Glycemic Characteristics and Clinical Outcomes of COVID-19 Patients Hospitalized in the United States


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**Abbreviations:** (ACE2) Angiotensin Converting Enzyme 2, (ADA) American Diabetes Association, (BG) blood glucose, (BMI) body mass index, (eGFR) estimated glomerular filtration rate, (ICU) intensive care unit, (IQR) interquartile range, (LOS) length of stay, (SARS) Severe Adult Respiratory Syndrome

**Keywords:** COVID-19, diabetes, glucose, Glytec, hospital, hyperglycemia, length of stay, mortality

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**Figures and Table Count:** 3 figures and 5 tables
Abstract

Introduction: Diabetes has emerged as an important risk factor for severe illness and death from COVID-19. There is a paucity of information on glycemic control among hospitalized COVID-19 patients with diabetes and acute hyperglycemia.

Methods: This retrospective observational study of laboratory-confirmed COVID-19 adults evaluated glycemic and clinical outcomes in patients with and without diabetes and/or acutely uncontrolled hyperglycemia hospitalized March 1-April 6, 2020. Diabetes was defined as A1C ≥ 6.5%. Uncontrolled hyperglycemia was defined as ≥ 2 blood glucoses (BG) > 180 mg/dl within any 24-hour period. Data was abstracted from Glytec’s data warehouse.

Results: Among 1122 patients in 88 U.S. hospitals, 451 patients with diabetes and/or uncontrolled hyperglycemia spent 37.8% of patient days having a mean BG > 180 mg/dl. Among 570 patients who died or were discharged, the mortality rate was 28.8% in 184 diabetes and/or uncontrolled hyperglycemia patients, compared with 6.2% of 386 patients without diabetes or hyperglycemia (p<0.001). Among the 184 patients with diabetes and/or hyperglycemia who died or were discharged, 40 of 96 uncontrolled hyperglycemia patients (41.7%) died compared with 13 of 88 diabetes patients (14.8%, p<0.001). Among 493 discharged survivors, those with diabetes and/or uncontrolled hyperglycemia had a longer median length of stay (LOS) compared with their comparison group (5.7 vs 4.3 days, p<0.001).

Conclusions: Among hospitalized patients with COVID-19, diabetes and/or uncontrolled hyperglycemia occurred frequently. These COVID-19 patients with diabetes and/or uncontrolled hyperglycemia had a longer LOS and markedly higher mortality than patients without diabetes or uncontrolled hyperglycemia. Patients with uncontrolled hyperglycemia had a particularly high mortality rate. We recommend health systems ensure inpatient hyperglycemia is safely and effectively treated.
Introduction

Diabetes has emerged as an important risk factor for severe illness and death from COVID-19. In a small retrospective study of 141 adult patients admitted to 2 hospitals in Wuhan, China, diabetes was present in 19% of cases, and nonsurvivors were significantly more likely to have diabetes than survivors (31% vs. 14%, P= 0.0051). In a larger multicenter study assessing risk factors for complications of COVID-19 in 1099 patients hospitalized in China with COVID-19 illness, diabetes was present in 27% of patients achieving the primary endpoint of intensive care unit (ICU) admission, mechanical ventilation or death, compared with 6.1% if none of these complications occurred.

Preliminary reports have shown that diabetes is also common among patients hospitalized in the U.S with COVID-19 illness. Among 7162 COVID-19 cases reported to the CDC February 12 – March 28, 2020 with accompanying information on underlying health conditions, diabetes was present in 24% of non-ICU and 32% of ICU patients. CDC’s COVID-19–Associated Hospitalization Surveillance Network (COVID-NET) identified the presence of COVID-19 in 28% of 178 patients in its network during March 2020. The New York Department of Health’s COVID-19 case fatality dashboard reported that as of April 11th 2020, diabetes was present in 3490 of 9371 patients who died (37%).

Despite a preponderance of evidence that diabetes is associated with poor COVID-19 outcomes, there is a paucity of information on inpatient glycemic control among patients with diabetes and acute hyperglycemia hospitalized with COVID-19. Direct correlation with clinical outcomes has not been established.

