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ORIGINAL RESEARCH

The Effect of Noninvasive Ventilation Support on COVID-19 Patients and Risk Factors for Invasive Ventilation – A Retrospective and Multicenter Study

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Background: Oxygen therapy (OT) is the most widely used supportive regime in patients with hypoxemic acute respiratory failure (ARF) due to severe acute respiratory syndrome coronavirus (SARS-CoV-2) infection. The aim of this study was to identify the effect of noninvasive ventilation support on coronavirus disease 2019 (COVID-19) patients and risk factors for invasive mechanical ventilation (IMV).

Methods: We retrospectively analyzed confirmed COVID-19 subjects from nine hospitals outside Wuhan. All hospitalized patients who tested positive for COVID-19 by real-time polymerase chain reaction between January 1st and March 31st, 2020, were recruited. The patients were divided into four groups based on the most advanced OT regime, including no OT, nasal oxygen therapy, high-flow nasal oxygen therapy (HFNOT) or noninvasive ventilation (NIV), and IMV. Multiple logistic regression models were performed to determine risk factors for IMV.

Results: Of the 683 recruited subjects, 315 (46.1%) subjects did not need OT, 300 (43.9%) received nasal oxygen therapy, 51 (7.5%) received HFNOT or NIV, while 17 (2.5%) subjects had to be intubated. The lactate in the OT group was higher than in the no OT group (2.7 vs 1.6, $P = 0.02$). In addition, HFNOT or NIV patients had a higher respiratory rate, but a lower PaO2 ($P < 0.001$). HFNOT and NIV had an obvious beneficial effect on ARF with 75% of COVID-19 patients recovering from respiratory failure. Patients with IMV were older ($P < 0.001$), had a higher rate of hypertension ($P < 0.001$) and more secondary bacterial infections ($P < 0.001$) compared to those without intubation. The multivariate model showed that secondary bacterial infection (OR = 6.87, $P = 0.009$) was independently associated with IMV failure among COVID-19 patients.

Conclusion: We identified that HFNOT and NIV had an obvious beneficial effect on ARF among COVID-19 patients. We also demonstrated that secondary bacterial infection was an independent risk factor for NIV failure in patients infected by SARS-COV2.

Keywords: COVID-19, SARS-CoV-2, oxygen therapy, invasive mechanical ventilation

Introduction

In December 2019, a novel coronavirus was identified by the Chinese Center for Disease Control and Prevention (CDC) and was named coronavirus disease 2019 (COVID-19). COVID-19 has since spread rapidly across the globe with rising prevalence and mortality rates. Strategies for the prevention and treatment of COVID-19 are urgently needed.[1,2]

To date, COVID-19 has caused more cases and fatalities than severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV).[3,4] Although COVID-19 patients sometimes die

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of shock, multiple organ failure or myocardial damage,[5,6] respiratory failure is obviously the main cause of mortality,[7] as reported in previous viral pandemics.[8] Most affected patients can be supported by noninvasive ventilation (NIV) until the lungs recover. If the situation deteriorates, use of advanced respiratory support, such as invasive mechanical ventilation (IMV) or extracorporeal membrane oxygenation (ECMO) systems are good alternatives to improve hypoxia. So, we speculated that COVID-19 patients may benefit from oxygen therapy in the same way as patients with other types of pneumonia. Notably, in the face of growing numbers of COVID-19 subjects, healthcare providers around the world may benefit from knowing the characteristics of those patients in whom NIV has failed. In addition, the precise risk factors for NIV failure have not been well defined. In this study, we sought to explore characteristics of COVID-19 patients who need of IMV, and particularly to identify risk factors for requiring IMV.

