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The social, demographic, and clinical predictors of COVID-19 severity: A national study of United States Veterans

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Bachelor of Arts
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2016

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An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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Abstract

The social, demographic, and clinical predictors of COVID-19 severity: A national study of United States Veterans
By Alyssa Greenhouse

Introduction: Understanding the risk factors for COVID-19 disease and severity remains a public health priority. Demographic and clinical factors put individuals at higher risk. These characteristics do not operate in a vacuum but coexist with social determinants of health (SDOH) to influence health outcomes. This study aims to identify how individual and community level SDOH characteristics along with demographic and clinical factors are associated with COVID-19 disease severity.

Methods: This national cross-sectional study investigated 220,848 active Veterans tested for COVID-19 between February 20, 2020 and October 20, 2021. Variables of interest included individual demographic, clinical, and SDOH characteristics. Census variables were incorporated for community SDOH factors. Multiple logistic regression models were constructed using a backwards elimination approach to examine factors associated with COVID-19 hospitalization and intensive care unit (ICU) admission.

Results: Participants were predominately male, 60 years or older, non-Hispanic white, had completed high-school or vocational/technical school, and lived in an urban residence. Compared to those not hospitalized, those who were hospitalized were older, more likely to be male, of Black/African American or Asian race, have an income less than $39,999, live in an urban residence, and have a higher Elixhauser comorbidity index. The strongest predictors for COVID-19 hospitalization included Gini inequality index (OR=2.88), race (non-Hispanic black or African American OR=1.48, Asian OR=1.48, and Native Hawaiian/other pacific or American Indian/Alaska native OR=1.25 compared to white), and income less than $39,999 (OR=1.22). Comorbid conditions with increased odds of hospitalization included heart failure (OR=1.93), chronic kidney disease (CKD) (OR=1.86) and chronic obstructive pulmonary disease (COPD) (OR=1.77). For COVID-19 ICU admission, Asian vs. White (OR=1.46), rural vs. urban (OR=1.22), COPD (OR=1.34), and CKD (OR=1.24) were the strongest demographic and comorbid predictors.

Discussion: A combination of clinical, demographic, individual SDOH, and community level SDOH factors predict COVID-19 hospitalization and can inform patient risk stratification and discharge planning. These factors can be incorporated into a comprehensive risk assessment tool for COVID-19 hospitalization while ICU admission may be better explained by laboratory values or hospital characteristics. Public health interventions should target communities of color with higher inequality indices and SDOH risk factors.

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Introduction

Since the early spread of a novel coronavirus in December 2019 and declaration of the global COVID-19 pandemic in March 2020, immense effort has focused on identifying the risk factors for Sars-Cov-2 infection, severe illness, and death. As of April 2022, the United States has experienced over 80 million cases and 900,000 deaths due to COVID-19 [1]. Hospitals remain inundated with patients due to emerging variants and are burdened with staff shortages [2]. Identifying and understanding the risk factors for poor COVID-19 outcomes remains a public health priority.

It is well documented that older individuals [3] and those of male gender [4] are at higher risk of poor COVID-19 outcomes, including hospitalization, requiring mechanical ventilation, and death. Additionally, those with underlying medical conditions including diabetes, chronic obstructive pulmonary disease (COPD), cardiovascular disease, chronic kidney disease (CKD), cancer, and obesity, experience worse health outcomes [5][6]. While the biological mechanisms by which these conditions increase an individual's risk are not fully understood, it is likely that they work in multiple ways, creating an environment of chronic inflammation, impairing the immune system, and further suppressing immune response with their respective treatments like angiotensin-converting enzyme -inhibitors (ACE-I) and angiotensin-receptor blockers (ARB) [7].

Moreover, a disproportionate share of COVID-19 illness and severity are borne by populations of color compared to those of White race and non-Hispanic ethnicity [8]. Both international and US data indicate that individuals of Black and Asian race and Hispanic ethnicity are more likely to be infected with SARS-CoV-2 [9-11], be hospitalized [12-16], require intensive care [17], require mechanical ventilation [18], and die due to COVID-19

[19][20]. A 2021 systematic review of racial and ethnic disparities in the COVID-19 pandemic reviewed this evidence and described general consensus in racial/ethnic disparities in the risk of infection, testing positive, and hospitalization. However, the authors reported difficulty summarizing the results due to inconsistency in the literature [21]. Now into the third year of the pandemic, a better understanding of the independent and joint effects of demographic and clinical factors on COVID-19 disease and severity is needed.

The United States Department of Veterans Affairs (VA) is the largest integrated health care system in the United States and serves 9 million Veterans each year in 1,293 health care facilities throughout the United States [22]. The Veterans Health Administration (VHA) offers uniquely robust data with COVID-19 information and individual patient demographics to investigate the causes of COVID-19 health disparities and risk factors. Several studies have utilized this unique data source to investigate COVID-19 testing and health outcomes.

A study of COVID-19 testing and test positivity among all U.S. Veterans in active clinical care concluded that Veterans of female gender, Black/African American race, Hispanic/Latino ethnicity, and low-income were more likely to be tested for COVID-19 and those living in rural areas, of younger age, and Asian race were less likely to be tested. All non-White race categories had a higher risk of receiving a positive test compared to White Veterans. While the authors utilized area-based socioeconomic covariates, including measures of unemployment, education, poverty, income inequality, internet and computer access, and food stamps, they only adjusted for these measures, rather than also investigating the relationship between socioeconomic status and the outcomes of interest. Additionally, other health outcomes, such as COVID-19 disease severity, were not investigated [23].