Glytec (Waltham, MA), an insulin software titration company, maintains a large data warehouse of patient clinical and glycemic data including transmitted information from contracted hospitals for lab confirmed COVID-19 cases, admission and discharge dates and death notifications. Point-of-care blood glucose test results (BGs) are transmitted and stored for all patients on contracted hospital units. In this study, we identified COVID-19 inpatients from the Glytec data warehouse treated during a 37-day period and analyzed all transmitted BGs during their hospital stay. We then characterized the COVID-19 patients from our contracted hospitals according to their: 1) clinical characteristics at hospital presentation, 2) inpatient glycemic control and 3) clinical outcomes.
Methods

Study Design
This retrospective observational study evaluated patients hospitalized with laboratory-confirmed COVID-19 illness between March 1 and April 6, 2020. We compared patients who had diabetes or uncontrolled hyperglycemia against each other and against contemporaneously hospitalized COVID-19 patients who did not have either diabetes or uncontrolled hyperglycemia. We evaluated: 1) baseline demographic and clinical features, 2) inpatient glycemic control, and 3) clinical outcomes, including length of stay (LOS) and in-hospital death metrics. Institutional Review Board approval was not required for this observational, retrospective study of routinely transmitted patient information.

Definitions
A diagnosis of COVID-19 illness was defined as a positive SARS-CoV-2 lab result or the presence of ICD-10 code U07.1, which indicates acute illness from SARS-CoV-2. Hospital admission was defined as patient presence in the hospital for ≥ 24 hours. Diabetes was defined as A1C ≥ 6.5%. Uncontrolled hyperglycemia was defined as being present when two or more BGs > 180 mg/dl occurred within any 24-hour period with an A1C < 6.5% or no A1C testing during hospitalization. Renal dysfunction was defined as estimated glomerular filtration rate (eGFR) < 60 ml/min. Admission lab tests were defined as having been time stamped within 24 hours of hospital presentation. An inactive patient was defined as a patient with a time stamped discharge or death notification.

Data Collection
For all COVID-19 patients identified in the Glytec data warehouse, we abstracted information on age, gender and body mass index (BMI). Glucose, creatinine, eGFR and anion gap were collected from admission labs. If A1C testing was performed during hospitalization, values transmitted to the Glytec data warehouse were abstracted. All transmitted BGs were abstracted, as well as time stamped admission, discharge and death notifications.

Outcome Measures
Data for patients meeting criteria for either diabetes or uncontrolled hyperglycemia were combined and compared with data from patients without evidence of diabetes or uncontrolled hyperglycemia to assess differences in 1) baseline clinical and demographic characteristics, 2) inpatient glycemic control
for all patients, 3) length of stay (LOS) for inactive patients, and 4) mortality for inactive patients.

A within-group subset analysis of inactive patients was performed comparing clinical characteristics and outcomes between patients meeting criteria for diabetes and patients with uncontrolled hyperglycemia against those with no diabetes designation.

Statistical Analysis

Differences in age and LOS were analyzed non-parametrically by median and Mann-Whitney tests because of non-normal distributions. Other continuous variables were analyzed parametrically by means, Standard Deviations, and T-tests. Differences in categorical variables were calculated with the Chi-Squared method and Fisher’s Exact Test. Analyses were performed with the use of Minitab 19®.

Results

Patient Characteristics

We identified 1122 patients with COVID-19 from 88 U.S. hospitals distributed across 10 states (Figure 1). A1C data was available for 282 patients. We identified 194 patients (17.3% of the total population) with diabetes (defined as having an A1C value ≥ 6.5%). We identified an additional 257 patients with uncontrolled hyperglycemia (defined as being present when two or more BGs > 180 mg/dl occurred within any 24-hour period with an A1C < 6.5% or no A1C testing during hospitalization. (Table 1).
The combined group of 451 patients with diabetes by A1C criteria and/or uncontrolled hyperglycemia (194 + 257), compared with 671 patients who did not meet diabetes or uncontrolled hyperglycemia criteria, contained a significantly higher percentage of males (59% vs. 53%, \( p = 0.035 \)). Patients with diabetes or uncontrolled hyperglycemia, compared with patients without diabetes or hyperglycemia, were significantly older (median age of 65 years vs. 61 years, \( p = 0.005 \)).
Admission Lab

The 451 patients in the combined diabetes and uncontrolled hyperglycemia group, compared with 671 patients without evidence of diabetes or ensuing uncontrolled hyperglycemia, demonstrated higher rates of hyperglycemia at admission (mean BG 202 vs. 114 mg/dl, p < 0.001) and renal dysfunction (40.6% vs. 23.5% with eGFR < 60, p < 0.001), as well as a higher mean anion gap (15.8 vs. 13.4 mEq/dl, p < 0.001) (Table 2).

