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Clinical Research Study

Impact of Stress Hyperglycemia in a Cohort of Brazilian Patients With COVID-19[☆,☆☆]

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ABSTRACT

Purpose: To evaluate the impact of stress hyperglycemia (SH) in a cohort of Brazilian patients with COVID-19 admitted to a tertiary care level hospital.
Methods: This retrospective cohort study enrolled 754 patients with COVID-19 hospitalized at Hospital Estadual de Bauru, São Paulo, in 2020. Data were collected from the E-pront system and covered sociodemographic, clinical, and laboratory aspects, including mechanical ventilation, comorbidities, and outcomes. Included patients were those >18 years old, with confirmed COVID-19 diagnosis, who required hospitalization, with or without preexisting type 2 diabetes (T2DM), or who developed SH. Patients younger than 18 years, with other types of diabetes, or incomplete data were excluded.
Results: Patients with SH had longer hospital and intensive care unit (ICU) stay ($P < .001$) as well as longer mechanical ventilation duration ($P < .001$). Additionally, this group needed a higher number of orotracheal intubations ($P < .001$) and presented higher mortality rates ($P < .001$) and fewer discharges 284 ($P < .001$) compared to patients with T2DM and normoglycemia.
Conclusions: Patients who developed SH presented poorer clinical outcomes; needed more frequently orotracheal intubation, mechanical ventilation, and longer hospitalization and ICU stay; and had higher mortality rates and fewer discharges compared to patients with T2DM and normoglycemia.

Introduction

The risk of infection, clinical manifestations, and adverse outcomes COVID-19-related are associated with the presence of comorbidities, especially type 2 diabetes mellitus (T2DM). Moreover, patients with COVID-19 have shown a 66% higher risk of developing diabetes mellitus (DM) compared to patients without this condition.[1]

Additionally, T2DM is an important risk factor for worse prognosis and is strongly associated with higher mortality rates.[2] However, stress hyperglycemia (SH), defined as hyperglycemia that occurs during acute physiological stress, commonly seen in critical illnesses,[3] was also found to be a predictor of poor prognosis for these individuals.[2,4-17] This condition can be even more severe in patients with COVID-19 due to the occurrence of inflammatory cytokine storms.

A meta-analysis involving 2,923 patients found that those who developed SH were at a higher risk of developing DM.[18] This scenario is relevant in the context of COVID-19 hospitalizations, since patients present a combination of mechanisms that can induce hyperglycemia, such as insulin resistance; immune cell dysfunction; preexisting factors that increase the risk of developing T2DM, such as

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obesity; undiagnosed hyperglycemia; and the use of steroids during hospitalization.[4,19]

The aim of this study was to evaluate the impact of SH in a cohort of patients with COVID-19 admitted to a tertiary care hospital in Brazil with a highly ethnically admixed population.

Methods

Study Design and Data Collection

This was a retrospective cohort study, carried out with 754 patients diagnosed with COVID-19, in 2020, who were hospitalized at Hospital Estadual de Bauru (HEB), a tertiary care public service facility in São Paulo state, Brazil.

Data were retrieved from an electronic medical record system called E-pront regarding sociodemographic, clinical, and laboratory aspects as well as those concerning mechanical ventilation, presence of comorbidities, prescriptions, and outcomes. Two researchers (AJMP and LFO) collected the data from September 2023 to February 2024. The collected information underwent a cross-validation by both authors to guarantee thoroughness and accuracy. Included patients were those >18 years of age with a confirmed diagnosis of COVID-19, who required hospitalization, with or without a previous diagnosis of T2DM, and those who developed SH, defined as the presence of at least 1 blood glucose value >140 mg/dL during hospitalization. Patients <18 years old, with other types of DM not classified as T2DM, and patients who did not have complete data information were excluded. The presence of T2DM was investigated by questioning the patients and/or their family members upon hospital admission.

