Aerosol-Generating Procedures and Workplace Safety: Improving Understanding, Leading by Example

Alexander P. Isakov, MD, MPH*

*Corresponding Author. E-mail: aisakov@emory.edu.

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In this issue of *Annals*, Professor Tzu-Yao Hung and colleagues examine aerosol dispersion associated with techniques commonly used in the emergency department (ED) to assist patients in need of supplemental oxygen. Nasal cannula oxygenation, nonrebreather masks, continuous and bilevel positive pressure ventilation (CPAP and BiPAP), and high-flow nasal cannulas are essential tools for the care of patients with hypoxemia. What risks they might pose to caregivers has been a topic of greater interest since the onset of the COVID-19 pandemic. As the authors note, SARS-CoV-2 can be transmitted from person to person by respiratory secretions, expelled droplets, and suspended droplet nuclei or aerosols generated while breathing, speaking, coughing, or sneezing. Aerosol-generating procedures such as manual ventilation before intubation, noninvasive ventilation, endotracheal intubation, and cardiopulmonary resuscitation further increase the presence of potentially infectious droplets and suspended droplet nuclei and further increase the risk of transmission.[1] For this reason, it is recommended that patients suspected or known to have COVID-19 who are receiving these interventions be placed in an airborne infection isolation room and that providers wear a National Institute for Occupational Safety and Health–approved and fit-tested N95 respirator, eye protection, gloves, and a gown for their protection and for the protection of other patients.[2]

Hung and colleagues developed a mannequin model using an atomized glycerol mixture to simulate the aerosol dispersion range during oxygen therapy in an airborne isolation resuscitation room having 12 air exchanges per hour with the primary goal of determining the length and width of aerosol dispersion distance from the mouth. A secondary objective was to evaluate the risk of aerosol exposure by measuring the aerosol concentration at the mannequin's head, trunk, and feet. They performed this evaluation not only for techniques recognized as aerosol-generating procedures such as noninvasive positive pressure ventilation (ie, CPAP and BiPAP) but also for other oxygenation techniques such as nasal cannula oxygen, nonrebreather masks, and high-flow nasal cannulas.

The authors describe that these techniques might be used to preoxygenate patients in preparation for endotracheal intubation or to support patients with hypoxemic respiratory failure in an effort to avoid mechanical ventilation.

The authors found the average aerosol dispersion length after 3 minutes from the onset of the intervention to be greatest for BiPAP (100 cm), followed in descending order by nasal cannula oxygenation with face coverings (86 cm), high-flow nasal cannulas with face coverings (67 cm), nonrebreather masks (63 cm), and CPAP (47 cm). The measured aerosol concentrations were higher collectively at the mannequin's head, trunk, and feet when compared with no oxygen supplementation devices for all interventions except for nonrebreather masks. The authors also evaluated ventilator-assisted preoxygenation—a technique perhaps more typically encountered in an operating room setting in the United States—which has the advantage of being a closed system; they found that no visible dispersions and lower measurable aerosol concentrations were observed.

The authors acknowledge that the model has limitations that could affect its validity and generalizability. Respirations were simulated using a ventilator and a smoke particle generator with fixed respirations and minute ventilations set at 10 and 20 L. There was no attempt to simulate coughing or sneezing; thus, the experimental conditions may not accurately replicate the conditions of a patient with respiratory distress. The experiment was performed in an airborne isolation room having 12 air exchanges per hour and downward air flow. Many EDs may need to treat patients with respiratory illnesses in rooms without these engineering controls and with different airflow dynamics, ambient temperature, and humidity. The use of a 1% glycerol solution may not be a true surrogate for the dissemination of potentially infectious suspended droplet nuclei, but it is a technique previously described to approximate aerosol dispersion.[3,4] All measurements were made 3 minutes after the intervention began; thus, further dispersion over time of a potentially infectious aerosol plume cannot be addressed. Finally, aerosol presence does not equate with infectious exposure. The clinical relevance of aerosol exposure depends on the viability of the attached virus and the number of viable organisms needed to cause the COVID-19 infection, which is not known with certainty, although SARS-CoV-2 has been shown to remain viable in aerosols for 3 hours under experimental conditions.[5]

