Original Research

AMERICAN ACADEMY OF OTOLARYNGOLOGY–HEAD AND NECK SURGERY FOUNDATION

OTO Open
2021, 5(2) 1–8

DOI: 10.1177/2473974X211016283
http://oto-open.org
SAGE

Severity of Sleep Apnea and COVID-19 Illness

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Abstract

Objective. To characterize the relationship between severity of sleep apnea and coronavirus disease 2019 (COVID-19) hospitalization and severe illness.

Study Design. Retrospective cohort study.

Setting. Montefiore Health System in the Bronx, New York.

Methods. The data set consisted of adult patients with an active diagnosis of obstructive sleep apnea in the past 2 years and a positive severe acute respiratory syndrome coronavirus 2 quantitative polymerase chain reaction test at our institution between March 16, 2020, and May 26, 2020. Sleep apnea severity and continuous positive airway pressure compliance data were abstracted from the electronic medical record. The *International Classification of Diseases, 10th Revision* was used to classify comorbidities.

Results. A total of 461 patients with sleep apnea tested positive for COVID-19, of whom 149 were excluded for missing data in the electronic medical record. Patients with moderate and severe sleep apnea had higher rates of COVID-19 hospitalization compared to those with mild sleep apnea (P = .003). This association was reduced when accounting for confounders, most notably the Charlson Comorbidity Index, a measure of comorbid illness burden. Moderate and severe sleep apnea were associated with increased Charlson Comorbidity Indices, compared to mild sleep apnea (P = .01). Sleep apnea severity was not associated with a composite outcome of mechanical ventilation, intensive care unit admission, and death.

Conclusion. Sleep apnea severity was associated with the Charlson Comorbidity Index and may be a risk factor for COVID-19 hospitalization. We found no evidence that sleep apnea severity among hospitalized patients was associated with a composite outcome of mechanical ventilation, intensive care unit admission, and death.

Keywords

COVID-19, SARS-CoV-2, obstructive sleep apnea

Received March 16, 2021; accepted April 11, 2021.

As the coronavirus disease 2019 (COVID-19) pandemic continues to spread worldwide, it is crucial to identify conditions that put individuals at increased risk for severe disease. Obesity, asthma, diabetes, hypertension, cardiac disease, and pulmonary disease are among the conditions that have been identified to increase risk.[1] A potential missing link connecting these conditions is obstructive sleep apnea. Obstructive sleep apnea is the most common sleeping disorder, affecting approximately 20% of the US population.[2] Sleep apnea is characterized by interruptions or reductions in airflow due to upper airway resistance. The association between sleep apnea and COVID-19 is anticipated, as previous studies have shown sleep apnea increases risk of community-acquired pneumonia[3] as well as perioperative acute respiratory distress syndrome (ARDS).[4]

Many mechanisms have been proposed for how sleep apnea exacerbates COVID-19–related respiratory failure, as well as cardiovascular manifestations. Sleep apnea—with comorbid obesity—may contribute to respiratory failure by exacerbating hypoxemia and the cytokine storm in patients with COVID-19 pneumonia.[1] Moreover, sleep apnea may increase risk of cardiovascular complications from COVID-19, such as arrhythmias, cardiac ischemia, and hypercoagulability.[5]

An important question is: how does sleep apnea influence COVID-19 disease severity? Recent studies[6,7] suggest that sleep apnea diagnosis was a risk factor for infection, hospital admission, mechanical ventilation, and mortality from COVID-19. An important, yet missing, piece of information is how COVID-19 disease severity differs in patients with mild, moderate, and severe sleep apnea. The objective of this study was to characterize the relationship between severity of sleep apnea and COVID-19 disease severity among patients who tested positive for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).

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Methods

Study Population and Setting

We conducted a single-center retrospective cohort study of adult patients with a prior diagnosis of obstructive sleep apnea who tested positive for SARS-CoV-2 on quantitative polymerase chain reaction assay (qPCR) and between March 16, 2020, and May 26, 2020 at Montefiore Medical Center. Montefiore Medical Center is the largest health care provider in the Bronx, with locations in Westchester County and lower Hudson Valley.[8] This study received institutional review board approval from the Albert Einstein College of Medicine and Montefiore Medical Center before medical record review and data collection.

