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SCIENTIFIC INVESTIGATIONS

Obstructive sleep apnea and COVID-19 clinical outcomes during hospitalization: a cohort study

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Study Objectives: Obstructive sleep apnea (OSA) is an extremely common sleep disorder. A potential association between OSA and coronavirus disease 2019 (COVID-19) severity has been proposed on the basis of similar comorbid medical conditions associated with both OSA and COVID-19.

Methods: We performed a retrospective review of 1,738 patients who were hospitalized with COVID-19 between March and October of 2020. Patients were classified based on the presence or absence of OSA diagnosis based upon the *International Classification of Diseases* (ICD; codes G47.33 and U07.1 for OSA and COVID-19, respectively). Other data were collected, including demographics, body mass index, and comorbid conditions. COVID-19 severity was compared between groups using the quick COVID-19 severity index.

Results: Quick COVID-19 severity index scores were higher in patients with OSA compared with those without OSA. However, the prevalence rates of type 2 diabetes ($P < .0001$), coronary artery disease ($P < .0001$), congestive heart failure ($P < .0001$), and chronic obstructive pulmonary diseases ($P < .0001$) were also significantly greater in the OSA group. Unadjusted models revealed higher risk of intensive care unit admission in patients with COVID-19 and OSA. However, such an association was attenuated and became nonsignificant after adjusting for age, sex, body mass index, and comorbid disease.

Conclusions: In our study, OSA does not appear to be an independent risk factor for worse COVID-19 outcomes in hospitalized patients. Further studies with larger sample sizes are needed to delineate the potential role of OSA in determining outcomes in hospitalized patients with COVID-19.

Keywords: obstructive sleep apnea, COVID-19, severity, hospitalization, comorbid conditions

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BRIEF SUMMARY

Current Knowledge/Study Rationale: The potential role of obstructive sleep apnea (OSA) on adverse consequences of COVID-19 has been proposed and the studies conducted in this regard are scarce. This study examines whether OSA is an independent risk factor for worse COVID-19 clinical outcome (mortality, length of hospital stay, intubation, and intensive care unit admission) in hospitalized patients.

Study Impact: OSA was not an independent risk factor for worse COVID-19 outcomes in hospitalized patients, but it is still reasonable to recommend screening for OSA in patients who acquire COVID-19 infection. This is based on the biological plausibility linking OSA to COVID-19–related comorbid conditions, which had been shown (in our study and other studies) to be the major determinant of COVID-19 outcomes.

INTRODUCTION

In December 2019, a novel coronavirus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was described in Wuhan, in the Hubei province of China, causing a pandemic that has affected close to 100 million and killed over 2 million people worldwide, with almost 25% of the deaths occurring in the United States.[1] The clinical presentation varies from asymptomatic to severe illness, characterized by acute respiratory distress syndrome and multiorgan dysfunction, and ultimately death.[2,3] Many risk factors have been identified and linked to the severity of coronavirus disease 2019 (COVID-19), including age > 60 years and comorbid diseases (such as obesity, hypertension, and diabetes mellitus [DM]), leukocytosis, and lymphopenia.[4]

Obstructive sleep apnea (OSA) is a common sleep disorder, characterized by repetitive episodes of collapse of the pharyngeal airway, which has been independently associated with many comorbid diseases of the cardiovascular, metabolic, and central nervous systems.[5] A potential association between OSA and COVID-19 severity has been proposed,[6,7] and is based on the similarities in the pathophysiology between these entities, as well as mutually enhancing mechanisms that foster both the risk of infection and the immune response to the virus.[8] OSA, which is characterized by intermittent hypoxia and sleep fragmentation, elicits a cascade of chronic low-grade systemic inflammatory processes involving oxidative stress secondary to excessive generation and propagation of reactive oxygen species, and induction of transcriptional pathways underlying many proinflammatory

mediators and inflammatory cytokines (eg, interleukin [IL]-6, tumor necrosis factor α [TNF-α], C-reactive protein [CRP], IL-1), ultimately resulting in systemic inflammation.[9] Similar to COVID-19, OSA displays substantial heterogeneity in the magnitude of the inflammatory response.