The diagnosis of COVID-19 was confirmed by reverse transcription polymerase chain reaction (RT-PCR), according to the hospital protocol. The sociodemographic data obtained were sex (male or female), age, self-reported color-race (White, *branca*; Black, *preta*; Brown, *parda*; Yellow, *amarela*; and Indigenous, *indígena*) according to the Brazilian Institute of Geography and Statistics (IBGE) classification.[20] This classification also takes into account the education level as follows: illiterate/incomplete primary education, complete primary education/incomplete secondary education, complete secondary education/incomplete high school, complete high school/some college, or college graduate.[21] Regarding clinical aspects, data obtained concerned weight, height, body mass index (BMI), and the presence of chronic diseases such as any type of DM and hypertension. Clinical data including systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), temperature (T), and respiratory rate (RR) were collected at admission. Additional data concerning mechanical ventilation were obtained, including length of intubation, controlled-pressure ventilation (CPV), tidal volume (TV), positive end-expiratory pressure (PEEP), inspired oxygen fraction (FiO_2), and inspiration time (iT).

Patients were then divided into 3 groups regarding glycemic status as follows: patients with T2DM, normoglycemic patients, and those who developed SH during hospitalization for COVID-19 treatment.

Statistical Analysis

Data were analyzed for normal distribution using the Shapiro-Wilk test, and presented as median (percentiles 25-75) if non-normally distributed or as mean ± standard deviation if normally distributed. Categorical variables were presented according to their absolute and relative frequencies. Comparative tests used were one-way ANOVA with Tukey's post hoc test, ANOVA repeated measures, Student's *t*-test, Wilcoxon signed-rank test, and Mann-Whitney U test. For analyzing the association between categorical variables, the Chi-square test (χ^2) was used. Finally, a logistic regression model was performed to assess the association between age and outcomes. Jamovi statistical software (Version 2.3.28) was used for statistical purposes. A $P < .05$ was considered to be statistically significant.[22]

Table 1
Sociodemographic and Anthropometric Data of the Studied Population

Variables	GROUPS		
	Normoglycemic (n = 334)	T2DM (n = 266)	SH (n = 154)
Age (years)	55.00 ± 19.6	**64.6 ± 13.7**[*]	**64.6 ± 16.4**[‡]
BMI (kg/m^2)	28.80 ± 7.28	30.00 ± 6.48	30.2 ± 8.11
Sex, *n* (%)	Male: 179 (53.6) Female: 155 (46.4)	Male: 141 (54.0) Female: 125 (46.0)	Male: 73 (47.4) Female: 81 (52.6)
Self-reported color-race, *n* (%)	White: 243 (72.8) Black: 30 (9.0) Brown: 59(17.6) Yellow: 1(0.3) Indigenous: 1 (0.3)	White:179(67.0) Black: 31 (11.1) Brown: 51(20) Yellow: 4(1.5) Indigenous: 1 (0.4)	White: 105(68.2) Black: 16 (10.4) Brown: 32(20.8) Yellow: 1(0.6) Indigenous: 0 (0)
Education Level			
Primary	174 (58.8)	178 (73.9)	86 (66.7)
Secondary	92 (31.0)	49 (20.3)	35 (27.1)
Incomplete college	7 (2.4)	3 (1.2)	5 (3.9)
Complete college	23 (7.8)	11 (4.6)	3 (2.3)

BMI = body mass index; SH = stress hyperglycemia; T2DM = type 2 diabetes mellitus. Median (percentiles 25-75).

[*] Comparison with T2DM e normoglycemic ($P < .001$).[†]Comparison with T2DM and SH.

[‡] Comparison with normoglycemic and SH ($P < .001$).

Results

Overall, 754 patients hospitalized due to COVID-19 participated in this study, with 5 patients being excluded for not having a confirmed diagnosis of COVID-19 by RT-PCR. In this cohort, 393 (52.1%) were male and 361 (47.9%),female, with a median age of 61 (range, 49-73) years and median BMI of 28.72 (range, 24.90-33.87) kg/m^2. Of these, 527 (70%) were White, 142 (18.8%) Brown, 77 (10.2%) Black, and 8 Yellow or Indigenous (0.01%). The majority of patients 498 (65.8%) had completed elementary school. At the time of admission, 266 (35%) were diagnosed with T2DM and 448 (65%) were normoglycemic. Among the entire sample, 154 (20.4%) presented with SH. The sociodemographic and anthropometric data of the studied population are presented in Table 1.

