Open Access Publish Free

http://jept.ir
doi 10.34172/jept.2024.15

Journal of Emergency Practice and Trauma
Volume 9, Issue 2, 2023, p. 114-119

Original Article

Comparison of high-flow nasal cannula and conventional oxygen therapy in treating COVID-19 patients referred to the emergency department: A randomized, single-blind clinical trial

Farhad Heydari[1], Majid Zamani[1], Mohammad Nasr-Esfahani[1], Fatemehsadat Mirmohammad Sadeghi[2], Faezeh Hedayati[1*]

[1]Department of Emergency Medicine, Al-Zahra Hospital, Faculty of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran
[2]Department of Internal Medicine, Al-Zahra Hospital, Faculty of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran

Received: November 11, 2023
Accepted: February 5, 2024
ePublished: May 30, 2024

***Corresponding author:**
Faezeh Hedayati,
Email: Fhedayati707@gmail.com

Citation: Heydari F, Zamani M, Nasr-Esfahani M, Mirmohammad Sadeghi F, Hedayati F. Comparison of high-flow nasal cannula and conventional oxygen therapy in treating COVID-19 patients referred to the emergency department: a randomized, single-blind clinical trial. Journal of Emergency Practice and Trauma 2023; 9(2): 114-119. doi: 10.34172/jept.2024.15.

Abstract

Objective: High-flow nasal cannula (HFNC) oxygen therapy has been recently implicated in the treatment of patients with acute respiratory failure (ARF). This study investigated the effect of this treatment on COVID-19 patients.

Methods: This was a prospective, randomized, single-blind clinical trial performed between June and November 2021 (Delta variant of the coronavirus) at Al-Zahra Hospital in Iran, on patients with COVID-19 referred to the emergency department (ED). COVID-19 patients who had peripheral oxygen saturation (SpO2) ≤ 90% despite receiving nasal oxygen (up to 6 L/min) were included in the study and randomly assigned to receive either HFNC or conventional oxygen therapy (COT) treatment. The patients were compared regarding vital signs, SpO2, and the need for endotracheal intubation and intensive care unit (ICU) admission. The calculated sample size was 35 patients in each group. The variables were compared using the chi-square, student's t-test, or Mann-Whitney U tests. The data was analyzed using SPSS version 25.

Results: Eighty-seven patients with a mean age of 65.3 ± 14.8 (62.1% male) were included. The two groups were similar in terms of age, sex, time interval from onset to diagnosis, and underlying diseases (hypertension, diabetes, coronary artery disease, etc.) ($P<0.05$). No statistically significant difference was reported between SpO2 and PaO2/FiO2 vital signs at the beginning of treatment between the two groups. One hour after treatment, respiratory rate, SpO2, and PaO2/FiO2 were better in the HFNC group compared to the COT group ($P<0.05$). Also, there was no significant difference between the two groups regarding in-hospital mortality or the need for endotracheal intubation or ICU admission.

Conclusion: Early use of HFNC oxygen therapy in patients with COVID-19 can improve SpO2, respiratory rate, and PaO2/FiO2 levels, making it highly valuable from a clinical point of view.

Keywords: Emergency department, COVID-19, High-flow nasal cannula, Hypoxia, Oxygen therapy

Introduction

After detecting its first cases in Wuhan (China) in December 2019, SARS-CoV-2 caused an epidemic of respiratory disease called COVID-19 (1). Common symptoms of COVID-19 include fever, myalgia, fatigue, and dry cough. Severe cases progressed to severe dyspnea and hypoxemia within a week of symptom onset. In patients with COVID-19 who needed hospitalization, respiratory failure and hypoxemia were about 20%, and more than twenty-five percent of them required treatment in the intensive care unit (ICU) (1-3).

Most COVID-19 cases were mild or asymptomatic or had influenza-like illness, but some of the patients developed severe pneumonia, acute respiratory distress syndrome (ARDS), multi-organ failure, and death (1-3).