<table>
<thead>
<tr>
<th>Variable</th>
<th>+ Diabetes and/or Uncontrolled Hyperglycemia (n=451)</th>
<th>- Diabetes or Uncontrolled Hyperglycemia (n=671)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Blood Glucose mg/dl, (SD)</td>
<td>202.4 (±117.7)</td>
<td>114.5 (±20.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean Anion Gap mEq/dl, (SD)²</td>
<td>15.8 (±6.3)</td>
<td>13.4 (±4.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean Serum Creatinine mg/dl, (SD)³</td>
<td>1.6 (±1.9)</td>
<td>1.3 (±1.6)</td>
<td>0.004</td>
</tr>
<tr>
<td>Mean eGFR, ml/min (SD)⁴</td>
<td>63.7 (±30.9)</td>
<td>73.5 (±30.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>eGFR categories, ml/min</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>eGFR &lt; 15, n (%)</td>
<td>21 (4.8)</td>
<td>28 (4.3)</td>
<td>0.069</td>
</tr>
<tr>
<td>eGFR 15 - 29, n (%)</td>
<td>44 (10.0)</td>
<td>18 (2.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>eGFR 30 - 59, n (%)</td>
<td>113 (25.8)</td>
<td>107 (16.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>eGFR ≥ 60, n (%)</td>
<td>260 (59.4)</td>
<td>499 (76.5)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

² Anion gap was available in 431 of 451 patients with diabetes and/or uncontrolled hyperglycemia (95.6%) and in 651 of 671 patients without diabetes or uncontrolled hyperglycemia (97.5%).
³ Creatinine was available in 432 of 451 patients with diabetes and/or uncontrolled hyperglycemia (95.8%) and in 651 of 671 patients without diabetes or uncontrolled hyperglycemia (97.5%).
⁴ eGFR was available in 438 of 451 patients with diabetes and/or uncontrolled hyperglycemia patients (97.1%) and in 652 of 671 patients without diabetes or uncontrolled hyperglycemia (97.2%).

Glycemic Outcomes

The combined diabetes and hyperglycemia group spent 3885 patient days in the hospital and the patients without diabetes or hyperglycemia accounted for 3793 patient days (Table 3). Out of the 3885 patient days of the combined diabetes and hyperglycemia group, 1470 patient days (37.8%) were spent with a mean BG > 180 mg/dl and 1004 patient days (25.8%) included at least one BG > 250 mg/dl. A hypoglycemic glucose concentration (BG < 70 mg/dl) was more common in patients with diabetes or hyperglycemia, occurring in 137 out of 3885 patient days (3.5%) compared with 39 out of 3793 patient days in patients without diabetes or hyperglycemia (1.0%, p < 0.001). Likewise, severe hypoglycemia (BG < 40 mg/dl) was significantly more frequent in the diabetes and hyperglycemia group,
occurring in 25 patient days (0.6%) compared with 3 patient days without diabetes or uncontrolled hyperglycemia ((0.1%, p < 0.001).

Table 3. Glycemic Outcomes in Patients with Diabetes and/or Uncontrolled Hyperglycemia (n=451) Compared with Patients without Diabetes or Hyperglycemia (n=671).