Exposure and Outcome Variables

Clinical data was extracted from the electronic medical record (EMR). The data set consisted of patients over 18 years old who met the criteria of (1) an active diagnosis code of obstructive sleep apnea (G47.3, G47.30, G47.33, R06.81) in the past 2 years and (2) a positive SARS-CoV-2 qPCR test at our institution, including inpatient and outpatient facilities, between March 16, 2020, and May 26, 2020.

The data extraction included the following: demographic characteristics (age, sex, patient-reported race and ethnic group, and ZIP code), body mass index (BMI) recorded within the previous 12 months, chronic conditions documented through diagnosis codes, date of positive SARS-CoV-2 qPCR, date of COVID-19–related hospital admission and discharge, date of admission and discharge from the intensive care unit (ICU), mechanical ventilation status and duration, and mortality.

Obstructive Sleep Apnea Status

Sleep apnea severity and continuous positive airway pressure (CPAP) compliance data were abstracted from physician documentation in the patient chart. In the absence of device-documented CPAP compliance data in the EMR, we used the most recent physician note citing patient-reported CPAP compliance. If a diagnostic polysomnogram was recorded, apnea-hypopnea index was used to classify sleep apnea severity as mild ($5 \leq \text{AHI} < 15$ events/h), moderate ($15 \leq \text{AHI} < 30$ events/h), and severe ($\text{AHI} \geq 30$ events/h).

COVID-19 Hospitalization and Severe Illness

Among all patients diagnosed with COVID-19, at both inpatient and outpatient centers, we investigated outcomes including admission to hospital, length of hospitalization, mechanical ventilation status, admission to the ICU, and mortality. Data extraction included dates of outcomes including date of first positive SARS-CoV-2 qPCR. Patients who received testing in the emergency department and were not admitted were assigned to the outpatient group. Patients who received outpatient testing and were later admitted for COVID-19 were included in the inpatient group. Dates of multiple hospitalizations were added together if readmission was due to active COVID-19 infection. Patients admitted for reasons definitively unrelated to COVID-19 and incidentally found to have a positive SARS-CoV-2 qPCR were excluded from our study. ICU admission was defined by intensive care accommodation status. All outcomes were defined within the time from data extraction, except for mortality, which was completed July 15, 2020.

Severe illness was defined as composite outcome of ICU admission, mechanical ventilation, or death.

Comorbidities

Comorbidities were extracted using the available *International Classification of Diseases* (*ICD;* 10th edition). We focused on 6 binary chronic conditions that have been shown to increase risk of COVID-19: cardiac and vascular disease,[9] chronic pulmonary disease,[10] diabetes mellitus,[11] hypertension,[12] and any malignancy or metastatic solid tumor, excluding malignant neoplasm of the skin[13] (see Appendix for list of *ICD-10* codes). In addition, the Charlson Comorbidity Index, indicating degree of burden of illness, was calculated for each patient. The Charlson Comorbidity Index incorporates 17 comorbidities, with subcategories for diabetes and liver disease. Comorbidities range from 1 to 6 points and are summated to a total Charlson Comorbidity Index. The total Charlson Comorbidity Index is predictive of 1-year mortality.[14]

Defining Race/Ethnicity, Socioeconomic Status, and Other Covariates

Variables such as sex, race, ethnicity, home address, BMI, and age were extracted from the electronic health record. Socioeconomic status was computed using 6 variables representing dimension of wealth and income from census data to compare individuals against the New York state average.

Statistical Methods

Demographic and clinical characteristics that were continuous variables were summarized by computing the mean and standard deviation or median and interquartile range as appropriate, and compared between groups using the 2-sample t test or Mann-Whitney U test depending on the distribution of the data. Categorical variables were summarized by computing frequencies and proportions, as well as compared between groups with the χ^2 test.

Logistic regression models were also fit to the data to estimate the unadjusted and adjusted odds ratios and 95% confidence intervals for admission to an inpatient unit. The main predictor variable of interest was sleep apnea severity. The adjusted regression model included the following variables as potential confounders: age, sex, socioeconomic status, Charlson Comorbidity Index, diabetes, hypertension, and cardiac or vascular disease.