Recently, a new oxygen treatment method called high-flow nasal cannula (HFNC) has become available to emergency physicians (previously, this method was used in the ICU). HFNC is a non-invasive oxygenation method that delivers warm and humidified oxygen up to a maximum flow of 60 L/min and can titrate fractional inspiratory oxygen (FiO2) up to 100%, even during acute respiratory distress. Previous studies in patients with acute respiratory failure (ARF) have shown a lower need for invasive mechanical ventilation (IMV). Studies have also demonstrated longer survival of patients using HFNC compared with conventional oxygen therapy (COT) and non-invasive ventilation (NIV). However, in some studies,

no significant difference was seen (4,5).

Not many clinical studies have investigated the use of HFNC in COVID-19 patients. Also, the clinical conditions of patients who have benefited from HFNC are unknown. However, it has been suggested that HFNC oxygen therapy in COVID-19 patients with ARF is safe, appropriate, and effective (3,6,7). In the emergency triage unit, shortness of breath is one of the common complaints of patients with COVID-19, a condition that affects more than half of the patients, and ARF is one of the main reasons for patient admission to the ICU (1,2). The usual treatments initially started for these patients include standard oxygen treatment with a cannula or an oxygen mask. However, these methods have limitations in treatment, especially for creating a high volume and controlled FiO2 (2,5). Even with an oxygen face mask, these methods will eventually bring the FiO2 to nearly 70%, which will decrease as respiratory failure progresses.

HFNC is an oxygen delivery technique first used in preterm infants and, more recently, in the ICU and postoperative recovery. HFNC can increase FiO2 up to 100% even during acute failure and respiratory distress (6-8). One possible drawback of using HFNC is the creation of respiratory particles and the spread of aerosols. Suggestions such as using HFNC in an isolation room with negative pressure and the complete fitting of the cannula have been given (9).

WHO guidelines recommend HFNC oxygen therapy before intubation of patients (10). Also, initial recommendations from China have reported HFNC as a beneficial measure; early reports in the United States cautioned against HFNC use, stating that it delayed intubation in patients unresponsive to face mask oxygen (11). However, with further experience in the United States, it has become clear that when used with sufficient caution, HFNC could relieve patients from respiratory failure and prevent endotracheal intubation (12). The early guidelines did not agree about the use of HFNC, with some favoring its use and some ruling against it (3,8,11,12).

Considering that, especially in Iran, the use of HFNC is mainly in the ICU or recovery after surgery, and it has been less investigated in emergency departments (EDs). Considering the lack of definitive findings regarding the usefulness of HFNC as the first line of treatment in COVID-19 patients with acute respiratory distress, in this study, the effectiveness of the HFNC oxygen therapy method in COVID-19 patients was investigated and compared with COT.

Methods

This prospective, randomized, single-blind clinical trial was performed between June and November 2021 (Delta variant of the coronavirus) at Al-Zahra Hospital in Isfahan, Iran, on patients with COVID-19 referred to the ED. The trial protocol was approved by the Ethics Committee of Isfahan University of Medical Sciences (code IR.MUI.MED.REC.1400.657). The study was also registered in the Iranian Registry of Clinical Trials (identifier: IRCT20180129038549N15). This study followed the CONSORT guidelines.

The included patients were adult patients ($\geq$18 years) who had a confirmed diagnosis of COVID-19 based on the polymerase chain reaction (PCR) test and whose oxygen level was less than 90% despite receiving nasal oxygen $\geq$3 L/min or a respiratory rate greater than 24 breaths per minute. Patients with unstable hemodynamics, decreased level of consciousness, obesity hypoventilation syndrome, and respiratory failure due to cardiopulmonary edema were excluded from the trial. Also, patients who did not tolerate the use of HFNC, patients who needed emergency intubation, and pregnant women were not included.

The COVID-19 cases admitted to the ED were initially treated with nasal cannula oxygen therapy for at least 15 minutes. Then, patients with peripheral SpO2$\leq$90% despite this oxygen therapy were included in the study. These subjects were divided into a case (A) and a control (B) group using the block randomization method (blocks of four). There were six possible blocks of four (ABAB-BABA-ABBA-BAAB-AABB-BBAA). A block was randomly selected, and the arrangement pattern for that block was used to allocate patients. Sampling continued until the sample size was reached. The researchers were blinded to randomization. All subjects were treated according to the clinical judgment of the attending physicians, hospital protocols, and routine clinical practice.

