

Dynamic Changes in Fasting Blood Glucose Levels During Hospitalization and at Discharge Among Pediatric Patients with COVID-19: A Retrospective Cohort Study in Southwest Iran

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Abstract

Background

While the clinical spectrum of COVID-19 in children is broad, the interplay between SARS-CoV-2 infection and acute glycemic fluctuations remains poorly understood in pediatric populations without pre-existing diabetes. This study aimed to compare fasting blood glucose (FBG) levels during admission and at discharge among children hospitalized with COVID-19 and to identify clinical predictors of these changes.

Methods

This retrospective study analyzed 600 children (aged < 18 years) with confirmed COVID-19 hospitalized at Abuzar Pediatric Hospital, Ahvaz, Iran (2021–2022). Patients with a history of diabetes were excluded. FBG levels were recorded at admission (initial) and prior to discharge (final). Data were analyzed using Wilcoxon signed-rank tests and Spearman's correlation via SPSS v.23.

Results

The mean age was 4.39 ± 4.77 years. A statistically significant increase was observed in FBG levels from admission (mean: 85.68 ± 35.87 mg/dl) to discharge (mean: 92.86 ± 32.87 mg/dl; $P < 0.001$). Admission FBG was positively correlated with age ($P = 0.026$). Furthermore, glycemic levels significantly varied based on underlying comorbidities ($P = 0.012$). However, sex, disease severity, length of stay (mean: 5.71 ± 3.75 days), and residential area (urban vs. rural) were not significant predictors of FBG fluctuations ($P > 0.05$).

Conclusion

COVID-19 is associated with significant FBG elevation during the recovery phase in children, particularly those with underlying conditions. These findings suggest that SARS-CoV-2 may exert a transient metabolic stress or direct pancreatic impact that persists until discharge, necessitating follow-up for potential long-term dysglycemia.

Introduction

The Coronavirus Disease 2019 (COVID-19) pandemic, caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), has presented an unprecedented global health crisis, with over 770 million confirmed cases and nearly 7 million deaths as of early 2024 [1, 2]. While initial observations suggested that pediatric populations experience a milder clinical course compared to adults, accumulating evidence indicates that children can manifest a diverse and complex clinical spectrum, ranging from

asymptomatic infection to life-threatening conditions such as Multisystem Inflammatory Syndrome in Children (MIS-C) [3, 4]. Recent epidemiological shifts, particularly with the emergence of highly transmissible variants, have led to increased hospitalization rates among children, necessitating a deeper investigation into the systemic metabolic consequences of the virus in this age group [5, 6].

One of the most significant extrapulmonary manifestations of COVID-19 is the disruption of glucose metabolism. In adults, "stress hyperglycemia" and new-onset diabetes have been robustly linked to increased morbidity, mechanical ventilation requirements, and mortality [7, 8]. However, the dynamics of Fasting Blood Glucose (FBG) in pediatric patients—particularly those without a prior history of diabetes—remain insufficiently characterized [9]. SARS-CoV-2 utilizes the Angiotensin-Converting Enzyme 2 (ACE2) receptor for cellular entry, which is highly expressed not only in the lungs but also in the pancreatic islet cells and hepatocytes [10, 11]. Recent molecular studies in 2023 have confirmed that SARS-CoV-2 can directly infect and replicate within human endocrine and exocrine pancreatic cells, leading to impaired insulin production and dysregulated glucose homeostasis [12, 13].

Furthermore, the cytokine storm associated with COVID-19, characterized by elevated levels of Interleukin-6 (IL-6) and C-Reactive Protein (CRP), contributes to transient insulin resistance and stimulates hepatic gluconeogenesis [14, 15]. A landmark study by Barreto et al. (2023) demonstrated that SARS-CoV-2 infection of hepatocytes actively stimulates gluconeogenic pathways, providing a potential mechanism for persistent hyperglycemia even after the acute respiratory phase has subsided [16]. In pediatric cohorts, this metabolic stress may be exacerbated by underlying comorbidities, such as obesity or chronic respiratory diseases, which are increasingly prevalent in industrial regions like Southwest Iran [17].

Despite these insights, most existing research has focused on cross-sectional admission glucose levels, with a significant gap in understanding how FBG levels evolve from the point of hospitalization to clinical recovery and discharge [18]. Identifying whether these glycemic fluctuations are transient or persist until discharge is crucial for determining the need for long-term metabolic follow-up in children [19, 20]. Therefore, the present study aimed to compare fasting blood glucose levels during admission and at the time of discharge among pediatric patients with COVID-19 in Ahvaz, Iran, and to identify the socio-demographic and clinical determinants of these glycemic trajectories.

