospital mortality, major cardiac complications, length of stay), and safety outcomes (severe hypoglycemia, hyperglycemic crises). Our objective was to determine which insulin strategy provides the best balance of efficacy and safety in ACS care in this setting, and to identify independent predictors of mortality and severe glycemic complications that might guide local protocol development and resource allocation [24,25].

Methods

Study design and setting

This multimodal comparative cross-sectional study combined retrospective medical-record review with prospective in-hospital observation. The study was performed at Shifa Medical Complex and European Gaza Hospital, the two tertiary referral centers in Gaza that admit ACS patients and manage inpatient glycemic control. Study period: January 2023 - January 2024.

Population and sampling

Consecutive adult patients (≥18 years) admitted with confirmed ACS (STEMI, NSTEMI, or unstable angina) who developed in-hospital hyperglycemia (admission glucose >180 mg/dL or need for insulin on admission) and were treated with one of four insulin strategies were eligible. Exclusions: diabetic ketoacidosis/hyperosmolar hyperglycemic state on admission, type 1 diabetes, chronic high-dose steroids, end-stage renal disease on dialysis, or hospital stay <48 hours. Total included: 350 patients.

Insulin strategies

Patients were grouped by the in-hospital insulin approach documented in the medical chart and applied by the treating team:

- Sliding Scale Insulin (SSI) - reactive correctional doses of short-acting insulin based on blood glucose thresholds.
- Basal-Bolus (BB) - long-acting basal insulin (once daily) plus scheduled rapid-acting boluses using standardized prandial/coverage algorithms adjusted to glucose readings.
- Carbohydrate Index (CI) - carbohydrate-counting insulin index-guided prandial insulin with individualized dosing.
- Premix (PM) - premixed insulin injections given per protocol (e.g. twice daily).

Data collection

A standardized abstraction form captured demographics, ACS subtype, comorbidities (diabetes, HTN, prior CAD), admission labs (glucose, HbA1c if available, creatinine), vital signs, Killip class, reperfusion therapy, insulin regimen details, bedside capillary glucose measurements, hypoglycemic episodes (< 70 mg/dL, severe < 40 mg/dL), and clinical outcomes (in-hospital mortality, heart failure, arrhythmia, reinfarction, length of stay). Prospective observation recorded timing of insulin doses and matched with nursing glucose checks for accuracy.

Outcomes

Primary: in-hospital mortality. Secondary: mean in-hospital glucose, glucose variability (SD of glucose readings), hypoglycemia incidence, length of hospital stay, and hyperglycemia-related complications.

Statistical analysis

Categorical data were compared with Chi-square or Fisher's exact test; continuous data with ANOVA or Kruskal-Wallis as appropriate. Multivariate logistic regression identified independent mortality predictors; variables with $p < 0.10$ in bivariate analysis were entered into the model. Significance threshold $p < 0.05$. Analysis performed with SPSS v26.

Ethical consideration

Ethical approval was obtained from the Institutional Review Board (IRB) of the Ministry of Health, Gaza prior to data collection. The study adhered to the ethical principles of the Declaration of Helsinki, ensuring respect for autonomy, confidentiality, and non-maleficence. Written informed consent was obtained from all participants or their legal guardians before interviews or follow-up calls. Participation was entirely voluntary, and patients were informed that refusal would not affect their treatment or access to services.

Results

We analyzed 350 patients with ACS and hyperglycemia treated with four insulin strategies: Sliding Scale (SS) n = 110 (31.4%), Basal-Bolus (BB) n = 95 (27.1%), Carbohydrate Index (CI) n = 75 (21.4%), and Premix (PM) n = 70 (20.0%). Mean age overall was 61.4 ± 11.8 years; 62% (n = 217) were male. Baseline prevalence of known diabetes was 48% (n = 168). STEMI accounted for 45% (n = 157) of

presentations, NSTEMI 40% (n = 140), and unstable angina 15% (n = 53). Below we present detailed tables and narrative interpretation. Table 1 shows baseline demographics were similar across groups; the sliding-scale group had a numerically larger proportion of patients with known diabetes and higher mean HbA1c, which may bias toward worse glycemic outcomes in that cohort. Age and gender distribution did not differ significantly.

