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Original Article

Symptomless multi-variable apnea prediction index assesses adverse outcomes in patients with Corona Virus Disease 2019

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ABSTRACT

Purpose: To explore the relationship between symptomless multi-Variable apnea prediction (sMVAP) index and adverse outcomes of patients with Corona Virus Disease 2019 (COVID-19).
Methods: According to the sMVAP quartiles, we divided all patients into four groups. The clinical electronic medical records, nursing records, laboratory findings, and radiological examinations for all patients with laboratory confirmed Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection were reviewed. Cox proportional hazard ratio (HR) models were used to determine the risk factors associated with in hospital death.
Results: A total of 97 patients were included in this study. The "Quartile 4" group 's ICU transfer rate was significantly higher than the "Quartile 1" group. Coronary heart disease, high d-dimer and sMVAP at admission were associated with increased odds of death.
Conclusions: Using the sMVAP index for obstructive sleep apnea hypopnea syndrome (OSAHS) risk assessment, and then predicting the adverse outcomes of COVID-19 patients, is an effective method. Therefore, the use of sMVAP index for OSAHS screening for inpatients with COVID-19 should be vigorously promoted, and high-risk patients should be effectively managed.
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1. Introduction

The outbreak of COVID-19 has lasted for more than half a year and has been steadily spreading at the global level, World Health Organization (WHO) had called it pandemic. During the epidemic, due to cross-infection issues, PSG has not been widely used in patients with COVID-19, which makes the impact of OSAHS on patients with COVID-19 unknown. At the same time, due to the lack of sufficient attention to OSAHS, many patients were not collected for OSAHS-related clinical manifestations such as neck circumference, snoring, and daytime sleepiness, Therefore, it is difficult to use the STOP-Bang questionnaire [1] and NoSAS questionnaire [2] to perform OSAHS screening for COVID-19 patients. The sMVAP index has proved to be an effective tool for screening OSAHS [3], including only parameters such as gender, age and body mass index (BMI). This study explored the relationship between sMVAP index and adverse outcomes of patients with COVID-19, trying to reveal the effect of OSAHS on COVID-19.

2. Methods

2.1. Study design and participants

This single-center, retrospective, observational study was done at Wuhan Union Hospital (Wuhan, China). We retrospectively analyzed patients from Jan 29, 2020, to Mar 23, 2020, who had been diagnosed with COVID-19, according to WHO interim guidance [4]. Laboratory confirmation of SARS-CoV-2 infection was performed by the local health authority.

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The Ethics Commission of the First Affiliated Hospital of Guangzhou Medical University approved this study (IRB:202051). Written informed consent was waived due to the rapid emergence of this infectious disease.

2.2. Data collection

We reviewed clinical electronic medical records, nursing records, laboratory findings, and radiological examinations for all patients with laboratory confirmed SARS-CoV-2 infection. The admission data of these patients were collected.

2.3. Outcomes

The primary outcome was the mortality from hospital admission to the cut off date. The cut-off date was set to the date of the last patient's outcome (death or discharge from hospital). In this study, the cut-off date was May, 2, 2020. Secondary outcome was the rate of any stay in ICU. Sepsis and septic shock were defined according to the 2016 Third International Consensus Definition for Sepsis and Septic Shock [5]. Secondary infection was diagnosed when patients showed clinical symptoms or signs of pneumonia or bacteremia and a positive culture of a new pathogen was obtained from lower respiratory tract specimens (qualified sputum, endotracheal aspirate, or bronchoalveolar lavage fluid) or blood samples after admission [5]. Acute kidney injury was diagnosed according to the KDIGO clinical practice guidelines [6] and acute respiratory distress syndrome (ARDS) was diagnosed according to the Berlin Definition [7]. The illness severity of COVID-19 was defined according to the Chinese management guideline for COVID-19 (version 7.0) [8].

2.4. Statistical analysis

The purpose of this study is to explore the relationship between sMVAP and adverse outcomes in patients with COVID-19. There were, therefore, no formal hypotheses being implemented to drive the sample size calculation and we included the maximum number of patients who met the inclusion criteria.

