Closed Bronchoscopy System: An Innovative Approach to Minimize Aerosolization During Bronchoscopy

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Health care workers performing aerosolizing procedures on patients with transmissible infections such as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) are at high-risk for disease acquisition. Current guidelines designed to protect health care workers during aerosolizing procedures prioritize personal protective equipment and enhanced infection control techniques, in particular during procedures such as intubation. To date, little emphasis has been placed on risk mitigation in the setting of bronchoscopy, a procedure that has significant aerosolization potential. Herein, we present an innovative closed bronchoscopy system designed to reduce aerosolization during bronchoscopy. (A&A Practice. 2021;15:e01417.)

GLOSSARY

COVID-19 = coronavirus disease 2019; **PEEP** = positive end-expiratory pressure; **PPE** = personal protective equipment; **SARS-CoV-2** = severe acute respiratory syndrome coronavirus 2

The current understanding of the spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus which causes coronavirus disease 2019 (COVID-19), is that the principal mode of infection is via respiratory droplets, however, contact transmission and aerosol transmission are also known to occur.[1] Health care workers who perform aerosol-generating procedures are at a greater risk for viral exposure. International guidelines developed from expert panels and specialty regulatory bodies aim to assist organizations in adapting workflows to reduce this risk of viral transmission.[2] The majority of risk mitigation strategies focus on ensuring providers don the appropriate personal protective equipment (PPE) and adopt enhanced infection control techniques periprocedurally. Additional layers of protection have been attempted through innovations such as "intubation boxes," aimed at the containment of viral particle spread.[3]

Bronchoscopy is a highly aerosolizing procedure, yet it lacks sufficient risk management strategies when performed in patients with confirmed COVID-19, apart from those already mentioned. Bronchoscopy is frequently performed within the spectrum of care of critically ill patients with COVID-19 where it can be used diagnostically, therapeutically or as an adjunct to assist in airway management procedures such as percutaneous tracheostomy, difficult intubation, or reintubation. Strategies to reduce viral exposure while performing bronchoscopy during a tracheostomy procedure, in a patient with confirmed COVID-19, have been described but focus mainly on reducing the risk posed by the surgery itself.[4]

In our institution, we have developed a closed bronchoscopy system that allows for bronchoscopy to be utilized while providing the health care team with an additional layer of protection from viral aerosolization. To evaluate the effectiveness of our closed bronchoscopy system, we simulated bronchoscopy in a ventilated mannequin—both with and without use of the novel device. Fluorescent dye was used as a surrogate for virus aerosolization in both experiments. The aim of our simulation was to assess airflow while using the closed bronchoscopy system in a ventilated model and evaluate if the system prevented the spread of aerosolized droplets during bronchoscopy.

METHODS

Closed Bronchoscopy System Set Up

The bronchoscope that is utilized in patients with COVID-19 at our institution is a 5.8-mm single-use bronchoscope with a 2.8-mm working channel (Ambu aScope 4 Broncho Large, Ambu Inc, Columbia, MD). This device was chosen because it is disposable and is also equipped with a large port for suctioning and clearing secretions during the procedure. To convert this device to a closed system, we make several simple modifications to the bronchoscope, using readily available disposable materials. We begin by covering the bronchoscope with a sheath from a pulmonary artery catheter that has been cut at either end to detach the transparent sheath (Figure 1A). To prevent aerosolization from the proximal end of the bronchoscope, we secure the end of the sheath to the bronchoscope by encircling it with heavy silk suture ties and overlying tape (Figure 1B). The distal end of the scope is then passed through a double swivel elbow with flip top cap and seal that provides a secure fit for the bronchoscope and does