<table>
<thead>
<tr>
<th>Variable</th>
<th>+ Diabetes and/or Uncontrolled Hyperglycemia (n=451)</th>
<th>- Diabetes or Uncontrolled Hyperglycemia (n=671)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BG Events, n (%)</td>
<td>19168</td>
<td>6532</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean Glucose, mg/dl (SD)</td>
<td>178.5 (±71.0)</td>
<td>116.6 (±25.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BGs &gt; 250 mg/dl, n (%)</td>
<td>2795 (14.6)</td>
<td>6 (0.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BGs &gt; 180 mg/dl, n (%)</td>
<td>7499 (39.1)</td>
<td>91 (1.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BGs 70-180 mg/dl, n (%)</td>
<td>11473 (59.9)</td>
<td>6389 (97.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BGs &lt; 70 mg/dl, n (%)</td>
<td>196 (1.0)</td>
<td>52 (0.8)</td>
<td>0.106</td>
</tr>
<tr>
<td>BGs &lt; 54 mg/dl, n (%)</td>
<td>69 (0.4)</td>
<td>10 (0.2)</td>
<td>0.009</td>
</tr>
<tr>
<td>BGs &lt; 40 mg/dl, n (%)</td>
<td>31 (0.2)</td>
<td>4 (0.1)</td>
<td>0.057</td>
</tr>
<tr>
<td>Patient Days, n (%)</td>
<td>3885 (50.6)</td>
<td>3793 (49.4)</td>
<td></td>
</tr>
<tr>
<td>Patient Days with Mean BG &gt; 180 mg/dl, n (%)</td>
<td>1470 (37.8)</td>
<td>46 (1.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Patient Days with at least 1 BG &gt; 250 mg/dl, n (%)</td>
<td>1004 (25.8)</td>
<td>6 (0.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Patient Days with at least 1 BG &gt; 180 mg/dl, n (%)</td>
<td>2252 (58.0)</td>
<td>91 (2.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Patient Days with at least 1 BG &lt; 70 mg/dl, n (%)</td>
<td>137 (3.5)</td>
<td>39 (1.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Patient Days with at least 1 BG &lt; 54 mg/dl, n (%)</td>
<td>63 (1.6)</td>
<td>16 (0.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Patient Days with at least 1 BG &lt; 40 mg/dl, n (%)</td>
<td>25 (0.6)</td>
<td>3 (0.1)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Clinical Outcomes

552 patients were still hospitalized at the time of analysis. Of the 570 inactive patients, 77 patients died for a mortality rate of 13.5% within these inactive patients. Of these 77 patients who died, 53 of them were among the 184 patients in the combined diabetes and uncontrolled hyperglycemia group (28.8%) compared with 24 of them who were among the 386 patients in the comparison unaffected group (6.2%, p < 0.001). (Table 4 and Figure 2).

Of 493 inactive patients who were discharged alive, the combined diabetes and uncontrolled hyperglycemia patient group (131 patients) experienced a significantly longer median LOS at 5.7 days compared with patients without diabetes or hyperglycemia at 4.3 days (362 patients, p < 0.001).
Table 4. Clinical Outcomes Among Patients Who Were Discharged or Died Comparing Diabetes and/or Uncontrolled Hyperglycemia (n=184) with Patients without Diabetes or Hyperglycemia (n=386).

<table>
<thead>
<tr>
<th>Variable</th>
<th>+ Diabetes and/or Uncontrolled Hyperglycemia (n=184)</th>
<th>- Diabetes or Uncontrolled Hyperglycemia (n=386)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, n (%)</td>
<td>184 (32.3)</td>
<td>386 (67.7)</td>
<td></td>
</tr>
<tr>
<td>Died in hospital, n (%)</td>
<td>53 (28.8)</td>
<td>24 (6.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean duration from admission to death (SD)</td>
<td>8.7 (±4.6)</td>
<td>7.9 (±4.4)</td>
<td>0.494</td>
</tr>
<tr>
<td>Median duration from admission to death (IQR)</td>
<td>7.5 (2.0-20.1)</td>
<td>6.9 (1.3-20.4)</td>
<td>0.560</td>
</tr>
<tr>
<td>Discharged Alive From hospital, n (%)</td>
<td>131 (71.2)</td>
<td>362 (93.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mean LOS in days (SD)</td>
<td>6.2 (±3.7)</td>
<td>5.0 (±3.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Median LOS in days (IQR)</td>
<td>5.7 (1.1-24.6)</td>
<td>4.3 (1.0-21.2)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Figure 2. Mortality Rates Among Patients Who Were Discharged or Died Comparing Diabetes and/or Uncontrolled Hyperglycemia (n=184) with Patients without Diabetes or Hyperglycemia (n=386).
**Subset Analysis**

Diabetes patients had a higher admission mean BG at 238.3 mg/dl compared with uncontrolled hyperglycemia patients at 175.3 mg/dl (p < 0.001) (Table 5). In a within-group subset analysis of 184 inactive patients with diabetes or uncontrolled hyperglycemia patients, 88 patients met criteria for diabetes (47.8%) and 96 met criteria for uncontrolled hyperglycemia (52.2%).

