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Early View

Research letter

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Please cite this article as: Li J, Fink JB, Elshafei AA, *et al*. Placing a Mask on COVID-19 Patients during High-Flow Nasal Cannula Therapy Reduces Aerosol Particle Dispersion. *ERJ Open Res* 2020; in press (https://doi.org/10.1183/23120541.00519-2020).

Placing a Mask on COVID-19 Patients during High-Flow Nasal Cannula Therapy Reduces Aerosol Particle Dispersion

Jie Li[1], PhD, RRT, RRT-ACCS, RRT-NPS; James B Fink[1,2], PhD, RRT; Ahmad A Elshafei[1], MS, RRT, RRT-ACCS; Laurel M Stewart[1]; Hannah J Barbian[3], PhD; Sara H Mirza[1,4], MD, MS; Lena Al-Harthi[3], PhD; David Vines[1], PhD, RRT; Stephan Ehrmann[5], MD, PhD.

[1] Department of Cardiopulmonary Sciences, Division of Respiratory Care, Rush University Medical Center, Chicago, IL.

[2] Aerogen Pharma Corp, San Mateo, CA.

[3] Department of Microbial Pathogens and Immunity, Rush University, Chicago, IL.

[4] Department of Pulmonary and Critical Care, Rush University Medical Center, Chicago, IL.

[5] CHRU Tours, Médecine Intensive Réanimation, CIC INSERM 1415, CRICS-TriggerSEP research network, Tours, France; and INSERM, Centre d'étude des pathologies respiratoires, U1100, Université de Tours, Tours, France.

* Correspondence: Jie Li, PhD, RRT, RRT-ACCS, RRT-NPS. 1620 W Harrison St, Tower LL1202, Chicago, IL. 60612. Email: Jie_Li@rush.edu

Introduction

High-flow nasal cannula (HFNC) has been shown to improve oxygenation and reduce the need for intubation for hypoxemic patients.[1] A retrospective study reported the effectiveness of HFNC to improve oxygenation of COVID-19 patients. [2] The transmission route of the SARS-CoV-2 virus remains controversial,[3] and concerns persist of potentially increased virus transmission when utilizing HFNC among COVID-19 patients. [3-5] Computational fluid dynamic simulations reported that wearing a surgical/procedure mask over HFNC may reduce aerosol droplet dispersion.[6] However, how far those results translate *in vivo* among infected patients is unknown. Furthermore, the infectious potential of dispersed aerosol droplets is uncertain. Thus, we aimed to investigate the amount of aerosol particles and their size distribution in the vicinity of COVID-19 patients during conventional nasal cannula and HFNC therapy with and without a mask, as well as virus detection in environment air samples taken during HFNC therapy. Our hypotheses were HFNC would generate similar or lower particle counts than conventional oxygen therapy and placing a mask over HFNC would reduce particle concentrations.

Methods

This prospective observational study (NCT04353531) was approved by the ethics committee (No. 20032402-IRB01, waived informed consent due to lack of contact and intervention) and implemented at Rush University Medical Center. Adult patients with laboratory confirmed COVID-19 and indicated to use HFNC were enrolled. This study was conducted in rooms of 4×4×2.8 m with a negative pressure of 0.0254 cmH_2O and air exchange frequency of 12 times per hour.

Five minutes before HFNC started while patients were using conventional nasal cannula (1600HFTLC-7-25, Salter Labs, Lake Forest, IL), two optical particle sizers (Model 3889, Kanomax, Andover, NJ) were placed longitudinally at 1 foot (30.5cm) and 3 feet (91.5cm) away from the patient's face to measure the aerosol concentration across particle size distribution (Supplemental Figure 1). HFNC was initiated at 50 L/min (Airvo2 and Optiflow; Fisher & Paykel Healthcare, Auckland, New Zealand) with fraction of inspired oxygen (F_IO_2) titrated to maintain pulse oximetry saturation at 92-95%. *Per* institution policy, patients were encouraged to wear a surgical/procedure mask over HFNC if tolerated. Particle concentrations were continuously monitored for 5 minutes before and after the patient wearing the mask in a semi-Fowler position with the head in neutral position.

A universal pump with a 25-mm filter cassette and gelatin filters (SKC, Inc. Eighty Four, PA) was used for sampling 10 L/min of room air for 1 hour after HFNC was initiated[7] and the cassette was placed 1 foot away from the patient's face. Following aerosol sampling, 0.5 ml RNAlater® was added to the filter and cassettes were stored at 4°C. QIAamp® Viral RNA Mini kit (QIAGEN, Hilden, Germany) was used to extract RNA from gelatin filters and excess RNAlater®. Quantitative reverse transcript polymerase chain reaction (RT-qPCR) was performed on 50% of the total RNA extract using 2019-nCoV-N2 primers and probes.[8] Serial dilution of positive control plasmids containing the SARS-CoV nucleocapsid gene were used to estimate the limit of detection.