Patients with T2DM ($P < .001$) and SH ($P < .001$) were older than normoglycemic patients. Among patients with T2DM, 209 (78.57%) used insulin during hospitalization, while 100% of patients with SH had to use it. Clinical and laboratory variables of patients are shown in Table 2.

A longer length of hospitalization was observed in patients with T2DM ($P < .001$) compared to normoglycemic patients. Patients with SH had longer length of hospitalization than both normoglycemic individuals ($P < .001$) and those with T2DM ($P < .001$). The length of stay in the intensive care unit (ICU) was longer in the group of patients with TDM2 ($P < .01$) compared to those who were normoglycemic. Patients who presented with SH had longer length of ICU stay compared to both normoglycemic patients ($P < .001$) and those with T2DM ($P < .001$). Normoglycemic patients had a mechanical ventilation duration of 3.50 (range, 1.00-9.25) days, which was shorter than that of patients with SH that was 9.00 (range, 5.00-14.00) days ($P = .007$).

A significant difference was found between the groups regarding clinical outcomes (orotracheal intubation, need for mechanical ventilation, death, and hospital discharge) ($P < .001$), as can be seen in Figure 1.

Regarding outcomes, patients with normoglycemia compared to those with SH, the following results were found: orotracheal intubation [$\chi^2(1) = 99.4$; OR: 0.878; 95 % CI: 0.078-0.190, $P < .001$]; mechanical ventilation [$\chi^2(1) = 107$; OR: 0.877; 95 % CI: 0.0725-0.175, $P < .001$]; hospital discharge [$\chi^2(1) = 17.6$; OR: 2.36; 95 % CI: 1.57-

Table 2
Clinical and Laboratory Variables of the Studied Patients

Variables	GROUPS		
	Normoglycemic (n = 334)	T2DM (n = 266)	SH (n = 154)
SBP (mmHg)	121 (115-138)	130 (118-142)	125 (109-140)
DBP (mmHg)	80.0 (67.5-80.5)	79.0 (68.5-84.0)	70.0 (60.0-80.0)
HR (bpm)	84.0 (71.8-98.0)	86.0 (76.0-107)	89.0 (75.3-98.8)
RR (bpm)	21.0 (19.0-24.0)	20.0 (19.0-25.0)	21.0 (19.0-24.5)
T (°C)	36.4 (36.0-37.0)	36.5 (35.8-37.0)	36.6 (36.0-37.3)
Hypertension (% *n*)	122 (36.5)	212 (79.7)	87 (56.5)
Length of hospitalization (days) (range)	5 (3-8)	8[†,‡] (4-12)	12[¶] (7-20)
Length of stay in the ICU (days) (range)	0.00 (0-3)	2[†,‡] (0-8)	7[¶] (2-15)
Infirmary length of stay (days) (range)	4 (2-6)	4 (1-7)	3 (0-8)
OTI (% *n*)[*]	50 (6.6)	95 (12.6)	91 (12.1)
Tracheostomy (% *n*)	2 (13.3)	8 (53.3)	5 (33.3)
Nasal cannula (% *n*)	205 (35.3)	158 (27.2)	81 (13.9)
Room air (% *n*)	8 (1.4)	3 (0.5)	0 (0)
CPV (cm H_2O) (range)_	25.0 (21.0-26.0)	24.5 (21.8-28.0)	25.0 (21.0-28.5)
TV (ml) (range)	420 (385-453)	440 (394-480)	425 (400-490)
PEEP (cm H_2O) (range)	8.0 (8.0-10.0)	8.0 (8.0-10.0)	9.0 (8.00-10.0)
FiO_2 (range)	1.00 (0.80-1.00)	1.00 (0.75-1.00)	1.00 (0.67-1.00)
iT (seg) (range)	1.00 (0.90-1.10)	1.00 (0.95-1.10)	1.00 (0.90-1.10)
Hospital discharge (% *n*)[*]	168 (22.3)	101 (13.4)	46 (6.1)
Readmission (% *n*)	13 (1.7)	22 (2.9)	11 (1.5)
Death (% *n*)[*]	46 (6.1)	86 (11.4)	72 (9.5)

CPV = controlled-pressure ventilation; DBP = diastolic blood pressure; FiO_2 = inspired oxygen fraction; HR = heart rate; iT = inspiration time; OTI = orotracheal intubation; PEEP = positive end-expiratory pressure; RR = respiratory rate; SBP = systolic blood pressure; T = temperature; T2DM = type 2 diabetes mellitus; TV = tidal volume. Median (percentiles 25-75), $P < .05$.

