Questions About Fugitive Aerosols: The Answer Is PPE

Since the severe acute respiratory syndrome (SARS) outbreak in 2003, there has been heightened attention toward minimizing the risk of occupational hazards for health care workers.[1,2] This includes a better understanding of donning and doffing personal protective equipment (PPE) for certain situations.[3,4] One situation particularly important for respiratory therapists is that revolving around aerosol-generating medical procedures (AGMPs).[1] AGMPs are classified as medical procedures that produce aerosols and droplets, increasing the risk of disease transmission to health care workers involved.[5,6] These concerns were amplified since the beginning of the SARS-CoV-2 (COVID-19) pandemic, as transmission occurs by inhaling respiratory droplets and aerosols.[5,7] Currently, the World Health Organization lists a handful of AGMPs as high risk for transmission (eg, intubation, extubation, bronchoscopy, cardiopulmonary resuscitation, noninvasive ventilation),[6] but high-flow nasal cannula (HFNC) oxygen therapy and nebulized treatments are not included even though they both produce aerosols and droplets.[8,9]

Although there is minimal evidence to support the increased risk of COVID-19 transmission from patients receiving HFNC oxygen therapy,[8] or nebulized treatments,[9-11] there are still concerns regarding their aerosol-generating properties.[2] When combined together, nebulized treatments given during HFNC oxygen therapy elicit more uncertainties.[10,12] Fugitive aerosols are defined as aerosols that have escaped the system, either before inhalation or after exhalation.[13] This emphasizes the concerns of secondary exposure to others within proximity of the patient and the risks of transmission.[9,13-15] As a response to minimize the potential for aerosol generation, clinicians opted to intubate patients early to treat all severity of COVID-19 respiratory complications,[16] and nebulized treatments were substituted for pressurized metered-dose inhalers (pMDIs) to prevent continuous aerosol generation.[10] However, the assumed benefits of these substitutions are debatable; emerging evidence suggests no differences between the prognoses of people who received early intubation compared to delayed intubation.[17-19] And patients being offered pMDI may have experienced decreased benefits of the therapy due to the coordination and proper inhalation techniques required for these devices.[7,20]

Table 1. List of Comparisons Between Different Interfaces and Mitigation Devices With Vibrating Mesh Nebulizer or Small-Volume Nebulizer in the Study by Harnois et al[14]

Nebulizer setup	
VMN + mouthpiece	SVN + mouthpiece
VMN + aerosol mask	SVN + aerosol mask
Nebulizer setup with mitigation devices	
VMN + mouthpiece + expiratory filter	SVN + mouthpiece + expiratory filter
VMN + face tent scavenger	SVN + face tent scavenger
VMN + Vapotherm scavenger mask	SVN + Vapotherm scavenger mask

SVN = small volume nebulizer
VMN = vibrating mesh nebulizer

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There are a few studies that have assessed the aerosol concentration and dispersion from these 2 interventions.[8,13,14,21,22] In this issue of the Journal, 2 randomized crossover trials evaluated these concerns and assessed the efficacy of a combination of interfaces and mitigation devices.[14,15] Healthy individuals were recruited to trial different interfaces with and without mitigation devices when receiving HFNC oxygen therapy and nebulized treatments of 3 mL saline. Li et al[15] assessed the concentrations of fugitive aerosols produced by different HFNC oxygen therapy devices with and without vibrating mesh nebulizer (VMN) and mitigation devices. In addition, transnasal aerosol delivery between 2 different HFNC devices was assessed in a simulated adult manikin. In their other study, Harnois et al[14] focused on measuring the concentration of fugitive aerosols across different interfaces for VMN and small-volume nebulizer (SVN) with and without mitigation devices. Particle sizes, concentration, and dispersion were measured for each setup. The comparisons

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Table 2. List of Different Setup Comparisons for High-Flow Nasal Cannula Oxygen Therapy With and Without Vibrating Mesh Nebulizer or Mitigation Devices in the Study by Li et al[15]

Comparison Between HFNC Devices With Different Mitigation Devices	
Vapotherm	Airvo 2
Vapotherm + surgical mask	Airvo 2 + surgical mask
Vapotherm + scavenger	Airvo 2 + scavenger
Comparison Between HFNC Devices With VMN	
Vapotherm + VMN	Airvo 2 + VMN
Vapotherm + VMN + surgical mask	Airvo 2 + VMN + surgical mask
Vapotherm + VMN + scavenger	Airvo 2 + VMN + scavenger

HFNC = high-flow nasal cannula
VMN = vibrating mesh nebulizer

between different interfaces, devices, and mitigation techniques are summarized in Tables 1 and 2.

Using nebulizers for drug delivery is relatively simple; it requires minimal effort from the patient, as the medication is inhaled during their normal breathing.[12] Nebulization can be administered across different devices, with jet-powered SVN and VMN as popular choices.[23] Between the two, VMN is believed to be more effective than SVN at delivering aerosolized medication, possibly due to the need of a higher driving flow to operate SVN.[13,14,23] Harnois et al[14] observed that interfaces produced less fugitive aerosols when a better seal is made; thus, mouthpieces had the lowest concentration compared to face masks with both types of nebulizers. They also observed that fugitive aerosols were further decreased by adding mitigation devices.

HFNC oxygen therapy has gained popularity for its ability to alleviate patients' work of breathing, tachypnea, and minimize the need for escalating respiratory support.[18,24] Its clinical use has become an essential respiratory treatment option and has become especially valuable during the COVID-19 pandemic to help conserve ventilator resources.[17] Compared to conventional oxygen therapy, HFNC oxygen therapy may decrease the risk of intubation[18] and decrease time to clinical recovery in patients infected with COVID-19.[25] Thus, it may be important to encourage the use of HFNC oxygen therapy when appropriate[19] and to know the risk of COVID-19 transmission when utilizing this therapy. Because of clinicians' concern about its aerosol-generating properties, there has been an interest in understanding the aerosol production and transmission of HFNC oxygen therapy. In the study by Li et al,[15] both devices produced fugitive aerosols of all sizes similar in concentration between Airvo 2 and Vapotherm, and neither mitigation devices reduced fugitive aerosol concentrations.