One study of adverse COVID-19 outcomes among Veterans tested across the U.S. between February 28 and May 14, 2020, identified that increasing age was associated with outcomes of hospitalization, mechanical ventilation, and death. Male gender, Black race, diabetes, hypertension, CKD, cirrhosis, alcohol dependence, and a higher comorbidity index were all associated with COVID-19 hospitalization and mechanical ventilation. Hispanic ethnicity, obesity, and urban residence were not associated with COVID-19 outcomes. [18].

Another study of Veterans tested across the U.S. between February 8 and March 30, 2020, reported a two-fold increased risk of testing positive among Black Veterans, but did not find race to be associated with hospitalization. Age, CKD, COPD, hypertension, vascular disease, and ACE-I/ARB medication exposure were associated with hospitalization in unadjusted models. Age remained the only significant association after adjusting for vital signs and laboratory data. This study only investigated Black race and was further limited by a small sample size, with only 585 positive COVID-19 cases and 297 of those patients being hospitalized during the study period [24]. In contrast, another study of COVID-19 positive U.S. Veterans between February 1 and June 30, 2020, reported Black race and Hispanic ethnicity were associated with increased odds of hospitalization compared to White patients. The analysis was restricted to non-Hispanic White, non-Hispanic Black, and Hispanic veterans due to low sample size among other races [25].

Despite the valuable information obtained from these studies conducted in the VA population; additional research is needed to understand the conflicting results and supplement the short study periods and small sample sizes. Moreover, the VA studies were limited in the incorporation of socioeconomic factors, only adjusting for these measures, or investigating rural/urban status [18][24]. Socioeconomic measures, more comprehensively described by the

Social Determinants of Health (SDOH) framework, are necessary to fully understand health outcomes and disparities. The SDOH are the conditions that people are born, grow, live, and work in, and the set of structures and systems that shape them [26][27]. Specific SDOH examples include income, education, and social support. These social dynamics give rise to the development of high-risk underlying medical conditions including diabetes, hypertension, depression, and asthma, and facilitate the spread of infectious diseases themselves [21][27]. There is a need for improved awareness and integration of SDOH into public health studies and interventions during public health emergencies [27].

Research investigating SDOH and socioeconomic disparities in COVID-19, has identified a higher risk of confirmed infection and death among those living in poverty, poor housing conditions, household crowding, and with lower levels of education [21]. A survival analysis of all recorded COVID-19 deaths in Sweden prior to May 7, 2020, reported those in the lowest income group were 5.4 times more likely to die than the highest income group and those without post-secondary education were more than twice as likely to die compared to those with post-secondary education [28]. An Ireland-based study of hospitalized COVID-19 patients concluded deprivation was a strong predictor of mortality [29]. Moreover, a study utilizing data from the UK Biobank reported the greatest attenuation of observed ethnic disparities in COVID-19 hospitalization occurred when accounting for socioeconomic factors, including education, household income, occupation, number of people living in the household, and area deprivation [16].

Among US literature, many studies utilize only zip code or county level SDOH data due to limitations in information systems and data collection. A study of COVID-19 cases in Massachusetts, observed elevated rates of COVID-19 in cities and towns with a higher level of poverty, lack of insurance, service and healthcare occupations, and lower median incomes [30]. Similarly, a study of 64 Louisiana parishes utilized the Area Deprivation Index and reported the most deprived neighborhoods had a 30% higher rate of COVID-19 infection to those in the least deprived [31]. A county and zip code analysis of COVID-19 cases and deaths in Illinois and New York revealed the highest rates of COVID-19 cases and deaths among the most disadvantaged counties regarding percent poverty, racialized economic segregation, percent crowding, and percent population of color [32]. While the neighborhood and environmental conditions are important social determinants, analyses restricted to only county and zip code level data do not allow for conclusions to be made at the individual level.

There is a need to leverage both community and individual health data to better identify those at highest risk of poor COVID-19 outcomes. The United States Veterans Eligibility Trends and Statistics (USVETS) dataset is a new resource that was introduced in 2019 to provide a comprehensive picture of individual level Veteran demographic and socioeconomic data and has not been utilized in the COVID-19 literature as far as we know. Further, there is a need to update the literature on COVID-19 outcomes among the VA population, as prior utilization of this nationwide data resource is primarily limited to the beginning of the pandemic, with short study time periods and limited sample sizes. In this study, we utilize a nationwide cohort from the VA health care system to investigate the characteristics of COVID-19 patients requiring hospitalization and admission to the intensive care unit (ICU). We identify how individual level and community level SDOH characteristics and demographic and clinical factors are associated with COVID-19 disease severity to aid in the identification of high-risk individuals and creation of targeted public health interventions to better protect our communities and reduce hospital burden.

Methods

Study Design and Population

This is a cross sectional study of Veterans in active care at the VHA, which utilizes a single, national electronic health record network. The study population included all VA enrollees with at least one inpatient hospital stay or outpatient encounter from January 1, 2018, to September 30, 2021. This was to ensure data was up to date and comprehensive. The analysis dataset included all who were tested for COVID-19 between February 20, 2020 and October 20, 2021 and had complete data across all variables of interest (n=220,848) (Figure 1).

This study was approved by the institutional review boards of the Atlanta VA Research and Development Committee and Emory University. It was granted a waiver of informed consent and is Health Insurance Portability and Accountability Act compliant.

Data Sources

This study had four primary data sources: 1) CDW, for demographic and clinical data; 2) USVETS for SDOH data; 3) U.S. Census American Community Survey (ACS) estimates for 2015-2019, for county level data and 4) COVID-19 Shared Data Resource for COVID-19 testing and health outcomes.

Data Measures

Variables were selected based on a review of the literature on COVID-19 outcomes among VA and non-VA populations conducted between May 24, 2021 and July 23, 2021.