In this study we examined the role of OSA as an independent risk factor for worsening clinical outcome in hospitalized patients testing positive for SARS-CoV-2.

METHODS

Design overview

We implemented a cohort design to retrospectively review 1,738 charts of patients who were hospitalized at Banner University Medical Center in both the Tucson and Phoenix campuses at the University of Arizona between March 1, 2020, and October 31, 2020. The study was approved by the University of Arizona Scientific Research Review Committee (IRB protocol number 2012280300). Patients were assigned to 2 groups based on the presence or absence of OSA diagnosis after searching the electronic medical records (EMRs) of specific *International Classification of Diseases*, *10th Revision* (ICD-10) codes (G47.33 for OSA and U07.1 for COVID-19 positive status or COVID-19 pneumonia). The G47.33 code was required to be associated with 1 of the following encounters: primary care physician documentation of having seen a copy of the sleep study report that was not scanned into the EMR, patient self-report of OSA diagnosis to physician, or the physician indicated a high degree of clinical suspicion of OSA based on the **S**noring, **T**iredness, **O**bserved apnea, high B**P**, **B**MI, **A**ge, **N**eck circumference, and male **G**ender (STOP-BANG) questionnaire. Unfortunately, formal sleep study reports were not always available for those cases assigned to the OSA group. Accordingly, the diagnosis of OSA was based on the ICD-10 code and did not include a formal review of sleep study reports. All patients included tested positive for SARS-CoV-2 as per a polymerase chain reaction (PCR)–based assay and were ≥ 18 and ≤ 100 years old. Exclusion criteria included participants younger than the age of 18 or older than the age of 100, patients with possible COVID-19 infection without PCR testing or those with a negative test, patients with an ICD-10 diagnosis of central sleep apnea (G47.31), participants who presented to outpatient clinics, participants who presented to the emergency department without inpatient admission, and duplicate patient records. There were a small number of instances that were attributed to the ICD-10 code of G47.30, which reflects "sleep apnea." Since this code is vague and might include central sleep apnea, we opted to exclude any patient who had only this ICD-10 code.

The initial search yielded a total of 4,065 potential cases. **Figure 1** illustrates the study flow diagram. Ultimately, a total of 1,738 patients were included in the final analysis (139 patients in the OSA group and 1,599 patients in the non-OSA group).

Data collection

In addition to OSA and COVID-19 diagnoses, other data were collected from the EMR, including demographics (age, sex, race, and ethnicity), body mass index (BMI; kg/m^2), comorbid diseases (including hypertension, DM, coronary artery disease, congestive heart failure, cerebrovascular disease, cancer, chronic kidney disease, and chronic obstructive pulmonary disease). Comorbid diseases were listed by the primary care physician in the patient's problem list. We also collected the patients' most common presenting admission symptoms (eg, fever, cough, dyspnea, nausea/vomiting, and diarrhea). Laboratory results were collected and included white blood cell count, hemoglobin, platelet count, lymphocyte count, CRP, and *d*-dimer levels. Clinical symptoms and laboratory values were captured from the first visit encounter, usually from the emergency room (ER) visit note or the admission history and physical examination note. Some laboratory values were missing and the numbers of patients who lacked these values are identified in **Table 1**. Finally, we compared COVID-19 severity in both groups using the quick COVID-19 severity index (qCSI) (**Table 2**).