Patients and Methods

Study Design and Subjects

We performed a retrospective analysis of data collected from nine COVID-19 designated hospitals outside Wuhan: the Second Xiangya Hospital, the first Attached Hospital of Shaoyang University, the Affiliated Shaoyang Central Hospital of University of South China, Zhuzhou Central Hospital, Yueyang Second People's Hospital, the First People's Hospital of Huaihua affiliated to the University of South China, the Second People's Hospital of Guilin, Xiangtan Central Hospital, and Loudi Central Hospital. This research was approved by the local Ethics Committee of the Second Xiangya Hospital (number: fabh003). All hospitalized patients who tested positive for COVID-19 by real-time polymerase chain reaction between January 1st and March 31st, 2020, were included.

We obtained baseline demographic data and clinical manifestations from a questionnaire designed by the CDC.[9] The treatment regimens and outcome data were collected from the electronic medical record. The laboratory findings on admission were collected. The data were checked by the doctors in charge and reviewed independently by two researchers. Patients with oxygen therapy (OT) were divided into three groups:[10] (1) subjects who received nasal oxygen therapy immediately after admission as an initial support strategy then succeeded, named the OT group; (2) subjects who had to receive HFNOT or NIV as a remedy strategy for ARF after the initial regular nasal catheter failed, and then succeeded (HFNOT or NIV group); and (3) patients in whom HFNOT or NIV failed and who received invasive mechanical ventilation (IMV) was administrated as a remedial procedure (IMV group). The date of disease onset was defined as the day when the first symptom was reported. The severity of disease was identified according to the diagnosis and treatment protocol for COVID-19.[9] The treatment regimen was based on the CDC protocol for COVID-19, which is the official document for COVID-19 management in China. All centers were asked to follow this document. All patients had completed the relevant examinations and treatment plans had been made according to the patient's condition, including the need for HFNOT, NIV and IMV. HFNOT or NIV was applied to subjects who presented with PaO2 < 60mmHg or an oxygenation index which is a ratio of PaO2 to fractional inspired oxygen concentration (FiO2) (PaO2/FiO2) of 300 or less despite oxygen delivery through a nasal catheter.[9] Criteria for IMV included failure to maintain a PaO2/FiO2<300 despite NIV, inability to protect the airways or to manage copious tracheal secretions, inability to tolerate the face mask, or progression of respiratory failure defined as sustained hypoxemia despite an increase in FiO2 or the appearance of hypercapnia.[9] If respiratory distress or hypoxemia did not improve or even worsened within a short time (1–2 hours) following HFNOT or NIV therapy, IMV was performed according to the National Health Commission of the People's Republic of China Chinese management guideline for COVID-19.[11] Secondary infection was diagnosed if patients had clinical symptoms or signs of nosocomial pneumonia or bacteremia combined with a positive culture of a new pathogen from a lower respiratory tract specimen (including the sputum, transtracheal aspirates, or bronchoalveolar lavage fluid, or from blood samples taken ≥48 h after admission).[12]

Statistical Analysis

Continuous variables are presented as mean and standard deviation (if data were normally distributed) and median and interquartile range (IQR) values (if data were not normally distributed). Categorical variables were described as frequency rates and percentages. Means for continuous variables were compared by paired *t*-tests or ANOVA test. Proportions of categorical variables were compared using the chi-squared test or Fisher exact test. Adjusted multiple logistic regression models were performed to determine the risk factors for IMV. A value of $P < 0.05$ was considered

statistically significant. All statistical analyses were performed using SPSS version 25.0 software.

Results

Demographics and Clinical Variables Among COVID-19 Subjects

We identified 683 hospitalized subjects infected by COVID-19. The median age of the recruited subjects was 43 years (IQR, 33–55). Hypertension (14.3%) and diabetes (8.9%) were the most common comorbidities. Of the 683 subjects, 315 (46.1%) did not receive OT, 300 (43.9%) had nasal oxygen therapy, and 68 patients underwent HFNOT or NIV; among these 68 patients, 51 patients recovered successfully from hypoxia, 17 patients had to be intubated, and 4 died (Figure 1). Patients with IMV were older (66 vs 52, $P < 0.001$), had a higher rate of hypertension (35.3% vs 29.4%, $P < 0.001$) and more secondary bacterial infections (58.8% vs 21.6%, $P < 0.001$) compared to those who recovered with HFNOT or NIV. Patients who needed IMV had longer hospital stays (26 vs 17 days, $P < 0.001$). Patients who recovered with regular OT received smaller amounts of corticosteroids ($P < 0.001$) and antibiotics ($P < 0.001$) compared to subjects who needed HFNOT, NIV or IMV (Table 1).