The sMVAP index is calculated as: $sMVAP = e^X/(1 + e^X)$, where "e" is natural constant (Its value is about 2.718281828459) and $X = -10.784 + 0.203 \times (BMI) + 0.043 \times (Age) + 1.004 \times (Gender: 0 = female, 1 = male)$ [3]. The sMVAP ranges from 0 to 1, with higher values indicating higher OSAHS risk. To provide clinically-relevant interpretations, we based analyses on sMVAP quartiles (patients were divided into four groups). We expressed descriptive data as mean (SD) or median (IQR) for continuous variables and number (%) for categorical variables. We assessed differences between different groups using one-way ANOVA or kruskal-wallis H test depending on parametric or nonparametric data for continuous variables and Fisher's exact test for categorical variables. Cox proportional HR models were used to determine HRs and 95% CIs between individual factors on mortality. Previous studies have shown blood levels of d-dimer and history of coronary heart disease associated with adverse clinical outcomes in patients with COVID-19 [17,18]. Some laboratory findings, including alanine aminotransferase (ALT), lactate dehydrogenase, high-sensitivity cardiac troponin I, and d-dimer, might be unavailable in emergency circumstances. Therefore, we chose d-dimer, coronary heart disease, and sMVAP index as the three variables for our multivariable Cox proportional HR models. Survival curves were developed using the Kaplan–Meier method with log-rank test. Time to events (death) were defined as the time from hospital admission to events. Since the P value of the log-rank test between the four groups was >0.05, we only performed survival analysis on the "Quartile 1" and "Quartile 4" group.

Tests were two-sided with significance set at α less than 0.05. The SPSS 24.0 software (IBM SPSS) was applied for all analyses.

3. Results

A total of 97 patients were included in this study (Fig. 1). The average age of all patients was 58 years (IQR 42.5–67.0), with 78.7% males (Table 1). 36.1% of patients had hypertension, while 15.5% of patients had Diabetes. 77.3% of patients had bilateral infiltrates on chest x-ray. The most common symptoms were cough (72.2%), fatigue (42.3%) and fatigue (23.7%). About four-fifths of patients (78.4%) were general disease status on admission, whereas 17.5% of patients should transfer to Intensive care unit (ICU) and required invasive mechanical ventilation. 58 (59.8%) patients received antibiotics and 84 (86.6%) received antivirals (Table 2). 73 (75.3%) patients were treated with high-flow nasal cannula, three (3.1%) with extracorporeal membrane oxygenation (ECMO), eight (8.2%) patients were treated with continuous renal replacement therapy (CRRT). The proportion of patients in the "Quartile 4" group using invasive mechanical ventilation was significantly higher than that in the "Quartile 1" group. There was no significant difference in the proportion of non-invasive mechanical ventilation (NIMV) between groups.

There were 82 patients (84.5%) discharged before the cut-off date. Although the mortality of the "Quartile 4" group is almost eight times that of the "Quartile 1" group, there was no significant difference in mortality between groups. The "Quartile 4" group 's ICU transfer rate was significantly higher than the "Quartile 1" group. The median time of hospital length of stay was 22 days (IQR 15–34.5) and there was no significant difference in that between groups. The most common complications was secondary infection (10.3%), acute kidney failure (8.2%) and respiratory failure (8.2%) (Table 2).

In univariable analysis, odds of in-hospital death was higher in "Quartile 4" group (Table 3). Old age, male sex, coronary heart disease, lactate dehydrogenase, high-sensitive cardiac troponin I, prothrombin time and d-dimer were also associated with death (Table 3). In the multivariable Cox proportional HR models, we found that coronary heart disease, high d-dimer and sMVAP at admission were associated with increased odds of death (Table 3). For the primary outcome, among 97 patients with SARS-CoV-2 infection, 15 (15.5%) patients had died before the cut-off date, and the mean duration from hospital admission to death was 67.8 days (IQR 54.7–81.0) in "Quartile 4" group (Fig. 2).