Among these 184 inactive patients, death occurred in 40 of 96 uncontrolled hyperglycemia patients (41.7%) compared with death in 13 of 88 diabetes patients (14.8%, p < 0.001) (Figure 3). In this 184-patient cohort, patients designated as having uncontrolled hyperglycemia, compared to patients with diabetes, had a longer median duration from admission to death (8.4 days vs. 6.0 days, p < 0.001). Among the 493 patients who were discharged alive, 131 patients had either diabetes or uncontrolled hyperglycemia. Among them were 56 patients with uncontrolled hyperglycemia (42.7%) and 75 patients with diabetes (57.3%). The former group, compared to the latter group, had a longer median hospital LOS (6.2 vs. 5.0 days, p < 0.001).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Diabetes and/or Uncontrolled Hyperglycemia Status (n=184)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Diabetes by A1C Criteria (n=88)</td>
<td>Uncontrolled Hyperglycemia by BG Criteria (n=96)</td>
</tr>
<tr>
<td>Patients, n (%)</td>
<td>88 (47.8)</td>
<td>96 (52.2)</td>
</tr>
<tr>
<td>Admission Mean Glucose mg/dL, (SD)</td>
<td>238.3 (±121.6)</td>
<td>175.3 (±107.2)</td>
</tr>
<tr>
<td>Mean A1C (SD)a</td>
<td>9.1 (±2.3)</td>
<td>5.9 (±0.4)</td>
</tr>
<tr>
<td>Died in the hospital, n (%)</td>
<td>13 (14.8%)</td>
<td>40 (41.7%)</td>
</tr>
<tr>
<td>Mean duration from admission to death (SD)</td>
<td>7.2 (±4.9)</td>
<td>9.2 (±4.5)</td>
</tr>
<tr>
<td>Median duration from admission to death (IQR)</td>
<td>6.0 (2.0-18.9)</td>
<td>8.4 (2.1-20.1)</td>
</tr>
<tr>
<td>Discharged Alive from hospital, n (%)</td>
<td>75 (85.2)</td>
<td>56 (58.3)</td>
</tr>
<tr>
<td>Mean LOS in days (SD)</td>
<td>5.8 (±3.5)</td>
<td>6.8 (±3.8)</td>
</tr>
<tr>
<td>Median LOS in days (IQR)</td>
<td>5.0 (1.1-24.6)</td>
<td>6.2 (1.1-20.7)</td>
</tr>
</tbody>
</table>

*a A1C was available for 88 diabetes patients (100% by study design) and 27 of 96 (28.1%) of patients with uncontrolled hyperglycemia.
Figure 3. Mortality Rates Among Patients Who Were Discharged or Died Comparing Diabetes Patients (n=88) with Hyperglycemia Patients (n=96).

Discussion

Among 1122 patients in 88 U.S. hospitals for COVID-19 treatment, 38.5% were found to have either diabetes by A1C criteria or uncontrolled hyperglycemia. As a combined group, patients with diabetes or uncontrolled hyperglycemia presented to the hospital at an older age, with a lower eGFR and with a higher anion gap than their comparison group without these diagnoses.

During admission, 37.8% of patient days in this group with diabetes or uncontrolled hyperglycemia were spent with a mean BG > 180 mg/dl, which is the ADA recommended upper limit target for most inpatients.5 This group also experienced higher rates of hypoglycemia, occurring in 3.5% of patient days, compared with 1.0% of patient days in the group without diabetes or uncontrolled hyperglycemia.

The overall mortality rate for inactive patients in our study population was 13.5%. In the combined diabetes or uncontrolled hyperglycemia group, 28.8% of patients did not survive hospitalization, representing a more than 4-fold higher in-hospital mortality rate compared with the mortality rate for COVID-19 inpatients without evidence for diabetes or uncontrolled hyperglycemia (6.2%).

Our study design combined patients meeting criteria for both diabetes and uncontrolled hyperglycemia to reduce the impact of potential misclassification
bias from failing to include for analysis many diabetes patients who did not have
an A1C performed during hospitalization. In a subset analysis of outcomes within
the diabetes and uncontrolled hyperglycemia group, we found that of the 53
deaths in this combined group, 75% occurred in patients designated as
uncontrolled hyperglycemia (and 25% in patients designated as having diabetes).
Patients designated as uncontrolled hyperglycemia presented to the hospital with a
significantly lower mean BG and were hospitalized for a longer duration between
admission and death than patients designated as having diabetes, raising the
possibility that acute hyperglycemia is an independent risk factor for mortality
from COVID-19.