Recently, transnasal pulmonary aerosol delivery (ie, administering nebulized treatments through HFNC oxygen therapy) has become a popular method to administer inhaled medications.[12] Together, it appears to provide greater aerosol delivery than conventional methods,[12,15,26] but this dual therapy brings many concerns about their fugitive aerosol production. However, recent studies suggest that appropriate flow setting, nebulizer, and HFNC device should be used together to maximize the inhaled dose[12] and to minimize fugitive aerosols.[15]

Aerosol production from nebulized treatments via VMN with HFNC oxygen therapy compared to HFNC alone did not differ when using Vapotherm.[15] Airvo 2 with VMN generated significantly greater aerosol concentrations (particle size 0.3–1.0 μm) than Airvo 2 alone, though this could be mitigated with the addition of a surgical mask.[15] Interestingly, adding VMN with or without the mitigation devices did not demonstrate differences in the Vapotherm. Li et al mentioned this might be due to the device's high-flow design and mechanism, which may also explain the decreased aerosol delivery noted in their in vitro study.[15] Similar to existing evidence, aerosol delivery increased with decreased flows.[12,22]

Employing various interface setups and mitigation devices, measuring aerosol particles at different distances, and comparing between different HFNC devices contributed to the major strengths of the studies by Li et al[15] and Harnois et al.[14] The variety and combination of setups and distances measured provided rich information on additional precautions to consider. Another strength was the inclusion of patient-reported evaluations of the comfort of these setups and interfaces, as it is equally important to consider patients' comfort when delivering any intervention.

However, limitations to these study designs include their small sample size and participant demographics. Only healthy individuals (one male out of 9) with a wide age range were included (18–65 y).[14,15] This limitation makes it difficult to determine whether the concentrations of fugitive aerosols reported in these studies are generalizable to people with different respiratory patterns, especially those with underlying respiratory diseases or conditions. Underlying respiratory diseases or conditions could exacerbate their inspiratory flows[22] and increase their likelihood to generate productive coughs,[12,15] which may influence the production

of fugitive aerosols. Since only Vapotherm and Airvo 2 were assessed, these results may not be applicable to other devices, such as Optiflow or mechanical ventilators with the capability to provide HFNC oxygen therapy. Another limitation is that in the in vitro study aerosol delivery was measured in 2 setups (delivery by Airvo 2 or Vapotherm).[15] The authors did not investigate the differences in aerosol delivery when mitigation devices were in place, but it is possible that by including mitigation devices aerosol delivery may be reduced.

Based on these 2 studies, there are several setup options to choose from when initiating HFNC oxygen therapy, nebulized treatments, or both. In situations where patients require nebulized treatment without HFNC oxygen therapy, it would be ideal to use a VMN setup with a mouthpiece and expiratory filter. Understandably, not all patients would have the coordination to make an adequate seal, so face masks with mitigative devices could be considered instead. In patients requiring both nebulized treatment and HFNC oxygen therapy, selecting the proper size of the nasal cannula with a surgical mask on top or a scavenger connected may help reduce aerosols and transmission.[12,21] However, one must also consider the efficacy of medication delivery when using HFNC oxygen therapy with a mitigation device.

Although wearing a surgical mask over their HFNC did not reduce fugitive aerosols in this study,[15] this simple technique is a recommended mitigation tactic to protect health care providers.[1,15] As acknowledged by the authors, the nonsignificant differences may be from their healthy sample,[15] as the authors' previous work did demonstrate a significant fugitive aerosol reduction when this setup was assessed in patients with COVID-19.[21] It is understandable to be concerned about the potential consequences of such suggestion, but this could be employed when health care providers need to be in close proximity of the patients for an extended period of time. Furthermore, a recent study reported an advantageous improvement of oxygenation when a surgical mask is worn over HFNC in patients with COVID-19 in the ICU for respiratory failure.[27]

Interfaces should be chosen based on the patients' needs and preferences. Across both studies, self-evaluated comfort scores were lower when mitigation devices were in place.[14,15] Participants also reported similar comfort levels between Airvo 2 and Vapotherm, but when VMN was inline, their comfort scores decreased.[15] This finding suggests that although some setups were innovative the expectation of compliance may present as a problem if the setup of the intended therapy is uncomfortable. When selecting an interface, there are other factors to consider, such as their noise level and the patients' level of claustrophobia.

These studies provide valuable information to guide clinicians on selecting interfaces and devices when considering HFNC oxygen therapy and nebulized treatments. Regardless, health care providers must don the appropriate PPE.[11] A recent systematic review deemed that there is an increased odds of contracting COVID-19 from the aerosol produced from nebulized treatments,[5] but that risk is significantly decreased when clinicians used the appropriate PPE.[5,28] Repeatedly, there exists an abundance of evidence that demonstrates proper PPE etiquette is the key to minimizing the risk of transmission to health care providers.[3,4,11,28] Even if PPE is donned, standing at least 3 feet away from the patient may be an additional precaution to minimize the risk of transmission.

With the current evidence, it is unfair to disregard the possibility of using these options due to the fear of virus transmission. These studies have elaborated on the current understanding of the factors that influence the production of fugitive aerosols during HFNC oxygen therapy and nebulized treatment therapies, though more studies are necessary to definitively conclude which setup would be optimal and to validate these findings in the relevant clinical populations.

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