Methods

Study Design and Setting

This retrospective cohort study was conducted at Abuzar Children's Hospital, the primary tertiary referral center for pediatric infectious diseases in Southwest Iran, affiliated with Ahvaz Jundishapur University of Medical Sciences (AJUMS). The study period spanned from March 2021 to March 2022, covering multiple waves of the COVID-19 pandemic in the region.

Participants and Selection Criteria

A total of 633 pediatric patients (aged 0 to 18 years) hospitalized with a confirmed diagnosis of COVID-19 were initially screened. Following the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines, we applied the following exclusion criteria: (1) Patients with a documented history of Type 1 or Type 2 Diabetes Mellitus; (2) Patients whose medical records were incomplete or distorted regarding laboratory data; and (3) Patients over 18 years of age. After screening, 600 patients met the eligibility criteria and were included in the final analysis via a census sampling method.

Data Collection and Variables

Data were extracted from the electronic and physical medical records using a standardized checklist. The primary outcome variables were:

1. Baseline FBG (FBG-1): The first fasting blood glucose measured within 24 hours of hospital admission.
2. Discharge FBG (FBG-2): The final fasting blood glucose measured within 24 hours prior to hospital discharge.

Independent variables included socio-demographic data (age, sex, and residential area) and clinical parameters (length of hospital stay, underlying comorbidities, and disease severity). Disease severity was categorized as "Moderate" (evidence of lower respiratory disease during clinical assessment or imaging with oxygen saturation 94%) or "Severe" (oxygen saturation < 94%, tachypnea, or respiratory distress) based on the WHO pediatric COVID-19 classification [1, 2].

Statistical Analysis

Data analysis was performed using IBM SPSS Statistics for Windows, version 23.0. Continuous variables were expressed as Mean $\pm$ Standard Deviation (SD), and categorical variables were presented as frequencies and percentages. The normality of data distribution was assessed using the Kolmogorov-Smirnov test. Given the non-normal distribution of glycemic data, the Wilcoxon signed-rank test was employed to compare FBG levels at admission and discharge. Spearman's rank correlation coefficient was used to evaluate the association between age, length of stay, and FBG changes. Differences between subgroups (sex, severity, comorbidities) were analyzed using the Mann-Whitney U test. A p-value of < 0.05 was considered statistically significant.

The study protocol was approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences [IR.AJUMS.REC.1401.462]. Patient confidentiality was strictly maintained by anonymizing the data during the extraction process. Since the study was retrospective, the requirement for informed consent was waived by the ethics committee.

Ethical Considerations

Results

Demographic and Clinical Baseline Characteristics

A total of 600 pediatric patients with confirmed COVID-19 were included in the final analysis. The study population exhibited a mean age of 4.39 ± 4.77 years, ranging from neonates (1 day) to adolescents (17 years). The cohort was nearly equally distributed by sex, with 305 (50.8%) males and 295 (49.2%) females. Regarding residential distribution, 307 (51.2%) patients were from urban areas, while 293 (48.8%) were from rural regions.

Clinical assessment at admission revealed that 382 (63.7%) patients presented with moderate disease severity, while 218 (36.3%) were classified as severe cases. The mean length of hospital stay (LOS) was 5.71 ± 3.75 days (range: 1 to 36 days). Underlying comorbidities were present in 13.2% ($n = 79$) of the participants, with the most frequent conditions being Cerebral Palsy (1.2%), Down Syndrome (1.0%), and G6PD deficiency (0.8%). The majority of the cohort (86.8%, $n = 521$) had no documented pre-existing medical conditions (Table 1).

Primary Outcome: Glycemic Trajectory from Admission to Discharge

The primary analysis focused on the dynamic changes in fasting blood glucose (FBG) levels. The mean FBG at admission was 85.68 ± 35.87 mg/dl. A statistically significant escalation in glycemic levels was observed at the time of discharge, with the mean FBG rising to 92.86 ± 32.87 mg/dl (Wilcoxon signed-rank test, $P < 0.001$). This upward trend indicates a persistent metabolic alteration throughout the hospitalization period despite clinical stabilization (Table 2).

Correlation of FBG with Age and Length of Stay

Spearman's rank correlation analysis was performed to evaluate the influence of age and duration of hospitalization on FBG levels. A statistically significant, albeit weak, positive correlation was identified between age and admission FBG ($\rho = 0.026$, $P = 0.026$), suggesting that older children may exhibit higher initial stress-induced glycemic responses. However, age did not significantly correlate with discharge FBG ($P = 0.579$) or the magnitude of FBG change ($P = 0.108$). Furthermore, the length of hospital stay showed no significant correlation with admission FBG ($P = 0.70$), discharge FBG ($P = 0.142$), or the FBG trajectory ($P = 0.169$).

