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COMMENTARY

Aerosol-generating procedures in the COVID era

Key words: aerosols, coronavirus, COVID-19, oxygen.

We are in the midst of a global pandemic related to infection with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causing coronavirus disease 2019 (COVID-19). Mild and asymptomatic cases are common; however, up to 20% of cases are severe enough to lead to hospitalization, although the risk of severe disease varies significantly according to age and underlying comorbidities.[1] Healthcare workers are at particular risk of infection, given their close proximity to patients with COVID-19 and the length of time spent within a potentially infectious area. Exhaled virus may potentially be spread via large droplets (>5 μm) or smaller aerosols (≤5 μm), with droplets falling to the ground or onto surfaces within close proximity of the patient, typically 1–2 m, and smaller aerosols becoming suspended in the air for longer periods, potentially enabling them to travel further distances.[2,3] The predominant means of spread for SARS-CoV-2 is felt to be droplet[3]; however, breathing, speech and coughing produce aerosols and droplets which exist together on a continuum and there is increasing recognition that airborne spread via small aerosol particles is also a potential mode of virus infection.[4–7]

Since the initial SARS infection in the early 2000s, there has been recognition that certain medical interventions (known as aerosol-generating procedures) increase the risk of infection, presumably due to the generation or dispersal of fine aerosol particles. A systematic review in 2012 of largely case-controlled studies suggested that procedures such as tracheal intubation, cardiopulmonary resuscitation with manual ventilation, tracheostomy and non-invasive ventilation were associated with an increased risk of infection in healthcare workers.[8] Although these procedures have been classified as aerosol 'generating', it is unclear whether the infection risk relates to the specific generation of aerosols, the increased dispersion of naturally generated aerosols or the close proximity that healthcare workers need to have to an infected airway. Subsequent studies have suggested that other interventions have the potential to be aerosol-generating procedures, such as bronchoscopies, spirometry, the nebulization of medications and high-flow oxygen therapy.[9–12] The classification of interventions as aerosol-generating procedures has relevance if it helps minimize nosocomial spread of infection via specific procedural protocols and/or if different levels of personal protective equipment (PPE) are utilized under different circumstances.

There is general agreement that invasive procedures of the upper airway (such as intubation and bronchoscopy) are considered high risk. A larger area of uncertainty and controversy is the potential risk from less invasive, but more commonly used interventions such as non-invasive positive-pressure ventilation (NIV) and oxygen (particularly high flow) therapy. The uncertainty exists because of a lack of definitive evidence due to the difficulty of performing studies in infected patients, and the impact that precautions have on service provision. Health services potentially need to trade off the perceived risk to staff and other patients against the individual benefits of treatments such as NIV and high-flow oxygen therapy. This is not a simple task given the large number of patients requiring treatment in a pandemic, particularly with oxygen therapy. Studies in the area have used different techniques to assess aerosol generation and dispersion such as detection of smoke particles using light,[6,11–13] laser light scattering[14,15] and direct aerosol particle measurement.[16,17] None of these techniques actually measure virus particles or their infectivity. These studies also did not clearly differentiate between the generation of aerosols in a patient from the dispersal of spontaneously exhaled aerosols. Some of these studies suggest that high-flow nasal oxygen or NIV (particularly in the setting of leak or a vented mask system) may increase aerosol dispersion to a greater distance from the patient than breathing room air or using low-flow devices, with the effect exacerbated by coughing.[12,18–20] However, other studies have suggested that high-flow oxygen or NIV do not provide any increased risk for the generation and dispersion of aerosols, compared to low-flow oxygen, at least when there is a good interface seal.[13,17] The impact of mask leak, which is common in the real world, is uncertain. An important consideration in this area is the fact that there is substantial inter-subject variability in spontaneous aerosol generation. This has been demonstrated in studies that have addressed the impact of oxygen therapy,[17] and in others that look at the potential infectivity and spread of coronaviruses in general.[21,22] Some subjects generate far more aerosols with coughing, talking or breathing than others, and the loudness of sound generation (such as from patients shouting) is also a factor that influences the increased production of aerosols.[5] Such a concept is likely to underpin at least some of the reason behind 'superspreader events', where individuals with a high infectivity interact with epidemiological factors to increase the risk for infection spread. It is possible that treatments such as NIV and high-flow oxygen therapy may be 'aerosol dispersing' and increase the distance travelled of aerosols and droplets produced by such patients. The problem is that when caring for patients with COVID-19, we do not know who these potentially more infective patients are, and we need universal conservative precautions regarding PPE.

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Another critical but often neglected consideration is the role of adequate room ventilation. It is important to note that most of the studies that have addressed the potential role of aerosol-generating procedures have performed these studies in rooms with at least 12 air exchanges per hour (therefore classified as 'negative-pressure' rooms). Although such rooms are ideal for nursing patients with COVID-19 or other types of respiratory infection and recommended by the World Health Organization, the reality for many hospitals is that such well-ventilated rooms are unavailable for many patients with COVID-19 infection (or suspected infection). This is particularly the case for old hospitals. At least one study has demonstrated the effect of a poorly ventilated room on the length of time that droplets and aerosols remain suspended in the air. Rooms with poor or no ventilation had significantly greater persistence of droplets and aerosols.[23] It is possible that negative-pressure rooms, with frequent air exchanges, may potentially ameliorate any significant aerosol dispersion from oxygen and NIV therapy. This leaves us more uncertain about the potential infection risk from aerosol dispersal from oxygen and NIV when patients are nursed in rooms without adequate air exchanges.

Are there ways to mitigate the potential for nosocomial infection even in the absence of a well-ventilated room? McGain *et al*. have piloted work using a personal ventilation hood which utilizes a portable high-efficiency particulate air (HEPA) filter and a plastic barrier to create a negative pressure surrounding the patient.[16] They have demonstrated that this hood can almost eliminate aerosols created from NIV or nebulization. Landry *et al*. have taken this one step further.[24] First, they used a live virus bacteriophage model to demonstrate that increasing mask leak from positive airway pressure (PAP) circuits, even at subclinical levels, can increase live virus environmental contamination (up to 3.86 m from the source) in a dose-dependent manner. A particularly important and practical aspect of this study is that measurements were not performed in negative-pressure rooms and live virus was detected well away from the patient. However, a simple plastic hood covering the subject connected to a portable HEPA filtration device was able to eliminate all evidence of virus contamination.

What can we conclude? The area remains difficult and contentious, but I believe there is increasing evidence that: (i) Aerosol generation varies substantially between individuals and is increased with behaviours such as coughing and loud phonation; (ii) oxygen and NIV are not aerosol generating, but may be aerosol dispersing under certain circumstances; (iii) with the ideal scenario of good mask seal and negative-pressure room ventilation, dispersion of aerosol may not be significant at distances beyond the patient; (iv) PAP and oxygen flow rates are likely to be less relevant to aerosol dispersion than the presence/absence of mask interface leak and room ventilation dynamics. In the setting of poor room ventilation, any mask leak can lead to virus contamination at room distances remote to the patient. (v) Finally, simple systems such as a patient hood combined with a portable HEPA filter have the potential to ameliorate or eliminate altogether the risk of virus dispersion from these therapies. Devices such as these require more urgent research if we are to minimize the risk of healthcare worker infection and the nosocomial spread of disease.

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