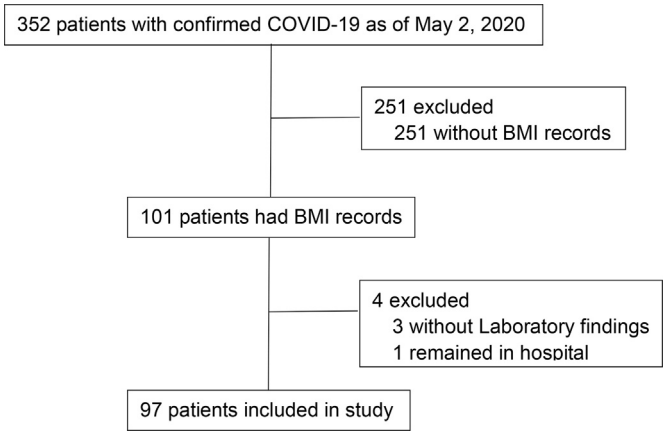

Fig. 1. Study flow diagram.

Table 1
Demographic, clinical, laboratory, and radiographic findings of patients on admission.

	Overall (n = 97)	sMVAP quartile				
		Quartile 1 (n = 24)	Quartile 2 (n = 25)	Quartile 3 (n = 26)	Quartile 4 (n = 22)	P value
Demographics and clinical characteristics						
Age, years	58.0 (42.5–67.0)	40.0 (30.0–50.5)	57.4 (13.9)[a]	61.3 (12.5)[b]	62.8 (14.2)[c]	<0.001
Sex						
Male	43 (44.3%)	1 (4.2%)	7 (28%)	17 (65.4%)[b,d]	18 (81.8%)[c,e]	
Female	54 (55.7%)	23 (95.8%)	18 (72%)	9 (34.6%)	4 (18.2%)	<0.001
BMI, kg/m^2	24.1 (3.5)	22.3 (2.6)	23.1 (3.2)	24.2 (2.9)	26.9 (3.7)[c,e,f]	<0.001
sMVAP	0.05 (0.03–0.09)	0.01 (0.01)	0.03 (0.01)[a]	0.07 (0.06–0.08)[b,d]	0.12 (0.11–0.18)[c,e,f]	<0.001
Chronic medical illness						
Hypertension	35 (36.1%)	4 (16.7%)	7 (28%)	15 (57.7%)[b]	9 (40.9%)	0.018
Coronary heart disease	7 (7.2%)	3 (12.5%)	2 (8%)	2 (7.7%)	0	0.478
Cerebrovascular disease	2 (2.1%)	1 (4.2%)	0	0	1 (4.5%)	0.357
Diabetes	15 (15.5%)	1 (4.2%)	4 (16%)	5 (19.2%)	5 (22.7%)	0.289
Chronic obstructive lung disease	2 (2.1%)	1 (4.2%)	1 (4%)	0	0	0.726
Chronic liver disease	3 (3.1%)	0	2 (8%)	0	1 (4.5%)	0.261
Carcinoma	6 (6.2%)	1 (4.2%)	2 (8%)	2 (7.7%)	1 (4.5%)	1
Current smoker	9 (9.3%)	0	2 (8%)	3 (11.5%)	4 (18.2%)	0.175
Respiratory rate >24 breaths per min	17 (17.5%)	2 (8.3%)	5 (20%)	7 (26.9%)	3 (13.6%)	0.357
Pulse ≥125 beats per min	2 (2.1%)	0	1 (4%)	0	1 (4.5%)	0.475
Fever (temperature ≥37.3 °C)	17 (17.5%)	2 (8.3%)	4 (16%)	6 (23.1%)	5 (22.7%)	0.489
Cough	70 (72.2%)	11 (45.8%)	20 (80%)	21 (80.8%)	18 (81.8%)	0.012
Sputum	29 (29.9%)	4 (16.7%)	9 (36%)	9 (34.6%)	7 (31.8%)	0.430
Myalgia	17 (17.5%)	2 (8.3%)	4 (16%)	6 (23.1%)	5 (22.7%)	0.489
Fatigue	41 (42.3%)	9 (37.5%)	12 (48%)	10 (38.5%)	10 (45.5%)	0.848
Nausea or vomiting	10 (10.3%)	4 (16.7%)	2 (8%)	2 (7.7%)	2 (9.1%)	0.772
Pharyngalgia	4 (4.1%)	2 (8.3%)	2 (8%)	0	0	0.274
Headache	3 (3.1%)	0	1 (4%)	2 (7.7%)	0	0.615
Dyspnea	23 (23.7%)	2 (8.3%)	7 (28%)	7 (26.9%)	7 (31.8%)	0.227
Nasal discharge	3 (3.1%)	1 (4.2%)	2 (8%)	0	0	0.454
General malaise	9 (9.3%)	1 (4.2%)	2 (8%)	2 (7.7%)	4 (18.2%)	0.453