Variable definitions

The qCSI includes 3 elements at the time of admission: respiratory rate, oxygen saturation (SpO_2), and supplemental oxygen flow rate (O_2 in L/minute). The components, scoring, and interpretation of the qCSI are illustrated in detail in **Table 3**.[10] The oxygen flow rate was obtained from the ER or admission note. All patients intubated at outside hospitals and transferred to Banner University Medical Centers (in Phoenix and Tucson) were included under the high-risk category. Similarly, all patients started on continuous positive airway pressure, bilevel positive airway pressure, 100% non-rebreather mask, Venturi masks, or high-flow nasal cannula therapy were included under the high-risk category.[11]

Statistical analyses

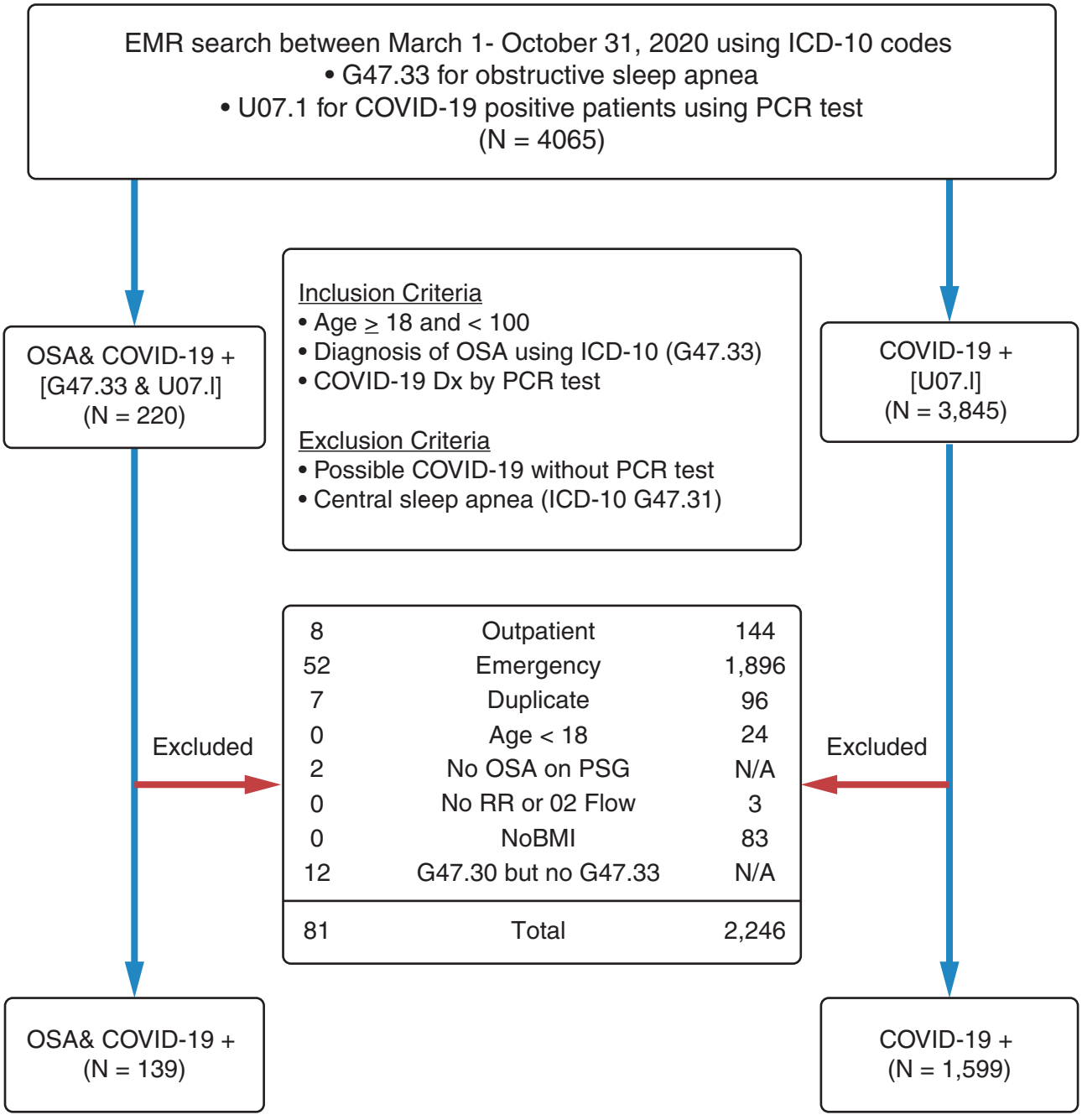
Continuous variables are reported as median and interquartile ranges. Categorical variables are reported as counts and percentages. All categorical variables were compared using Fisher's exact test or chi-square test, and continuous variables were compared using the nonparametric Wilcoxon rank sum test. Odds ratios (ORs) and corresponding 95% confidence intervals (CIs) were calculated using logistic regression models to evaluate risk factors for intubation, intensive care unit (ICU) admission, and in-hospital mortality. Multiple linear regression was used to determine the factors associated with hospital length of stay. The selection of variables for the regression analysis was based on known risk factors for OSA and COVID-19 pneumonia severity markers. No imputation was made for missing data and those individuals were excluded from the study. Analysis was performed with STATA software, version 15.1 (StataCorp LLC, College Station, TX). For all the statistical analyses, a 2-tailed $P < .05$ was considered significant.