Differences in Symptoms and Lab Findings Among COVID-19 Patients without or with Different Kinds of Oxygen Therapy

Patients with NIV or IMV had a higher rate of dry cough, dyspnea, fever, and fatigue compared to those who did not need oxygen therapy or received nasal oxygen therapy.

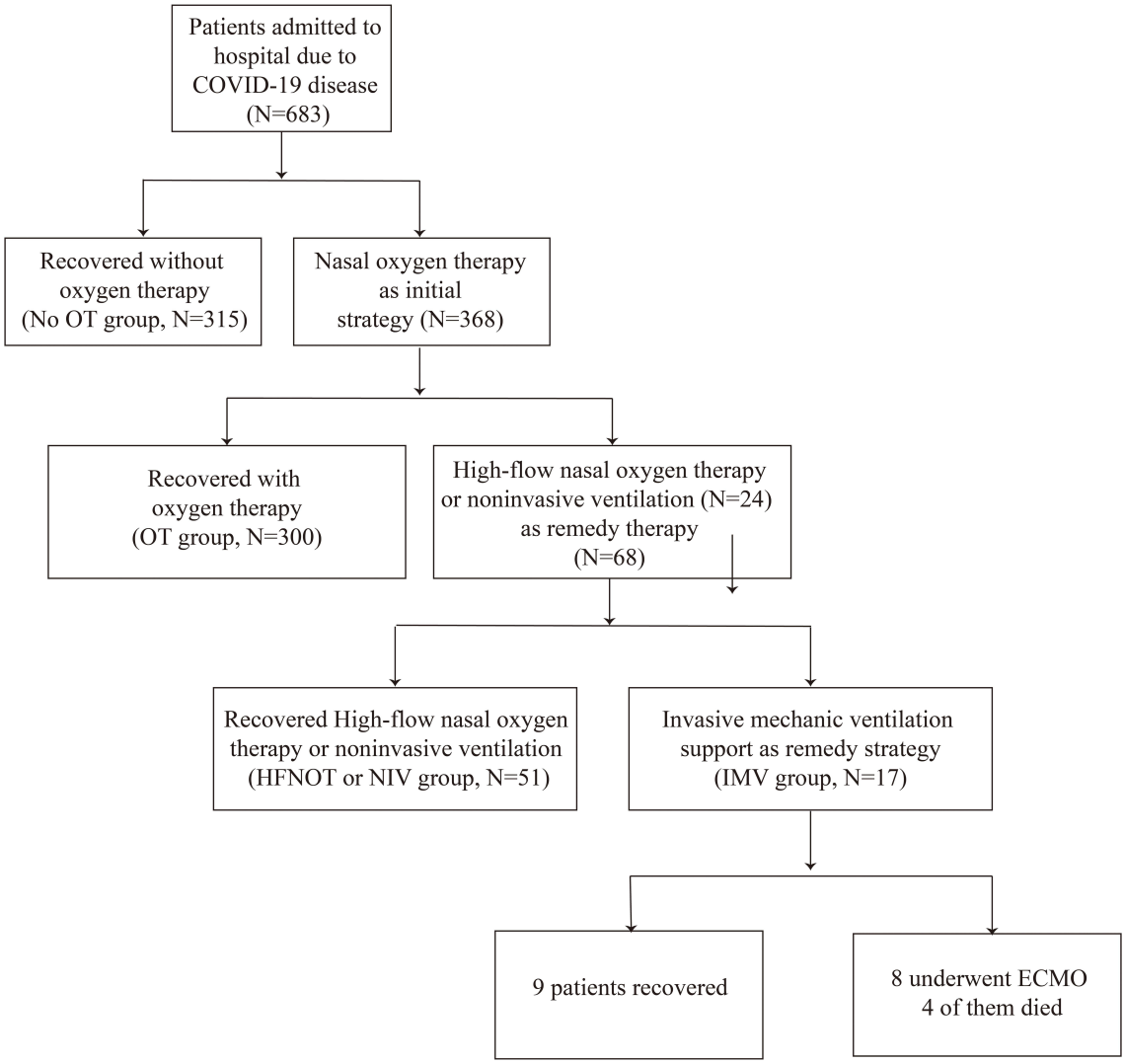

Figure 1 The flow chart of the study. Of the 683 subjects, 315 (46.1%) did not receive OT, 300 (43.9%) had nasal oxygen therapy, 68 patients underwent HFNOT or NIV; among these 68 patients, 51 patients successfully recovered from hypoxia, 17 patients had to be intubated, and 4 patients died.

Table 1 Demographics and Clinical Variables Among COVID-19 Subjects

Variables	All (N=683)	No OT (N=315)	OT (N=300)	HFNOT or NIV (N=51)	IMV (N=17)	P[a]
Age (IQR)	43 (33–55)	41 (30–50)#&^	45 (34–64)*&^	52 (43–64)*#^	66(54–80)*#&	<0.001
Gender: Female (%)	332 (48.6)	158(50.2)	149 (49.7)	20 (39.2)	6 (35.3)	0.34
BMI (IQR)	23 (21–26)	23 (21–26)	24 (22–26)	23 (21–25)	23 (20–27)	0.55
Exposure						
Contact with Wuhan (%)	533 (78.0)	257 (81.6)	230 (76.7)	35 (68.6)	11 (64.7)	0.26
Comorbidities, any (%)	221 (32.4)	74 (23.5)#&^	106 (35.3)*&^	29 (56.9)*#	12 (70.6)*#	<0.001
Diabetes (%)	61 (8.9)	22 (7.0)	28 (9.3)	9 (17.6)	2 (11.8)	0.09