In the study group, HFNC oxygen therapy was used for patients. The basic parameters were as follows: temperature 37 °C to 34 °C, initial flow rate 50 L/min up to 60 L/min as needed, and oxygen concentration 50%. The parameters were changed according to the oxygen level (SpO2) and the patient's tolerance to maintain SpO2$\geq$93%. The cases treated with HFNC were transferred to the emergency isolation room, and a surgical mask was draped over the HFNC. A non-rebreather face mask ($\geq$6 L/min) was used in the control group to maintain SpO2$\geq$93%. The subjects were placed in the prone position, underwent the above treatments for at least one hour, and were then evaluated. If the patients did not reach the target SpO2 level, non-invasive methods, including endotracheal intubation, were used in both groups based on the physician's opinion.

The need for intubation and ICU admission and in-hospital mortality (28 days) were investigated in the patients, and the results were compared between study and control groups. Vital signs, including heart rate (HR), respiratory rate (RR), systolic and diastolic blood pressure (SBP and DBP), and SpO2, and arterial blood gas variables were recorded at the beginning of treatment in the two groups. These parameters were re-examined and recorded in the patients one hour after the start of the treatment.

Then, the results were compared between the two groups.

The sample size of 35 patients in each group was considered with a power of 80%, a significance level of 5%, an effect size of 50%, and a standard deviation of 6.5% (for the main research variable SpO2). To ensure the power of the study, at least 42 patients in each group were considered to account for the probable dropout rate of 20%.

$$N=(Z_{1-\alpha/2}+Z_{1-\beta})^2\,(\delta_1^2+\delta_2^2)\,/\,(\mu_1-\mu_2)^2$$

After data were collected, they were analyzed using SPSS version 25. Continuous variables were expressed as mean and standard deviation, and categorical data were expressed as numbers and percentages. The chi-square test was performed to compare categorical data, and the student's t-test or the Mann-Whitney U test was performed for continuous variables. A significance level of less than 0.05 was considered.

Results

Enrollment included 87 patients (Figure 1). The mean age of the participants was 65.3 ± 14.8 years, and 62.1% of them (54 people) were male. The two groups were similar in terms of age ($P=0.090$), gender ($P=0.563$), and underlying diseases, including lung disease ($P=0.756$), hypertension ($P=0.554$), diabetes ($P=0.866$), coronary artery disease ($P=0.747$), etc. The baseline characteristics of subjects are reported in Table 1. There was no statistically significant difference between the two groups considering the SpO2 ($P=0.699$) and PaO2/FiO2 ($P=0.620$) vital signs at the beginning of treatment. Also, the two groups did not differ in the interval from onset to diagnosis (7.6 ± 1.1 days in COT vs. 7.8 ± 0.8 days in the HFNC group, $P=0.910$). One hour after treatment, respiratory rate, SpO2, and PaO2/FiO2 were better in the HFNC group compared to the COT group ($P<0.05$) (Table 2). ICU admission was required in 34.9% of patients (15 cases) in the COT group versus 20.5% (9 cases) in the HFNC group ($P=0.132$). Endotracheal intubation was required

Table 1. Baseline characteristics and clinical data of the patients

	HFNC group (n = 44)	COT group (n = 43)	*P* value
Age, years	62.6 ± 16.5	68.1 ± 12.4	0.090[a]
Gender, n (%)			0.563[b]
Male	26 (59.1)	28 (65.1)	
Female	18 (40.9)	15 (34.9)	
Underlying diseases, n (%)			
Lung disease	10 (22.7)	11 (25.6)	0.756[b]
Coronary artery disease	8 (18.2)	9 (20.9)	0.747[b]
Diabetes mellitus	13 (29.5)	12 (27.9)	0.866[b]
Hypertension	21 (47.7)	18 (54.5)	0.554[b]
Chronic kidney disease	2 (4.5)	1 (2.3)	0.570[b]
Interval from onset to diagnosis (day)	7.8 ± 0.8	7.6 ± 1.1	0.910[a]
Admitted to ICU, n (%)	9 (20.5)	15 (34.9)	0.132[c]
Intubation rate, n (%)	4 (9.1)	8 (18.6)	0.198[c]
In hospital mortality, n (%)	3 (6.8)	6 (14.0)	0.275[c]

Variables are presented as mean (standard deviation) or frequency (%).
[a] Analyzed using independent student's t-test
[b] Analyzed using chi-square test or Fisher's exact test
[c] Analyzed using Mann-Whitney U-test