A post hoc 1-way analysis of variance (ANOVA) followed by Dunnett's multiple comparisons test was used to determine if the Charlson Comorbidity Index differed by severity category of sleep apnea.

A 2-sided α of less than .05 was considered statistically significant. All statistical analyses were performed using GraphPad Prism (version 8.00 for Mac; GraphPad Software).

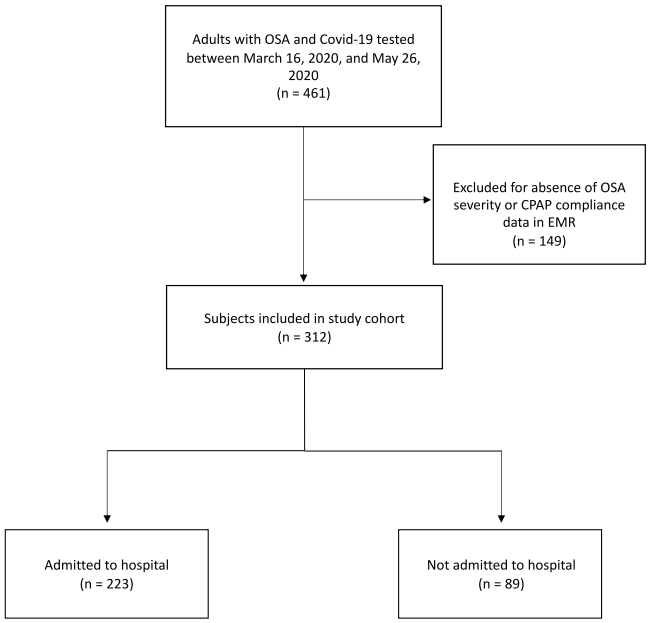

Figure 1. Flowchart of the study.

Results

A total of 461 patients had a positive SARS-CoV-2 qPCR test at our institution and a prior diagnosis of sleep apnea; 149 patients had no record of sleep apnea severity and compliance data in their EMR and were excluded from further analysis. Of the remaining 312 patients, 123 patients had only compliance data, 15 patients had only severity data, and 173 patients had both (**Figure 1**).

At the time of analysis, all 223 inpatients were discharged. The cohort was 51% female, the mean (SD) age was 59.3 (3.77) years, and the mean (SD) BMI was 36.84 (8.73) kg/m^2.

Predictors of Hospitalization

Patients hospitalized for COVID-19 were more likely to have severe sleep apnea compared to those not hospitalized (61.6% vs 36.7%; P = .003; **Table 1**). Hospitalized patients were also older (61.7 vs 53.4 years; $P < .001$) and more likely to be male (53.5% vs 38.2%, $P = .02$) compared to nonhospitalized patients. Comorbid conditions also differed significantly between the groups. Hospitalized patients had higher mean scores on the Charlson Comorbidity Index and a higher prevalence of diabetes, hypertension, and cardiac or vascular disease. In contrast, CPAP compliance, BMI, ethnicity, race, and socioeconomic status were not significantly different between admitted and nonadmitted patients. Of note, the rate of undocumented sleep apnea severity in the EMR was significantly higher in the admitted group (45.7% vs 23.6%; $P = .0002$).

A univariate logistic regression model showed that moderate and severe sleep apnea were associated with higher odds of hospitalization compared to mild sleep apnea, and results were statistically significant (odds ratio [OR] = 2.69 for moderate vs mild, 95% CI, 1.15-6.52; OR = 4.29 for severe vs mild, 95% CI, 2.09-9.02; **Table 2**).

A multivariable logistic regression analysis, which included variables deemed to be potential confounders, showed that moderate and severe sleep apnea were associated with higher odds of hospitalization compared to mild sleep apnea, but the results were not statistically significant (adjusted OR [aOR] = 2.31 for moderate vs mild, 95% CI, 0.83-6.67; aOR = 1.83 for severe vs mild, 95% CI, 0.72-4.64; **Table 3**). In this model, the only significant independent predictors of hospitalization were age (aOR = 1.03 per 1-year increase, 95% CI, 1.03-1.07), sex (aOR = 0.39 for female vs male, 95% CI, 0.17-0.86), and Charlson Comorbidity Index (aOR 1.45 per unit increase in score, 95% CI, 1.19-1.81).