Hypertension (%)	98 (14.3)	30 (9.5)#&^	47 (15.7)*&^	15 (29.4)*#^	6 (35.3)*#&	<0.001
Illness onset until hospitalization	4.0 (2–7)	3.0 (1–6)#	3.0 (3–8)*	4.0 (3–8)	4.0 (1–7)	0.003
Shock (%)	7 (1.0)	0 (0)	0 (0)	2 (3.9)*#	5 (29.4)*#&	<0.001
Hospital days (IQR)	16 (11–23)	16 (11–22) ^	15 (12–23) ^	17 (12–27) ^	26 (20–35)*#&	<0.001
Day to recovery (IQR)	21 (16–28)	19 (15–25)#&^	21(16–28)*^	24 (17–31)*	29 (25–37)*#	<0.001
Secondary bacterial infection (%)	38 (5.6)	7 (2.2)&^	10 (3.3)&^	11 (21.6)*#^	10 (58.8)*#&	<0.001
Antibiotics (%)	326 (47.7)	101 (32.1)#&^	164 (54.6)*&^	45 (88.2)*#	16 (94.1)*#	<0.001
Corticosteroids (%)	149 (21.8)	15 (4.8)#&^	80 (26.7)*&^	41 (80.4)*#	13 (76.5)*#	<0.001
Respiratory rate	20 (20–20)	20 (19–20)	20 (20–21)	20 (20–22)*#^	20 (20–20)	<0.001

Notes: [a]P value for statistical difference among the four groups (No OT, OT, HFNOT or NIV, and IMV). *Means statistic difference with No OT group, #Means statistic difference with OT group, &Means statistic difference with HFNOT or NIV group, ^Means statistic difference with IMV group.

Abbreviations: COVID-19, coronavirus disease 2019; N, number of subjects; IQR, interquartile range; OT, oxygen therapy; HFNOT, high-flow nasal oxygen therapy; NIV, non-invasive ventilation; IMV, invasive mechanical ventilation.