RESULTS

Demographic data

The median age in the OSA and non-OSA groups was 58.3 and 57.5 years, respectively, and included a similar proportion of male participants (53% in the OSA group compared with 49% in the non-OSA group). There was a high proportion of Hispanic patients in our study (45% in the OSA group and 49% in the

Figure 1—Study flow diagram.



BMI = body mass index, COVID-19 = coronavirus disease 2019, Dx = diagnosis, EMR = electronic medical record, ICD-10 = *International Classification of Diseases, 10th Revision*, PSG = polysomnography, OSA = obstructive sleep apnea, PCR = polymerase chain reaction, RR = respiratory rate.

non-OSA group). The proportion of patients in other race/ethnicity groups is shown in **Table 1**. As expected, BMI was significantly greater in the OSA group (compared with the non-OSA group (**Table 1**) ($P < .0001$).

Comorbid diseases and COVID-19 severity

Some comorbid diseases (such as hypertension, cerebrovascular disease, and cancer) were similarly distributed in both groups (**Table 1**). However, the prevalence rates of type 2 DM ($P < .0001$), coronary artery disease ($P < .0001$), congestive heart failure ($P < .0001$), and chronic obstructive pulmonary disease ($P < .0001$) were significantly higher in the OSA group (**Table 1**). Fever, dyspnea, and nausea/vomiting were more frequently recorded in the OSA than in the non-OSA group (**Table 1**). Other symptoms, such as cough and diarrhea, were not different between the 2 groups. Laboratory values were also distributed similarly in both groups, except for increased frequency of leukopenia and

Table 1—Demographic data, presenting symptoms, laboratory workup, and comorbid diseases in both groups.

	OSA Sample (n = 139)	Non-OSA Sample (n = 1,599)	*P*
Age,† y	58.3 (43.4–67.5)	57.5 (41.8–68.8)	.86
Sex, male, n (%)	74 (53)	777 (49)	.29
Race/ethnic group, n (%)			.74
Hispanic	62 (45)	789 (49)	
White non-Hispanic	46 (33)	451 (28)	
Black	13 (9)	117 (7)	
Asian/Pacific Islander	1 (0.7)	16 (1)	
Native American	15 (11)	188 (12)	
Other/multiple	1 (0.7)	29 (2)	
Unknown	1 (0.7)	10 (0.5)	
BMI,† kg/m^2	40.5 (34.0–47.9)	30.1 (25.9–35.7)	< .0001
Comorbid diseases, n (%)			
Hypertension	64 (46)	632 (39)	.13
Diabetes mellitus	88 (63)	701 (44)	< .0001
Coronary artery disease	40 (29)	246 (15)	< .0001
COPD	34 (24)	163 (10)	< .0001
Chronic kidney disease	47 (34)	317 (20)	< .0001
Cancer	12 (9)	139 (9)	.40
Cerebrovascular disease	13 (9)	162 (10)	.59
Congestive heart failure	45 (32)	240 (15)	< .0001
Symptoms, n (%)			
Fever††	56 (46)	530 (37)	.05
Cough	80 (58)	875 (55)	.52
Dyspnea	88 (63)	830 (52)	.009
Nausea/vomiting	27 (19)	202 (13)	.02
Diarrhea	10 (7)	138 (9)	.56
Laboratory values†			
WBC, cells/mm^3	6.8 (5–9.6)	7.7 (5.6–10.8)	.003
Lymphocytes, $\times$1000/μL	1.0 (0.6–1.4)	1.0 (0.6–1.4)	.83
Hemoglobin, g/dL	12.9 (11–14.2)	13 (11.2–14.5)	.46
Platelets, $\times$1000/mm^3	204 (155–279)	224 (169–297)	.03
CRP, mg/L	89.3* (36.7–149.2)	89.8** (38.2–169.5)	.57
D-Dimer, ng/mL	1,023*** (635–1,773)	1,105**** (630–2,073)	.38