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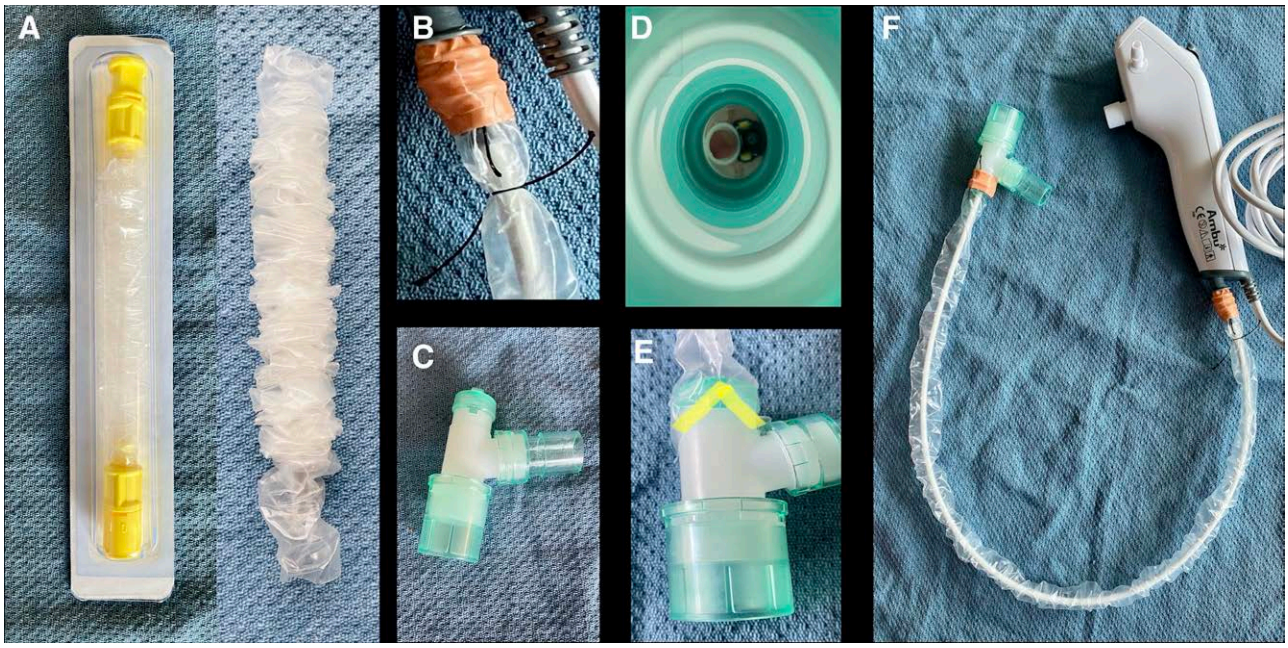

Figure 1. Stepwise assembly of closed bronchoscopy system. A, Pulmonary artery catheter sheath that is cut on either end. B, Pulmonary artery catheter sheath is advanced over the bronchoscope and secured at the proximal end with a heavy silk suture and tape to create a seal. C, Swivel elbow is connected to the endotracheal tube at the distal end and allows passage of the bronchoscope through the diaphragm on the proximal end. D, View of the 5.8-mm bronchoscope as it passes through the diaphragm of the swivel elbow. A tight seal is created that prevents air leakage and maintains airway pressure. E, Slit required on the pulmonary artery catheter sheath to fit over the elbow. The distal end of the sheath with the slit is then secured to the proximal end of the swivel elbow using heavy sutures and tape, creating a seal. F, Final assembly of closed circuit that is ready to be attached to the endotracheal tube and used throughout the procedure to limit the escape of particles and protect users from handling the contaminated part of the bronchoscope after it enters the airway.

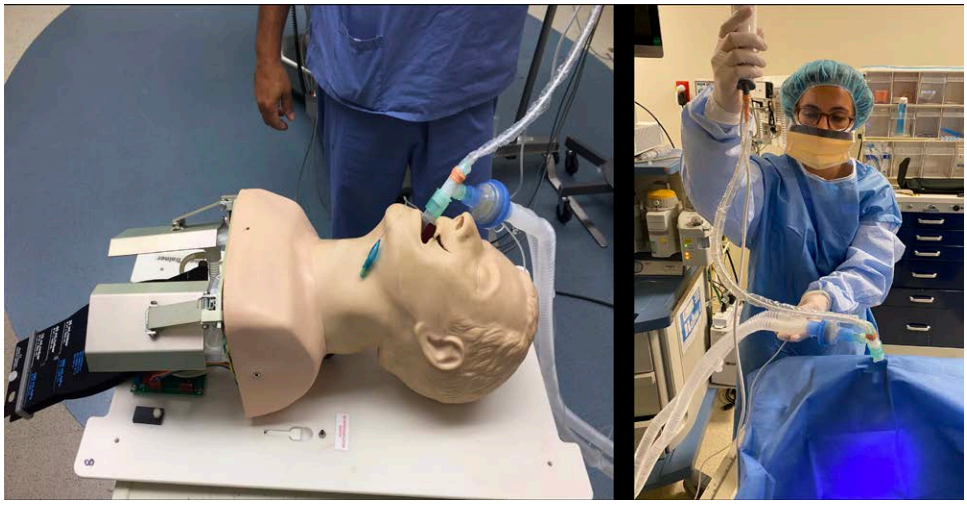

Figure 2. Intubated mannequin with a test lung attached to allow for simulated ventilation. The closed bronchoscopy system is attached to the endotracheal tube which is also connected to the anesthesia machine allowing for positive pressure ventilation.