Demographic Variables

Age, gender, and race/ ethnicity were obtained from the CDW. Gender was categorized male or female. Race/ethnicity was reported as Non-Hispanic White, Non-Hispanic Black or African American, Asian, American Indian/ Alaska Native or Native Hawaiian/ other Pacific, or Hispanic/Latino.

Clinical and Behavioral Variables

Select high-risk comorbid conditions and the Elixhauser Comorbidity index [33] were extracted from the CDW based on International Classification of Diseases-10 (ICD-10) diagnostic codes. The presence of a medical condition was determined by having at least one inpatient or outpatient diagnosis between January 2018 to March 2020. The following underlying conditions associated with severe COVID-19 were included as reported by the Centers for Disease Control and Prevention (CDC) [6]: asthma, coronary artery disease, CKD, COPD, cancer, diabetes, heart failure, human immunodeficiency virus (HIV), hypertension, liver disease, stroke, obesity, and mental health conditions (including schizophrenia, delusional disorders, schizoaffective disorder, bipolar disorder, major depressive disorder, persistent mood disorder, and anxiety disorders). Alcohol use disorder and tobacco use disorder were investigated as health behaviors.

SDOH Variables

SDOH variables were extracted from the USVETS database. Estimated household income (either self-reported or estimated based on a variety of demographic factors including age, occupation, home ownership, and median income for the local area) was categorized into one of three categories according to percent distribution divided into tertiles (less than $39,999; $40,000-$69,999; greater than $70,000). Marital status was defined married or single. In the USVETS dataset, if marital status could not be determined and there were two names in the household with gender of Male and Female, within a certain age range of each other, then marital status was inferred married or single. Rural/urban residence was defined by the rural-urban commuting area codes which classify U.S. census tracts as rural or urban using measures of population density, urbanization, and daily commuting [34]. Household size indicated the total number of occupants in a household and was categorized as one, two, three, or four-plus individuals in a household. Education indicates the highest known education of the first individual in the household. The first individual in the household is defined by predetermined rules designated by USVETS researchers. This variable provides insight into the education level of the household and was categorized as having completed a high school degree or attended vocational/technical school, completed a college degree, or completed graduate school.

Census Variables

Community level effects were analyzed through county level census variables. These included the Gini index [35], median household income, average household size, percent of the county population below the federal poverty level (FPL), and percent of the county population with a high school diploma.

Outcomes

The outcome of interest was COVID-19 disease severity. This was operationally defined by whether a patient was hospitalized or not and whether they were admitted to the ICU or not.

The COVID-19 Shared Data Resource identified those who were hospitalized and those admitted to the ICU within 60 days of their positive COVID-19 test.

Statistical Analysis

The demographic, clinical, and SDOH characteristics of COVID-19 patients requiring hospitalization were described with respect to the distributions of the variables of interest using counts and percentages for categorical variables and means and standard deviations for continuous variables. Subsequently, crude bivariate analyses were performed with chi-square tests and t-tests to examine baseline characteristics according to COVID-19 hospitalization status. Results were considered significant at the $p < 0.05$ levels.

Multiple logistic regression models were constructed to examine the factors associated with COVID-19 severity requiring hospitalization. The initial model included all candidate predictor variables, including the Elixhauser comorbidity index, with hospitalization within 60 days as the outcome. A second model was constructed using select underlying conditions previously studied in the literature to be associated with COVID-19 disease and severity instead of the comorbidity index. Using backwards elimination with an alpha of 0.05 for variable retention, the models were reduced to variables independently associated with hospitalization. A subgroup multivariable logistic regression analysis with backwards elimination of ICU admission among hospitalized COVID-19 patients was performed. Similarly, two models were constructed with ICU admission within 60 days as the outcome. The first model utilized the Elixhauser comorbidity index, while the second analyzed individual medical conditions. The results of the final models were expressed as multivariable adjusted odds ratios (OR) and corresponding 95% confidence intervals (CI). The predictive value of each model was assessed by calculating a c-statistic, which lies between the values 0.5 and 1. A value closer to 0.5 indicates a model with poor discriminative power. A c-statistic above 0.7 designates good predictive ability and above 0.95 indicates high discriminative power [36][37]. All analyses were conducted using SAS Enterprise Guide version 8.2 (SAS Institute, Cary, North Carolina).

Results

From the 220,848 patients included in the analysis, 39,471 (17.8%) were hospitalized within 60 days of their positive COVID-19 test. Of those, 15,082 patients (38.2%) were admitted to the ICU within 60 days. A comparison of characteristics between Veterans who were hospitalized and those who were not demonstrated meaningful (10%) significant differences ($p<0.0001$) with respect to age, female gender, Black or African American race, Asian race, Hispanic or Latino ethnicity, income of less than $39,999 per year, income of greater than $70,000 per year, rural residence, one person in the household, four or more people in the household, coronary artery disease, CKD, COPD, cancer, diabetes, heart failure, HIV, hypertension, liver disease, stroke, the Elixhauser comorbidity index, alcohol use disorder, and tobacco use disorder (Table 1).