Disease severity status						
Mild	1 (1%)	1 (4.2%)	0	0	0	0.474
General	76 (78.4%)	21 (87.5%)	20 (80%)	22 (84.6%)	13 (59.1%)	0.113
Severe	3 (3.1%)	1 (4.2%)	1 (4%)	1 (3.8%)	0	1
Critical	17 (17.5%)	1 (4.2%)	4 (16%)	3 (11.5%)	9 (40.9%)[c]	0.012
Laboratory findings						
White blood cell count, × 10^9 per L	6.0 (4.5–7.8)	6.4 (4.0–7.9)	5.8 (4.0–7.2)	5.8 (4.7–7.9)	5.9 (4.9–9.5)	0.700
Lymphocyte count, × 10^9 per L	1.3 (0.8–1.8)	1.3 (0.6)	1.5 (0.9–2.2)	1.2 (0.6)	1.2 (0.5)	0.497
Hemoglobin, g/dL	126 (114–135)	118.5 (105.0–127.5)	123.8 (15.9)	132.5 (12.1)[b]	125.5 (24.5)	0.006
Platelet count, × 10^9 per L	199.0 (158.5–257.5)	209.0 (174.3–269.3)	194.2 (88.5)	204.0 (157.3–251.5)	193.5 (145.0–334.5)	0.606
Albumin, g/L	33.3 (7.0)	34.3 (8.8)	35.3 (7.2)	32.3 (5.3)	31.3 (5.9)	0.181
ALT, U/L	30.0 (20.0–48.5)	24.5 (13.0–31.5)	34.1 (17.5)	35 (23–56)	31.0 (23.0–49.3)	0.071
Lactate dehydrogenase, U/L	204.0 (163.5–356.0)	185.5 (140.8–243.3)	208.8 (156.5–380.0)	200.5 (169.8–371.8)	259.5 (195.8–433.3)[c]	0.023
Creatinine, μmol/l	60.6 (51.9–77.8)	49.9 (42.3–56.6)	57.3 (52.9–73.9)[a]	71.0 (16.1)[b]	76.9 (22.9)[c]	<0.001
CRP, mg/L	5.7 (1.0–39.5)	3.8 (0.7–19.2)	16.3 (2.9–42.7)	4.1 (0.5–36.6)	16.3 (2.8–87.7)	0.166
High-sensitive cardiac troponin I, ng/mL	3.2 (1.7–21.7)	1.8 (0.6–7.0)	1.8 (0.6–26.0)	7.7 (2.3–18.0)	11.7 (2.8–35.3)	0.031
Prothrombin time, s	12.9 (12.2–13.8)	12.7 (12.1–13.2)	13.1 (12.3–13.5)	13.1 (12.2–14.2)	13.0 (12.0–13.9)	0.410
D-dimer, μg/L						
≤0.5	49 (50.5%)	15 (62.5%)	13 (52%)	13 (50%)	8 (36.4%)	
>0.5	48 (49.5%)	9 (37.5%)	12 (48%)	13 (50%)	14 (63.6%)	0.367
Procalcitonin, ng/mL	0.1 (0–0.2)	0.1 (0–0.1)	0.1 (0–0.2)	0.1 (0.1–0.1)	0.1 (0.1–0.2)	0.438
BNP, pg/mL	49.6 (23.8–113.1)	33.8 (21.3–180.0)	69.5 (56.6)	49.6 (13.1–120.0)	64.9 (42.7–118.1)	0.831
Imaging features						
Bilateral pulmonary infiltration	75 (77.3%)	16 (66.7%)	23 (92%)	18 (69.2%)	18 (81.8%)	0.108

Data are mean (SD), median (IQR) or n (%). BMI, body mass index; sMVAP, symptomless multi-variable apnea prediction; ALT, alanine aminotransferase; CRP, c-reactive protein; BNP, brain natriuretic peptide.