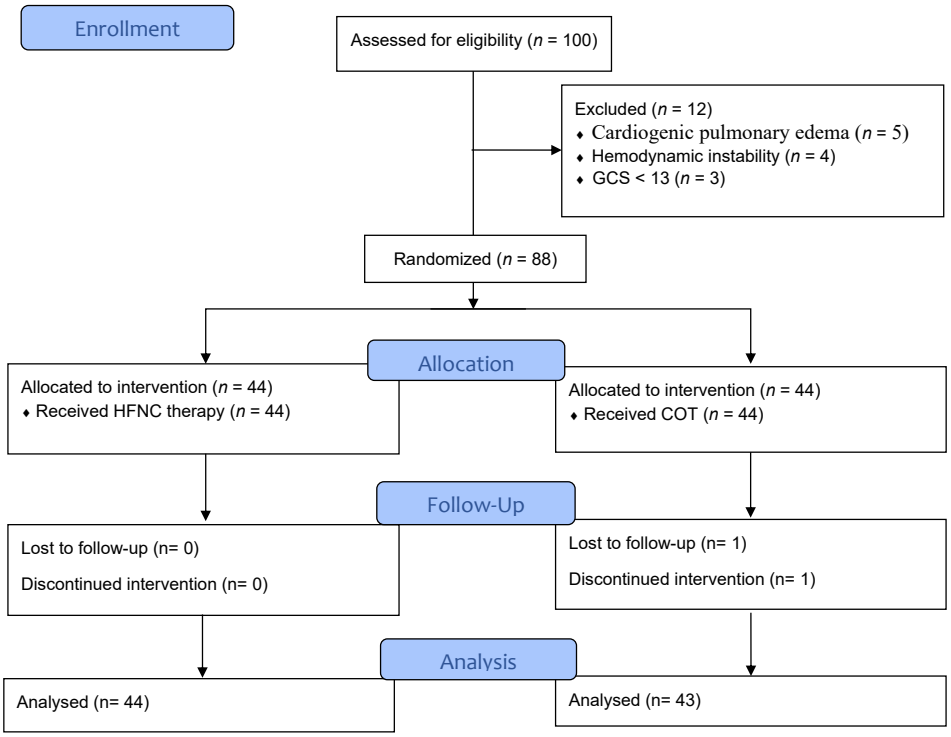

Figure 1. CONSORT flow diagram

Table 2. Effect of oxygen therapy on clinical parameters in the HFNC and COT groups

Variables		Groups		*P* value
		HFNC group (*n* = 44)	COT group (n = 43)	
SBP	Baseline	129.4 ± 14.7	131.2 ± 15.1	0.626
	After	123.6 ± 15.8	128.3 ± 12.6	0.112
DBP	Baseline	80.5 ± 9.1	81.4 ± 11.5	0.925
	After	77.9 ± 11.6	79.7 ± 9.2	0.411
Heart rate	Baseline	87.4 ± 18.3	86.7 ± 12.8	0.835
	After	79.7 ± 14.5	81.5 ± 12.1	0.326
Respiratory rate	Baseline	23.4 ± 5.3	24.9 ± 6.5	0.224
	After	20.1 ± 5.1	22.8 ± 6.0	0.029
Pulse oximetry	Baseline	84.8 ± 5.2	85.5 ± 5.9	0.699
	After	93.1 ± 6.2	89.8 ± 5.8	0.009
pH	Baseline	7.34 ± 0.11	7.33 ± 0.15	0.556
	After	7.34 ± 0.08	7.31 ± 0.08	0.065
PCO2	Baseline	37.15 ± 8.03	38.11 ± 7.95	0.669
	After	39.53 ± 18.8	40.93 ± 11.33	0.526
HCO3	Baseline	21.58 ± 3.63	20.86 ± 3.55	0.326
	After	22.28 ± 4.74	23.01 ± 8.84	0.556
PaO2/FiO2	Baseline	224.2 ± 12.7	216.8 ± 5.7	0.620
	After	268.9 ± 10.1	238.4 ± 6.9	0.025

HFNC: high-flow nasal cannula; COT: conventional oxygen therapy; PH: potential of hydrogen; PCO2: partial pressure of carbon dioxide; HCO3: bicarbonate; PaO2/FiO2: partial pressure of arterial oxygen/fraction of inspired oxygen; DBP: Diastolic blood pressure; SBP, Systolic blood pressure. Data are presented as mean and standard deviation.
[a] Analyzed using independent student's t-test.

in 18.6% of patients (8 cases) in the COT group versus 9.1% (4 cases) in the HFNC group ($P = 0.198$). In-hospital mortality was 6.8% in the study group and 14.0% in the control group ($P = 0.275$). These statistics were lower in subjects treated with HFNC, but the differences were not significant (Table 1).