†Values represent median and interquartile range. ††Fever defined as temperature > 100.4°F. Sixteen patients had missing data from the OSA group and 150 from the non-OSA group. *16 values were N/A and excluded from analysis. **278 values were N/A and excluded from analysis. ***14 values were N/A and excluded from analysis. ****385 values were N/A and excluded from analysis. BMI = body mass index, COPD = chronic obstructive pulmonary disease, CRP = C-reactive protein, N/A = not available, OSA = obstructive sleep apnea, WBC = white blood cells.

Table 2—COVID-19 severity at the time of admission in both groups.

	OSA (n = 139)	Non-OSA (n = 1,599)	*P*
Mild	30 (22)	535 (33)	.02
Moderate	38 (27)	360 (22)	
Severe	71 (51)	706 (44)	

Values are n (%). COVID-19 severity calculated using the qCSI. COVID-19 = coronavirus disease 2019, OSA = obstructive sleep apnea, qCSI = quick COVID-19 severity index.

thrombocytopenia in the OSA group compared with the non-OSA group (Table 1). COVID-19 severity comparisons revealed significantly more severe COVID-19 cases in the OSA group (51% vs 44% in the non-OSA group; $P = .02$) (Table 4).

OSA impact on COVID-19 hospital metrics

To assess the impact of OSA on hospitalized patients, 4 major outcomes were included, namely, (1) length of hospital stay, (2) ICU admission, (3) intubation for mechanical ventilation, and (4) overall mortality. Using stepwise logistic regression, we developed 3 models: model 1 included OSA alone without adjustment

Table 3—The qCSI component, scoring, and interpretation.

	Score	
Variable	**Value**	**Points**
Respiratory rate, breath/min	≤ 22	0
	23–28	1
	> 28	2
Pulse oximetry*	> 92%	0
	89%–92%	2
	≤ 88%	5
O_2 flow rate, L/min	≤ 2	0
	3–4	4
	5–6	5
	Interpretation	
qCSI Score	**Risk Level**	**Risk of Critical Illness** at 24 H**
≤ 3	Low	4%
4–6	Low-intermediate	30%
7–9	High-intermediate	44%
10–12	High	57%

*The lowest value recorded during the first 4 hours of the patient encounter. **Defined by oxygen requirement (> 10 L/min by low-flow device, high-flow device, noninvasive, or invasive ventilation) or death. COVID-19 = coronavirus disease 2019, qCSI = quick COVID-19 severity index.

Table 4—COVID-19 worsening parameters in both groups (before adjustment).

	OSA (n = 139)	Non-OSA (n = 1,599)	*P*
Length of hospital stay, d	13.8	11.7	.057
Intubation	42 (30%)	255 (16%)	.17
ICU admission	73 (53%)	679 (42%)	.03
Mortality	25 (18%)	255 (16%)	.53

COVID-19 = coronavirus disease 2019, ICU = intensive care unit; OSA = obstructive sleep apnea.

for confounding variables; model 2 included adjustment for age, sex, and BMI; and model 3 included adjustment for age, sex, BMI, and comorbid diseases.