Variable	Total (n = 350)	Sliding Scale (n = 110)	Basal-Bolus (n = 95)	Carb Index (n = 75)	Premix (n = 70)	p-value
Age, mean ± SD (yrs)	61.4 ± 11.8	62.5 ± 12.0	59.8 ± 11.2	61.1 ± 11.6	63.2 ± 12.3	0.11
Male, n (%)	217 (62.0)	70 (63.6)	59 (62.1)	46 (61.3)	42 (60.0)	0.97
Known diabetes, n (%)	168 (48.0)	62 (56.4)	42 (44.2)	30 (40.0)	34 (48.6)	0.07
Hypertension, n (%)	210 (60.0)	70 (63.6)	56 (58.9)	43 (57.3)	41 (58.6)	0.76
Prior CAD, n (%)	105 (30.0)	40 (36.4)	24 (25.3)	20 (26.7)	21 (30.0)	0.18
STEMI, n (%)	157 (44.9)	54 (49.1)	41 (43.2)	28 (37.3)	34 (48.6)	0.25
HbA1c available, n (%)	200 (57.1)	58 (52.7)	60 (63.2)	38 (50.7)	44 (62.9)	0.15
Mean HbA1c (when available), %	8.1 ± 1.8	8.6 ± 1.9	7.6 ± 1.7	7.9 ± 1.6	8.2 ± 1.8	0.02

Table 1: *Demographic and baseline clinical characteristics (n = 350).*

Table 2 presents the sliding-scale cohort presented with significantly higher admission glucose (mean 228 mg/dL) compared with basal-bolus (164 mg/dL) and carbohydrate index groups (172 mg/dL); this difference was statistically significant (ANOVA $p < 0.001$) and suggests baseline imbalance that was adjusted for in multivariate models.

Variable	Total	SS	BB	CI	PM	p-value
Admission glucose, mg/dL mean ± SD	192.6 ± 54.3	228 ± 54	164 ± 39	172 ± 42	198 ± 48	<0.001
Serum creatinine, mg/dL, mean ± SD	1.12 ± 0.42	1.18 ± 0.45	1.05 ± 0.36	1.09 ± 0.41	1.15 ± 0.43	0.20
Killip class ≥ 2, n (%)	88 (25.1)	33 (30.0)	20 (21.1)	13 (17.3)	22 (31.4)	0.06
Peak troponin (xULN), median (IQR)	6.5 (2.0-18.0)	8.1 (2.8-21.7)	5.0 (1.8-14.0)	5.6 (1.6-12.0)	7.2 (2.4-17.3)	0.08

Table 2: *Admission labs and hemodynamic indices.*

Narrative (Table 3) basal-bolus therapy achieved the best in-hospital glycemic control (mean 156 ± 33 mg/dL), highest proportion of readings within the 100 - 180 mg/dL target (72%), and lowest glucose variability compared with Sliding Scale and Premix (all $p < 0.001$). Hypoglycemia rates were low and not significantly different across regimens.

Metric	SS (n = 110)	BB (n = 95)	CI (n = 75)	PM (n = 70)	p-value
Mean in-hospital glucose (mg/dL)	205 ± 46	156 ± 33	162 ± 36	186 ± 42	<0.001
Glucose SD (variability) mg/dL	42 ± 15	26 ± 11	23 ± 9	34 ± 12	<0.001
% readings in target 100-180 mg/dL	32%	72%	68%	44%	<0.001
Hypoglycemia <70 mg/dL, n (%)	7 (6.4)	9 (9.5)	3 (4.0)	4 (5.7)	0.21
Severe hypoglycemia (< 40 mg/dL), n (%)	1 (0.9)	2 (2.1)	0	0	0.30

Table 3: *In-hospital glycemic control metrics.*

Table 4 presents mortality was highest in the Sliding-Scale group (14.5%) and lowest in the Basal-Bolus group (6.3%; p = 0.03). Similarly, the Sliding-Scale group had the longest mean hospital stay (7.8 days) and higher rates of major heart-failure/cardiogenic shock compared with Basal-Bolus and CI groups. These differences persisted after adjustment for age, admission glucose, and Killip class in multivariate models.