A 1-way analysis of variance (ANOVA) showed a significant association of Charlson Comorbidity Index values and sleep apnea severity. Mean Charlson Comorbidity Index increased with increasing sleep apnea severity (**Table 4**).

Predictors of Critical Illness in Hospitalized Patients

Of the 223 patients in the admitted cohort, 82 patients (36.7%) experienced critical illness, defined by admission to the ICU (22.4%), mechanical ventilation (25.1%), or death (25.1%). Of patients with critical illness, 56 (68.3%) died and 26 (31.7%) were discharged alive after mechanical ventilation or admission to the ICU. The median (IQR) length of hospital stay was 7 (4-12) days.

Sleep apnea severity and CPAP compliance were not significantly different among patients based on composite outcomes of mortality, mechanical ventilation status, and ICU admission (**Table 5**). Patients with critical illness had higher median (IQR) Charlson Comorbidity Index (3.5 [2-5] vs 2 [1-5], $P = .0125$).

Discussion

This is the first study to analyze the relationship between severity of sleep apnea and COVID-19 disease. Our results suggest a dose-response relationship in that patients with moderate and severe sleep apnea have a higher risk of hospital admission from COVID-19 compared to those with mild sleep apnea. This relationship was attenuated when adjusted for covariates, notably the Charlson Comorbidity Index, which was the strongest independent predictor of hospital admission. Among hospitalized patients, sleep apnea severity and CPAP compliance were not predictive of critical illness. In a post hoc analysis, we found that sleep apnea severity was associated with degree of comorbid illness burden, measured by the Charlson Comorbidity Index.

Sleep apnea and COVID-19 share several prominent risk factors, such as age, obesity, diabetes, and hypertension.[15,16] Many mechanisms have been proposed to explain the physiologic connection. Sleep apnea may exacerbate hypoxia[1], immunologic dysregulation,[17] hypercoagulability,[18,19] arrhythmias,[5] and microaspiration[6] in patients with COVID-19 infection.

Several studies have sought to investigate the relationship between sleep apnea and COVID-19 disease. A study based in New England found that sleep apnea was associated with COVID-19–related death, hospitalization, ventilator use, and

Table 1. Baseline Characteristics of 312 Patients Tested Positive for Severe Acute Respiratory Syndrome Coronavirus 2 by May 26, 2020.

Characteristic	Admission		*P* value
	Yes (n = 223)	No (n = 89)	
Sleep apnea severity, if documented, No. (%)			.0003
Mild	20 (16.6)	29 (42.6)	
Moderate	26 (21.6)	14 (20.5)	
Severe	74 (61.6)	25 (36.7)	
Undocumented sleep apnea severity, No. (%)	103 (45.7%)	21 (23.6%)	.0002
CPAP compliance if documented, No. (%)			.60
Noncompliant/refused	112 (52.6)	47 (56)	
Compliant	101 (47.4)	37 (34)	
Undocumented CPAP compliance, No. (%)	10 (4.9%)	5 (5.6%)	.67
Age, mean (SD), y	61.66 (13.42)	53.38 (12.9)	.0001
Sex, No. (%)			.02
Male	119 (53.5)	34 (38.2)	
Female	104 (46.5)	55 (61.8)	
BMI, mean (SD), kg/m^2	37.28 (9.01)	35.75 (7.918)	.16
Ethnicity, No. (%)			.42
Spanish/Hispanic/Latino	88 (39.5)	42 (47.2)	
Not Spanish/Hispanic/Latino	118 (52.9)	40 (44.9)	
Unavailable/declined/unknown	17 (7.6)	7 (7.9)	
Race, No. (%)			.22
White	29 (13.0)	14 (15.7)	
Black	98 (43.9)	28 (31.5)	
Asian	2 (0.9)	3 (3.4)	
American Indian or Alaska Native	2 (0.9)	0 (0)	
Other Pacific Islander	1 (0.4)	0 (0)	
Other	78 (35.0)	40 (44.9)	
Unavailable/declined/unknown	13 (5.8)	4 (4.9)	
Socioeconomic status, mean (SD)	–3.117 (2.635)	–2.585 (2.974)	.12
Charlson Comorbidity Index, median (IQR)	3 (1-5)	0 (0-0.5)	<.0001
Diabetes, No. (%)			.04
No	102 (45.7)	52 (58.4)	
Yes	121 (54.3)	37 (41.6)	
Hypertension, No. (%)			.0004
No	37 (16.6)	31 (34.8)	
Yes	186 (83.4)	58 (65.2)	
Pulmonary disease, No. (%)			.20
No	100 (44.8)	47 (52.8)	
Yes	123 (55.2)	42 (47.2)	
Cardiac or vascular disease, No. (%)			.02
No	76 (34.1)	43 (48.3)	
Yes	147 (65.9)	46 (51.7)	
Malignancy, No. (%)			.37
No	210 (94.2)	86 (96.6)	
Yes	13 (5.8)	3 (3.4)	