Patients who recovered with regular OT had a lower level of WBC, neutrophil, platelets, creatine kinase and creatinine relative to those who needed IMV. The patients who failed to recover with HFNOT or NIV had a higher level of WBC, platelets and hemoglobin compared to those in whom hypoxia was corrected with HFNOT or NIV (Tables 2 and 3).

The Effect of HFNOT or NIV on COVID-19 Patients with Respiratory Failure

Sixty-eight patients underwent HFNOT or NIV, of whom 51 subjects improved while 17 patients deteriorated. Both PaO2 and the oxygenation index improved substantially after 2 hours of HFNOT or NIV therapy (88.9mmHg vs 61.9mmHg, $P < 0.001$; 372 vs 225, $P < 0.001$). Oxygen saturation also improved after receiving HFNO or NIV therapy (97.2% vs 93%, $P < 0.001$) (Table 4).

Univariate and Stepwise Multivariate Analysis of Risk Factors for the Need of IMV

Seventeen of 683 subjects in the cohort needed IMV. Univariate analysis showed that several factors were risk factors for the requirement of IMV, including age (odds ratio (OR) = 1.06, 95% confidence interval (CI) = 1.03–1.07, $P < 0.001$), HBP (OR = 3.12, 95% CI = 1.08–9.11, $P = 0.04$), secondary bacterial infection (OR = 31.62, 95% CI = 9.91–110.92, $P < 0.001$), sputum production (OR = 4.7, 95% CI = 1.62–13.41, $P = 0.004$), dyspnea (OR = 9.77, 95%, CI = 3.22–29.61, $P < 0.001$), fatigue (OR = 4.85, 95% CI = 1.62–14.55, $P = 0.005$), and neutrophil count (OR = 1.15, 95% CI = 1.03–1.28, $P = 0.01$). The multivariate model showed that secondary bacterial infection (OR = 6.87, 95% CI = 1.63–29.02, $P = 0.009$) was independently associated with the need for IMV (Table 5).

Discussion

The most important finding of our study was that secondary bacterial infection was an independent risk factor for NIV failure among COVID-19 patients, suggesting that clinicians should be alert to bacterial infections, and if necessary, could even consider prophylactic antibiotics. We also found that oxygen therapy had an obvious beneficial effect on ARF due to SARS-COV2 infection.

In this study, we put HFNOT and NIV patients in the same group for analysis, as a study by Grieco et al[13] showed that there was no significant difference in the number of days free of respiratory support within 28 days between COVID-19 patients treated with helmet non-invasive ventilation and HFNOT.

Gamberini et al,[14] who investigated the risk factors associated with the inability to liberate COVID-19 patients

Table 2 Differences in Symptoms Among COVID-19 Patients without or with Different Kinds of Oxygen Therapy

Variables	All (N=683)	No OT (N=315)	OT (N=300)	HFNOT or NIV (N=51)	IMV (N=17)	P^a
Dry cough	440 (64.4)	206 (65.4) ^	180 (60.0) &^	39 (76.5) #	15(88.2) *#	0.02
Sputum production	169 (24.7)	92 (29.2) #	57 (19.0) *^	12 (23.5)	8 (47.1) #	0.004
Dyspnea	101 (14.8)	31 (9.8) &^	38 (12.7) &^	21 (41.2) *#	11 (64.7) *#	<0.001
Runny nose	3 (0.4)	3 (1.0)	0 (0.0)	0 (0.0)	0 (0.0)	0.32
Sore throat	39 (5.7)	12 (3.8) #	27 (9.0) *&	0 (0.0) #	0 (0.0)	0.007
Nasal congestion	15 (2.2)	13 (4.1) #	2 (0.7) *	0 (0.0)	0 (0.0)	0.02
Chest tightness	27 (4.0)	10 (3.2)	11 (3.7)	4 (7.8)	2 (11.8)	0.15
Palpitation	3 (0.4)	2 (0.6)	0 (0.0)	1 (2.0)	0 (0.0)	0.22
Hemoptysis	26 (3.8)	1 (0.3) #^	21 (7.0) *	1 (2.0) ^	3 (17.6) *&	<0.001
Fever	466 (68.2)	199 (63.2) &^	206 (68.7) &^	44 (86.3) *#	17 (100) *#	<0.001
Headache	51 (7.5)	21 (6.7) &	21 (7.0) &	8 (15.7) *#	1 (5.9)	0.14
Fatigue	202 (29.6)	89 (28.3) ^	80 (27.3) ^	20 (39.2)	11 (64.7) * #	0.004
Myalgia	74 (10.8)	53 (16.8) #&	17 (5.7) *	3 (5.9) *	1 (5.9)	<0.001
Diarrhea	57 (8.3)	27 (8.6)	23 (7.7)	6 (11.8)	1 (5.9)	0.77
Nausea	33 (4.8)	8 (2.5) &^	17 (5.7)	6 (11.8) *	2 (11.8) *	0.01
Vomit	8 (1.2)	4 (1.3)	3 (1.0)	1 (2.0)	0 (0.0)	0.90

