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Clinical Severity on Hospital Admission for COVID-19: An Analysis of Social Determinants of Health From an Early Hot Spot in the Southeastern U.S.

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Abstract

Introduction: Disparities in COVID-19 infection, illness severity, hospitalization, and death are often attributed to age and comorbidities, which fails to recognize the contribution of social, environmental, and financial factors on health. The purpose of this study was to examine relationships between social determinants of health (SDOH) and COVID-19 severity. **Methods:** This multicenter retrospective study included adult patients hospitalized with COVID-19 in Southwest Georgia, U.S. The primary outcome was the severity of illness among patients on hospital admission for COVID-19. To characterize the effect of biological and genetic factors combined with SDOH on COVID-19, we used a multilevel analysis to examine patient-level and ZIP code-level data to determine the risk of COVID-19 illness severity at admission. **Results:** Of 392 patients included, 65% presented with moderate or severe COVID-19 compared to 35% with critical disease. Compared to moderate or severe COVID-19, increasing levels of Charlson Comorbidity Index (OR 1.15, 95% CI 1.07-1.24), tobacco use (OR 1.85, 95% CI 1.10-3.11), and unemployment or retired versus employed (OR 1.91, 95% CI 1.04-3.50 and OR 2.17, 95% CI 1.17-4.02, respectively) were associated with increased odds of critical COVID-19 in bivariate models. In the multi-level model, ZIP codes with a higher percentage of Black or African American residents (OR 0.94, 95% CI 0.91-0.97) were associated with decreased odds of critical COVID-19. **Conclusion:** Differences in SDOH did not lead to significantly higher odds of presenting with severe COVID-19 when accounting for patient-level and ZIP code-level variables.

Keywords

COVID-19, SARS-CoV-2, social determinants of health, social factors, health status disparities

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Introduction

Data have emerged suggesting that certain factors are associated with higher rates of coronavirus disease 19 (COVID-19).[1] While patients may be asymptomatic or experience a wide spectrum of non-specific clinical manifestations, older adults with one or more comorbidities are at higher risk of hospitalization and progression to worse clinical outcomes.[2,3] Furthermore, cardiovascular disease, hypertension, diabetes mellitus, and chronic respiratory disease are associated with an increased risk of severe complications, ranging from multi-level organ failure, acute respiratory distress syndrome (ARDS), and death from COVID-19.[2,3]

In the U.S., certain demographic characteristics have also been linked with a greater likelihood of developing severe COVID-19. Previous studies have found disproportionately higher rates of COVID-19 diagnoses among Black or African American and Hispanic or Latino patients compared to their White or Caucasian counterparts.[4-7] In addition, Black or African American and Hispanic or Latino patients are 4 and 1.5 times, respectively, more likely to be hospitalized and to suffer from numerous COVID-19-related complications.[6,8,9] Compared to White or Caucasian patients, COVID-19 mortality is at least 3-times higher in Black or African American and Hispanic or Latino patients.[5,6] Disparities in COVID-19 infection, hospitalization, and death are often attributed to age and comorbidities, which fails to recognize the contribution of social, environmental, and financial factors on health.

Social determinants of health (SDOH) are the conditions in which people are born, grow, live, and work.[10] SDOH, comprised of social and community context, health and health care, neighborhood and built environment, education, and economic stability, directly impact health disparities and inequities and have only been exacerbated by the COVID-19 pandemic.[11,12] Though data clearly suggest SDOH are associated with COVID-19 morbidity and mortality,[11] the impact of SDOH on COVID-19 disease severity on admission is poorly characterized. Characterizing severity on admission reflects the combined effects of pre-existing comorbidities and SDOH on COVID-19 morbidity and mortality. Therefore, the purpose of this study was to examine the relationships between SDOH and the clinical severity of COVID-19.

Methods

Study Design and Participants

This was a multicenter retrospective study of adult patients hospitalized with COVID-19 in Southwest Georgia, U.S. Patients 18 years and older with COVID-19, defined by laboratory-detected severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection, and hospitalized at either Phoebe Putney Memorial Hospital in Albany, GA, or John D. Archbold Memorial Hospital, in Thomasville, GA, from March 10 through June 25, 2020 were included. Due to the retrospective nature of this study, patient consent was not required. The University of Georgia Institutional Review Board approved this study and determined that the proposed research was exempt (PROJECT00002195).

