

Enclosure with augmented airflow to decrease risk of exposure to aerosolized pathogens including coronavirus during endotracheal intubation. Can the reduction in aerosolized particles be quantified?

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Abstract

Introduction: As the pandemic of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2 or COVID-19) has impacted hospital routines in recent weeks, recommendations to reduce healthcare worker infections are being developed.

Methods: We report preliminary experience with the efficacy of an enclosure with augmented airflow to decrease the risk of exposure to aerosolized pathogens during airway management including endotracheal intubation. A particle generator was used to test the efficacy of the reduction of aerosolized particles by measuring their concentration within the enclosure and in the environment.

Results: No reduction in the concentration of aerosolized particles was noted with the enclosure flap open, whether the interior suction was on or off. However, with the enclosure closed and no augmented airflow (suction off), the particle concentration decreased to 1.2% of baseline. The concentration decreased even further, to 0.8% of baseline with the enclosure closed with augmented airflow (suction on).

Discussion: Aerosolized particulate contamination in the operating room can be decreased using a clear plastic enclosure with minimal openings and augmented airflow. This may serve to decrease the exposure of healthcare providers to aerosolized pathogens.

KEYWORDS

anesthesia, coronavirus, infection control, intubation, pandemic

1 | INTRODUCTION

The recent coronavirus pandemic has increased awareness of the need for techniques to limit transmission of infectious agents during anesthetic care.¹ Healthcare workers are at particular risk during procedures with exposure to aerosolized particulate matter, including tracheal intubation.² The primary modes of viral transmission included contact with contaminated environmental surfaces and aerosolization.³ During anesthetic care, the potential for aerosol

transmission is high during airway manipulation including bag-valve-mask ventilation, direct laryngoscopy, endotracheal intubation, and tracheal extubation.⁴⁻⁶ Although the use of personal protective equipment (PPE) reduces the transmission of infectious agents from a patient to the healthcare provider, other techniques to limit aerosolization and the use of barriers to protect against contamination of infectious agents into the environment may also be helpful.⁷⁻⁹ However, none of these maneuvers have been quantitatively tested for a reduction in aerosolized particles. To reduce aerosolized

particles in the operating room during endotracheal intubation and tracheal extubation, we propose using a clear plastic enclosure with limited openings and augmented airflow evacuation. We describe a novel device, made from routinely available equipment and items in the operating room and demonstrate its efficacy in limiting aerosolization during simulated bag-valve-mask ventilation and airway management.

2 | METHODS

Measurement of aerosolized particle concentration did not involve human subjects, and therefore, according to hospital guidelines for clinical research, Institutional Review Board approval was not necessary. A stainless steel tube was used to hold a plastic enclosure with limited openings and augmented airflow evacuation away from the patient's face and torso to allow adequate room for bag-valve-mask ventilation, endotracheal intubation, and tracheal extubation. (Figure 1) The hollow stainless steel metal bar with evacuation holes is first attached to the bed. A tarp with dimensions of 60 inches by 33 inches was then draped over the bar and taped to the bed. A standard clear plastic bag that is cut open can be used for this. A space for the patient to be slid underneath is left so that the patient's torso is covered. A flap measuring 18 inches by 22 inches is attached and taped to the bed. The clear plastic sheets from the Bair Hugger™ packaging can be used for this. This arrangement leaves two slits on the sides for passage of airway equipment, monitoring cables, and the arms of the anesthesia provider. (Figure 2) The stainless steel tube was hollow, and 8 holes were drilled in it to allow suction to evacuate the airspace. These tubes were attached to a suction canister and the operating room wall suction (40-50 L/min) which is then filtered and exhausted to the atmosphere per hospital protocol. Two pipes can be used for larger patients with one attached to the right side of the bed to support the plastic in the front and a second one attached to the left side of the bed, farther down to form the back support. Stainless steel pipe was chosen as it can be sterilized and reused.

PortaCount Respirator Fit Tester and a particle generator (TSI Incorporated, Shoreview, Minnesota) were used to test the efficacy of the reduction of aerosolized particles during simulated anesthesia induction, endotracheal intubation, and tracheal extubation within the clear plastic enclosure with minimal openings and augmented airflow evacuation. Qualitative fit testing involving microscopic salt particles of 0.04 micrometers in median diameter was used. Qualitative fit testing involving aerosolized particles is a reproducible reliable method to ensure that respirators and facemasks have a proper seal and thereby provide protection from exposure to aerosolized particles. This is not reproducible with a semi-open enclosure with slits to allow passage of airway equipment, monitors, and hands/arms of the anesthesia provider. However, a measurement of the difference in the concentration of particles within and outside the enclosure is achievable with the same equipment. This was obtained by placing the aerosol particle generator within the enclosure.