Discussion

The present study showed that HFNC oxygen therapy was associated with improved respiratory rate ($P = 0.029$), SpO2 ($P = 0.009$), and PaO2/FiO2 ($P = 0.025$) compared to COT in ED patients presenting with COVID-19. It demonstrated no significant reduction in the need for ICU admission ($P = 0.132$) and endotracheal intubation ($P = 0.198$) with HFNO oxygen therapy.

HFNC may have potential clinical benefits for cases with acute hypoxemic respiratory failure. Previous research has shown that HFNC is associated with decreased necessity of endotracheal intubation, lower mortality, reduced need for ICU hospitalization, and less need for re-intubation in hypoxemic ARF resulting from various causes (13-15).

Although respiratory failure is a common finding in patients with severe COVID-19 infection, the patterns of hypoxemia associated with COVID-19 are different compared to typical respiratory failure and ARDS. Subjects with COVID-19 maintain lung compliance at low PaO2/FiO2 ratios (7,16). These differences in pathophysiology could account for differences in the efficacy of HFNC. Evidence obtained during this pandemic demonstrated the feasibility of using HFNC to treat cases with hypoxemic ARF due to COVID-19 in the non-ICU setting or for cases with a poorer prognosis who cannot be admitted to the ICU due to lack of ICU beds (17,18).

HFNC oxygen therapy reduced the need for endotracheal intubation compared with COT in critically ill non-COVID-19 patients with hypoxemic ARF. As a result, it has recently been strongly recommended in clinical guidelines (19). Similarly, some previous studies have also shown the possibility that HFNC treatment is more effective than COT in treating COVID-19 patients (7,20). HFNC has been shown to be a valuable therapeutic modality during pandemics for ICU resource management (beds and ventilators), and it has been used widely and heterogeneously in studies (21). Therefore, in resource-constrained healthcare systems, HFNC can treat hypoxemic ARF in approximately half of its recipients without the need for IMV in a non-ICU setting, with pulse oximeter monitoring as an affordable and available device (21).

A clinical trial of 22 people with severe COVID-19 pneumonia reported that initial oxygen therapy with HFNC improved SpO2, respiratory rate, infectious indices, and decreased ICU length of stay compared with COT (22). Considering the early treatment in the present study, similar results were obtained. Furthermore, early oxygen therapy with HFNC is an effective respiratory therapy based on multicenter retrospective research, which reported that patients with COVID-19 who fail HFNC treatment had poor prognoses, with a reported mortality rate of 65% (5).

In our study, the mortality rate of cases who received oxygen with HFNC was lower than that of cases who received normal oxygen. However, the difference was not significant (6.8% vs. 14.0%, $P = 0.275$). Zhou et al (23) found that 41 of their 191 hospitalized COVID-19 cases were treated with HFNC in the ICU and ward. Non-surviving patients were more treated with HFNC compared to surviving patients (61% vs. 6%, $P < 0.001$).

Geng et al (24) treated eight COVID-19 patients with HFNC and showed favorable results in all cases. Before the administration of HFNC, the PaO2/FiO2 level of the eight patients was 259.88 ± 58.15 mm Hg, and after 24 hours, the PaO2/FiO2 level reached 280–450 mm Hg, and all patients were discharged without the need for endotracheal intubation. These results are in line with the findings of the current study. Wang et al (25) showed that of 17 patients treated with HFNC, treatment failure occurred in 41% of cases. Notably, the failure rate was zero in cases with PaO2/FiO2 > 200 and 63% in patients with PaO2/FiO2 ≤ 200. Another study reported that

lower initial PaO2/FIO2 is associated with treatment failure (26). Considering that the mean PaO2/FiO2 in the patients of the present study was more than 200, our results were different.