[a] Compared with the "Quartile 2" group, P value of the "Quartile 1" was ≤0,05.
[b] Compared with the "Quartile 3" group, P value of the "Quartile 1" was ≤0,05.
[c] Compared with the "Quartile 4" group, P value of the "Quartile 1" was ≤0,05.
[d] Compared with the "Quartile 2" group, P value of the "Quartile 3" was ≤0,05.
[e] Compared with the "Quartile 2" group, P value of the "Quartile 4" was ≤0,05.
[f] Compared with the "Quartile 3" group, P value of the "Quartile 4" was ≤0,05.

Table 2
Treatments and outcomes.

	Overall (n = 97)	sMVAP quartile				P value
		Quartile 1 (n = 24)	Quartile 2 (n = 25)	Quartile 3 (n = 26)	Quartile 4 (n = 22)	
Treatments						
Antibiotics	58 (59.8%)	18 (75%)	14 (56%)	14 (53.8%)	12 (54.5%)	0.378
Antiviral treatment	84 (86.6%)	17 (70.8%)	21 (84%)	26 (100%)[b]	20 (90.9%)	0.013
Corticosteroids	36 (37.1%)	5 (20.8%)	7 (28%)	11 (42.3%)	13 (59.1%)[c]	0.037
Intravenous immunoglobin	22 (22.7%)	4 (16.7%)	5 (20%)	6 (23.1%)	7 (31.8%)	0.684
High-flow nasal cannula oxygen therapy	73 (75.3%)	14 (58.3%)	23 (92%)[a]	21 (80.8%)	15 (68.2%)	0.037
Invasive mechanical ventilation	17 (17.5%)	1 (4.2%)	4 (16%)	3 (11.5%)	9 (40.9%)[c]	0.012
Non-invasive mechanical ventilation	9 (9.3%)	0	3 (12%)	2 (7.7%)	4 (18.2%)	0.167
ECMO	3 (3.1%)	0	1 (4%)	0	2 (9.1%)	0.134
CRRT	8 (8.2%)	0	2 (8%)	1 (3.8%)	5 (22.7%)	0.032
Prognosis						
Discharge from hospital	82 (84.5%)	23 (95.8)	21 (84%)	23 (88.5%)	15 (68.2%)	0.084
Death	15 (15.5%)	1 (4.2%)	4 (16%)	3 (11.5%)	7 (31.8%)	0.084
Outcome						
Any stay in ICU	17 (17.5%)	1 (4.2%)	4 (16%)	3 (11.5%)	9 (40.9%)[c]	0.012
Hospital length of stay, days	22.0 (15.0–34.5)	24.7 (10.3)	16 (12–30)	25.7 (11.8)	28.2 (12.4)	0.132
Complications						
Septic shock	4 (4.1%)	0	0	0	4 (18.2%)	0.002
Secondary infection	10 (10.3%)	0	3 (12%)	0	7 (31.8%)[c]	<0.001
Acute kidney failure	8 (8.2%)	0	3 (12%)	1 (3.8%)	4 (18.2%)	0.091
DIC	2 (2.1%)	0	1 (4%)	0	1 (4.5%)	0.475
pneumothorax	1 (1%)	0	0	0	1 (4.5%)	0.227
Stress ulcer	2 (2.1%)	1 (4.2%)	1 (4%)	0	0	0.726
ARDS	4 (4.1%)	0	1 (4%)	1 (3.8%)	2 (9.1%)	0.453
Respiratory failure	8 (8.2%)	0	3 (12%)	2 (7.7%)	3 (13.6%)	0.299
Heart failure	1 (1%)	0	0	0	1 (4.5%)	0.227
Sepsis	1 (1%)	0	0	0	1 (4.5%)	0.227
Acidosis	2 (2.1%)	0	0	0	2 (9.1%)	0.050
Viral myocarditis	3 (3.1%)	0	1 (4%)	2 (7.7%)	0	0.615
Hypoproteinemia	2 (2.1%)	0	1 (4%)	1 (3.8%)	0	1
Coagulopathy	1 (1%)	1 (4.2%)	0	0	0	0.474