Table 2 reports the results for the two regression models using backwards elimination for COVID-19 hospitalization. Model 1 utilized the Elixhauser comorbidity index while model 2 analyzed individual comorbid conditions. After backwards elimination, only median household income was removed from model 1 ($p=0.3088$). All other variables were retained with p-values less than 0.05. Significant odds ratios were produced for the following variables from largest to smallest: Gini inequality index (OR 2.88), non-Hispanic Black or African American race compared to White race (OR 1.48), Asian race compared to White race (OR 1.48), Native

Hawaiian/ other Pacific or American Indian/ Alaska Native race compared to White race (OR 1.25), income less than $39,999 per year compared to greater than $70,000 per year (OR 1.22), Hispanic ethnicity compared to non-Hispanic White race (OR 1.20), 10-year increase in age (OR 1.20), being single compared to married (OR 1.17), having one person in the household compared to two people (OR 1.13), average household size (OR 1.12), income less than $69,999 per year compared to greater than $70,000 per year (OR 1.11), Elixhauser comorbidity index (OR 1.08), completing high-school/vocational school/ technical school compared to completing graduate school (OR 1.05), and county percent below FPL (OR 1.02). Decreased odds ratios were reported for female gender compared to male (OR 0.78), rural compared to urban residency (OR 0.89), and county percent with a high-school diploma (OR 0.98). The calculated c-statistic for model 1 was c=0.752.

Backwards elimination for Model 2 removed median household income (p=0.2520), education (p=0.5738), and the presence of HIV as a comorbid condition (p=0.1589). All other comorbid conditions were retained in the model with a p-value less than 0.05. The following odds ratios were computed from largest to smallest: heart failure (OR 1.93), CKD (OR 1.86), COPD (OR 1.77), liver disease (OR 1.58), stroke (OR 1.43), cancer (OR 1.35), diabetes (OR 1.26), mental health conditions (OR 1.23), alcohol use disorder (OR 1.22), coronary artery disease (OR 1.18), tobacco use disorder (OR 1.05), hypertension (OR 1.04), asthma (OR 0.95), and obesity (OR 0.94) (Figure 2). Compared to Model 1, odds ratios in Model 2 remained the same or increased for the following variables: Gini inequality index (OR 3.07), Asian race compared to White race (OR 1.48), Hispanic ethnicity compared to non-Hispanic White race (OR 1.21), a 10-year increase in age (OR 1.21), and county percent below FPL (OR 1.02). The following odds ratios remained above the null but decreased: non-Hispanic Black or African

American race compared to White race (OR 1.40), Native Hawaiian/ other Pacific or American Indian/ Alaska Native race compared to White race (OR 1.21), income less than $39,999 per year compared to greater than $70,000 per year (OR 1.17), being single compared to married (OR 1.15), having one person in the household compared to two people (OR 1.10), an increase in average household size (OR 1.10), income less than $69,999 per year compared to greater than $70,000 per year (OR 1.08). Decreased odds ratios remained for: female gender compared to male (OR 0.81), rural compared to urban residency (OR 0.87), and county percent with a high-school diploma (OR 0.98). The calculated c-statistic for model 2 was c=0.749.

Table 3 reports the results for the two regression models using backwards elimination for COVID-19 ICU admission. Model 3 utilized the Elixhauser comorbidity index while model 4 analyzed individual comorbid conditions. After backwards elimination for model 3, income (p=0.6010), household size (p=0.3327), and the Gini inequality index (p=0.2693) were removed. All other variables were retained with p-values less than 0.05. Significant odds ratios were reported for the following: Asian race compared to WWhite race (OR 1.46), rural compared to urban residence (OR 1.22), average household size (OR 1.14), completing high-school/vocational school/ technical school compared to completing graduate school (OR 1.12), completing college compared to completing graduate school (OR 1.12), non-Hispanic Black or African American race compared to White race (1.07), 10-year age increase (OR 1.03), and an increase in the Elixhauser comorbidity index (OR 1.02). Decreased odds ratios were reported for female gender compared to male (OR 0.82), single compared to married (OR 0.95), and county percent with a high-school diploma (OR 0.99). The calculated c-statistic for model 3 was c=0.577.

Following backwards elimination for model 4, age (p=0.6578), income (p=0.5880), household size (p=0.5917), comorbidities including liver disease (0.5776), cancer (0.4713), obesity (p=0.3243), hypertension (p=0.2821), coronary artery disease (0.2097), HIV (p=0.1170), and stroke (0.0823), along with tobacco use disorder, the Gini inequality index (p=0.6507) and county percent below FPL (p=0.2677) were removed from the model. All other variables were retained in the model with a p-value less than 0.05. The following odds ratios were computed from greatest to least: COPD (OR 1.34), CKD (OR 1.24), heart failure (OR 1.19), diabetes (OR 1.13), mental health conditions (OR 0.91), alcohol use disorder (OR 0.90), and asthma (OR 0.90) (Figure 2). Compared to Model 3, significant odds ratios in Model 4 remained for Asian race compared to White race (OR 1.40) and average household size (OR 1.10). Being single compared to married changed to increased odds (OR 1.15) and rural residence compared to urban residence became protective (OR 0.87). Decreased odds ratios remained for female gender compared to male (OR 0.83), and county percent with a high-school diploma (OR 0.98). The calculated c-statistic for model 4 was c=0.582.

Discussion

In this study we identified a combination of clinical factors along with demographic, SDOH, and community level SDOH factors predicting the need for hospitalization and ICU admission. This is valuable information for identifying populations for targeted public health interventions. Patients of racial/ethnic groups and those with preexisting conditions can be assessed based on individual and community SDOH characteristics for increased education and follow-up upon hospital discharge or improved access to personal protective equipment, COVID-19 testing, and vaccination.