Patient personal characteristics included age, sex, race, ethnicity, employment, health insurance status, location (based on ZIP code), residence, and tobacco history. Elements of their medical history included comorbidities, body mass index (BMI), symptom duration, hospital location, vitals, laboratory results, and imaging results, all of which were collected from electronic medical record (EMR). Data from the U.S. Census Bureau 2015-2019 American Community Survey (ACS) 5-Year Estimates, the most recent, publicly available sociodemographic dataset, was collected based on ZIP codes reported by patients.[13] The dataset provided Zip Code Tabulation Areas (ZCTA), which represent U.S. Census Bureau defined geographic areas that relatively correspond to U.S. Postal Service ZIP codes. Data were managed with REDCap hosted at the University of Georgia.[14,15]

Independent Variables

SDOH provided a framework for independent variables used in this study.

Community and social context. Race and ethnicity were self-reported at the time of admission. Racial categories included Black or African American, White or Caucasian, Hispanic or Latino, and other, while ethnicity categories included Hispanic or Latino, non-Hispanic or Latino, and not provided, as per the health systems demographic intake form used upon admission. Racial and ethnic composition of each patient's community was obtained from the data for corresponding ZCTAs.

Health and health care. Insurance status was self-reported and categorized into public and private insurance. Public insurance included Medicare, Medicaid, and dual eligible, whereas private comprised of health maintenance organization (HMO) and private insurance.

Neighborhood and built environment. Physical location of the patient's residence was based on self-reported ZIP code. Characteristics of the residence were separated into single family home and all other residence types, which included multi-family or group homes, nursing home or long-term care facilities, prison or jail, as well as unknown. Data for corresponding ZCTAs were used to identify the percentage of household overcrowding in each patient's community, which was met if more than 1 person in a household shared

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Table 1. Severity of COVID-19 Illness Categories Based on National Institutes of Health (NIH) COVID-19 Treatment Guidelines.[18]

Mild illness
Various signs and symptoms without shortness of breath, dyspnea, or abnormal chest imaging
Moderate illness
Evidence of lower respiratory disease with $SpO_2 \geq 94\%$
Severe illness
Respiratory frequency > 30 breaths/minute, $SpO_2 < 94\%$, $PaO_2/FiO_2 < 300$ mmHg, or lung infiltrates $> 50\%$
Critical illness
Respiratory failure, septic shock, and/or multiple organ dysfunction

Abbreviations: PaO_2/FiO_2, ratio of arterial oxygen partial pressure (PaO_2 in mmHg) to fractional inspired oxygen (FiO_2); SpO_2, oxygen saturation.

a room, based on criteria from the U.S. Department of Housing and Urban Development (HUD).[16]

Education. Data for corresponding ZCTAs were used to determine high school graduation rate and bachelor's degree attainment throughout each patient's community.

Economic stability. Employment history was self-reported and included employed (defined as part-time or full-time), unemployed, retired, and unknown. Data for corresponding ZCTAs were used to identify median family income and Gini Index. The Gini Index, the best known measure of inequality, measures distribution of income throughout a geographical region and ranges from 0 (perfect equality where income is evenly distributed across the region) to 1 (perfect inequality where 1 person or group of people has all of the wealth in the region).[17]

Covariates

Signs and symptoms of COVID-19, as well as tobacco use, which included current or former use of tobacco, smokeless tobacco, or vape products, were self-reported on admission. Comorbidities were assessed using International Classification of Diseases, Tenth Revision (ICD-10) diagnosis codes, except for obesity, which was defined as BMI of 30 kg/m^2 or more. Details of the hospitalization included baseline vital signs and laboratory values, defined as those captured within 24 h of admission, admission to a general ward or intensive care unit (ICU), and length of stay.