[*] Variables with statistical difference ($P < .001$) between the groups.

[¶] Comparison with T2DM and normoglycemic ($P < .001$).

[†] Comparison with T2DM and SH ($P < .001$);

[‡] Comparison with normoglycemic and SH ($P < .001$).

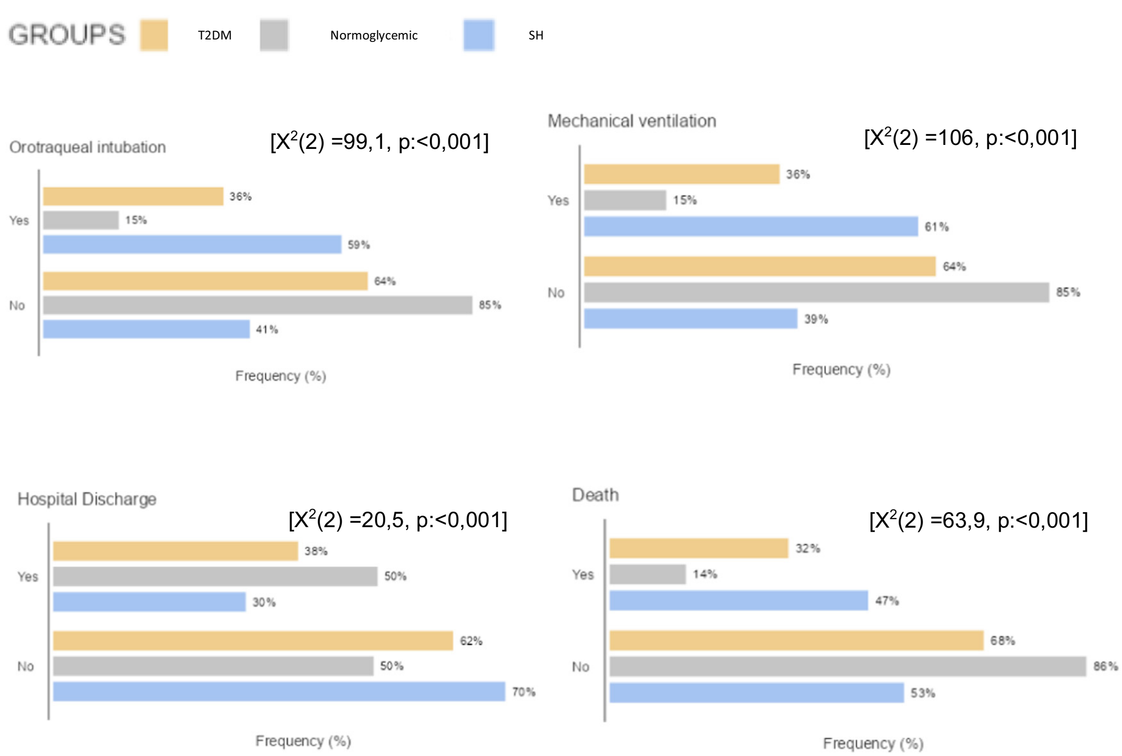

Figure 1. Clinical outcomes among the studied groups.
MV = mechanical ventilation; OTI = orotracheal intubation; T2DM = type 2 diabetes mellitus.
[*]Analysis: Chi-square Association Test, contingency tables, independent samples ($P < .05$).

3.55, $P < .001$]; and death [$\chi^2(1) = 62.2$; OR: 0.817; 95 % CI: 0.117-0.285, $P < .001$]. The results led to a conclusion that normoglycemia favors hospital discharge.