Our results were consistent with the racial/ethnic disparities reported by much of the COVID-19 literature as well [9-21]. These observed racial disparities were not explained by the incorporation of socioeconomic variables or comorbid medical conditions and remained significant in all four models for hospitalization and ICU admission. Those of Asian and non-Hispanic Black or African American race experienced the highest odds of hospitalization compared to non-Hispanic White. The odds for ICU admission decreased among non-Hispanic Black and African Americans, which might suggest that the association between Black/African American race and ICU admission is better explained by the presence of comorbid conditions and SDOH factors. When adjusting for covariates, other studies have reported no racial/ethnic disparities in COVID-19 ICU admission [24][40]. Alternatively, it could represent a bias among providers when considering the admission of patients of Black or African American race into the ICU. In contrast, the odds of ICU admission remained high for Asian race.

The comorbid conditions with the greatest odds ratios for both hospitalization and ICU admission were consistent with associations found in the literature [12][24]. While it was surprising that asthma and obesity did not produce increased odds of poor outcomes in this study, prior VA literature has also not found obesity to be associated with adverse outcomes [18] and CDC reports mixed evidence for the risk of asthma [6]. This knowledge can help identify higher-risk and lower-risk patient populations for the prioritization of hospital and clinic-based COVID-19 interventions. According to this study, patient populations with heart failure, CKD, and COPD should be prioritized. For example, the provision of COVID-19 protective equipment and vaccinations could be directed towards dialysis centers to target those patients with severe kidney disease. In contrast, patients with asthma or obesity should be further assessed for other risk factors including race/ethnicity and SDOH prior to intervention.

Overall, the models for COVID-19 hospitalization had good predictive ability [36]. Utilizing the Elixhauser comorbidity index produced a slightly larger c-statistic for COVID-19 hospitalization, suggesting that this was a better predictor than the individual comorbid conditions. This is valuable for future COVID-19 disease modeling and risk stratification, as the use of a single index value can increase both precision and efficiency. These results can aid in the creation of an individualized risk assessment tool for proactive patient outreach and clinical decision-making in the outpatient setting to prevent hospitalization.

The models for ICU admission had low discriminative power, suggesting that other factors unaccounted for in the models might better explain the risk of ICU admission. The odds ratios of comorbid conditions in the ICU model all decreased compared to their respective odds of COVID-19 hospitalization. Additionally, certain conditions had decreased odds, suggesting a protective factor, for ICU admission. Prior studies suggest that ICU admission might instead be influenced more by in-hospital factors, including laboratory values and hospital characteristics rather than external factors like SDOH [24][38]. Therefore, efforts to mitigate ventilator shortages and burdens on ICU-related resources would be better targeted towards other risk-factors not studied in this analysis.

This study has at least five strengths. First, this study examined robust nationwide data available from the unified patient identifier system of the VHA system. Second, data from several VHA datasets were combined across a 20-month period, yielding a large sample size to investigate gender and racial/ethnic groups not consistently analyzed in the literature [24][25]. Third, utilizing the USVETS data resource also allowed for the investigation of individual SDOH characteristics, a gap in the current Veteran and U.S. COVID-19 literature [10]. Fourth, this study incorporated both individual and county SDOH data to acknowledge and analyze the influence of social factors on both the individual and community level. Finally, two models were created for each outcome, examining the Elixhauser index as a single predictive variable and also investigating individual comorbidities. Other studies have examined several of these factors but did not report the relationships or levels of significance, limiting the ability of the analyses and results to inform public health decision-making [23][24].

Despite the strengths of this study, there are at least five limitations. First, the Veteran population historically tends to be older, predominately male, and have a greater burden of chronic health conditions compared to the general population [39]. As such, the results from this study population may be limited in generalizability. Second, while some USVETS variables were imputed based off proprietary algorithms if considerable data was missing, certain variables could not be used due to substantial missing data (e,g., occupation). Third, SDOH data was collected based off predetermined USVETS dataset rules. For example, the marital status variable assumed single/married status based only on the combination of male-female genders in a household. Fourth, health outcomes, including hospitalization and ICU admission, were defined in the COVID-19 Shared Data Resource as having occurred within a broad, 60-day window. Finally, this study did not analyze interaction due to the large number of variables included in the models.

Future research can build upon this study by investigating the interaction amongst the identified risk factors to further understand how the demographic, clinical, and social characteristics interplay and influence COVID-19 outcomes. The persistence of racial/ethnic disparities in all models also calls for more examination, as identifying the disparity does not explain it. The role of healthcare provider bias was not investigated in this study and may influence access to preventative care and treatment. While studies often focus on Black versus

White race, this study suggests a need to further investigate a substantially increased risk of poor outcomes among Asian Veterans. Future analyses should also consider incorporating laboratory results including hemoglobin A1c, glomerular filtration rate, and blood pressure measurements, to investigate the severity of comorbid conditions and trajectory of the hospital course on COVID-19 ICU admission.

Conclusion

We advocate for the incorporation of individual and community level SDOH factors into future COVID-19 risk stratification and outcome modeling. Furthermore, the identified risk factors can be used to create a comprehensive risk assessment tool to identify individual patients and patient populations who are higher risk for COVID-19 hospitalization and would most benefit from hospital and clinic-based interventions. In addition to interventions in the clinical setting, public health interventions should be targeted towards communities of color with higher inequality indices and other SDOH risk factors. Racial/ethnic health disparities remain unexplained by individual and community socioeconomic status or the presence of comorbid conditions and calls for investigation into the presence and effect of bias and racism within the healthcare system.

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Figure 1: Consort diagram of patients tested for SARS-CoV-2 across nationwide VHA facilities between February 20, 2020 and October 20, 2021 with complete data.