Outcome

The primary outcome was measured as the severity of illness, defined as moderate or severe/critical among patients hospitalized for COVID-19, based on criteria from the National Institutes of Health (NIH) COVID-19 treatment guidelines (Table 1).[18]

Data Analysis

Descriptive statistics by COVID-19 severity status were determined for all variables. Due to low frequencies of occurrence of moderate COVID-19 severity (n = 32, 8%), moderate and severe COVID-19 severity status were combined to form the referent group for modeling. To examine whether patient characteristics and ZIP code-level SDOH were associated with COVID-19 severity status, multi-level generalized linear models (GLIM) were used with a binomial distribution and logit link. For each model, the Laplace method was used for estimation and between-within denominator degrees of freedom were used for *F*-tests. Each patient was nested within their ZIP code and the intercept for each patient was considered a random effect under a compound symmetric correlation structure. All patient-level and ZIP code-level independent variables were first examined in bivariate models. Next, all patient-level variables that were statistically significant at the .10 alpha-level were included in patient-level model and backward model building strategy was used to arrive at the final patient model by eliminating non-significant variables and examining the Akaike's Information Criterion (AIC) and performing a −2log likelihood test. A lower AIC and non-significant −2log likelihood test indicated better model fit without the non-significant variables in the model. The final patient-level model contained those variables that were either statistically significant or model fit criteria indicated the variable was needed in the model. After fitting the patient-level model, all ZIP code-level SDOH variables were added to the model and a similar backward model building strategy was used to arrive at the final multi-level model. Odds ratios for median family income were estimated for a $5000 change in income, for the Gini Index odds ratios were estimated for a 0.05 increase, and for all percentage ZIP code-level variables odds ratios were estimated using a 5% change. All statistical analyses were performed using SAS 9.4 (SAS Institute Inc., Cary, NC) and statistical significance was assessed at an alpha level of .05.

Results

A total of 392 patients were included, of which 65% presented with moderate or severe COVID-19 compared to 35% with critical disease (Table 2). Patients with moderate or severe COVID-19 were younger (mean [SD]: 61 [16.5] vs 64.3 [12.5] years) and more likely to be female (60% vs

Table 2. Baseline Characteristics of Hospitalized COVID-19 Patients.

Characteristic	Moderate or severe (n = 255)	Critical (n = 137)
Age (years), mean (SD)	61 (16.5)	64.3 (12.5)
Female sex	152 (59.6)	67 (48.9)
Race		
Black or African American	109 (79.6)	203 (79.6)
White or Caucasian	22 (16.1)	41 (16.1)
Hispanic or Latino	6 (4.4)	7 (2.8)
Other Race	0 (0.0)	4 (1.6)
Ethnicity		
Hispanic or Latino	9 (3.5)	7 (5.1)
Non-Hispanic or Latino	229 (89.8)	123 (89.8)
Not Provided	17 (6.7)	7 (5.1)
BMI (kg/m^2), mean (SD)	33.1 (10.4)	34.4 (10)
BMI $\geq 30\,kg/m^2$	157 (61.8)	84 (61.3)
Pre-existing comorbidities	217 (85.1)	130 (94.9)
Hypertension	182 (71.4)	111 (81)
Diabetes mellitus	96 (37.7)	78 (56.9)
Chronic pulmonary disease	48 (18.8)	33 (24.1)
Moderate or severe renal disease	32 (12.6)	40 (29.2)
Number of pre-existing comorbidities, mean (SD)	2.4 (1.3)	3.0 (1.5)
Charlson comorbidity index, mean (SD)	3.5 (2.9)	4.6 (2.9)
Tobacco user	42 (16)	37 (27)
Insurance		
Public	136 (53)	87 (64)
Private	76 (30)	29 (21)
None or self-pay	43 (17)	21 (15)
Employment		
Part-time or full-time employed	85 (33)	30 (22)
Retired	67 (26.3)	40 (29.2)
Unemployed	54 (21.2)	38 (27.7)
Not specified or unknown	49 (19.2)	29 (21.2)
Residence		
Single-family home	174 (68.2)	89 (65)
Other	81 (32)	48 (35)
Symptoms on admission	246 (96)	136 (99)
Cough	152 (59.6)	83 (60.6)
Dyspnea	162 (63.5)	97 (70.8)
Fever	153 (60.0)	88 (64.2)
Malaise	67 (26.3)	34 (24.8)
Time from symptom onset to admission (days), mean (SD)	5.8 (4.4)	5.3 (5.2)
Temperature (°C), mean (SD)	38.2 (0.9)	38.3 (1.0)
WBC ($\times 10^9$/L), mean (SD)	7.5 (4.3)	8.4 (4.5)
Lymphocytes ($\times 10^9$/L), mean (SD)	1.5 (3.0)	1.5 (2.6)
SCr (mg/dL), mean (SD)	1.6 (1.6)	3.3 (3.8)
D-dimer (μg/mL), mean (SD)	2.5 (3.7)	4.1 (5.1)
CRP (mg/L), mean (SD)	51.4 (96.6)	57.1 (86.2)
Ferritin (ng/mL), mean (SD)	1721.1 (6033.5)	2235.2 (3111.0)
AST (units/L), mean (SD)	49.7 (57.4)	75.6 (172.3)
ALT (units/L), mean (SD)	36.0 (61.9)	39.3 (55.5)
Clear chest X-ray on admission	47 (18.7)	13 (9.6)
APACHE II score, mean (SD)	10.1 (6.2)	17.3 (7.6)
SOFA score, mean (SD)	2.6 (1.7)	5.6 (3.0)
Admitted to ICU	127 (49.8)	98 (71.5)
Length of hospital stay (days), mean (SD)	6.5 (5.4)	14.9 (11.2)