Abbreviations: BMI, body mass index; CPAP, continuous positive airway pressure; IQR, interquartile range.

ICU admission.[6] Similarly, a study based in Chicago, Illinois, found that patients with sleep apnea had approximately an 8-fold greater risk for COVID-19 infection and approximately double the risk of COVID-19–related respiratory failure.[7] The Coronavirus SARS-CoV-2 and Diabetes Outcomes (CORONADO) study in France found that in hospitalized patients with diabetes and COVID-19, sleep apnea was associated with increased risk of early death.[20]

These studies support our hypothesis that sleep apnea is a risk factor for COVID-19 severe illness.

Table 2. Odds Ratios Associating Sleep Apnea With Coronavirus Disease 2019 Hospitalization: Unadjusted Model.

Sleep apnea severity	Odds ratio	95% CI	*P* value
Mild	1 (reference)		
Moderate	2.69	(1.15-6.52)	.03
Severe	4.29	(2.09-9.02)	<.0001

Table 3. Odds Ratios Associating Sleep Apnea With Coronavirus Disease 2019 Hospitalization: Adjusted Model.

Characteristic	Adjusted odds ratio	95% CI	*P* value
Sleep apnea severity			
Mild	1 (reference)		
Moderate	2.31	(0.83-6.67)	.11
Severe	1.83	(0.72-4.64)	.20
Socioeconomic status	1.823	(0.79-1.01)	.06
Charlson Comorbidity Index	1.45	(1.19-1.81)	.0006
Age	1.033	(1.003-1.067)	.04
Sex			
Male	1 (reference)		
Female	0.39	(0.17-0.86)	.02
Diabetes			
No	1 (reference)		
Yes	1.11	(0.52-2.36)	.79
Hypertension			
No	1 (reference)		
Yes	1.091	(0.42-2.76)	.85
Cardiac or vascular disease			
No	1 (reference)		
Yes	1.20	(0.54-2.62)	.65

Table 4. Comparison of Charlson Comorbidity Index Across Sleep Apnea Severity Among All Patients.

	Sleep apnea severity			
Characteristic	Mild (n = 49)	Moderate (n = 40)	Severe (n = 99)	*P* value[a]
Charlson Comorbidity Index, mean (SD)	1.31 (1.93)	2.50 (2.96)	2.73 (2.74)	.01

[a]By analysis of variance test. The multiple comparison adjusted *P* value with Dunnett's method with "mild" as the control is .06 and .004 for "moderate" and "severe" sleep apnea, respectively.

Nonetheless, the absence of sleep apnea severity data limits interpretation of their results. This study is the first to specifically investigate severity of sleep apnea and its relationship to COVID-19 outcomes.