Data are mean (SD), median (IQR) or n (%). sMVAP, symptomless multi-variable apnea prediction. ECMO, extracorporeal membrane oxygenation; CRRT, continuous renal replacement therapy; ICU, intensive care unit; DIC, disseminated intravascular coagulation; ARDS, acute respiratory distress syndrome.
[a] Compared with the "Quartile 2" group, P value of the "Quartile 1" was ≤0,05.
[b] Compared with the "Quartile 3" group, P value of the "Quartile 1" was ≤0,05.
[c] Compared with the "Quartile 4" group, P value of the "Quartile 1" was ≤0,05.

4. Discussion

This retrospective cohort study identified the relationship between OSAHS risk and the mortality and ICU transfer rate in patients in Wuhan who were hospitalised with COVID-19. In particular, coronary heart disease, d-dimer levels greater than 0.5 μg/L, and higher sMVAP on admission were associated with higher odds of in-hospital death. Additionally, elevated ICU transfer rate and the incidence of complications were more commonly seen in higher sMVAP patients. To our knowledge, this is the first study to explore the association between sMVAP index and COVID-19.

During the COVID-19 pandemic, considering that SARS-CoV-2 was highly contagious, sleep monitoring for inpatients was inconvenient to carry out. A multi-center study from Europe pointed out that the number of polysomnography in Lab fell by more than 70% during the pandemic [9]. The Canadian Chest Association also recommends that patients should not be tested for sleep disordered breathing during the pandemic unless a clinician determines that a case is "extremely urgent" [10]. At the same time, despite the lack of clinical trials, based on the pathophysiology of OSAHS, some scholars believe that OSAHS could lead to increased risk of COVID-19 infection and severity [11–13]. We have noticed that there are two small sample studies showing that 21%–28.6% of critically ill COVID-19 patients were accompanied by OSAHS on admission [14,15]. Although the above studies did not analyze the impact of OSAHS on the prognosis of critically ill COVID-19 patients, one of the studies pointed out that patients with coexisting conditions were at risk for severe disease and poor outcomes after ICU admission [14], which indirectly reflects the negative impact of OSAHS on the progress of COVID-19. At this time, it is particularly important to choose a simple and accurate OSAHS screening tool, such as STOP-Bang questionnaire and NoSAS questionnaire. However, in the early stage of the epidemic in Wuhan, in the face of a large number of patients, medical staff may have no time to pay attention to the patients' OSAHS history, such as snoring and sleepiness, and they also have no time to measure patients' neck and abdominal circumference. Therefore, we cannot use the above questionnaires to assess patients' OSAHS risk.

Table 3
Risk factors associated with in-hospital death.