The Wilcoxon sign rank test was used to compare variables across conditions. A p-value < 0.05 was considered significant. Data analysis was conducted with SPSS software (SPSS 26.0; Chicago, IL)

Results

Nine patients (5 male) were enrolled (mean age: 63 ± 15 years). The duration between COVID-19 confirmation and inclusion was 4 days (interquartile range: 0-7). HFNC flow was set at 50 (50-60) L/min while fraction of inspired oxygen (F_IO_2) was set at 0.60 (0.55-0.75). Chest X-ray showed bilateral multifocal airspace opacities for all patients.

Prior to HFNC, five patients were evaluated during conventional nasal cannula at 11 (10-15) L/min, and then switched to HFNC. The remaining four patients were excluded from this analysis, due to the utilization of noninvasive ventilation (n=1), nonrebreather mask (n=1) prior to HFNC, or the lack of baseline measurement due to the immediate requirement for HFNC (n=2). For the five evaluated patients, the concentration of particles of ≤0.3μm, 0.5-1μm and 1-3μm was slightly lower with HFNC therapy compared to the conventional nasal cannula, at 3 feet away from the patients' face. Larger particles (> 5μm) were present in similar amounts (Table 1). Among the nine patients, six patients could be evaluated with and without a mask, as three refused or could not tolerate wearing a surgical/procedure mask during HFNC therapy. The concentration of particles of 0.5-5μm at one foot from the head of the patient was lower while wearing the mask. In contrast, concentrations of smaller (≤0.3μm) and larger (5-10μm) particles were similar in both conditions. At 3 feet away, the concentration of particles was reduced while wearing a mask, but statistical significance was reached only for particles of 1-3μm (Table 1).

None of the room air samples showed detectable SARS-CoV-2 virus genetic material despite a detection limit of two viral copies per reaction.

Discussion

Wearing a surgical/procedure mask over HFNC reduced the concentration of particles with sizes 0.5-5μm, particularly at 1 foot from the patients' face. This finding confirms results of computational fluid dynamic simulations.[6] Large particles (5-10 μm) settle at close distance and are more easily blocked by personal protection equipment. In contrast, very small particles (<0.3μm) may more readily pass through and around the mask. Our findings suggest that particles ranging from 0.5-5μm are effectively blocked or diverted by the surgical/procedure mask.[3] These results have important implications for daily clinical practice. Even though the number of very small particles far exceeds larger particles, their probability of containing viral material is much lower (virus size is estimated to be 0.125 μm, thus only very few may be contained in a < 0.5 μm droplet). Furthermore, particle of 0.5-5μm are the most likely to deposit in the respiratory tract of healthcare workers.[3] Thus, reducing their concentration in the patients' vicinity is clinically meaningful, as it may reduce the risk of healthcare workers inhaling aerosol generated by patients.

Compared to conventional nasal cannula at 10-15 L/min, the concentration of aerosol particles ≤ 5μm was lower with HFNC therapy at 3 feet from the patients' face, even though significance was not reached across the whole range of particle sizes. Our findings are consistent with reports that particle concentrations with HFNC at 50 L/min were lower than with a conventional nasal cannula at 4 L/min or a face mask at 15 L/min, with particle geometric sizes measured in the 1-2 μm range.[9]

SARS-CoV-2 viral RNA was not detected in the room air samples during HFNC treatment for COVID-19 patients, consistent with prior reports that sampled negative pressure rooms[7]. This might be due to the frequent air exchange reducing the number of sampled particles, including virus-containing particles, below the limit of virus detection.[3,7] In contrast,

others detected SARS-CoV-2 in the air inside a temporary single toilet room without a ventilation system[3] and hospital rooms with no negative pressure.[10]Even though our patients were enrolled at an early phase of confirmed COVID-19 (0-7 days), the virus load carried by patients on the study day were unknown.

Aerosol transmission and deposition are complexed and affected by the room size, room air exchange frequency, the air humidity and human activity inside the room.[3] Thus our findings are limited to institutions with similar settings. Future studies are needed to investigate the mechanisms of particle movement in air with the use of different oxygen therapy devices. Baseline particle concentrations were not measured in our study. Aerosol particles measurements were limited to 2 locations, future studies might consider several other positions in particular in the coronal plane after the patients' face. It was reported that the horizontally expelled droplets including large droplets could travel a long distance,[11] wearing the mask over HFNC might redirect the aerosol particle distribution to the coronal plane, where clinicians usually stand. HFNC did not generate higher aerosol particle concentrations than conventional nasal cannula and wearing a surgical/procedure mask reduced aerosol particle concentrations in the patients' vicinity and should be encouraged if it is well tolerated.

Author Contributions: JL took responsibility for the integrity of the work as a whole, from inception to published article. JL and JBF conceived of the idea. AAE, LMS and JL implemented data collection, HJB performed SARS-CoV-2 qPCR testing and LA coordinated and directed the virus detection studies, JL performed data analysis and drafted the manuscript. JL, LA, SE and JBF interpreted the data. JBF and SHM supervised the process. SE and JBF provided critical revision on the manuscript. All authors reviewed and approved the final version.