Stress hyperglycemia, defined by the American Diabetes Association (ADA) as a
transient elevation in blood glucose in the setting of acute illness or after surgery
in a patient with an A1C < 6.5%, is associated with longer LOS, longer ventilator
management time and increased mortality.7-10 A variety of immune system
abnormalities has been postulated to explain the relationship between
hyperglycemia and immune dysfunction, including impairment in
polymorphonuclear and monocytic white blood cell chemotaxis and phagocytosis,
complement function, and cytokine dysregulation.12-14 During the 2003 Severe
Adult Respiratory Syndrome (SARS) epidemic, acute hyperglycemia in
previously healthy patients without known diabetes (as well as patients with
known diabetes) was identified as a complication of SARS illness and a risk
factor for respiratory failure and death.15,16 Furthermore, immunohistochemical
stains of cadaveric pancreatic tissue revealed Angiotensin Converting Enzyme 2
(ACE2) immunostaining in pancreatic islet cells similar to lung alveolar
epithelium and myocardium.17 ACE2 is a recognized receptor protein for corona
virus attachment and direct islet cell toxicity during infection appears plausible as
a contributor to acute hyperglycemia.17

The findings in this retrospective, observational study are subject to several
limitations. Our study protocol was designed for a descriptive analysis and it was
beyond the scope of this assessment to evaluate the magnitude of association
between diabetes and/or uncontrolled hyperglycemia and clinical outcomes, or to
assess the impact of insulin therapy on glycemic control and clinical outcomes.
Our dataset did not include recognized comorbidities for death from COVID-19,
such as hypertension or cardiovascular disease.1-4 Furthermore, it was beyond the
scope of this study to capture other recognized predictors of clinical outcomes,
such as health system size and glycemic care policies, patient demographics such
as ethnicity or payer source, or clinically relevant information on ICU admission
or ventilator use. Because of limited SARS-CoV-2 test availability and the
newness of the ICD-10 code U07.1 for COVID-19 illness, we likely missed cases
in patients for whom either lab test results or diagnosis coding was not reported
before discharge. Diagnosis codes for diabetes and A1C data, potentially available
from previous admissions, were not abstracted for this analysis. Compared with
diabetes prevalence rates among hospitalized patients in CDC case reports and COVID-NET, the absence of this information likely led to misclassification bias toward uncontrolled hyperglycemia in patients with underlying diabetes.

To our knowledge, this is the first published report characterizing glycemic control in patients hospitalized with COVID-19 in the U.S. Two important questions raised by this data are 1) whether the high rates of death from COVID-19 in this study are predominantly due to metabolic derangements with associated sequelae, and 2) whether acute hyperglycemia plays a role which can be ameliorated through effective glycemic management. A longitudinal assessment of glycemic control was beyond the scope of this assessment. To address study limitations and provide greater insights into the impact of glycemic control on clinical outcomes, additional studies will be forthcoming and we anticipate reporting outcomes associated with longitudinal glycemic control in the near future.

The finding that patients who would go on to have uncontrolled hyperglycemia had lower admission mean BG concentrations compared with diabetes patients suggests an opportunity to manage uncontrolled hyperglycemia over the course of a hospitalization. Hospitals are already constrained in managing the care of COVID-19 positive patients because of the scarcity of personal protection equipment as well as fear of catching the disease by some hospital workers.

As a result, the medical team might try to reduce caregiver-patient contact, with attendant risk of decreasing the frequency of BG assessments and avoiding IV insulin and basal-bolus insulin therapy. In our view, in the absence of evidence to the contrary, clinicians should interpret COVID-19 associated hyperglycemia as a potential indicator of pancreatic islet cell injury and a risk for poor outcome. Clinicians should treat hyperglycemia to achieve BG targets < 180 mg/dl for most patients. This equates to basal-bolus insulin therapy in most non-ICU patients and continuous insulin infusion in the critically ill as directed by national guidelines.

Conclusions: Among hospitalized patients with COVID-19, diabetes and/or uncontrolled hyperglycemia occurred frequently. These COVID-19 patients with diabetes and/or uncontrolled hyperglycemia had a longer LOS and markedly higher mortality than patients without diabetes and/or uncontrolled hyperglycemia. Patients with uncontrolled hyperglycemia had a particularly high mortality rate. We recommend health systems ensure inpatient hyperglycemia is safely and effectively treated.

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