	Univariable HR (95% CI)	p value	Multivariable HR (95% CI)	P value
Demographics and clinical characteristics				
Age, years				
<65	1 (ref)	–	–	–
≥65	3.35 (1.19–9.43)	0.022	–	–
Male sex (vs female)	5.62 (1.59–19.93)	0.008	–	–
BMI, kg/m^2				
<28	1 (ref)		–	–
≥28	0.80 (0.18–3.52)	0.762	–	–
Current smoker (vs nonsmoker)	3.20 (0.88–11.64)	0.078	–	–
Comorbidity present (vs not present)	1.39 (0.49–3.90)	0.534	–	–
Chronic obstructive pulmonary disease	5.09 (0.67–38.91)	0.117	–	–
Coronary heart disease	3.57 (1.01–12.68)	0.049	15.40 (3.09–76.92)	0.001
Diabetes	1.45 (0.41–5.14)	0.565		
Hypertension	2.13 (0.77–5.88)	0.143		
Laboratory findings				
White blood cell count, × 10^9 per L				
<4	0.34 (0.04–2.70)	0.309	–	–
4–10	1 (ref)		–	–
>10	2.65 (0.89–7.90)	0.082	–	–
Lymphocyte count, × 10^9 per L	1.09 (0.99–1.19)	0.075		
Platelet count, × 10^9 per L				
<100	3.54 (0.99–12.70)	0.052	–	–
100–300	1 (ref)	–	–	–
>300	0.40 (0.05–3.10)	0.380	–	–
ALT, U/L				
≤40	1 (ref)	–	–	–
>40	2.12 (0.77–5.85)	0.146	–	–
Lactate dehydrogenase, U/L				
≤245	1 (ref)	–	–	–
>245	29.78 (3.91–226.74)	0.001	–	–
High-sensitive cardiac troponin I, ng/mL				
≤28	1 (ref)	–	–	–
>28	4.07 (1.31–12.64)	0.015	–	–
Prothrombin time, s				
≤16	1 (ref)	–	–	–
>16	15.04 (4.11–55.02)	<0.001	–	–
D-dimer, μg/L				
≤0.5	1 (ref)	–	1 (ref)	–
>0.5	3.44 (1.09–10.79)	0.035	4.47 (1.22–16.35)	0.024
Procalcitonin, ng/mL				
≤0.5	1 (ref)	–	–	–
>0.5	2.03 (0.27–15.40)	0.496	–	–
Others				
sMVAP				
Quartile 1	1 (ref)	–	1 (ref)	–
Quartile 2	4.19 (0.47–37.45)	0.200	6.52 (0.68–62.13)	0.103
Quartile 3	2.96 (0.31–28.50)	0.347	4.82 (0.46–50.38)	0.189
Quartile 4	8.83 (1.09–71.80)	0.042	17.11 (1.70–172.65)	0.016

CI, confidence interval; HR, hazard ratio; BMI, body mass index; sMVAP, symptomless multi-variable apnea prediction; ALT, alanine aminotransferase.

Previous studies reported that old age, male sex and obesity are independent risk factors for COVID-19 mortality [16–18]. Although the above indicators are also risk factors for OSAHS, it is relatively one-sided to use one or two alone to evaluate the risk of OSAHS. The sMVAP index proves to be a practical OSAHS screening tool [3], including parameters such as age, gender, and BMI that only need to be extracted from the patient's electronic medical record. In this current study, the increased D-dimer and history of coronary heart disease were associated with poor prognosis, reflecting the direct effect of patients' coagulation function and cardiac dysfunction on mortality, consistent with previous reports [19,20].

This study has several limitations. First, due to the specificity of SARS-CoV-2, none of the patients underwent PSG test, so the efficacy of SMVAP index in screening OSAHS could not be evaluated. Secondly, since this study is a retrospective study, we cannot collect this information of sequential organ failure assessment (SOFA) score and acute physiology and chronic health evaluation II (APACHE II) score.