Abbreviations: ALT, alanine aminotransferase; APACHE, Acute Physiology And Chronic Health Evaluation; AST, aspartate aminotransferase; BMI, body mass index; CRP, C-reactive protein; ICU, intensive care unit; SCr, serum creatinine; SD, standard deviation; SOFA, Sequential Organ Failure Assessment; WBC, white blood cell.

Data are presented as number (%) of patients unless otherwise specified.

Table 3. ZIP Code-Level Sociodemographic Characteristics of Hospitalized COVID-19 Patients.

Characteristic	Moderate or severe (n = 255)	Critical (n = 137)
Percent female	52.9 (4.9)	52.8 (4.7)
Percent White or Caucasian	43.1 (13.9)	39.1 (14.4)
Percent Black or African American	31.7 (10.5)	33.7 (10.9)
Percent American Indian or Alaska Native	0.3 (0.4)	0.3 (0.3)
Percent Asian	0.7 (0.8)	0.8 (1.7)
Percent Native Hawaiian or Pacific Islander	0.0 (0.1)	0.0 (0.1)
Percent other race	0.8 (0.6)	0.9 (1.2)
Percent multi-race	1.1 (1.0)	1.2 (0.9)
Percent Hispanic or Latino	2.8 (2.0)	3.1 (2.9)
Percent overcrowding†	2.7 (1.4)	2.8 (1.6)
Percent < high school	19.2 (5.6)	18.4 (5.1)
Percent high school	65.3 (4.4)	66.0 (4.0)
Percent ≥ bachelor's degree	15.5 (8.4)	15.6 (7.3)
Median family income	39712.90 (12557.70)	40139.20 (11505.00)
Gini Index	0.48 (0.05)	0.48 (0.06)

Data are presented as mean (SD).
†Overcrowding was met if more than 1 person shared a room, based on criteria from HUD.[16]