Hospital admission is an important outcome for infection, as only 4.6% of adult patients with COVID-19 ultimately get admitted.[21] In a univariate analysis, we found patients with moderate and severe sleep apnea were more likely to be admitted to the hospital with COVID-19 as compared to those with mild sleep apnea. This association was reduced after adjusting for covariates, including the Charlson Comorbidity Index. The Charlson Comorbidity Index is a well-validated instrument that uses 17 weighted comorbidities to predict 1-year all-cause mortality.[14] In an adjusted model, we found the Charlson Comorbidity Index to be the strongest independent predictor of COVID-19 hospital admission in patients with varying degrees of sleep apnea. This is supported by other studies that also found the Charlson Comorbidity Index to be predictive of COVID-19 illness severity.[22,23] Although the Charlson Comorbidity Index is undoubtably an important risk factor for severe COVID-19 illness, it is important to consider the complicated relationship between the index and sleep apnea severity.

Table 5. Characteristics of 223 Patients Admitted for Coronavirus Disease 2019 by May 26, 2020.

Characteristic	Composite outcome		*P* value
	Yes (n = 82)	No (n = 141)	
Sleep apnea severity, if documented, No. (%)			.91
Mild	7 (16.7)	13 (16.7)	
Moderate	10 (23.8)	16 (20.5)	
Severe	25 (59.5)	49 (62.8)	
Undocumented sleep apnea severity, No. (%)	37 (45.1%)	63 (44.7%)	.95
CPAP compliance, if documented, No. (%)			.19
Noncompliant/refused	37 (45.1)	75 (53.2)	
Compliant	42 (54.9)	59 (46.8)	
Undocumented CPAP compliance, No. (%)	3 (3.7%)	7 (4.1%)	.87
Age, mean (SD), y	63.17 (13.71)	60.79 (13.21)	.69
Sex, No. (%)			.08
Male	50 (61.0)	69 (48.9)	
Female	32 (39.0)	72 (51.1)	
BMI, mean (SD), kg/m^2	37.13 (9.25)	37.37 (8.909)	.85
Ethnicity, No. (%)			.23
Spanish/Hispanic/Latino	29 (35.4)	59 (41.8)	
Not Spanish/Hispanic/Latino	49 (59.8)	69 (48.9)	
Unavailable/declined/unknown	4 (4.9)	13 (9.2)	
Race, No. (%)			.86
White	12 (14.6)	17 (12.1)	
Black	37 (45.1)	61 (43.3)	
Asian	1 (1.2)	1 (0.7)	
American Indian or Alaska Native	0	2 (1.4)	
Other Pacific Islander	0	1 (0.7)	
Other	26 (31.7)	52 (36.9)	
Unavailable/declined/unknown	6 (7.3)	7 (5.0)	
Socioeconomic status, mean (SD)	–2.784 (2.541)	–3.314 (2.679)	.15
Charlson Comorbidity Index, median (IQR)	3.5 (2–5)	2 (1–5)	.01
Diabetes, No. (%)			.33
No	41 (50)	61 (43.3)	
Yes	41 (50)	80 (56.7)	
Hypertension, No. (%)			.82
No	13 (15.9)	24 (17.0)	
Yes	69 (84.1)	117 (83.0)	
Pulmonary disease, No. (%)			.29
No	33 (40.2)	67 (47.5)	
Yes	49 (59.8)	74 (52.5)	
Cardiac or vascular disease, No. (%)			.57
No	26 (31.7)	50 (35.5)	
Yes	56 (68.3)	91 (64.5)	
Malignancy, No. (%)			.64
No	78 (95.1)	132 (93.6)	
Yes	4 (4.9)	9 (6.4)	

Abbreviations: BMI, body mass index; CPAP, continuous positive airway pressure; IQR, interquartile range.

As a post hoc analysis, we identified a positive correlation between severity of sleep apnea and the Charlson Comorbidity Index. It is largely recognized that sleep apnea contributes to increased comorbidity and mortality.[24] Although previous studies have found a positive association between chronic comorbidities and sleep apnea severity,[25] this study is the first to do so with the Charlson Comorbidity Index. This finding suggests sleep apnea severity is a marker for general health and further underscores the importance of screening, especially in high-risk populations.

Nevertheless, the causality and directionality of the relationship between sleep apnea and the Charlson Comorbidity Index remain unclear, making it difficult to determine their independent influences on COVID-19 illness severity. In the future, large-scale studies are necessary to delineate these interrelated disease processes.