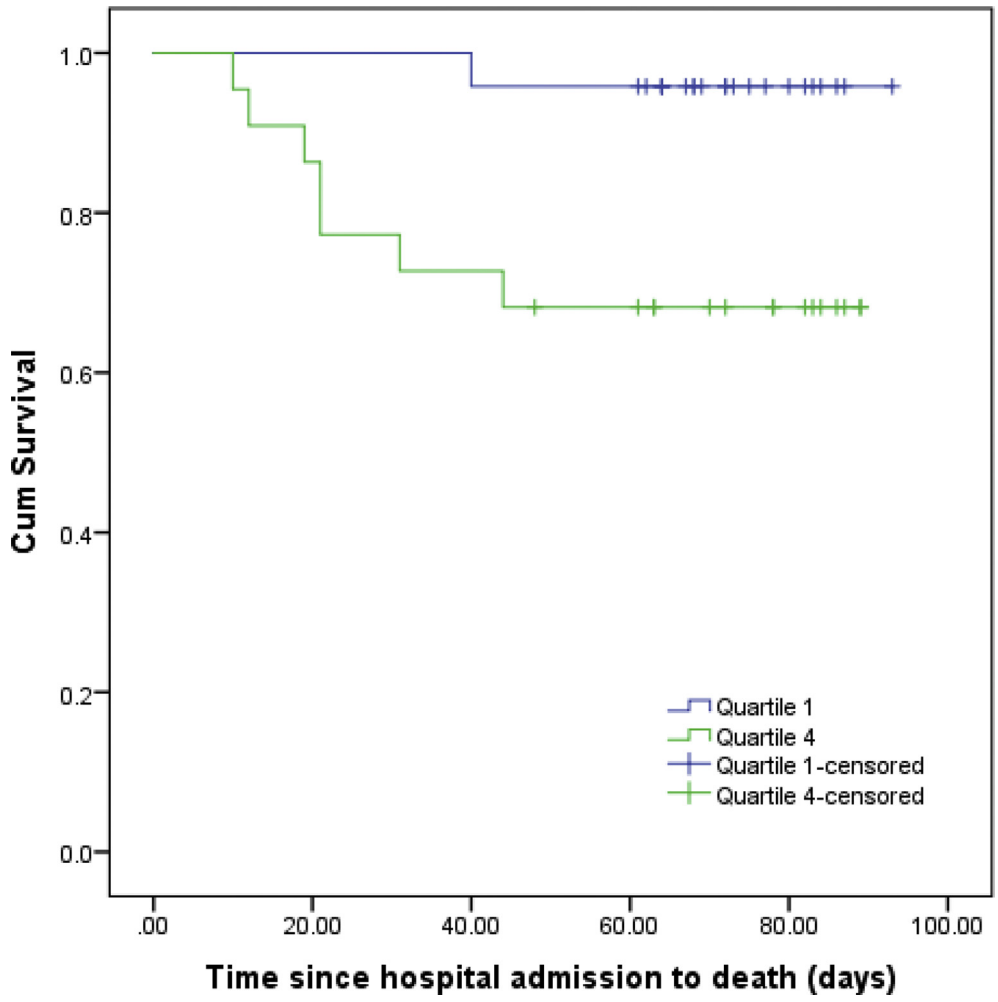

Fig. 2. Survival of patients with COVID-19.

5. Conclusions

In conclusion, this study confirms that using the sMVAP index for OSAHS risk assessment, and then predicting the adverse outcomes of COVID-19 patients, is an effective method. Therefore, the use of sMVAP index for OSAHS screening for inpatients with COVID-19 should be vigorously promoted, and high-risk patients should be effectively managed.

Disclosure statement

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CRediT authorship contribution statement

Sun Zhang: Methodology, Software, Writing - original draft. **Yuanda Xu:** Conceptualization, Methodology. **Jieying Li:** Methodology, Software. **Kang Wu:** Formal analysis. **Tao Wang:** Formal analysis. **Xiaofen Su:** Investigation. **Qian Han:** Methodology. **Yin Xi:** Investigation, Resources. **Yong Gao:** Resources. **Hongbo Wang:** Data curation. **Yu Hu:** Resources. **Chunli Liu:** Visualization, Conceptualization. **Pixin Ran:** Supervision. **Nuofu Zhang:** Writing - review & editing. **Nanshan Zhong:** Project administration.

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Abbreviations list

COVID-19	Corona Virus Disease 2019
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
WHO	World Health Organization
PSG	polysomnography
OSAHS	obstructive sleep apnea hypopnea syndrome
sMVAP	symptomless multi-variable apnea prediction
BMI	body mass index
IRB	institutional review board
ALT	alanine aminotransferase
AST	aspartate aminotransferase
CRP	c-reactive protein
BNP	brain natriuretic peptide
DIC	disseminated intravascular coagulation
ARDS	acute respiratory distress syndrome
DVT	deep venous thrombosis
ECMO	extracorporeal membrane oxygenation
CRRT	continuous renal replacement therapy
IMV	invasive mechanical ventilation
NIMV	non-invasive mechanical ventilation

ICU	intensive care unit
SOFA	sequential organ failure assessment
APACHE II	acute physiology and chronic health evaluation II
SD	standard deviation
IQR	interquartile range
CI	confidence interval
HR	hazard ratio

Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2020.08.031.

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