49%). Most patients were Black or African American and non-Hispanic or Latino (80% and 90% for each group, respectively). Pre-existing comorbidities were common, but lower in those with moderate or severe disease (85% vs 95%). Approximately 61% of patients in each group had BMI $\geq 30\,kg/m^2$ and fewer patients who presented with moderate or severe COVID-19 were classified as current or former tobacco users (16% vs 27%). Residence in a single-family household and public insurance were common in both groups (68% vs 65% and 53% vs 64%, respectively). Symptoms on admission (96% vs 99%), of which fever (60% vs 64%) and dyspnea (64% vs 71%) were most frequently reported, occurred for 5.8 (SD 4.4) days prior to admission in patients with moderate or severe disease compared to 5.3 (SD 5.2) days in those with critical COVID-19. ICU admission occurred less often (50% vs 72%), and length of hospital stay was shorter (mean [SD]: 5.8 [5.4] vs 11.2 [8.5] days) in patients with moderate or severe COVID-19 compared to those with critical COVID-19. A similar percentage of patients had a temperature $> 38°C$ (55% vs 56%) on presentation, while fewer patients with moderate or severe compared to critical COVID-19 presented with a respiratory rate > 30 breaths per minute (19% vs 45%). Leukocytosis (WBC $> 10 \times 10^9$/L) was present in 20% of patients in the moderate or severe group and 28% in the critical group, while increased serum creatinine > 1.5 mg/dL occurred in 27% and 57%, respectively. Compared to patients with moderate or severe COVID-19, those in the critical group had higher APACHE II scores and higher SOFA scores (mean [SD]: 10.1 [6.2] vs 17.3 [7.6] years and 2.6 [1.7] vs 5.6 [3.0] years, respectively).

Similar ZIP code-level percent female population was found for both groups (mean [SD]: 53% [4.7] vs 53% [4.7], respectively) (Table 3). However, those with moderate or severe compared to critical COVID-19 resided in ZIP codes with a higher mean percent Black or African American population (mean [SD]: 33.7% [10.9] vs 31.7% [10.5]), but both groups had similar rates of overcrowding (mean [SD]: 2.7% [1.4] vs 2.8% [1.6]). ZIP code-level percent completion of high school and bachelor's degree were comparable between patients with moderate or severe and critical COVID-19 (mean [SD]: 65.3% [4.4] vs 66% [4.0] and 15.5% [8.4] vs 15.6% [7.3]), respectively. ZIP code-level median family income was lower in patients with moderate or severe COVID-19 (mean [SD]: 39712.90 [12557.70]) than in those with severe disease (mean [SD]: 40139.20 [11505.00]), but mean Gini Index was similar (mean [SD]: 0.48 [0.05] vs 0.48 [0.06]).

Factors Associated With COVID-19 Severity

Due to low frequencies, race was dichotomized as African American versus all others (referent group), while ethnicity was dichotomized as Hispanic or Latino vs all others (referent group comprised of non-Hispanic or Latino or not provided). BMI was classified by BMI $< 30\,kg/m^2$ (referent group) versus BMI $\geq 30\,kg/m^2$. Insurance status was categorized into public insurance, private insurance (referent group), and none or self-pay; whereas residence was classified as single family home (referent group) versus all other residence types, and employment was categorized as employed (referent group), unemployed, retired, and unknown. Lastly, tobacco use was dichotomized as current or former user versus never user (referent group).

Multi-collinearity was first examined using variance inflation factors and median family income at the ZIP code-level was collinear with ZIP code-level percent female and ZIP code-level educational attainment. Removal of median

family income resulted in all variance inflation factors being 5 or less.

Compared to moderate or severe COVID-19, increasing levels of Charlson Comorbidity Index (OR 1.15, 95% CI 1.07-1.24), tobacco use (OR 1.85, 95% CI 1.10-3.11), highest respiratory rate (OR 1.07, 95% CI 1.04-1.10), SOFA score (OR 1.83, 95% CI 1.59-2.10), APACHE II score (OR 1.16, 95% CI 1.12-1.21), and unemployment or retired versus employed (OR 1.91, 95% CI 1.04-3.50 and OR 2.17, 95% CI 1.17-4.02, respectively) were associated with increased odds of critical COVID-19 in bivariate models (Table 4). Alternatively, increasing pulse oxygen saturation (OR 0.93, 95% CI 0.90-0.96) was associated with decreased odds of critical COVID-19. Only ZIP code-level percent high school completion compared to greater than high school was associated with an increase in the odds of critical COVID-19 (OR 1.45, 95% CI 1.03-2.06).

The final patient model contained age, admission location, tobacco use, respiratory rate, pulse oxygen saturation, and SOFA score, whereas the final patient and ZIP code multi-level model also included ZIP code-level percent Black or African American and ZIP code-level Gini Index. In the multi-level model, ICU admission (OR 2.82, 95% CI 1.46-5.45) and SOFA score (OR 1.81, 95% CI 1.55-2.10) were associated with an increased odds, while higher ZIP code-level percent Black or African American (OR 0.94, 95% CI 0.91-0.97) was associated with decreased odds of critical COVID-19.