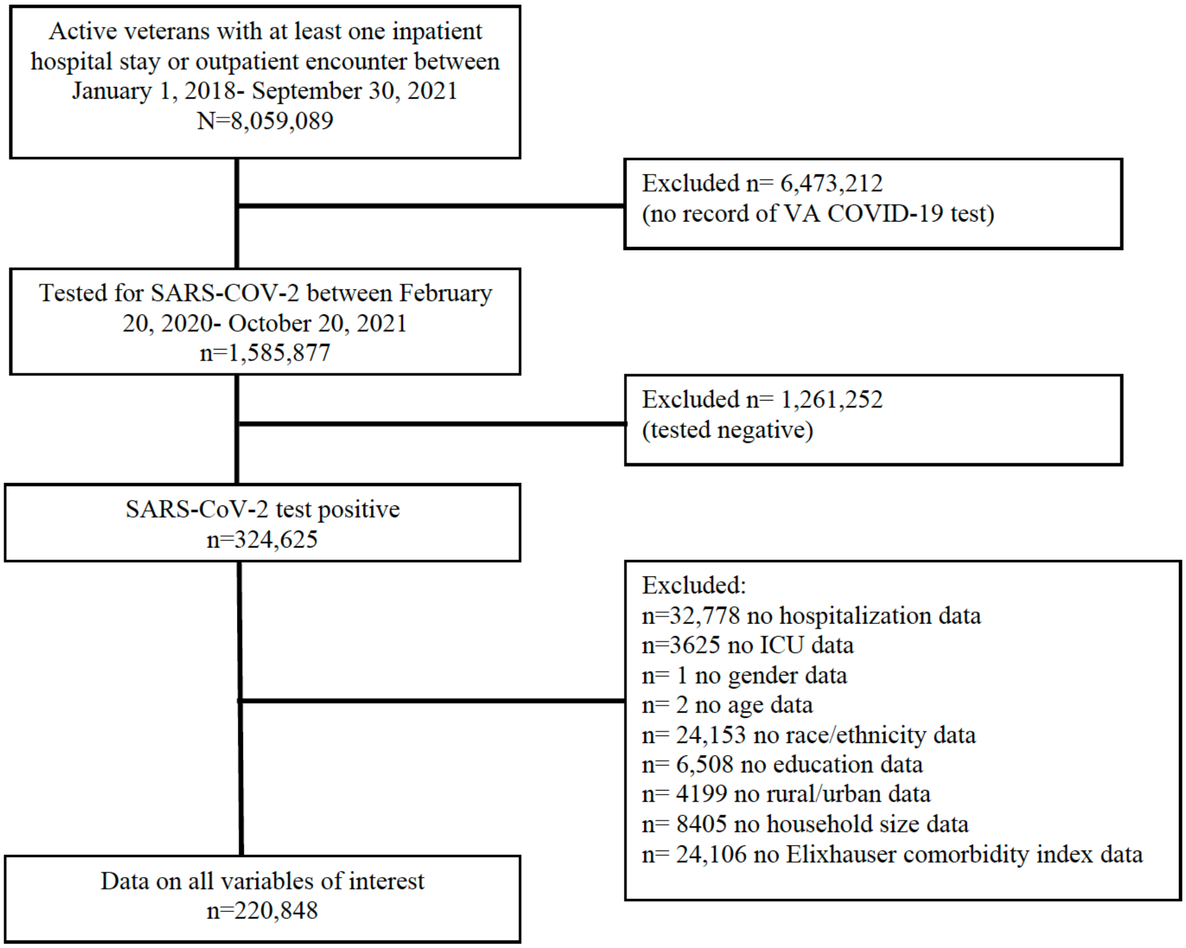

Figure 2: Forest plot of odds ratios for statistically significant comorbid medical conditions for COVID-19 hospitalization (blue) and ICU admission (red).