Model 1 showed a greater likelihood of ICU admission in the OSA group compared with the non-OSA group (OR: 1.49; 95% CI, 1.03–2.07; $P = .03$) (**Table 4**). After adjusting for age, sex, BMI, and comorbid diseases (models 2 and 3), the risk was attenuated to become statistically nonsignificant (**Table 5**). Similarly, as shown in **Table 5**, the length of hospital stay in model 1 was longer by 2.1 days in the OSA group compared with the non-OSA group (13.8 vs 11.7 days; $P = .057$). However, after adjusting for age, sex, BMI, and comorbid diseases, the association was no longer statistically significant. The association between presence of OSA and intubation or overall mortality was not statistically significant in all 3 models (**Table 5**).

Table 5—Logistic regression analysis using 3 models.

	Odds Ratio or Coef.	*P*	95% CI
ICU Admission			
Model 1*	1.46	.03	1.03–2.07
Model 2**	1.08	.69	0.75–1.56
Model 3***,†	0.86	.46	0.58–1.28
Length of hospital stay			
Model 1	2.09 (coef.)	.057	−0.65 to 4.25
Model 2	0.64 (coef.)	.57	−1.60 to 2.88
Model 3†	−1.13 (coef.)	.32	−3.34 to 1.08
Intubation			
Model 1	1.3	.17	0.89–1.9
Model 2	0.95	.81	0.63–1.43
Model 3†	0.70	.11	0.46–1.09
Mortality			
Model 1	1.16	.53	0.73–1.82
Model 2	1.01	.98	0.62–1.63
Model 3†	0.75	.27	0.44–1.25

*Model 1: OSA without adjustment. **Model 2: Model 1 after adjustment for age, sex, and BMI. ***Model 3: Model 1 after adjustment for age, sex, BMI, and comorbid diseases (hypertension, diabetes mellitus, coronary artery disease, chronic obstructive pulmonary disease, cerebrovascular diseases, congestive heart failure, cancer, and chronic kidney disease). †The Nagelkerke's R^2 (%) for the linear regression of LOS is 8.4%, ICU admission (12%), intubation (12.6%), and mortality (18.2%). All values are for model 3. BMI = body mass index, CI = confidence interval, coef. = coefficient, COPD = chronic obstructive pulmonary disease, ICU = intensive care unit, LOS = length of hospital stay, OSA = obstructive sleep apnea.

The associations between comorbid diseases and COVID-19–related morbidity and mortality are shown in **Table 6**. All comorbid diseases shown in **Table 6** were associated with adverse consequences. The associations were greatest for congestive heart failure, cardiovascular disease, and chronic obstructive disease.

DISCUSSION

In this study, we examined the association between OSA and selected COVID-19–related clinical outcomes in hospitalized patients. The unadjusted model showed statistical significance in ICU admission and a trend toward statistical significance in the length of stay for patients with OSA. However, this effect dissipated once the model was adjusted for age, sex, BMI, and comorbid diseases. Our results concur with the only study to date, by Cade et al,[12] that evaluated the impact of OSA on similar COVID-19 outcomes. The researchers conducted a retrospective analysis of 4,668 patients diagnosed with COVID-19, which included 443 cases who also had OSA. In this study by Cade et al, OSA was associated with a greater risk of overall mortality, both before any adjustment and after adjusting for demographics. However, similar to our findings, the increased risk of intubation,

Table 6—The impact of age, sex, BMI, OSA, and comorbid diseases on different clinical outcomes in hospitalized patients tested positive for COVID-19 in the fully adjusted model (model 3).