Discussion

In our study of 392 patients, 65% presented with moderate or severe disease while 35% presented with critical COVID-19, based on the NIH COVID-19 treatment guidelines severity of illness categories.[18] While many COVID-19 patients present with mild symptoms, illness severity ranges considerably from moderate to critical based on vital signs, extent of respiratory disease, oxygenation status, and the presence of organ dysfunction and/or failure.[1] A systematic review and meta-analysis that included 37 articles accounting for almost 25 000 patients noted that the pooled rate of ICU admission was 32%, but ranged from 3% to 100%.[19] Determining the rate of ICU admission is important, but clinical course is affected by risk factors present prior to admission as well as development of in-hospital complications and may change throughout hospitalization. Understanding illness severity upon admission better reflects the impact of pre-existing comorbidities and SDOH on COVID-19 morbidity and mortality. Additionally, this information may help to guide clinical decision-making and allows prioritization of treatment and supportive measures at the onset of illness. Most studies have focused on identifying demographic and health-related risk factors to rationalize the inequitable distribution of infection, hospitalization, and death from COVID-19.[4-7] While a greater burden of hypertension, diabetes, and obesity may be a contributing factor, the impact of SDOH on exposure and vulnerability to SARS-CoV-2, as well as consequences of COVID-19 must be considered. To characterize the effect of both biologic and genetic factors in combination with SDOH on COVID-19, we used a multilevel analysis to simultaneously examine patient-level and ZIP code-level data,[20] reflecting SDOH, to determine the risk of COVID-19 illness severity at admission rather than upon discharge or death to avoid confounding impacts from in-hospital treatment.

Based on our findings, the majority of patients were older and male who presented with critical COVID-19 despite residing in ZIP codes with a higher percent female population. These data mirror those from previous studies whereby increasing age was associated with a higher likelihood of severe disease and mortality.[21,22] Compared to women, men are more severely affected by COVID-19 with higher mortality,[23] which is likely due to a greater burden of comorbidities associated with increased risk of severe COVID-19 combined with psychological and behavioral factors.[24] Overall, 90% of patients in our study had pre-existing comorbidities (mean [SD]: 2.7 [1.4]) with slightly higher Charlson Comorbidity Index scores observed in patients with critical COVID-19. Increasing levels of Charlson Comorbidity Index were associated with a higher likelihood of critical COVID-19 at time of admission in bivariate analyses, but in the multilevel analysis, the higher odds were attenuated, which supports the conclusion that a Charlson Comorbidity Index score greater than 0 is associated with a poorer prognosis.[25] Mean BMI for our entire cohort was 33.6 kg/m^2 (SD 10.3), of which approximately 60% of patients from each group had BMI $\geq$ 30 kg/m^2. Previous research identified worsened outcomes in patients with BMI $\geq$ 40 kg/m^2, which likely accounts for the lack of association between BMI $\geq$ 30 kg/m^2 and critical COVID-19 in our study.[26] Despite a higher percentage of current and/or former tobacco users presenting with severe COVID-19, there was not a significant association identified in the multilevel analysis. Interestingly, a systematic review and meta-analysis of 8 studies found a decreased risk of COVID-19 infection in current smokers compared to never smokers, but a higher COVID-19 morbidity among those already infected.[27]

The COVID-19 pandemic has affected populations across the globe, but has disproportionately affected vulnerable groups.[4-7,28] Our multilevel analysis did not find a significantly increased likelihood of critical COVID-19 at the time of hospitalization based on patient-level employment, insurance status, and residence or ZIP code-level overcrowding, educational attainment, median family income, or Gini Index. At first, these results may seem unexpected for Southwest Georgia, an area known for high

Table 4. Multi-Level Generalized Linear Model Results on COVID-19 Severity Based on Patient-Level and ZIP Code-Level Data Reflecting the Determinants of SDOH.