He et al (9) reviewed 36 critically ill subjects with COVID-19 who received oxygen by HFNC. They demonstrated that 26 cases recovered and were discharged, while ten subjects (28%) required IMV. They found some factors to be effective in treatment success. These factors included choosing the appropriate size and location of the nasal cannula, starting the initial flow at 60 L/min and 37 °C in cases with respiratory distress, and treatment with a target SpO2 > 95% in patients without chronic respiratory disease. Similar settings were used in the present study and other studies related to HFNC therapy for COVID-19 patients (23-25,27,28).

A multicenter retrospective research investigated the feasibility of non-invasive ventilatory support therapy for hypoxemic ARF patients associated with COVID-19 outside the ICU setting and found that 163 of 671 patients were treated with HFNC (24.3%). In patients receiving HFNC, 71% of endotracheal intubation was prevented (17). Although the study was retrospective, it is interesting that no significant difference in primary outcomes (endotracheal intubation and mortality rate) was shown between patients receiving HFNC compared with CPAP and NIV. In line with this study, in our study, oxygen therapy with HFNC did not lead to a reduction in the need for intubation and ICU admission ($P = 0.198$ and $P = 0.132$, respectively).

Demoule et al (29) conducted a retrospective ICU trial to compare the outcome of oxygen therapy with HFNC and COT in people with COVID-19. The proportion requiring IMV at day 28 was significantly lower in patients receiving HFNC (55% vs. 72%; $P < .001$), while no significant difference in mortality was observed (29). Also, Patel et al stated that using HFNC in COVID-19 cases with mild to severe hypoxic respiratory failure may significantly reduce the need for IMV without a noticeable effect on mortality (8).

Limitation

While one of the current studies' strengths is that it is prospective, it also has limitations. Its small sample size and single-center nature are among its limitations. The inability to blind the treating team to the devices used may have biased the outcomes.

Conclusion

Early use of HFNC oxygen therapy in COVID-19 patients with hypoxic ARF can improve SpO2, respiratory rate, and PaO2/FiO2 levels compared to COT, making it a valuable treatment for COVID-19 patients. It is recommended that clinical trials with a larger sample size investigate the effectiveness of oxygen therapy with HFNC in hypoxic ARF patients.

Authors' Contribution

Conceptualization: Farhad Heydari, Majid Zamani, Mohammad Nasr-Esfahani, Fatemehsadat Mirmohammad Sadeghi, Faezeh Hedayati.
Data curation: Farhad Heydari, Mohammad Nasr-Esfahani, Faezeh Hedayati.
Formal analysis: Farhad Heydari, Faezeh Hedayati.
Funding acquisition: Farhad Heydari.
Investigation: Farhad Heydari, Majid Zamani, Mohammad Nasr-Esfahani, Fatemehsadat Mirmohammad Sadeghi, Faezeh Hedayati.
Methodology: Farhad Heydari, Majid Zamani, Mohammad Nasr-Esfahani, Fatemehsadat Mirmohammad Sadeghi, Faezeh Hedayati.
Project administration:Farhad Heydari, Faezeh Hedayati.
Resources: Farhad Heydari.
Software: Farhad Heydari, Faezeh Hedayati.
Supervision: Farhad Heydari, Majid Zamani, Mohammad Nasr-Esfahani.
Validation: Farhad Heydari.
Investigation: Farhad Heydari, Majid Zamani, Mohammad Nasr-Esfahani, Fatemehsadat Mirmohammad Sadeghi, Faezeh Hedayati
Visualization: Farhad Heydari.
Writing–original draft: Farhad Heydari, Faezeh Hedayati.
Writing–review & editing: Farhad Heydari, Majid Zamani, Mohammad Nasr-Esfahani, Fatemehsadat Mirmohammad Sadeghi, Faezeh Hedayati.

Competing Interests

None.

Ethical Approval

Ethical approval was obtained from the Ethics Committee of Isfahan University of Medical Sciences (IR.MUI.MED.REC.1400.657).

Funding

This study was supported by financial grant from Isfahan University of Medical Sciences.