Notes: [a]P value for statistical difference among the four groups (No OT, OT, HFNOT or NIV, and IMV). *Means statistic difference with No OT group, #Means statistic difference with OT group, &Means statistic difference with HFNOT or NIV group, ^Means statistic difference with IMV group.

Abbreviations: COVID-19, coronavirus disease 2019; N, number of subjects; IQR, interquartile range; OT, oxygen therapy; HFNOT, high-flow nasal oxygen therapy; NIV, non-invasive ventilation; IMV, invasive mechanical ventilation.

Table 3 Differences in Lab Findings Among COVID-19 Patients without or with Different Kinds of Oxygen Therapy

Variables	All (N=683)	No OT (N=315)	OT (N=300)	HFNOT or NIV (N=51)	IMV (N=17)	P^a
WBC	4.8 (3.7–6.2)	5.0 (3.9–6.3) ^	4.6 (3.6–6.0) ^	4.9 (4.1–6.0) ^	6.7 (4.4–9.1) *#&	0.009
Lym	1.2 (0.8–1.7)	1.3 (0.9–1.7) &	1.2 (0.9–1.6) &	0.8 (0.6–1.2) *#	0.6 (0.4–0.9)	0.02
Neutrophil	3.0 (2.3–4.1)	3.1 (2.3–4.1) ^	2.9 (2.1–3.8) ^	3.6 (2.8–4.8)	5.2 (4.2–7.8) *#	0.03
Platelets	196 (148–249)	219 (165–264) #&^	183 (143–240) *^	185 (144–213) *^	148 (124–165) *#&	<0.001
Hb	133 (123–145)	135 (126–147) #	130 (120–143) *&	133 (124–152) #^	131 (116–136) &	0.005
PT	12 (10–13)	12 (11–13) #	12 (11–13) *	12 (11–13)	12 (11–13)	0.002
APTT	32 (29–36)	32 (28–36)	33 (30–36)	32 (26–37)	32 (26–38)	0.44
ALT	21 (15–31)	21 (15–36) #	21 (15–28) *&	28 (18–41) #	23 (19–33)	0.005
AST	24 (19–31)	23 (18–31) &	24 (19–31) &	44 (86.3) *#	29 (22–45)	0.009
Albumin	40 (26–44)	42 (39–45) &^	39 (36–42)	35 (33–40) *	33 (29–37) *	0.04
Globulin	26 (23–29)	25 (19–30) #&^	26 (23–28) *&	29 (27–31) *#	27 (26–32) *	<0.001
CK	68 (46–108)	64 (45–98) &^	68 (46–106) &^	108 (54–195) *#	168 (81–240) *#	<0.001
Creatinine	63 (51–76)	65 (55–77) ^	58 (45–72) ^	65 (55–80)	67 (55–87) *#	0.01
BUN	4.1 (3.2–5.1)	3.8 (3.1–4.6) &	4.3 (3.2–5.3) &	5.1 (3.8–8.1) *#	6.5 (4.1–8.1)	<0.001
LDH	181 (147–224)	180 (154–221) &^	171 (141–211) &	241 (188–318) *#	464 (305–511)	<0.001
Lactate	1.8 (1.2–2.6)	1.6 (1.0–2.3) #	2. 7 (1.9–3.1)*	1.84 (1.25–2.71)	2.20 (1.05–3.20)	0.02
PH	7.5 (7.4–7.5)	7.4 (7.4–7.5)	7.5 (7.4–7.5)	7.5 (7.4–7.5)	7.5 (7.4–7.5)	0.21
PaCO2	36.7 (32.9–41.1)	35.1 (28.7–37.7)	37.5 (33.0–41.4)	35.2 (29.6–38.7)	33.8 (27–88.9)	0.29
PaO2	84.8 (72.4–94.6)	94.1 (84.3–109)&^	83.4 (71.2–89.4) &	67.2 (48.8–82)*#^	75 (54–97) *	<0.001