	Mortality	Intubation	ICU Admission	LOS
Type 2 DM	1.18 (0.89–1.59), .25	1.35 (1.06–1.72), .02	1.52 (1.22–1.88), < .0001	2.46 (1.21–3.72), < .0001
CAD	0.95 (0.67–1.37), .79	0.65 (0.46–0.91), .01	0.80 (0.59–1.07), .14	−1.99 (−3.7 to −0.28), .02
HTN	0.89 (0.65–1.22), .48	1.35 (1.04–1.75), .02	1.08 (0.86–1.35), .53	3.22 (1.90–4.53), < .0001
CHF	2.11 (1.48–3.00), < .0001	2.95 (2.16–4.04), < .0001	2.68 (1.97–3.64), < .0001	3.31 (1.57–5.05), < .0001
CVD	1.60 (1.10–2.34), .02	1.48 (1.04–2.11), .03	1.47 (1.05–2.07), .02	0.61 (−1.33 to 2.55), < .0001
COPD	2.25 (1,58–3.21), < .0001	2.55 (1.84–3.55), < .0001	2.02 (1.46–2.82), < .0001	5.72 (3.85–7.59), < .0001
OSA	0.75 (0.44–1.25), .27	0.70 (0.46–1.09), .11	0.86 (0.58–1.28), .46	−1.13 (−3.34 to 1.08), .32
BMI	1.01 (1.00–1.04), .04	1.03 (1.01–1.04), < .0001	1.03 (1.00–1.04), < .0001	0.12 (0.04–0.18), .003
Age	1.04 (1.03–1.05), < .0001	1.00 (0.99–1.01), .81	1.01 (1.00–1.02), .01	−0.01 (−0.05 to 0.03), .54
Sex	1.83 (1.38–2.43), < .0001	1.81 (1.43–2.28), < .0001	1.55 (1.27–1.90), < .0001	1.88 (0.73–3.02), .001

Values are presented as odds ratio (95% CI), *P* value. BMI = body mass index, CAD = coronary artery disease, CHF = congestive heart failure, CI = confidence interval, COPD = chronic obstructive pulmonary disease, COVID-19 = coronavirus disease 2019, CVD = cerebrovascular disease, DM = diabetes mellitus, HTN = systemic hypertension, ICU = intensive care unit, LOS = length of hospital stay, OSA = obstructive sleep apnea.

ICU admission, or inpatient admission associated with OSA disappeared after adjustment for demographics, BMI, and medical comorbidities. As such, the similarity of our findings and those of Cade et al reinforce the concept that underlying comorbid diseases are the primary drivers contributing to the worsening of COVID-19 clinical outcomes.

The extant literature addressing the risk of OSA as a risk factor in COVID-19 morbidity and mortality is extremely scarce. In a large observational study evaluating the phenotypic characteristics and prognosis of inpatients with COVID-19 and diabetes (Coronavirus SARS-CoV-2 and Diabetes Outcomes (CORONADO) study),[14] combined intubation for mechanical ventilation and/or death within 7 days of admission in diabetic patients who tested positive for COVID-19 was assessed as a primary outcome. Treated OSA was independently associated with a higher risk of death on day 7 (OR: 2.8; 95% CI, 1.46–5.38; $P = .002$). In another study, Maas et al[15] concluded that OSA (after adjusting for age, BMI, and type 2 DM) was associated with a greater risk for acquiring COVID-19 infection (OR: 1.65; 95% CI, 1.36–2.02) and respiratory failure (OR: 1.98; 95% CI, 1.65–2.37). Conversely, Strausz et al[16] concluded in a retrospective cohort that OSA was not associated with an increased risk for contracting COVID-19 infection but increased the risk of hospitalization after adjusting for sex, BMI, and comorbid diseases (OR: 2.93; 95% CI, 1.02–8.39; $P = .05$). The sample size of patients with OSA in this study was small (n = 38). Other reports consisted primarily of case series and case studies proposing that OSA might be associated with increased morbidity and mortality in patients with COVID-19.[17–21]

Our study revealed that patients with OSA had a higher qCSI score compared with those without OSA ($P = .02$). Based on such findings, we would expect that patients with OSA would manifest worse clinical outcomes. However, we did not find such an association.

Several factors may explain our findings. The most important is the possibility of misclassification of participants in both groups. Using the ICD-10 code (G47.33) as a surrogate for OSA diagnosis and the lack of G47.33 as a surrogate of "non-OSA" can be associated with high rates of misclassification. In our study, we tried to

Table 7—SLIM scoring system "size 5."