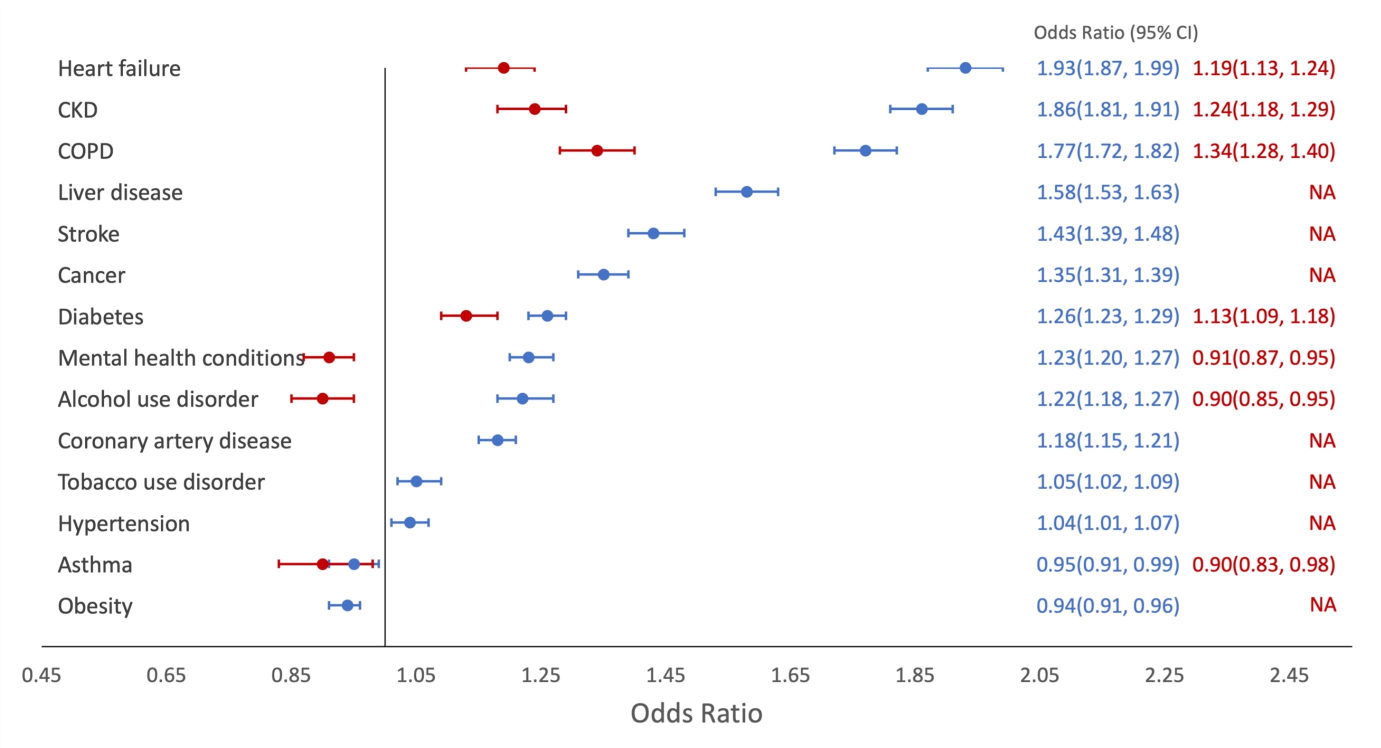

Table 1: Sociodemographic characteristics of COVID-19 positive patients by hospitalization status in a national Veteran population, n=220,848.

Participant characteristics	Not hospitalized (n= 181,377))	Percent/ SD	Hospitalized 60d from diagnosis (n=39,471)	Percent/ SD	p-value
Age	60.1	±15.4	67.4	±13.3	<.0001
Gender					<.0001
M	161,585	89.1%	37,334	94.6%	
F	19,792	10.9%	2,137	5.4%	
Race/Ethnicity					<.0001
Non-Hispanic White	121,986	67.3%	24,324	61.6%	
Non-Hispanic Black or African American	40,962	22.6%	11,440	29.0%	
Asian	1,546	1.0%	296	0.8%	
American Indian/ Alaska Native or Native Hawaiian/ other Pacific	2,923	1.6%	639	1.6%	
Hispanic or Latino	13,960	7.7%	2,772	7.0%	
Education					0.1435
Completed high-school or vocational/technical school	134,144	74.0%	29,156	73.9%	
Completed college	29,062	16.0%	6,452	16.4%	
Completed grad school	18,171	10.0%	3,863	9.8%	
Income					<.0001
Less than $39,999 per year	64,261	35.4%	16,940	42.9%	
Less than $69,999 per year	72,276	39.9%	14,762	37.4%	
Greater than $70,000 per year	44,840	24.7%	7,769	19.7%	

Marital status					<.0001
Married/ inferred married	84,875	46.8%	19,674	49.8%	
Single/ inferred Single	96,502	53.2%	19,797	50.2%	
Rural/urban					<.0001
Rural	33,735	18.6%	6,234	15.8%	
Urban	147,642	81.4%	33,237	84.2%	
Household size					<.0001
1 person	45,797	25.3%	11,235	28.5%	
2 people in household	48,675	26.8%	10,740	27.2%	
3 people in household	39,609	21.8%	8,173	20.7%	
4+ people in household	47,296	26.1%	9,323	23.6%	
Chronic conditions (Disease present)					
Asthma	13,277	7.3%	2,795	7.1%	P=.0977
Coronary artery disease	41,164	22.7%	16,944	42.9%	<.0001
CKD	28,126	15.5%	15,229	38.6%	<.0001
COPD	35,319	19.5%	16,318	41.3%	<.0001
Cancer	23,872	13.2%	9,392	23.8%	<.0001
Diabetes	71,303	39.3%	22,282	56.5%	<.0001
Heart Failure	20,133	11.1%	13,432	34.0%	<.0001
HIV	1,312	0.7%	423	1.1%	<.0001
Hypertension	116,482	64.2%	31,785	80.5%	<.0001
Liver disease	23,310	12.9%	8,483	21.5%	<.0001
Stroke	21,871	12.1%	10,421	26.4%	<.0001
Obesity	75,326	41.5%	18,167	46.0%	<.0001
Mental health conditions	98,214	54.15%	22,697	57.5%	<.0001
Elixhauser Comorbidity Index	4.5	±8.7	13.5	±11.6	<.0001

Alcohol use disorder	24,510	13.5%	6,757	17.1%	<.0001
Tobacco use disorder	27,888	15.4%	7,542	19.1%	<.0001
Census variables					
Gini index	0.4586	±0.0333	0.4642	±0.0351	<.0001
Median household Income	$60,443.30	± $15,368.00	$60,310.50	± $15,146.50	P=0.1187
Average household size	2.6	±0.25	2.6	±0.25	P= 0.0010
Percent below FPL	7.6%	±2.6%	7.8%	±2.8%	<.0001
Percent with a high school diploma	16.5 %	±4.5%	16.2 %	±4.2%	<.0001

CKD: Chronic Kidney Disease, COPD: Chronic Obstructive Pulmonary Disease, HIV: Human Immunodeficiency Virus, FPL: Federal Poverty Level

Table 2: Multivariate Logistic Regression Analysis and Prediction Model Using Backward Elimination for COVID-19 Hospitalization.