Notes: [a]P value for statistical difference among the four groups (No OT, OT, HFNOT or NIV, and IMV). *Means statistic difference with No OT group, #Means statistic difference with OT group, &Means statistic difference with HFNOT or NIV group, ^Means statistic difference with IMV group.

Abbreviations: COVID-19, coronavirus disease 2019; N, number of subjects; IQR, interquartile range; OT, oxygen therapy; HFNOT, High-flow nasal oxygen therapy; NIV, non-invasive ventilation; IMV, invasive mechanical ventilation; WBC, white blood cell; Lym, lymphocyte; Hb, hemoglobin; PT, Prothrombin Time; APTT, activated partial thromboplastin time; ALT; alanine aminotransferase; AST, aspartate aminotransferase; Ck, creatine kinase; BUN, blood urea nitrogen; LDH, Lactate dehydrogenase.

from mechanical ventilation, found that age, sequential organ failure assessment score on intensive care unit admission, respiratory system compliance, PaO2/FiO2, renal and cardiovascular complications were independent risk factors which was different from our study. Previous studies showed that hypertension was the most common

Table 4 The Effect of HFNOT or NIV on COVID-19 Patients with Respiratory Failure

Variables	Before HFNOT or NIV	After HFNOT or NIV	*P*
PH	7.4 (7.4–7.5)	7.4 (7.4–7.5)	0.55
PaO2 (mmHg)	61.9 (54.6–67.6)	88.9 (75.7–97.3)	<0.001
PaCO2 (mmHg)	35.0 (31.9–38.0)	37.7 (32.5–39.4)	0.05
SpO2(%)	93.0 (91.0–94.0)	97.2 (95.8–98.0)	<0.001
Oxygenation index	224.9 (213.6–244.8)	372.1 (337.1–428.8)	<0.001

Note: Oxygenation index = PaO2/FiO2.

Abbreviations: COVID-19, coronavirus disease 2019; HFNOT, high-flow nasal oxygen therapy; NIV, non-invasive ventilation; PaO2, partial artery pressure of oxygen; PaCO2, partial artery pressure of carbon dioxide; SpO2, oxygen saturation.

comorbidity, and hypertensive patients may be at greater risk of dying from COVID-19.[1,15] The rate of hypertension in this cohort of patients was low, one of the possible reasons being the younger median age than in previously reported studies (43 vs 51, 49). However, hypertension is not usually an independent risk factor associated with mortality. In our study, we found that patients who needed intubation had higher a rate of hypertension, but we also clarified that hypertension was not an independent risk factor for NIV failure. Additional research is needed to determine whether ACE inhibitors and angiotensin receptor blockers are helpful for patients with COVID-19. We found no difference in diabetes prevalence among patients with different kinds of oxygen therapy.