	Values
Age ≥ 60 y	4 points (+)
Hypertension	4 points (+)
BMI ≥ 30 kg/m^2	2 points (+)
BMI ≥ 40 kg/m^2	2 points (+)
Female	6 points (−)

Add points in all rows to get the total score. OSA is predicted if total points > 1". BMI = body mass index, OSA = obstructive sleep apnea, SLIM = Supersparse Linear Integer Model.

Table 8—SLIM scoring for participants in both groups.

SLIM	OSA + COVID-19	OSA − COVID-19	%	Total
−6	1	129	1	130
−4	9	240	4	249
−2	28	164	15	192
0	14	292	5	306
2	30	314	9	344
4	31	171	15	202
6	12	185	6	197
8	13	95	12	108
10	1	9	10	10
Total	139	1,599		1,738

COVID-19 = coronavirus disease 2019, OSA = obstructive sleep apnea, SLIM = Supersparse Linear Integer Model.

minimize this potential problem in the OSA group by reviewing the medical charts in all 139 patients, and confirmed that all these patients were current or past users of a CPAP device. Therefore, we believe it highly probable that all 139 patients in the OSA group had an OSA diagnosis, even in the absence of a polysomnography or home sleep apnea test report. In the non-OSA group, it was not possible to use such an approach. Therefore, we used a simple questionnaire that is validated to assess the risk of OSA. The Supersparse Linear Integer Model (SLIM) is a machine-learning method for creating medical scoring systems. It is an accurate screening tool with sensitivity of 64.2% and specificity of 77%.[13] It performs similar to the state-of-the-art screening tools, yet it uses simple and principal extractable data from EMRs. We used the "size 5" SLIM score that depends on using age, BMI, sex, and hypertension to predict the risk of OSA (**Table 7**).[13] Approximately 55% of the non-OSA group had a SLIM score > 1, suggesting that they are at high risk of OSA. At the same time, 75% of the OSA group had a SLIM score > 1, suggesting that 1/4 of the OSA group might not have OSA (**Table 8**). Therefore, while not excluding the possibility that some in the non-OSA group had OSA, the SLIM score reinforces the contention that the non-OSA group had less risk for OSA.

Our study is retrospective and was conducted in only 2 academic health care centers, and therefore the study is prone to selection bias; consequently, the findings may not be generalizable. We also did not assess the impact of positive airway pressure (PAP) therapy for OSA on COVID-19 morbidity and mortality. This was not possible since PAP therapy adherence data were not available in the EMR. Another limiting factor is COVID-19 severity assessment. We used the qCSI score for most of the patients and for a small percentage of these patients (intubated from another hospital, on nonrebreather mask, Venturi mask, high-flow nasal cannula, CPAP, or bilevel PAP), we assumed that they are under the severe category. Using these 2 scoring systems carries a risk of misclassification bias. Similarly, using the SLIM score to predict the risk of OSA in both OSA and non-OSA groups carries a misclassification bias, which eventually can overestimate or underestimate the association and the outcome.

CONCLUSIONS

Our study suggests that OSA was not an independent risk factor for worse COVID-19 outcome in hospitalized patients and underscores the role of comorbid diseases as major determinants of worse clinical outcome. However, the strong relationship between OSA and these comorbidities warrants the investigation of the role of OSA as an independent risk factor for worse COVID-19 outcome. Future prospective studies are needed with larger sample sizes to overcome our study limitations and to more confidently assess the association between OSA and clinical outcomes in hospitalized patients with COVID-19.

ABBREVIATIONS

CI, confidence interval
COVID-19, coronavirus disease 2019
DM, diabetes mellitus
OR, odds ratio
OSA, obstructive sleep apnea
qCSI, quick COVID-19 severity index
SARS-CoV-2, severe acute respiratory syndrome coronavirus 2
SLIM, Supersparse Linear Integer Model

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