Funding/Support: This study was sponsored the unrestricted grant by Fisher & Paykel Healthcare Ltd. The company had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Competing Interests: Dr. Li discloses research support from Fisher & Paykel Healthcare Ltd and Rice foundation. Dr. Fink is Chief Science Officer for Aerogen Pharma Corp, San Mateo, CA, USA. Dr. Vines provides consulting for Ohio Medical and has research support for Teleflex Medical. Dr. Ehrmann reports consultancies from Aerogen Ltd, research support from Aerogen Ltd, Fisher & Paykel healthcare, Hamilton medical, travel reimbursements from Aerogen Ltd and Fisher & Paykel. Other authors have no conflicts to disclose.

Ethical approval: This study was approved by the institutional review board in Rush University Medical Center (approval No. 20032402-IRB01).

Clinicaltrial registration: NCT 04353531

References

1. Li J, Jing GQ, Scott JB. Year in review 2019: High-flow nasal cannula (HFNC) oxygen therapy for adult patients. Respir Care, 2020, 65 (4) 545-557
2. Wang K, Zhao W, Li J, Shu W, Duan J. The experience of high-flow nasal cannula in hospitalized patients with 2019 novel coronavirus-infected pneumonia in two hospitals of Chongqing, China. Ann Intensive Care. 2020;10(1):37.
3. Dhand R, Li J. Coughs and sneezes: Their role in transmission of respiratory viral infections, including SARS-CoV-2. Am J Respir Crit Care Med, 2020. 202(5):651-659.
4. Li J, Fink JB, Ehrmann S. High-flow nasal cannula for COVID-19 patients: low risk of bio-aerosol dispersion. Eur Respir J 2020; 55(5):2000892.
5. Hui DS, Chow BK, Lo T, et al. Exhaled air dispersion during high-flow nasal cannula therapy versus CPAP via different masks. Eur Respir J. 2019; 53: 1802339
6. Leonard S, Atwood CW Jr, Walsh BK, et al. Preliminary findings on control of dispersion of aerosols and droplets during high-velocity nasal insufflation therapy using a simple surgical mask: Implications for the high-flow nasal cannula. Chest. 2020; 158(3):1046-1049..
7. Liu Y, Ning Z, Chen Y, Guo M, Liu Y, Gali, et al. Aerodynamic characteristics and RNA concentration of SARS-CoV-2 aerosol in Wuhan hospitals during COVID-19 outbreak. Nature 2020; 582, 557–560.
8. Centers for Disease Control and Prevention. CDC 2019-novel coronavirus (2019-nCoV) real-time RT-PCR diagnostic panel. https://www.fda.gov/media/134922/download
9. Gaeckle NT, Lee J, Park Y, et al. Aerosol generation from the respiratory tract with various modes of oxygen delivery [published online ahead of print, 2020 Aug 21]. Am J Respir Crit Care Med. 2020;10.1164/rccm.202006-2309OC. doi:10.1164/rccm.202006-2309OC.

10. Guo ZD, Wang ZY, Zhang SF, et al. Aerosol and surface distribution of severe acute respiratory syndrome coronavirus 2 in hospital wards, Wuhan, China, 2020. Emerg Infect Dis. 2020;26(7):1583-1591.
11. Xie X, Li Y, Chwang AT, Ho PL, Seto WH. How far droplets can move in indoor environments--revisiting the Wells evaporation-falling curve. Indoor Air. 2007;17:211-225.

Table 1. Aerosol particle concentrations of different sizes during conventional nasal cannula therapy and HFNC therapy with- and without a mask

	Conventional nasal cannula vs HFNC (n = 5)						**HFNC with vs without a mask (n = 6)**					
	Concentration at 1 foot			**Concentration at 3 feet**			**Concentration at 1 foot**			**Concentration at 3 feet**		
	Conventional cannula	HFNC	p	Conventional cannula	HFNC	p	No mask	Mask	p	No mask	Mask	p
≤0.3µm	710,212±622,173	581,273±513,067	0.138	743,822±658,053	570,318±490,647	0.043	706,247±510,591	706,611±531,585	0.753	653,710±460,070	633,964±439,677	0.249
0.3-0.5µm	29,598±25,464	22,914±18,332	0.686	36,511±32,609	24,666±20,414	0.08	23,020±17,297	21,911±17,796	0.046	23,275±18,722	21,802±17,307	0.173
0.5-1µm	2,821±1464	2,744±1317	0.50	3,966±2758	2,593±1,243	0.043	2,575±1,124	1,980±1,083	0.028	2,380±1,118	2,053±1,082	0.173
1-3µm	913±368	876±436	0.345	943±499	732±316	0.043	758±348	544±274	0.028	647±295	501±252	0.028
3-5µm	436±166	418±242	0.50	423±200	355±179	0.08	386±225	266±117	0.028	319±171	254±124	0.116
5-10µm	205±77	194±127	0.50	152±86	142±80	0.225	197±177	129±65	0.173	135±114	107±58	0.753

Conventional nasal cannula therapy was performed at 10-15 L/min; HFNC, high-flow nasal cannula. 1 foot = 30.5 cm. Values are indicated in particles per cubic foot.


High-flow nasal cannula
Particle sizer
Particle sizer
filter cassette with vacuum pump
Hill-Rom
NOV 20