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Short communication

Particulate generation with different oxygen delivery devices

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ARTICLE INFO

Keywords: Aerosol Droplets Particle generation Particle measurement Coronavirus High flow oxygen

ABSTRACT

Background: The Coronavirus pandemic has a high mortality rate in patients that are mechanically ventilated, which has led to an ever increasing interest in noninvasive forms of oxygenation. The use of these devices has the theoretical risk of increased exposure risk because of possible particulate generation. This study aimed to quantify the particulate generation associated with different oxygen devices.

Methods: This was a prospective single center study conducted during September 2020 using ten healthy adult volunteers. Testing was conducted in a negative pressure hospital room using a light scattering particle counter. The oxygen devices used were a nasal cannula, an OxyMask™, a non-rebreathing mask, and a high flow system. Particle measurements were obtained at baseline in the room and then with each oxygen delivery device and pre-specified oxygen flow rates. These measurements were obtained different distances from the volunteer with their mouth open. A Wilcoxon/Kruskal-Wallis test was performed on each separate oxygen modality with all flow rates as one model.

Results: The particle concentrations were slightly non-significantly increased with the OxyMask™ and non-rebreathing mask at the closest distance measured. As the distance increased, these counts decreased closer to ambient levels. The nasal cannula and high flow nasal cannula particle counts were not significantly different from ambient measurements at either distance.

Conclusion: Nasal cannula, OxyMask™, non-rebreathing mask, and high flow oxygen did not generate any additional aerosols or droplets above a baseline room measurement, but further studies are necessary to determine infectious risk.

1. Introduction

The Coronavirus pandemic (COVID-19) caused by the severe acute respiratory syndrome coronavirus 2 has a mortality range from 36% to 97% in patients that are mechanically ventilated [1,2]. This high mortality has led to an ever increasing interest in noninvasive forms of oxygenation. The use of these devices has the theoretical risk of increased exposure risk to healthcare workers because of possible aerosolization of particles [3]. We sought to quantify and compare the particulate generation associated with healthy adults wearing different oxygen devices at different flow rates.

2. Methods

This was a prospective single center study conducted during September 2020. Healthy adult volunteers without pulmonary disease were identified for this study. The Institutional Review Board approved this study (20–005544).

Testing was conducted in a negative pressure hospital room that was 63.2 m² in size with 12.9 air changes per hour. A light scattering particle counter (FLUKE® 983; Everett, WA) was used to simultaneously measure six channels of particle sizes (0.3, 0.5, 1, 2, 5, 10 μm) for this study, which was calibrated and zeroed before each measurement according to manufacturer’s recommendations. Each measurement sampled one liter of air. The International Organization for Standardization endorses this type of particle counter [4]. The particle sizes measured were separated into aerosol and droplet categories according to their size which was less than 5 μm and 5–10 μm, respectively [5]. Because there was minimal variance in the ambient particle counts from day to day, the particle counts were corrected to the ambient level by taking the difference between the measured level and the ambient level taken immediately before that oxygen device.

The oxygen devices used were a nasal cannula (SOFTECH®, Hudson RCI®; Teleflex Medical; Dublin, Ireland), an OxyMask™ (Southmedic;...
Ontario, Canada), and a non-rebreathing mask with a safety vent (Hudson RCI; Teleflex Medical; Dublin, Ireland). The high flow system used consisted of an air/oxygen blender (2002F70D Bio-Med Devices Inc.; Guilford, CT), tubing with humidification chamber (Fisher & Paykel Healthcare Ltd.; Auckland, New Zealand), heater (Fisher & Paykel Healthcare Ltd.; Auckland, New Zealand), and nasal cannula (Optiflow™; Fisher & Paykel Healthcare Ltd.; Auckland, New Zealand).

Ambient measurements were made with no oxygen flowing before each oxygen device was tested and was taken at the central point in the room with two people in the room. The oxygen flow rates used were 2 LPM to 10 LPM for the nasal cannula, 2 LPM to 10 LPM for the Oxymask™, 2 LPM to 10 LPM for the non-rebreathing mask, and 10 LPM to 60 LPM for the high flow nasal cannula system. The participant wearing the oxygen did not wear a procedural or surgical mask. The oxygen concentration was set at 21%, for the high flow system. At each increment, particle counts were obtained at pre-specified distances of 4 cm and 0.3 m from the participants face with the participant’s mouth open. The participant did not talk or cough during the measurements.

All analyses were performed using JMP® version 14.1.0 (SAS Institute Inc.; Cary, NC). A nonparametric distribution of measurements was assumed. A Wilcoxon/Kruskal-Wallis test was performed looking for significance of each separate oxygen modality with all flow rates as one model. If the oxygen modality model was significant, then a Steel test with control was performed to compare each group to a single control which was the ambient room measurement. Data was displayed as median with IQR. A p-value less than 0.05 was considered significant.

3. Results

All ten of participants were free of cardiac and pulmonary disease. The median age was 32.5 years (IQR 29.8–44.0 years) and seven were male (70%).

Table 1 shows the corrected particle counts per liter of sampled air separated by oxygen delivery modality, flow rates, and distances for the two sizes of particles (aerosols and droplets). Both sized particles had no significant increases from the ambient measurements for all oxygen delivery modalities, despite increasing flow rates and proximity to the participant.