Outcome	SS (n = 110)	BB (n = 95)	CI (n = 75)	PM (n = 70)	p-value
In-hospital mortality, n (%)	16 (14.5)	6 (6.3)	6 (8.0)	9 (12.8)	0.03
Length of stay, mean ± SD (days)	7.8 ± 3.1	5.1 ± 2.4	5.6 ± 2.6	6.9 ± 3.0	<0.001
Major HF or cardiogenic shock, n (%)	24 (21.8)	9 (9.5)	7 (9.3)	13 (18.6)	0.01
Reinfarction, n (%)	6 (5.5)	3 (3.2)	2 (2.7)	3 (4.3)	0.68
Hyperglycemia-related complications (infection, thrombosis), n (%)	25 (22.7)	11 (11.6)	10 (13.3)	14 (20.0)	0.04

Table 4: *Clinical outcomes and complications.*

Table 5 illustrates after adjustment, sliding-scale therapy remained independently associated with increased odds of in-hospital mortality (AOR 2.90, 95% CI 1.21-6.96, p = 0.016) compared to Basal-Bolus. Higher admission glucose and greater glucose variability were also independent predictors of mortality. Age and higher Killip class significantly increased mortality risk; known diabetes did not independently predict mortality after controlling for acute glycemia and severity.

Predictor	Adjusted OR	95% CI	p-value
Sliding Scale vs BB	2.90	1.21 - 6.96	0.016
Premix vs BB	1.80	0.78 - 4.12	0.16
Carb Index vs BB	1.37	0.52 - 3.64	0.53
Age (per year)	1.03	1.01 - 1.06	0.02
Male sex	0.95	0.52 - 1.72	0.86
Known diabetes	1.45	0.90 - 2.33	0.12
Admission glucose (per 10 mg/dL)	1.12	1.05 - 1.20	<0.001
Glucose SD (per 10 mg/dL)	1.20	1.02 - 1.41	0.03
Killip class ≥2	2.60	1.46 - 4.63	0.001

Table 5: *Multivariate logistic regression - predictors of in-hospital mortality (reference: Basal-Bolus).*

Discussion

This multimodal comparative study supports the superiority of Basal-Bolus insulin over Sliding-Scale and Premix regimens in managing ACS-related hyperglycemia; Basal-Bolus produced the most stable glycemia, highest time-in-range, shortest length of stay, and lowest mortality. Our findings align with inpatient studies demonstrating improved metabolic stability and clinical outcomes with physiological insulin replacement strategies compared to reactive sliding-scale approaches [16-19]. The observed association between glucose variability (SD) and mortality mirrors growing evidence that short-term glycemic fluctuations independently predict adverse cardiovascular events beyond mean glucose levels [20-22]. Sliding-scale insulin has been criticized in the literature for permitting prolonged hyperglycemia and greater variability - mechanisms that plausibly account for the higher complication and mortality rates we observed [23,24].

Carbohydrate Index-guided therapy performed well in terms of glucose stability and low hypoglycemia rates, consistent with studies showing individualized carbohydrate-based dosing reduces prandial spikes [25-27]. However, its operational complexity (dietary analysis, staff training) can be a limiting factor in resource-constrained hospitals. Premixed insulin offered intermediate outcomes and carries known limitations for flexibility in acute care [28-30].

Importantly, our multivariate analysis highlights that admission glucose and glucose variability were independent mortality predictors, not merely diabetes history - underlining that stress hyperglycemia per se is pathogenic in ACS [31-35]. These results provide actionable evidence to guide local protocols: favor a Basal-Bolus approach where feasible, implement measures to reduce glucose variability, and ensure protocols to limit sliding-scale-only strategies.

This was an observational multimodal study with non-random allocation to insulin regimens. Baseline imbalances - notably higher admission glucose and HbA1c in the SSI group - could confound associations despite multivariate adjustment. Operational differences and clinician selection biases (sicker patients receiving simpler regimens) may also influence outcomes. Finally, the study was limited to two hospitals in Gaza; generalizability outside similar resource settings requires caution.

Conclusion

In this comparative multimodal study of 350 ACS patients with hyperglycemia, Basal-Bolus insulin achieved superior glycemic control, shorter hospital stay, and lower in-hospital mortality compared with Sliding-Scale and Premix strategies. Sliding-Scale insulin was associated with higher glucose variability, more complications, and an independent increase in mortality odds. Carbohydrate Index-guided therapy showed promising stability and low hypoglycemia but requires additional resources. We recommend institutional adoption of Basal-Bolus protocols for ACS patients when feasible, with close monitoring to minimize hypoglycemia and efforts to reduce glucose variability. A randomized controlled trial in this population would be valuable to confirm causality and refine optimal glycemic targets in ACS.

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