not allow air leakage around the entry site (Figure 1C, D). A small slit on the distal end of the pulmonary artery catheter sheath is required to allow it to fit over the elbow. This end is then tightly secured by once again encircling it with heavy silk sutures and reinforcing it with tape (Figure 1E). This new closed bronchoscopy system is then connected to the endotracheal tube which has been temporarily clamped during disconnection to further minimize exposure to aerosolized virus particles until the device is secured in place. The novel apparatus ultimately creates a closed system and enables us to utilize the bronchoscope freely while minimizing the potential aerosolization that the provider may routinely encounter during the procedure (Figure 1F).

Experiment 1; Bronchoscopy With Closed System in a Ventilated Mannequin

A mannequin equipped with a single test lung was intubated with a standard 7.5-mm oral endotracheal tube. Fluorescent dye was then added to the inside of the endotracheal tube to simulate visible respiratory secretions. Ventilation was performed using a standard closed breathing circuit, with the following parameters: tidal volume of 500 mL, rate of 14 breaths per minute, positive end-expiratory pressure (PEEP) of 20 cm H_2O (Figure 2). The closed bronchoscopy system was constructed, as described above, and connected to the endotracheal tube of the mannequin. The operator performing bronchoscopy was equipped

Figure 3. Ultraviolet light examination of the distal and proximal ends of the closed bronchoscopy system after it has been passed through the endotracheal tube several times. The fluorescent dye is contained within the sheath housing the bronchoscope with no environmental contamination or leakage from the proximal end.

with standard PPE (eg, gloves, gown, eye protection, head cover, and mask) and positioned at the head of the model airway. Before the bronchoscope was introduced through the endotracheal tube, the environment was screened with ultraviolet light to confirm the absence of fluorescent dye. The bronchoscope was then advanced into the endotracheal tube and withdrawn several times, while maintaining ventilation, thereby closely simulating a typical clinical scenario. Near the end of the procedure, both the proceduralist and the surrounding environment were reevaluated with the ultraviolet light to assess whether florescent dye was present, thereby evaluating the efficacy of the closed bronchoscopy system in restricting escape of the dye.

Experiment 2: Bronchoscopy Without Closed System in a Ventilated Mannequin

In this experiment, we simulated bronchoscopy in a ventilated mannequin by attaching a double swivel elbow to the endotracheal tube and then passing the bronchoscope through the diaphragm of the elbow, without the addition of a closed bronchoscopy system. Before the start of this experiment, we decontaminated the environment, bronchoscope, and mannequin of fluorescent dye and confirmed decontamination with ultraviolet light. Fluorescent dye was again placed into the endotracheal tube to simulate respiratory secretions. To simulate bronchoscopy, the bronchoscope was advanced into the endotracheal tube and withdrawn, while maintaining ventilation. Toward the end of the procedure, the proceduralist and surrounding environment were reevaluated with ultraviolet light to assess for environmental contamination of fluorescent dye that may have occurred during bronchoscopy.

RESULTS

In the first experiment, the closed bronchoscopy system contained the fluorescent dye within our closed system throughout the entire procedure. Florescent dye was visible along the bronchoscope and within the sheath housing the bronchoscope itself, but not elsewhere outside the system, including the proximal end of the bronchoscope (Figure 3) (Supplemental Digital Content, Video 1, http://links.lww.com/AACR/A421). Furthermore, the system remained intact during the procedure, with no leakage from the sheath occurring on delivery of a maximal PEEP of 20 cm H_2O. At the end of the procedure, examination with ultraviolet light did not reveal any contamination outside of the closed bronchoscopy system. Operator handling of the bronchoscope and maneuverability was unaffected by the closed bronchoscopy system.