Since age differed among groups, the final model was adjusted for age and outcomes (hospital discharge and death) adhering to the assumptions required for the analysis. The linear regression analysis showed that age (dependent variable) is significantly associated with the variables "death" and "hospital discharge." The model presented $R^2 = 0.109$, indicating that 10.9% of the variation in age can be explained by the predictors ($P < .001$). Individuals who died, were on average, 9.19 years older than those who survived (95% CI: 6.04-12.33; $P < .001$), while individuals who were not discharged from the hospital were, on average, 5.21 years younger than those who were discharged (95% CI: −8.04 to −2.38; $P < .001$).

Discussion

In the present study, patients who presented with SH needed more frequently orotracheal intubation and mechanical ventilation, had longer hospitalization stay length, longer ICU stay, and higher mortality rates than patients in the other two groups. On the other hand, normoglycemic patients had higher rates of hospital discharges.

Overall, SH and a history of DM were found to be independent predictors of mortality and morbidity among patients with COVID-19.[4] Patients with both conditions were evaluated separately in the present study. The presence of SH makes it challenging to confirm whether the hyperglycemia was due to the presence of undiagnosed or a recently diagnosed DM.[5]

It is important to note that the definition of SH varies across different studies, making it difficult to compare the results found in different cohorts. In this study, according to the HEB guidelines, SH was defined as the presence of blood glucose levels >140 mg/dL during hospitalization, similar to another Brazilian study conducted in Porto Alegre,[23] which classified SH by the presence of glucose values >140 mg/dL without a previous history of DM (HbA1c < 6.5%). However, several studies that evaluated SH during the COVID-19 pandemic adopted different glucose cutoff values.[4,6-8]

The percentage of SH (20.4%) in this study was similar to that found in an Italian study, in which 24.35% of patients presented with this condition.[9] Nonetheless, in the previously mentioned Brazilian study, the percentage of patients with SH was 40.54%.[23] Another study with different criteria for defining SH (two random blood glucose values >180 mg/dL within 24 hours) also presented a similar proportion, of about 20.8%.[7]

However, the rates of normoglycemic (35%) and T2DM (65%) patients in the aforementioned Italian study differed from ours, since 20.64% of their patients had T2DM while 54.98% were normoglycemic.[6] In the Brazilian study performed in Porto Alegre, 42.7% of patients had T2DM and only 16.75% were normoglycemic. The reason for this, could be that only those patients who had their HbA1c values known were included, which differs from our sample.[24]

No significant difference was found between groups regarding sex. However, males were more frequently found in the normoglycemic (53.59%) and T2DM (53%) groups while women were the majority in the SH group (52.59%). These data are in disagreement with those from a Lithuanian study, which found that male patients had more frequently mild (58.2%) and intermittent hyperglycemia (55.1%) than female patients during hospitalization.[8]

Age is considered a risk factor for COVID-19 infection. This was found in a meta-analysis encompassing 59 studies, which showed 65% higher risk of COVID-19 infection in patients >70 years of age.[24] The reason for this, could be that older people have a more compromised immune system than do younger individuals, and also present an age-related chronic proinflammatory state.[24,25] The present study has found that patients with T2DM and SH were older than those with normoglycemia. Furthermore, patients who died in this cohort were 9.19 years older than those who survived. Therefore, age was found to be a highly relevant factor influencing death and/or discharge. This finding is in accordance with data from several other studies conducted in different places such as Italy, Vietnam, and Lithuania.[6-8]

Obesity has been found to be a risk factor for the need of ventilatory support and mortality in patients with COVID-19.[9,26] In the current study, no significant difference in BMI was found among the three analyzed groups, in accordance with data from Italy, Vietnam, and China.[6,7,9] However, a study performed in Wuhan, China, showed higher BMI rates among patients with T2DM compared to those with other hyperglycemic conditions or normoglycemia during hospitalization.[5]