References

1. Heydari F, Abbasi S, Shirani K, Zamani M, Masoumi B, Majidinejad S, et al. Predictive performance of qSOFA in confirmed COVID-19 patients presenting to the emergency department. Tzu Chi Med J. 2023;35(2):182-7. doi: 10.4103/tcmj.tcmj_132_22.
2. Sanz-Moncusí M, Rosselló-Sancho J, Garcia-Alamino JM. Use of high-flow nasal cannula in COVID-19 has improved effectiveness, safety and tolerability when applied in lateral position compared with prone positioning. Intensive Crit Care Nurs. 2021;66:103061. doi: 10.1016/j.iccn.2021.103061.
3. Calligaro GL, Lalla U, Audley G, Gina P, Miller MG, Mendelson M, et al. The utility of high-flow nasal oxygen for severe COVID-19 pneumonia in a resource-constrained setting: a multi-centre prospective observational study. EClinicalMedicine. 2020;28:100570. doi: 10.1016/j.eclinm.2020.100570.
4. Ángel Mejía VE, Arango Isaza D, Fernández Turizo MJ, Vasquez Trespalacios EM, Rincón JA. High flow nasal cannula useful for severe SARSs-CoV-2 pneumonia. Med Intensiva (Engl Ed). 2022;46(2):107-9. doi: 10.1016/j.medine.2021.01.004.
5. Duan J, Zeng J, Deng P, Ni Z, Lu R, Xia W, et al. High-flow nasal cannula for COVID-19 patients: a multicenter retrospective study in China. Front Mol Biosci. 2021;8:639100. doi: 10.3389/fmolb.2021.639100.
6. Duan J, Chen B, Liu X, Shu W, Zhao W, Li J, et al. Use of high-