The highest particle concentrations were achieved with the Oxymask™ and non-rebreathing mask at closest the distance measured. As the distance increased, these counts decreased closer to ambient levels. The nasal cannula and high flow nasal cannula particle counts were not significantly different from ambient measurements at either distance.

4. Discussion

This study suggests that oxygen supplementation with different oxygen delivery devices was not associated with an increase in particulate generation above ambient measurements, either aerosols or droplets in healthy patients. This study quantifies the particulate generation with these oxygen delivery devices and confirms the low potential for aerosol generation, which has been suggested by prior reports [6,7].

The Oxymask™ and non-rebreathing mask had the highest counts above ambient for both aerosols and droplets. The nasal cannula systems direct the air/oxygen mixture into the patient’s nose while the Oxymask™ and non-rebreathing mask direct the air/oxygen mixture directly in front of the patient and not into the patient. This allows for potential dispersion of this mixture in the room more easily.

This study provides valuable information guiding the use of different oxygen delivery devices in potentially infectious patients, such as those with COVID-19. Specifically in COVID-19, the use of high flow nasal cannula has shown a reduction in the need for mechanical ventilation, but no change in mortality when compared to patients who did not receive this form of oxygen therapy [8]. Because of the increased flow through the respiratory tract and the nature of an “open circuit” to the external environment, there is theoretical concern that delivery of oxygen in these manners may potentially increase exposure to healthcare workers [3,9].

A limitation of this study was the small size of healthy participants, which may not allow extrapolation to patients with pulmonary disease. In addition, we were unable to account for the effects of coughing and possible potentiating effect it may have on the different deliver devices. This study was also not designed to detect larger particle sizes that may be emitted from using oxygen devices.

In conclusion, using nasal cannula, Oxymask™, non-rebreathing mask, and high flow oxygen in healthy subjects does not generate any additional aerosols or droplets above a baseline room measurement.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contributions

All authors (SAH, KGL, ASL, ASN, and NMP) had substantial contributions to the conception and design of this work; acquisition, analysis, and interpretation of the data; drafting and revising this.
manuscript; final approval of this version to be published; and all agree to be accountable for all aspects of the work.

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Scott A. Helgeson: Conceptualization, Funding acquisition, Formal analysis, Writing – original draft, All authors (SAH, KGL, ASL, ASN, and NMP) had substantial contributions to the conception and design of this work; acquisition, analysis, and interpretation of the data; drafting and revising this manuscript; final approval of this version to be published; and all agree to be accountable for all aspects of the work. Augustine S. Lee: Conceptualization, Funding acquisition, Formal analysis, Writing – original draft, All authors (SAH, KGL, ASL, ASN, and NMP) had substantial contributions to the conception and design of this work; acquisition, analysis, and interpretation of the data; drafting and revising this manuscript; final approval of this version to be published; and all agree to be accountable for all aspects of the work. Kaiser G. Lim: Conceptualization, Funding acquisition, Formal analysis, Writing – original draft, All authors (SAH, KGL, ASL, ASN, and NMP) had substantial contributions to the conception and design of this work; acquisition, analysis, and interpretation of the data; drafting and revising this manuscript; final approval of this version to be published; and all agree to be accountable for all aspects of the work.

Declaration of competing interest

All authors (SAH, KGL, ASL, ASN, and NMP) report no financial or intellectual conflicts.

References

[1] S.C. Auld, M. Caridi-Scheible, J.M. Blum, C. Robichaux, C. Kraft, J.T. Jacob, et al., ICU and ventilator mortality among critically ill adults with coronavirus disease 2019, Crit. Care Med. 48 (9) (2020) e799–e804.
[2] S. Richardson, J.S. Hirsch, M. Narasimhan, J.M. Crawford, T. McGinn, K. W. Davidson, et al., Presenting characteristics, comorbidities, and outcomes among 5700 patients hospitalized with COVID-19 in the New York city area, Jama 323 (20) (2020) 2052–2059.
[3] J.C.-H. Cheung, L.T. Ho, J.V. Cheng, E.Y.K. Cham, K.N. Lam, Staff safety during emergency airway management for COVID-19 in Hong Kong, Lancet Respir. Med. 8 (4) (2020) e19.
[4] IOf Standardization, Clean rooms and Associated Controlled Environments, 2 ed., ISO, Switzerland, 2015.
[5] [cited 7/23/2020], Natural Ventilation for Infection Control in Health-Care Settings, World Health Organization, Geneva, 2009 [cited 7/23/2020]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK143281/.
[6] J. Li, J.B. Fink, S. Ehrmann, High-flow nasal cannula for COVID-19 patients: low risk of bio-aerosol dispersion, Eur. Respir. J. 55 (5) (2020) 2000892.
[7] N.T. Gaeckle, J. Lee, Y. Park, G. Kreykes, M.D. Evans, C.J. Hogan Jr., Aerosol generation from the respiratory tract with various modes of oxygen delivery, Am. J. Respir. Crit. Care Med. 202 (8) (2020) 1115–1124.
[8] N. Tran, M. Severn, C.L. Pessoa-Silva, J. Cunhy, Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic review, PLoS One 7 (4) (2012), e35797.