Concerning self-reported color-race, a study conducted in the northeastern region of Brazil has found that the majority of patients with COVID-19 were Brown (64.10%), followed by 18.75% White, 8.0% Black, 4.97% Yellow, and 0.61% Indigenous.[16] However, the current study, conducted in São Paulo state, has found that the majority of patients were White (70.0%), followed by Brown (18.8%), Black (10.2%), and Yellow or Indigenous (0.01%). An explanation for this findings could be differences in the population ethnic-racial background among Brazilian geographic regions. In the Northeast, the admixed population represents 59.6% of the total, while in Southeast, the proportion of admixed individuals is 38.7%, with the White population representing 49.9%, according to IBGE.[27] Another Brazilian study conducted in Bahia, observed that 49.0% of hospitalizations occurred among White individuals, followed by Brown (42.0%) and Black individuals (7.1%). However, 49.6% of deaths occurred among Brown patients, followed by White individuals (41%), as noted in Epidemiological Bulletin No. 17 from the Brazilian Ministry of Health. The reason for this, could be the impact of social determinants of health–disease binomial, which leads to higher prevalence of chronic diseases among Brown and Black people, as well as poorer access to private and public health care facilities found within and among minorities.[28,29] In regard to self-reported color-race, our study has a unique approach, since we evaluated a highly ethnically admixed population differing significantly from other studies that followed mostly homogeneous populations formed mainly by Caucasians and Asians.[8,9]

In a French study analyzing 10,650 patients diagnosed with COVID-19, patients with incomplete secondary education comprised 49.6% of the total sample while those with complete secondary education amounted to 30.0% and those with higher education levels for 20.3%.[30] In the present study, 65.8% of the patients had completed only elementary school. This rate was lower than the average national rate of 54.5% for complete basic education, according to IBGE.[26] An Indian study showed that illiterate patients and those with lower educational levels with COVID-19 had more frequently the need for oxygen therapy and noninvasive and invasive ventilation compared to those with higher education levels. Several social factors that affect people with lower educational attainment may have contributed to this, such as greater exposure to hazardous health conditions, poor working and housing environments, unequal access to high-quality health care, higher rates of clinical comorbidities, and lower access to vaccination.[31]

Hypertension has been found to be highly prevalent in patients with COVID-19, mostly among patients with T2DM, with rates ranging from 71% to 76%.[7,23] This is in accordance with data found in the present study, which showed 79.7% of patients with T2DM presenting with this condition. However, no differences in average values of SBP and DBP were found, as described in studies conducted in China, Italy, and Vietnam.[5-7]

In the present study, a significant difference was observed among the 3 groups regarding the need for mechanical ventilation and orotracheal intubation, especially in the comparative analysis between SH and normoglycemic patients (OR: 0.877; 95 % CI: 0.0725-0.175, $P < .001$). Additionally, the normoglycemic group had shorter mechanical ventilation duration (in days) compared to the SH group ($P = .007$). The previously mentioned Italian study, in agreement with our findings, has shown a significant difference in the need for mechanical ventilation among the normoglycemic, SH, and T2DM groups,[6] with the SH group showing the highest need. Furthermore, studies conducted in the United States found that the need for mechanical ventilation was higher in the SH group compared to the normoglycemic group.[11,12] Invasive mechanical ventilation, which primarily includes orotracheal intubation and tracheostomy, has also shown significant differences among patients with normoglycemia, T2DM, and new-onset hyperglycemia in a Vietnamese population, with the highest rates occurring in the SH group.[7] This is consistent with the present study, which found a higher incidence of orotracheal intubation among patients presenting with SH.

The length of hospitalization was evaluated in days, regarding the total length of hospital, infirmary, and ICU stay. It was found that patients from the T2DM group had longer length of hospitalization and ICU stay compared to normoglycemic patients. However, the SH group, compared to the other two groups, experienced even longer hospitalization and ICU lengths of stay (P < .001). This difference found between patients with T2DM and SH could be explained by the hospitals protocols, since those patients with a previous diagnosis of T2DM generally receive more rigorous glycemic control, more frequent adjustments in insulin doses, as well as greater care when introducing medications that can cause hyperglycemia (such as corticosteroids).[32] Moreover, comparatively, normoglycemic patients had higher chances of hospital discharge compared to the SH group (OR: 2.36; 95 % CI: 1.57-3.55, P < .001). The aforementioned Italian study did not observe differences in hospitalization duration among the 3 groups.[6] On the other hand, the study conducted in Lithuania has found that patients with mild hyperglycemia had longer hospital stay compared to normoglycemic patients.[8] Additionally, a Portuguese study from a Lisbon hospital has found that hyperglycemia at admission was associated with a higher likelihood of ICU admission.[13]