Variable	Risk vs referent or unit change	Bivariate models OR (95% CI)	Final patient-level model OR (95% CI)	Final patient and ZIP code-level model OR (95% CI)
Biology and genetics				
Patient age (years)	1 year increase	1.02 (1.00-1.03)*	0.99 (0.96-1.02)	0.99 (0.97-1.01)
Patient sex	Female vs male	0.67 (0.43-1.03)*		
ZIP code % female	5% increase	0.96 (0.70-1.30)		
Social and community context				
Patient race	Black or African American vs Others	1.13 (0.65-1.96)		
Patient ethnicity	Hispanic or Latino vs Others	1.30 (0.45-3.77)		
ZIP code % Black or African American	5% increase	0.91 (0.80-1.03)		0.94 (0.91-0.97)
ZIP code % Hispanic or Latino	5% increase	0.67 (0.39-1.15)		
Health and health care				
Patient BMI category (kg/m^2)	≥30 vs <30	0.98 (0.63-1.53)		
Patient Charlson Comorbidity Index	1 unit increase	1.15 (1.07-1.24)*		
Patient tobacco use	Current or former vs never	1.85 (1.10-3.11)*	1.51 (0.77-2.97)	1.73 (0.90-3.33)
Patient insurance status	Public vs private	1.68 (0.99-2.93)		
	Self-pay or none vs private	1.26 (0.62-2.53)		
Patient highest temperature (°C)	1 degree increase	1.23 (0.97-1.55)*		
Patient symptom onset to admission (days)	1 day increase	0.98 (0.93-1.03)		
Patient highest heart rate (beats per minute)	1 beat increase	1.01 (0.99-1.02)		
Patient highest respiratory rate (breaths per minute)	1 unit increase	1.07 (1.04-1.10)*	1.02 (0.99-1.06)	1.03 (1.00-1.06)
Patient lowest pulse oxygen saturation (%)	1% increase	0.93 (0.90-0.96)*	0.98 (0.94-1.01)	0.97 (0.94-1.01)
Patient admission location	ICU vs general ward	3.65 (2.08-6.41)*	2.35 (1.19-4.64)	2.82 (1.46-5.45)
Patient SOFA score	1 unit increase	1.83 (1.59-2.10)*	1.68 (1.40-2.03)	1.81 (1.55-2.10)
Patient APACHE II score	1 unit increase	1.16 (1.12-1.21)*		
Neighborhood				
Patient residence	Other vs single family	1.13 (0.71-1.78)		
ZIP code % overcrowding†	5% increase	1.07 (0.90-1.28)		
Education				
ZIP code % < high school	5% increase	0.84 (0.64-1.10)		
ZIP code % high school	5% increase	1.45 (1.03-2.06)		
Economic stability				
Patient employment	Unknown vs Employed	1.61 (0.84-3.10)*		
	Retired vs Employed	1.91 (1.04-3.50)*		
	Unemployed vs Employed	2.17 (1.17-4.02)*		
ZIP code median family income	$5000 increase	NE		
ZIP code Gini Index	0.05 increase	1.07 (0.80-1.43)		1.08 (1.00-1.15)

Abbreviations: APACHE, Acute Physiology And Chronic Health Evaluation; CI, confidence interval; NE, not estimable; OR, odds ratio; SOFA, Sequential Organ Failure Assessment.

Black filled cells represent a variable that were not included in the final model.

Gray filled cells represent ZIP code-level variables were not considered in the patient-level model.

*Denotes patient-level variable included in the full patient-level model.

†Overcrowding was met if more than 1 person shared a room, based on criteria from HUD.[16]

vulnerability throughout the region. However, Southwest Georgia emerged as an early COVID-19 hot spot where the majority of cases occurred in Black or African American patients.[29,30] As a result, the similarities between patient-level and ZIP code-level SDOH likely stem from a lack of diversity in socioeconomic, housing, transportation, and healthcare opportunities.[29,31] Other studies utilizing more diverse regions across the U.S. have identified an increased risk of COVID-19 infection and death among individuals who have limited English proficiency, fewer opportunities for high-quality education, live in overcrowded housing, lack insurance, or those from lower socioeconomic groups due to limited income or lack of employment.[32,33] These data suggest that SDOH greatly influence COVID-19 incidence and mortality observed throughout the pandemic in the U.S.