Clinical implications

What is already known

- With the recent COVID-19 pandemic, barrier measures to protect healthcare workers have been proposed. None of these have been quantitatively tested for a reduction in aerosolized particles.

What this article adds

- This study uses a quantitative measurement in the reduction of aerosolized particles in a plastic enclosure with augmented airflow.

The concentrations of the particles were measured in the enclosure and at approximate head level of the theoretical anesthesia provider. (Figure 3) The concentration of aerosolized particles was measured at six different times, and the highest measurement recorded: (1) with the enclosure closed without augmented airflow (suction off); (2) with the enclosure closed with augmented airflow (suction on); (3) with the enclosure closed and arms inserted to stimulate endotracheal intubations without augmented airflow; (4) with enclosure closed and arms inserted to simulate endotracheal intubation with augmented airflow; (5) with the enclosure flap facing the provider open without augmented air flow; and (6) with the enclosure flap facing the provider open with augmented airflow.

3 | RESULTS

The results during the six conditions in 1000 particles per cubic centimeter are shown in Table 1. The greatest reduction in particles was with the enclosure closed using augmented airflow with suction which resulted in a decrease to 0.8% of baseline. The highest concentrations were noted when the flap was open. With the front flap open, the equilibrium of particles inside and outside the tent was the same with or without augmented airflow evacuation.

4 | DISCUSSION

Endotracheal intubation has been associated with the highest risk of exposure to aerosolized particles and the risk of healthcare worker contamination given the proximity of the healthcare provider to the patient's airway.¹ With routinely available and relatively inexpensive equipment, we were able to fashion an enclosure which may decrease a healthcare worker's exposure to aerosolized particulate matter and pathogens during airway management. This report also provides a description of how to use a standard particle generator to evaluate barrier devices. This technique can be used in future studies to evaluate the effectiveness of such devices.

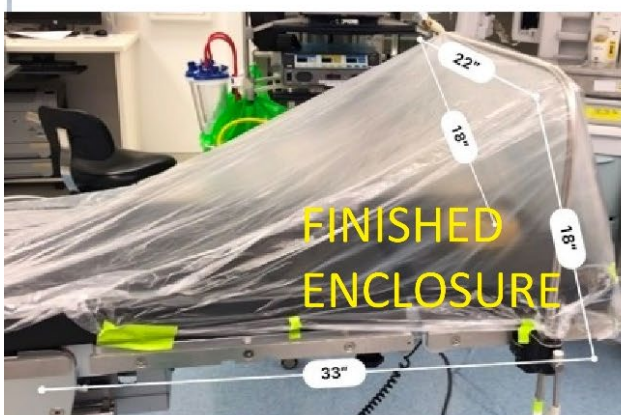
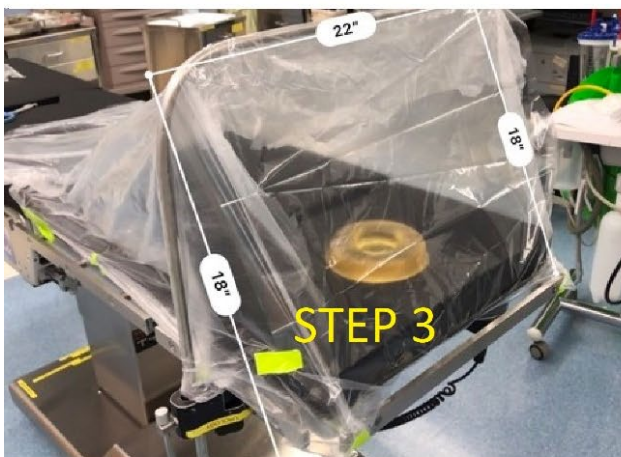


FIGURE 1 Steps for construction of the plastic tent. The hollow pipe, with holes drilled into it, is placed on the left side of the bed [Colour figure can be viewed at wileyonlinelibrary.com]

We acknowledge that this simulation study conducted in a laboratory has limitations as it may not truly replicate the clinical environment. The measurements from this study involved static positions and may not accurately measure concentrations during movement. Further studies are warranted to determine feasibility, ease of endotracheal intubation using either video laryngoscopes or standard direct laryngoscopy, and patient comfort with use of the enclosure. Videolaryngoscopy, if available, should be considered if the plastic barrier is not translucent and impairs vision. The administration of premedication to provide anxiolysis and sedation may improve patient behaviors prior to the induction of anesthesia, especially given the possibility of increased anxiety with the use of an enclosure.

The high concentration of particles in the enclosure is due to the small volume of air in the enclosure and the high rate of particle generation. The usual ambient concentration used for fit testing of respirators is between 15 and 25×10^3 , and the concentration in the enclosure was over ten times this number.¹⁰ This high concentration was noted both inside and outside the enclosure when the flap was open. This differs from the clinical scenario, as after the patient's trachea is intubated and connected to the anesthesia circuit, there would be a cessation of particles released from the patient and the concentration would decline over time.