Subgroup Analysis by Sex, Residence, and Disease Severity

Subgroup analyses were conducted to identify potential determinants of FBG fluctuations. Mann-Whitney U tests revealed no statistically significant differences in FBG levels between male and female patients ($P = 0.316$). Similarly, the residential area (urban vs. rural) did not significantly impact the glycemic profile at admission or discharge ($P = 0.533$).

Regarding clinical severity, although patients with severe COVID-19 exhibited slightly higher mean FBG levels at admission (88.16 ± 49.30 mg/dl) compared to moderate cases (84.26 ± 25.17 mg/dl), this difference did not reach statistical significance ($P = 0.76$). Glycemic trajectories remained comparable across both severity groups.

Impact of Underlying Comorbidities

The presence of pre-existing medical conditions was identified as a significant factor influencing FBG levels. Patients with underlying comorbidities exhibited significantly different glycemic patterns at both time points compared to previously healthy children ($P = 0.012$). Children with underlying diseases maintained higher FBG levels, confirming their increased metabolic vulnerability during the infection and recovery phases.

Table 1
Baseline Demographic and Clinical Characteristics of the Study Population
(N = 600)

Variable	Category	Frequency(N)	Percentage(%)
Age(Y)	Mean $\pm$ SD	4.77 $\pm$ 4.39	-
	Median(IQR)	(6.0–1.0)2.85	-
	Min-Max	17.00-0.03	-
Sex	Male	305	50.8\%
	Female	295	49.2%
Residence	Urban	307	51.2%
	Rural	293	48.8%
Disease Severity	Moderate	382	63.7%
	Severe	218	36.3%
Length of stay	Mean $\pm$ SD	3.75 $\pm$ 5.71	—
Underlying Comorbidities*	Present	79	13.2\%
	Absent	521	86.8%
Note: IQR, Interquartile Range; SD, Standard Deviation.			

Table 2
Glycemic Trajectory: Comparison of Fasting Blood Glucose (FBG) Levels from Admission to Discharge

Time Point	Mean(mg/dl)	SD	Range(Min- Max)	P- value(Wilcoxon test)
Admission(FBG-1)	85.68	35.87	405 – 35	0.001 >
Discharge(FBG-2)	92.86	32.87	450 – 40	—
Difference(Δ)	7.18	29.41	-410 to + 250	—
Note: Statistically significant difference based on Wilcoxon signed-rank test.*				

Table 3
Univariate Analysis of Determinants Associated with Fasting Blood Glucose (FBG) Fluctuations

Variable	Admission FBG		Discharge FBG	
Age(year)	Mean(SD)	P – value	Mean(SD)	p-vauce
	(4.77)4.39		(4.77)4.39	0.579
				0.026
Sex	(38.20)87.10	0.316	(31.40) 91.50	0.412
Male	(33.15)84.25		(33.90) 93.65	
Female	(34.50) 86.05			
Residence				
Urban				

Discussion

The metabolic impact of SARS-CoV-2 in the pediatric population remains a critical frontier in COVID-19 research. Our study, analyzing 600 non-diabetic children, revealed a statistically significant escalation in Fasting Blood Glucose (FBG) from admission to discharge (P < 0.001). This phenomenon of late-phase glycemic rise suggests that the metabolic disturbances triggered by COVID-19 may outlast the acute respiratory symptoms, pointing toward a prolonged state of insulin resistance or delayed pancreatic recovery.

Glycemic Trajectories and Pancreatic Impact

The significant increase in FBG during the recovery phase (mean: 92.86 mg/dl at discharge) aligns with the findings of Lopez-Sanchez et al. (2024) and Tanaka et al. (2024), who documented that pediatric

metabolic recovery often lags behind clinical stabilization [5, 20]. Pathophysiologically, this can be explained by the high expression of ACE2 receptors in the endocrine pancreas [11]. Steenblock et al. (2023) demonstrated through autopsy and biopsy studies that SARS-CoV-2 infiltration into pancreatic islets results in chronic sub-acute inflammation, even after systemic viral clearance [12]. This islet-cell fatigue is further aggravated by the viral-mediated apoptosis of beta cells, as recently confirmed by Qadir et al. (2023) [13]. Our findings suggest that in children, this process may manifest as a progressive rise in glucose levels throughout the hospital stay.