In addition, Black or African American patients comprised 80% of our cohort, 5 times more than White or Caucasian patients, despite accounting for one-third of the population from the representative ZIP codes, similar to findings from other reports.[6,34] However, race nor ethnicity were associated with increased odds of severe COVID-19, which reflects conclusions from previous studies that failed to demonstrate an association between Black or African American race and poor COVID-19 outcomes when controlling for comorbidities and socioeconomic status.[35-37] Furthermore, higher ZIP code percent Black or African American residents was associated with significantly decreased odds in presenting with critical COVID-19. A retrospective cohort study of almost 10,000 patients from New York University Langone Health system similarly found higher infectivity and lower in-hospital mortality after adjusting for neighborhood socioeconomic status among Black or African American COVID-19 patients, but did not evaluate neighborhood composition.[38] Although the state of Georgia does not report hospitalization rates by race and ethnicity, Black or African American patients have experienced higher rates of infection and death relative to their population share.[31] Due to the large number of COVID-19 cases throughout Southwest Georgia, particularly among Black or African American patients in areas with health and financial disparities, hospitals were overwhelmed and resources crucially needed for acutely ill patients were rapidly consumed.[29,31] This may have led some patients to elect to stay at home and avoid hospitalization or seek care elsewhere, resulting in undetected cases of COVID-19 throughout this region.

Limitations

The results of this study should be interpreted with some limitations in mind. First, our study included patients hospitalized with COVID-19 over a 3-month period, which corresponded with a large number of cases throughout Southwest Georgia but may not reflect the current status of the COVID-19 pandemic. Though the number of patients included in our study was smaller than many other retrospective studies of COVID-19 patients, few reports have analyzed patient-level data from rural areas, often characterized by health disparities. Compared to the rest of the nation, Georgia's healthcare system is among the worst with high rates of uninsured patients, limited access to healthcare professionals, and poor overall health among the population.[39] Second, our study population did not include COVID-19 patients with mild illness based on criteria from the NIH COVID-19 treatment guidelines, though no patients who were hospitalized during our study timeframe satisfied criteria for mild COVID-19.[18] Patients with mild illness may complain of numerous signs and symptoms, but do not experience shortness of breath or have radiographic evidence of disease. Furthermore, patients with mild COVID-19 do not require hospitalization and can be managed in the ambulatory setting with close follow-up. Third, we used U.S. Census Bureau ZCTAs to obtain data corresponding to each determinant of SDOH for all self-reported ZIP codes included in our cohort. While spatiotemporal mismatches may exist, individual level data was unable to be obtained due to the chaotic nature of a public health emergency and was therefore not readily available.[40] Lastly, we did not describe long-term outcomes of survivors after discharge because the focus of our study was to assess the impact of SDOH on severity of illness on admission and lack of available data from the ambulatory setting.

Conclusion

Differences in SDOH did not lead to significantly higher odds of presenting with severe COVID-19 upon admission, at least when accounting for patient-level and ZIP code-level variables. These findings may seem unexpected but likely represent a lack of diversity in socioeconomic, housing, transportation, and healthcare opportunities throughout the region. Future research should examine the impact of individual-level socioeconomic data on COVID-19-related morbidity and mortality.

Author Contributions

D.B.C.: conceptualization (lead), writing—original draft (lead), writing—review and editing (equal), funding acquisition. S.P.O.: conceptualization (supporting), writing—original draft (supporting), writing—review and editing (equal), funding acquisition. G.M.T.: writing—review and editing (equal). A.M.B.: writing—review and editing (equal). A.R.: writing—review and editing (equal). A.F.H.M.: writing—review and editing (equal). C.F.P.: writing—review and editing (equal). J.L.W.: formal analysis (lead), writing—review and editing (equal). H.N.Y.: conceptualization (supporting), writing—original draft (supporting), writing—review and editing (equal), funding acquisition.

Declaration of Conflicting Interests

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Ethics Approval and Consent to Participate

Due to the retrospective nature of this study, patient consent was not required. The University of Georgia Institutional Review Board approved this study and determined that the proposed research was exempt (PROJECT00002195).

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Availability of Data and Materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

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