VIDEO+

In the second experiment, bronchoscopy was performed using the standard method, without the closed bronchoscopy system. Throughout this simulation, fluorescent dye was visible along the distal end of the bronchoscope, as well as on the proceduralist's gloves and gown, on the surgical field, and the air within the local environment (Figure 4; Supplemental Digital Content, Video 2, http://links.lww.com/AACR/A422).

VIDEO+

DISCUSSION

Bronchoscopy is a procedure commonly performed in critically ill patients and is associated with a high degree of aerosolization. When performed on patients harboring pathogens such as SARS-CoV-2, there may be considerable risk of viral transmission to the health care provider performing the procedure. In a recent case series of bronchoscopy in mechanically ventilated patients with COVID-19, 1 of 2 proceduralists became infected with SARS-CoV-2 and developed COVID-19.[5] This not only reinforces the degree of aerosolization which occurs with bronchoscopy, but it also highlights the dangers of this procedure to those performing it, even when equipped with proper PPE.

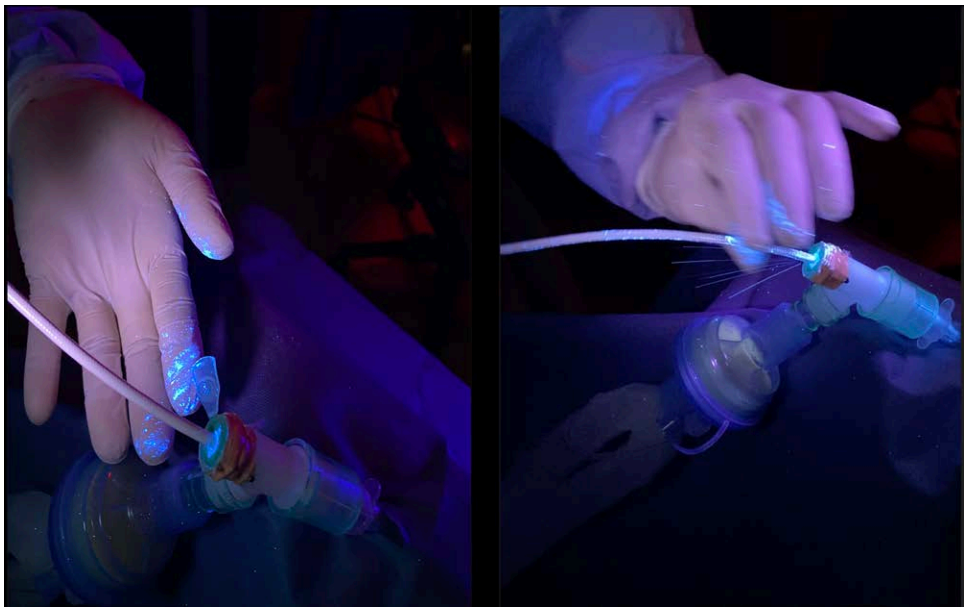

Figure 4. Ultraviolet light examination of the distal end of the bronchoscopy system without the closed system after the bronchoscope has been passed in and out of the endotracheal tube several times. There is also contamination of the proceduralist's gown and gloves as well as the procedural environment. Additionally, we see high velocity particles being ejected from the port where the bronchoscope enters the endotracheal tube into the local environment.

Measures to mitigate risk, such as donning adequate PPE, limiting the procedure to experienced operators, and clamping the endotracheal tube when disconnecting from the circuit, should be routinely implemented. Nonetheless, these measures alone do not provide sufficient protection for providers performing bronchoscopy. We believe our closed bronchoscopy system offers an additional layer of protection for health care workers who perform these invasive and high-risk procedures. This intervention minimizes the aerosolization of respiratory secretions during simulated bronchoscopy, while exhibiting no discernible impact on operator handling or patient safety.

Our experiments suggest that use of the closed bronchoscopy system reduces the risk of exposure to aerosolized particles during simulated bronchoscopy, although we cannot definitively conclude that it eliminates all risk. Our methods relied on the ability to detect fluorescent particles with the naked eye, which limited our ability to detect smaller particles that could potentially lead to infection. In addition, this system does not mitigate against other high-risk elements of the procedure, including connecting and disconnecting the bronchoscope, as well as disposal of the device.

We suggest the use of this novel, closed bronchoscopy system, along with other measures including adequate PPE, clamping of the endotracheal tube during circuit disconnections, and limiting the number of personnel who perform the procedure to further reduce the risk of exposure to transmissible diseases such as SARS-CoV-2.

DISCLOSURES

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