In the current study, a significant difference was observed regarding mortality among the 3 analyzed groups, with the SH group showing the highest mortality rates. Moreover, a significant difference was observed between SH and normoglycemic patients (OR: 0.817; 95 % CI: 0.117-0.285, P < .001). This difference was also found in the previously mentioned Italian study, in which higher mortality rates were found in the SH group compared to the normoglycemic group.[6] These findings are consistent with several studies showing higher mortality rates in patients with hyperglycemia compared to normoglycemic patients.[7,9,12,17] An American study has shown that the presence of hyperglycemia nearly doubled the risk of mortality in patients with SH (OR: 3.07, 95 % CI: 2.79-3.37).[14]

It is known that hyperglycemia is a consequence of the pathophysiological mechanisms of COVID-19 infection. The SARS-CoV-2 virus enters target cells via angiotensin-converting enzyme 2 (ACE2) receptors. Thus, by inhibiting ACE2 entry into the cell, COVID-19 increases the production of angiotensin II, which has proinflammatory mechanisms.[15,19] ACE2 is therefore crucial in balancing the inflammatory response, as well as in glucose homeostasis, since ACE2 receptors are also expressed in the pancreas. In this context, the reduction in insulin secretion could be the result of direct damage to pancreatic cells caused by COVID-19 infection.[15] Moreover, hyperglycemia occurs in acute illnesses due to insulin resistance and increased glucose synthesis resulting from augmented lipolysis, decreased glucose uptake by the muscles, and increased hepatic glucose production.[15]

It should be mentioned that hyperglycemia resulting from increased hepatic gluconeogenesis results from elevated counterregulatory hormones and acute beta-cell dedifferentiation. This process is also present in patients with T2DM, but it occurs more chronically among these individuals. Additionally, differences between SH and T2DM may arise since patients with preexisting T2DM are more aware of their condition and often seek better glycemic control through more consistent blood glucose monitoring compared to patients who develop SH.[33] The pathophysiological basis and metabolic effects of COVID-19 infection justify the findings of this study.

The present study has some limitations. The first is related to its retrospective observational design, which does not allow an establishment of a causality among the findings. Additionally, the collection of preexisting data may have led to some biases. Incomplete data were found for many patients, such as body weight, height, BMI and insulin dose per weight. The researchers also did not have access to HbA1c levels, as occurred in previous studies, making it difficult to differentiate patients with previous T2DM from those with SH. Some conditions, such as the rates and doses of glucocorticoids used and the parameters related to renal function during hospitalization, were not assessed, which may also represent a limitation of the present analysis. Furthermore, although the present study was conducted at a tertiary care center in the countryside of São Paulo state, limiting this study to a single center could have led to potential selection bias, making the generalization of the findings difficult. The most important strength of the current study was the evaluation of COVID-19-related outcomes in a large cohort of a highly admixed Brazilian population. This cohort comprised patients with SH, T2DM, and normoglycemia. Furthermore, it was possible to compare several aspects of clinical, laboratory, and mechanical ventilation data, making this study even more comprehensive. Additional studies are needed to better elucidate the impact of SH and T2DM on clinical outcomes in critically ill hospitalized patients.

In conclusion, patients who developed SH showed poorer clinical outcomes, needed more frequently orotracheal intubation and mechanical ventilation as well as longer hospitalization and ICU stay, and had higher mortality rates and fewer discharges compared to patients with T2DM and normoglycemia.

Declaration of competing interest

None.

CRediT authorship contribution statement

Ana Julia de Magalhães Pina: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Data curation. **Luís Fernando de Oliveira:** Writing – original draft, Methodology, Investigation, Data curation. **Letícia de Oliveira Nascimento:** Data curation, Conceptualization. **Deborah Maciel Cavalcanti Rosa:** Validation, Data curation, Conceptualization. **Jefferson Barela:** Data curation, Conceptualization. **Bruno Martinelli:** Software, Methodology, Formal analysis, Data curation, Conceptualization. **Carlos Antonio Negrato:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Formal analysis.

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