The time required for the ambient concentration of potential pathogens to decrease to an acceptable level after endotracheal intubation may vary based on air circulation within the enclosure. However, the front to the enclosure can be kept closed during and after airway management to allow the concentration of aerosolized particles to decrease thereby allowing surgery to proceed



FIGURE 2 Side view of the device with mannequin inside to simulate a patient. Two hollow pipes are used for larger patients with one attached to the right side of the bed to support the plastic in the front and the other attached to the left side of the bed to form the back support [Colour figure can be viewed at wileyonlinelibrary.com]

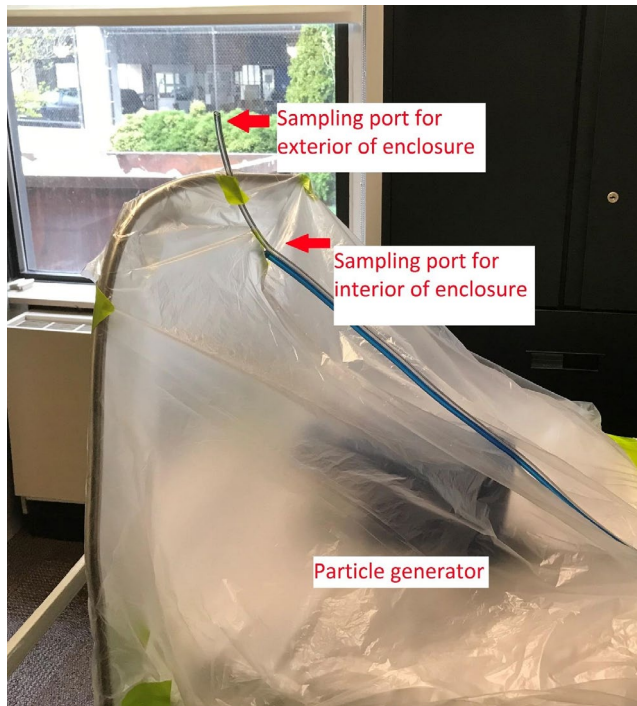


FIGURE 3 Particle generation was placed inside the enclosure. The concentration of particles was measured inside and outside the airspace as shown [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Particle concentration per cubic centimeter inside and outside the airspace

| Condition | Interior of airspace (within tent) | Exterior or airspace (outside of tent) |
|-----------|------------------------------------|--|
| 1 | 269.4 | 3.3 (1.2%) |
| 2 | 233.6 | 1.9 (0.8%) |
| 3 | 225.7 | 4.3 (1.9%) |
| 4 | 233.6 | 2.5 (1.1%) |
| 5 | 269.4 | 269.4 (100%) |
| 6 | 269.4 | 269.4 (100%) |

Note: Six conditions: (1) Enclosure closed, no augmented airflow (suction off). (2) Enclosure closed, augmented airflow (suction on). (3) Enclosure closed with arms inserted, no augmented airflow (suction off). (4) Enclosure closed with arms inserted, augmented airflow (suction on). (5) Enclosure flap facing the provider open, no augmented airflow (suction off). (6) Enclosure flap facing the provider open, augmented airflow (suction on).

^aConcentration measured in 1000 particles per cm³.

immediately. Care also would be necessary when removing the enclosure to not contaminate oneself and or the room with the contained aerosolized particle or secretions that may have been deposited on the inside of the enclosure. Additional studies are needed to measure particle concentration during the act of endotracheal intubation and after removal of the enclosure. It may also be useful to compare this technique with other protective measures such as endotracheal intubation in a negative pressure room, or in rooms

with laminar flow and high air movement (>60 air changes/hour). A specific protocol for removing the enclosure would be helpful in decreasing the risk of exposure of healthcare workers. This would require further study regarding the time required for a reduction in the aerosolized particles after airway procedures.

As the device does not remove all risk of contact with aerosolized pathogens, use of this enclosure does not allow for decreased vigilance or changes in recommendations for use personal protective equipment and negative pressure or laminar high air movement rooms. However, it may decrease the number of aerosolized particles that anesthesia providers and other operating room staff are exposed to during endotracheal intubation and extubation. Furthermore, the plastic drape will provide additional protection during coughing and forceful expulsion of particles but care must be taken to decrease coughing and forceful breathing upon extubation.¹¹ This study did not evaluate the efficacy of this device in transmission of aerosolized pathogens or changes in clinical safety for healthcare workers. Further investigations in the clinical setting are warranted to address these limitations.

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CONFLICT OF INTEREST

None of the authors have any conflicts of interest or relationships, financial or otherwise that might be perceived as influencing the author's objectivity.

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