These limitations do not detract from the authors' important contributions to the literature regarding health care personnel safety during care of a potentially infectious patient with hypoxemia. As noted, all forced air techniques to supplement oxygenation, except for ventilator-assisted preoxygenation, resulted in measurable aerosol dispersion even when source control was applied. This included simple nasal cannula oxygenation, albeit measured using a flow rate (15 L/min) typically reserved for apneic oxygenation during endotracheal intubation.[6] Aerosol dispersion with high-flow nasal cannula oxygenation, recommended for adults with COVID-19 and acute hypoxemic respiratory failure despite conventional oxygen therapy, was more than that with CPAP, a modality recognized as an aerosol-generating procedure.[7] The concern about nosocomial transmission of respiratory pathogens during the use of high-flow nasal cannulas has been previously raised.[8] The favorable findings associated with ventilator-assisted preoxygenation may generate further interest in the study of noninvasive positive pressure ventilation techniques that employ viral filters on the exhaust port.

Experimental studies examining the risk of exposure to potentially infectious droplets and aerosols are important for informing infection prevention practices for personnel working in multiple patient care settings, including emergency medical services, ambulatory care clinics, EDs, hospital wards, ICUs, long-term care facilities, and others. They are a vital complement of retrospective case-control and cohort studies.[9] It has been noted that a "significant research gap exists in the epidemiology of the risk of transmission of acute respiratory infections from patients undergoing aerosol generating procedures to healthcare personnel."[9] Experimental models and epidemiologic studies will continue to provide the best evidence to inform infection prevention practices as prospective studies evaluating the outcome of unprotected exposure could never proceed because of ethical concerns.

Does this study inform practice? Does improved understanding and awareness about aerosol dispersion associated with commonly used techniques to augment oxygenation and increased concentration of potentially infectious aerosols, whether at the head or the foot of the bed, influence our behavior? We and our patients would likely benefit if it did. Early in the pandemic, the frontline health care personnel had a reported 3-fold greater risk of contracting COVID-19 than the general population.[10] Previous epidemics of acute respiratory illnesses have also significantly affected health care personnel. In 2003, 37% of the 128 cases in a single hospital outbreak of severe acute respiratory syndrome (SARS) in Toronto, Canada, were the hospital staff.[11] Patients are also at risk. A 2015 outbreak of Middle East Respiratory Syndrome in South Korea involved 186 cases and 38 fatalities. Of the 186 cases, 44% were patients who had been exposed through nosocomial transmission at 16 hospitals.[12]

The daily application of a hierarchy of controls to prevent disease transmission and adherence to sound infection prevention practices are important for the safety of health care personnel and the patients that they serve. The availability of isolation rooms and high-quality personal protective equipment is important but largely not within the control of clinicians. Practices, like "Identify, Isolate, and Inform," to more quickly recognize patients at greater risk of harboring a contagious respiratory infectious disease can be implemented at triage and at the bedside and can inform the need for additional safety precautions.[13] Close adherence to standard and transmission-based precautions, including consistent use of personal protective equipment in daily practice, are important for interrupting the transmission of respiratory and other illnesses. Perhaps this is where we as clinicians can have the greatest result in our workplace. A Cochrane review was conducted to identify the barriers to and facilitators of health care personnel adherence to these measures for respiratory infectious diseases.[14] Among many factors that influenced the adherence were support from managers, workplace culture, and a belief in the value of infection prevention practices and the benefit of compliance.[14] Authors of another review noted that observed noncompliance among colleagues could hinder compliance with infection prevention measures and advocated for "leading by example."[15] Clinicians providing emergency care for patients already manage multiple demands and must overcome seemingly endless obstacles for the care of their patients. Let us also strive to do our part as leaders in emergency care by becoming more knowledgeable about communicable disease risks in our workplace, applying practices known to interrupt transmission, and leading by example for the benefit of our colleagues, our patients, and ourselves.

Supervising editor: William R. Mower, MD, PhD.

Author affiliation: From the Section of Prehospital and Disaster Medicine, Department of Emergency Medicine, Emory University School of Medicine, Atlanta, GA.

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