flow nasal cannula and noninvasive ventilation in patients with COVID-19: a multicenter observational study. Am J Emerg Med. 2021;46:276-81. doi: 10.1016/j.ajem.2020.07.071.
7. Agarwal A, Basmaji J, Muttalib F, Granton D, Chaudhuri D, Chetan D, et al. High-flow nasal cannula for acute hypoxemic respiratory failure in patients with COVID-19: systematic reviews of effectiveness and its risks of aerosolization, dispersion, and infection transmission. Can J Anaesth. 2020;67(9):1217-48. doi: 10.1007/s12630-020-01740-2.
8. Patel M, Gangemi A, Marron R, Chowdhury J, Yousef I, Zheng M, et al. Retrospective analysis of high flow nasal therapy in COVID-19-related moderate-to-severe hypoxaemic respiratory failure. BMJ Open Respir Res. 2020;7(1):e000650. doi: 10.1136/bmjresp-2020-000650.
9. He G, Han Y, Fang Q, Zhou J, Shen J, Li T, et al. [Clinical experience of high-flow nasal cannula oxygen therapy in severe COVID-19 patients]. Zhejiang Da Xue Xue Bao Yi Xue Ban. 2020;49(2):232-9. doi: 10.3785/j.issn.1008-9292.2020.03.13. [Chinese].
10. World Health Organization (WHO). Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected. Interim guidance. Pediatr Med Rodz. 2020;16(1):9-26. doi: 10.15557/PiMR.2020.0003.
11. Xu DY, Dai B, Tan W, Zhao HW, Wang W, Kang J. Effectiveness of the use of a high-flow nasal cannula to treat COVID-19 patients and risk factors for failure: a meta-analysis. Ther Adv Respir Dis. 2022;16:17534666221091931. doi: 10.1177/17534666221091931.
12. Crimi C, Pierucci P, Renda T, Pisani L, Carlucci A. High-flow nasal cannula and COVID-19: a clinical review. Respir Care. 2022;67(2):227-40. doi: 10.4187/respcare.09056.
13. Frat JP, Thille AW, Mercat A, Girault C, Ragot S, Perbet S, et al. High-flow oxygen through nasal cannula in acute hypoxemic respiratory failure. N Engl J Med. 2015;372(23):2185-96. doi: 10.1056/NEJMoa1503326.
14. Nagata K, Morimoto T, Fujimoto D, Otoshi T, Nakagawa A, Otsuka K, et al. Efficacy of high-flow nasal cannula therapy in acute hypoxemic respiratory failure: decreased use of mechanical ventilation. Respir Care. 2015;60(10):1390-6. doi: 10.4187/respcare.04026.
15. Thille AW, Muller G, Gacouin A, Coudroy R, Decavèle M, Sonneville R, et al. Effect of postextubation high-flow nasal oxygen with noninvasive ventilation vs high-flow nasal oxygen alone on reintubation among patients at high risk of extubation failure: a randomized clinical trial. JAMA. 2019;322(15):1465-75. doi: 10.1001/jama.2019.14901.
16. Ottestad W, Søvik S. COVID-19 patients with respiratory failure: what can we learn from aviation medicine? Br J Anaesth. 2020;125(3):e280-1. doi: 10.1016/j.bja.2020.04.012.
17. Franco C, Facciolongo N, Tonelli R, Dongilli R, Vianello A, Pisani L, et al. Feasibility and clinical impact of out-of-ICU noninvasive respiratory support in patients with COVID-19-related pneumonia. Eur Respir J. 2020;56(5):2002130. doi: 10.1183/13993003.02130-2020.
18. Villarreal-Fernandez E, Patel R, Golamari R, Khalid M, DeWaters A, Haouzi P. A plea for avoiding systematic intubation in severely hypoxemic patients with COVID-19-associated respiratory failure. Crit Care. 2020;24(1):337. doi: 10.1186/s13054-020-03063-6.
19. Rochwerg B, Einav S, Chaudhuri D, Mancebo J, Mauri T, Helviz Y, et al. The role for high flow nasal cannula as a respiratory support strategy in adults: a clinical practice guideline. Intensive Care Med. 2020;46(12):2226-37. doi: 10.1007/s00134-020-06312-y.
20. Nasa P, Azoulay E, Khanna AK, Jain R, Gupta S, Javeri Y, et al. Expert consensus statements for the management of COVID-19-related acute respiratory failure using a Delphi method. Crit Care. 2021;25(1):106. doi: 10.1186/s13054-021-03491-y.
21. Tonetti T, Grasselli G, Zanella A, Pizzilli G, Fumagalli R, Piva S, et al. Use of critical care resources during the first 2 weeks (February 24-March 8, 2020) of the COVID-19 outbreak in Italy. Ann Intensive Care. 2020;10(1):133. doi: 10.1186/s13613-020-00750-z.
22. Teng XB, Shen Y, Han MF, Yang G, Zha L, Shi JF. The value of high-flow nasal cannula oxygen therapy in treating novel coronavirus pneumonia. Eur J Clin Invest. 2021;51(3):e13435. doi: 10.1111/eci.13435.
23. Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet. 2020;395(10229):1054-62. doi: 10.1016/s0140-6736(20)30566-3.
24. Geng S, Mei Q, Zhu C, Yang T, Yang Y, Fang X, et al. High flow nasal cannula is a good treatment option for COVID-19. Heart Lung. 2020;49(5):444-5. doi: 10.1016/j.hrtlng.2020.03.018.
25. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. JAMA. 2020;323(11):1061-9. doi: 10.1001/jama.2020.1585.
26. Vianello A, Arcaro G, Molena B, Turato C, Sukthi A, Guarnieri G, et al. High-flow nasal cannula oxygen therapy to treat patients with hypoxemic acute respiratory failure consequent to SARS-CoV-2 infection. Thorax. 2020;75(11):998-1000. doi: 10.1136/thoraxjnl-2020-214993.
27. Xu Z, Shi L, Wang Y, Zhang J, Huang L, Zhang C, et al. Pathological findings of COVID-19 associated with acute respiratory distress syndrome. Lancet Respir Med. 2020;8(4):420-2. doi: 10.1016/s2213-2600(20)30076-x.
28. Lagi F, Piccica M, Graziani L, Vellere I, Botta A, Tilli M, et al. Early experience of an infectious and tropical diseases unit during the coronavirus disease (COVID-19) pandemic, Florence, Italy, February to March 2020. Euro Surveill. 2020;25(17):2000556. doi: 10.2807/1560-7917.es.2020.25.17.2000556.
29. Demoule A, Vieillard Baron A, Darmon M, Beurton A, Géri G, Voiriot G, et al. High-flow nasal cannula in critically III patients with severe COVID-19. Am J Respir Crit Care Med. 2020;202(7):1039-42. doi: 10.1164/rccm.202005-2007LE.