The Role of Stress Hyperglycemia and Age

We observed a positive correlation between age and admission FBG ($P = 0.026$). This is consistent with the meta-analysis by Bellia et al. (2023), which suggested that the sympathoadrenal response to viral stress matures with age [9]. Older children likely exhibit a more pronounced release of counter-regulatory hormones, such as cortisol, glucagon, and growth hormone, which counteract insulin action [7, 8]. Cheng et al. (2023) also noted that stress-induced hyperglycemia is more prevalent in adolescents compared to younger children, potentially due to the evolving hormonal milieu during puberty [8].

Comorbidities and Metabolic Vulnerability

Consistent with global pediatric cohorts (e.g., Feldstein et al., 2024), our study showed that underlying comorbidities are major determinants of FBG levels ($P = 0.012$) [4]. Children with systemic conditions like cerebral palsy or congenital heart disease often possess a pre-existing pro-inflammatory state. Gustine and Jones (2024) reported that in these vulnerable groups, the SARS-CoV-2-induced cytokine storm (specifically IL-6 and TNF- α) creates a significant metabolic hit, leading to pronounced insulin resistance in peripheral tissues [14]. Furthermore, our data supports the hypothesis by Pirola and Sookoian (2024) that comorbidities exacerbate hepatic gluconeogenesis, as the liver becomes more sensitive to inflammatory signals during COVID-19 [17].

Mechanistic Insights: Hepatic and Cellular Dysregulation

The rising trend in FBG toward discharge can also be interpreted through the lens of hepatic glucose output. Barreto et al. (2023) recently provided groundbreaking evidence that SARS-CoV-2 directly infects hepatocytes and manipulates the gluconeogenic pathway by upregulating enzymes like phosphoenolpyruvate carboxykinase (PEPCK) [16]. This manipulation provides a sustained supply of glucose, which may explain why we observed higher levels at discharge than at admission. Moreover, Zhong et al. (2023) suggested that transient hyperglycemia during the recovery phase might be an evolutionary response to provide energy for tissue repair, although it poses long-term risks for metabolic health [15].

Nonsignificant Determinants: Sex and Severity

Interestingly, sex and disease severity did not significantly influence FBG in our cohort. This contrasts with some adult studies, such as Wang et al. (2023), where males and severe cases consistently showed

higher hyperglycemia [18]. The lack of sex-based differences in our study may be attributed to the prepubertal age of our population (mean age: 4.39 years), where sex-hormone-driven differences in ACE2 expression are negligible [19]. Furthermore, our observation that severity does not dictate glycemic levels in children is echoed by Zachariah (2023), who noted that even mild pediatric COVID-19 cases can exhibit surprising systemic markers of inflammation and endocrine stress [3].

Clinical Implications and Limitations

The discharge hyperglycemia observed in Ahvaz emphasizes the need for a shift in clinical practice. As suggested by Lopez-Sanchez (2024), children—especially those with comorbidities—should be screened for dysglycemia at the time of discharge to prevent undiagnosed post-viral diabetes [20].

Despite its strengths, including a large sample size (N = 600) and the unique Iranian pediatric context, this study has limitations. The retrospective design precluded the measurement of C-peptide or insulin resistance markers (HOMA-IR). Additionally, we did not account for the potential glycemic effects of corticosteroids used during treatment, a common confounder in COVID-19 studies.

Abbreviations

FBG: Fasting Blood Glucose; COVID-19: Coronavirus Disease 2019; SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus 2; WHO: World Health Organization; ACE2: Angiotensin-Converting Enzyme 2; LOS: Length of Stay; MIS-C: Multisystem Inflammatory Syndrome in Children; SD: Standard Deviation; IQR: Interquartile Range.

Declarations

Ethics approval and consent to participate

The study protocol was formally approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences[IR.AJUMS.REC.1401.462] . Due to the retrospective nature of the study and the use of anonymized electronic medical records, the requirement for informed consent from the participants or their legal guardians was waived by the university's ethics committee.

Consent for publication

Not applicable. The data analyzed in this study are aggregated and anonymized, and no individual patient data or identifiable personal information (such as names or photographs) are published in this manuscript.

Availability of data and materials

The datasets generated and analyzed during the current study are not publicly available because they contain information that could compromise participant privacy but are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that they have no competing interests (financial or non-financial) that could have influenced the results or the interpretation of the presented study.

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Authors' contributions

All authors contributed to the study conception and design. Farkhondeh Jamshidi and Arezoo Aminian were responsible for data collection and initial drafting of the manuscript. Mehdi Torabizadeh performed the statistical analysis and data interpretation. Mohammad Esmaeil Motlagh provided critical review and edits of the manuscript. Maryam Rostami provided overall supervision and final approval of the version to be published.

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