An all-cause mortality rate of 25.1% among admitted patients in our study was higher than in other large-scale studies in New York City.[26] Interestingly, we found no significant correlation between sleep apnea severity or CPAP compliance and composite outcome of ICU admission, mechanical ventilation, or mortality. This finding may be attributed to the overall poor health of our inpatient population, with a median Charlson Comorbidity Index of 3. It is plausible that in individuals with higher comorbid illness burden, the impact of sleep apnea in COVID-19 disease severity is negligible. Furthermore, inpatient management changed dramatically within the first months of the pandemic, and disparities in care may complicate the distinction of risk factors associated with poor outcomes.

This study has several limitations. Most importantly, data on patients' CPAP compliance and sleep apnea severity were imperfect due to inaccuracies of chart review. As studies found sleep apnea to be a risk factor for severe COVID-19 illness, we expected some level of protection in CPAP-compliant patients. Our finding that CPAP compliance was unrelated to illness severity is likely attributed to unreliable reporting in the EMR. CPAP compliance is objectively defined as a minimum of 4 hours a night for 70% of nights. Studies about CPAP efficacy are largely based on this definition, and patients who fall short may not achieve full benefits. Furthermore, patients are likely unaware of this definition and may consider themselves compliant despite suboptimal usage of the device. Patients have also been found to overestimate their CPAP usage.[27] We presume that these factors played in a role in our CPAP compliance findings. Future studies should rely on device-recorded CPAP compliance data to accurately study the relationship between CPAP compliance and COVID-19 illness severity.

Another important limitation to consider is the rate of undocumented sleep apnea severity, which differed significantly between the inpatient group and outpatient group. Missing data may be distributed disproportionately, which would implicate the findings of the study. In addition, documented sleep apnea severity may be inaccurate or outdated. Sleep apnea severity was abstracted from the most recent polysomnogram or physician note, which may differ from severity at the time of COVID-19 infection. In particular, sleep apnea severity may be underestimated as severity increases with age.[28]

Selection bias, specifically in the outpatient cohort, is another major limitation of this study. Our hospital system was not the sole provider of COVID-19 testing in the Bronx. The City of New York established several outpatient COVID-19 testing sites, and there may be noteworthy differences in patient population among testing sites. Furthermore, patients tested in the outpatient cohort may have been later admitted to another hospital without our knowledge. As Montefiore is the largest health care provider in the Bronx, we presume this effect to be minimal.

The absence of a control group without sleep apnea is another limitation of this study. This group was excluded as we believe our patient population has a high proportion of undiagnosed sleep apnea. The Bronx has the highest rate of obesity (33.6%) and diabetes (12.4%) compared to other boroughs in New York City.[29,30] In patients with obesity and diabetes, the risk of sleep apnea is increased significantly, with 1 study citing an 86% prevalence of sleep apnea in patients with both conditions.[31] As obesity and diabetes are also risk factors for COVID-19 severity, patients with these conditions were already overrepresented in our inpatient population. For these reasons, a control group without sleep apnea was excluded from this report.

Conclusion

Notwithstanding these limitations, this study suggests a dose-response relationship in that patients with more severe sleep apnea have increased risk of hospitalization from COVID-19 infection. In addition, this study suggests that sleep apnea severity is positively correlated with the Charlson Comorbidity Index. We strongly recommend increased sleep apnea screening as it relates to overall morbidity and mortality and may be a predictor of COVID-19 disease severity. Furthermore, the Charlson Comorbidity Index should be considered as an assessment tool for risk stratification in patients with COVID-19. Future research should focus on device-documented CPAP compliance to understand how treatment of disease affects COVID-19 outcomes.

Author Contributions

Meryl B. Kravitz, study design, data analysis, manuscript preparation, and final approval; **Elizabeth Yakubova**, data collection, manuscript revision, and final approval; **Nick Yu**, data collection, manuscript revision, and final approval; **Steven Y. Park**, study design, manuscript revision, and final approval.

Disclosures

Competing interests: None.

Sponsorships: None.

Funding source: None.

Supplemental Material

Additional supporting information is available at http://journals.sagepub.com/doi/suppl/10.1177/2473974X211016283

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