A previous study showed that among 17 HFNOT patients, 7 (41%) experienced HFNC failure and received NIV as a rescue therapy. Two (29%) patients were subsequently intubated after NIV failure.[16] In our study, 68 patients received HFNOT or NIV and 17 (25%) of them received IMV as a rescue therapy. The findings of this study revealed that HFNOT had a high success rate, and showed obvious improvement in PaO2 and oxygenation index, but 25% of patients treated with HFNOT had to be further intubated. As a result, there is a urgent need to figure out some of the risk factors related to the requirement for IMV. We conducted a multivariate analysis of risk factors for the need of IMV and found that secondary bacterial infection was an independent risk factor for IMV. Physicians should thus be alert to secondary bacterial infection in patients with NIV.

Our study has strengths and limitations. It clearly identified an independent risk factor for the requirement of IMV, providing some suggestions for physicians caring for COVID-19 patients. This was a retrospective study, and although the use of HFNOT or NIV and transition to intubation was based on the Chinese treatment protocol for COVID-19, different physicians have different opinions on the timepoint to switch to intubation. In addition, mortality was not as high as reported for COVID-19 patients in China. In fact, in China, the mortality of COVID-19 in most regions (outside Wuhan) is less than 1%,[17] The higher mortality in Wuhan may due to the lack of medical

Table 5 Univariate and Stepwise Multivariate Analysis of Risk Factors for the Need of IMV

Variable	Univariate			Multivariate		
	OR	95% CI	*P*	OR	95% CI	*P*
Age (years)	1.06	1.03–1.07	0.001	1.03	0.98–1.07	0.24
Hypertension	3.12	1.08–9.11	0.04	1.50	0.33–6.71	0.59
Bacterial infection	31.62	9.91–100.92	<0.001	6.87	1.63–29.02	0.009
Dry cough	3.88	0.86–17.47	0.07	–	–	–
Sputum production	4.70	1.62–13.41	0.004	2.53	0.64–10.03	0.19
Dyspnea	9.77	3.22–29.61	<0.001	2.79	0.59–13.14	0.20
Hemoptysis	3.76	0.99–14.32	0.05	–	–	–
Fever	5.86	1.79–19.2	0.09	–	–	–
Fatigue	4.85	1.62–14.55	0.005	2.74	0.74–10.19	0.13
White blood cell	1.17	1.03–1.32	0.02	1.19	0.52–2.70	0.68
Neutrophil	1.15	1.03–1.28	0.01	0.93	0.40–2.16	0.87
Platelets	0.99	0.98–1.00	0.004	0.99	0.97–1.00	0.08
Hemoglobin	0.98	0.95–1.01	0.15	–	–	–
Creatine kinase	1.00	1.00–1.01	0.001	1.00	1.00–1.01	0.22
Creatinine	1.01	1.00–1.01	0.05	–	–	–

Abbreviation: IMV, invasive mechanical ventilation.

staff, personal protective equipment and ventilators at the early stage of the disease outbreak. In addition, this also may due to the population is relatively young and with few comorbidities in this study when compared with populations more commonly encountered in Western hospitals.[18]

Conclusion

We identified that HFNOT and NIV had an obvious beneficial effect on ARF among COVID-19 patients. We also demonstrated that secondary bacterial infection was an independent risk factor for NIV failure in patients infected by SARS-COV2.

Abbreviations

COVID-19, Coronavirus disease 2019; IQR, interquartile range, ICU, intensive care unit; CDC, Chinese Center for Disease Control and Prevention; OT, oxygen therapy; HFNOT, high flow nasal oxygen therapy; NIV, noninvasive ventilation; IMV, invasive mechanical ventilation; SARS-COV-2, severe acute respiratory syndrome coronavirus 2; ARF, acute respiratory failure.

Data Sharing Statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics Approval

The research protocol was approved by the local Ethics Committee of the Second Xiangya Hospital of Central South University (number: fabh003) and conducted in accordance with the Declaration of Helsinki and its amendments. Informed consent was waived because of the retrospective nature of the study and the analysis used anonymous clinical data.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

None of the authors have a conflict of interest that could affect this manuscript.

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