	Model 1 Elixhauser index		**Model 2 Individual comorbidities**	
	Odds Ratio	95% CI	Odds Ratio	95% CI
Age (10 year increment)	1.20	1.19, 1.22	1.21	1.20, 1.22
Gender: Female vs male reference	0.78	0.74, 0.82	0.81	0.77, 0.85
Race: "White" reference				
Non-Hispanic Black or African American	1.48	1.44, 1.53	1.40	1.36, 1.44
Asian	1.48	1.29, 1.69	1.48	1.30, 1.70
Hispanic	1.20	1.14, 1.26	1.21	1.16, 1.28
Native Hawaiian/ other Pacific or American Indian/ Alaska Native	1.25	1.14, 1.38	1.21	1.10, 1.33
Education: "Completed grad school" reference				
Completed high-school/vocational/technical school	1.05	1.01, 1.10	--	--
Completed college	1.01	0.97, 1.06	--	--
Income: "Greater than $70,000 per year" reference				
Less than $39,999 per year	1.22	1.18, 1.26	1.17	1.14, 1.21
Less than $69,999 per year	1.11	1.07, 1.14	1.08	1.04, 1.11
Household size: "2 people" reference				
1 person	1.13	1.09, 1.17	1.10	1.07, 1.14
3 people	0.99	0.97, 1.03	1.00	0.97, 1.04
4+ people	1.00	0.97, 1.03	1.00	0.97, 1.03
RUCA: Rural vs urban reference	0.89	0.86, 0.92	0.87	0.84, 0.90
Marital status: Single vs. married reference	1.17	1.14, 1.20	1.15	1.12, 1.18
Elixhauser index score	1.08	1.08, 1.08	--	--
Comorbidities: "Disease-free" reference				
Asthma	--	--	0.95	0.91, 0.99
CAD	--	--	1.18	1.15, 1.21
CKD	--	--	1.86	1.81, 1.91
COPD	--	--	1.77	1.72, 1.82
Cancer	--	--	1.35	1.31, 1.39
Diabetes	--	--	1.26	1.23, 1.29
Heart failure	--	--	1.93	1.87, 1.99
HIV	--	--	--	--

Hypertension	--	--	1.04	1.01, 1.07
Liver disease	--	--	1.58	1.53, 1.63
Stroke	--	--	1.43	1.39, 1.48
Obesity	--	--	0.94	0.91, 0.96
Mental health conditions	--	--	1.23	1.20, 1.27
Alcohol use disorder	--	--	1.22	1.18, 1.27
Tobacco use disorder	--	--	1.05	1.02, 1.09
Census variables				
Gini index	2.88	1.78, 4.66	3.07	1.90, 4.96
Median household income	--	--	--	--
Average household size	1.12	1.06, 1.18	1.10	1.05, 1.16
Percent below FPL	1.02	1.01, 1.03	1.02	1.01, 1.03
Percent with high-school diploma	0.98	0.97, 0.98	0.98	0.97, 0.98
****C Statistic per model*	***c = 0.752***		***c = 0.749***	

CKD: Chronic Kidney Disease, COPD: Chronic Obstructive Pulmonary Disease, HIV: Human Immunodeficiency Virus, FPL: Federal Poverty Level

Table 3: Multivariate Logistic Regression Analysis and Prediction Model Using Backward Elimination for COVID-19 ICU admission.

	Model 3 Elixhauser index		**Model 4 Individual comorbidities**	
	Odds Ratio	95% CI	Odds Ratio	95% CI
Age (10 year increment)	1.03	1.01, 1.04	--	--
Gender: Female vs male reference	0.82	0.74, 0.90	0.83	0.75, 0.92
Race: "White" reference				
Non-Hispanic Black or African American	1.07	1.02, 1.12	1.05	1.00, 1.10
Asian	1.46	1.15, 1.84	1.40	1.11, 1.78
Hispanic	1.04	0.95, 1.13	1.05	0.96, 1.14
Native Hawaiian/ other Pacific or American Indian/ Alaska Native	0.89	0.75, 1.05	0.87	0.73, 1.03
Education: "Completed grad school" reference				
Completed high-school/vocational/technical school	1.12	1.04, 1.20	--	--
Completed college	1.12	1.03, 1.22	--	--
Income: "Greater than $70,000 per year" reference				
Less than $39,999 per year	--	--	--	--
Less than $69,999 per year	--	--	--	--
Household size: "2 people" reference				
1 person	--	--	--	--
3 people	--	--	--	--
4+ people	--	--	--	--
RUCA: Rural vs urban reference	1.22	1.15, 1.30	0.87	0.84, 0.90
Marital status: Single vs. married reference	0.95	0.91, 0.99	1.15	1.12, 1.18
Elixhauser index score	1.02	1.017, 1.021	--	--
Comorbidities: "Disease-free" reference				
Asthma	--	--	0.90	0.83, 0.98
CAD	--	--	--	--
CKD	--	--	1.24	1.18, 1.29
COPD	--	--	1.34	1.28, 1.40
Cancer	--	--	--	--
Diabetes	--	--	1.13	1.09, 1.18
Heart failure	--	--	1.19	1.13, 1.24
HIV	--	--	--	--

Hypertension	--	--	--	--
Liver disease	--	--	--	--
Stroke	--	--	--	--
Obesity	--	--	--	--
Mental health conditions	--	--	0.91	0.87, 0.95
Alcohol use disorder	--	--	0.90	0.85, 0.95
Tobacco use disorder	--	--	--	--
Census variables				
Gini index	--	--	--	--
Median household income	1.00	1.00, 1.00	--	--
Average household size	1.14	1.04, 1.24	1.10	1.05, 1.16
Percent below FPL	0.99	0.98, 1.00	--	--
Percent with high-school diploma	0.99	0.98, 0.99	0.98	0.97, 0.98
****C Statistic per model*	***c = 0.577***		***c = 0.582***	

CKD: Chronic Kidney Disease, COPD: Chronic Obstructive Pulmonary Disease, HIV: Human Immunodeficiency Virus, FPL: Federal Poverty Level