Continuous Negative Pressure Operative Field Barrier for Combined Open Tracheostomy and Percutaneous Endoscopic Gastrostomy Tube Placement During Coronavirus Disease 2019

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Respiratory failure in coronavirus disease 2019 (COVID-19) patients with prolonged endotracheal intubation may require a tracheostomy and percutaneous endoscopic gastrostomy (PEG) tube placement to facilitate recovery. Both techniques are considered high-risk aerosol-generating procedures and present a heightened risk of exposure to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) for operating room personnel. We designed, simulated, and implemented a portable, continuous negative pressure, operative field barrier system using standard equipment available in hospitals to enhance health care provider safety during high-risk aerosol-generating procedures. (A&A Practice. 2020;14:e01371.)

Glossary

CDC = Centers for Disease Control and Prevention; COVID-19 = coronavirus disease 2019; FDA = Food and Drug Administration; HEPA = high-efficiency particulate air; ICU = intensive care unit; OR = operating room; PEG = percutaneous endoscopic gastrostomy; SARS-CoV-2 = severe acute respiratory syndrome coronavirus 2; ULPA = ultra-low particulate air

O ur knowledge and understanding of coronavirus disease 19 (COVID-19) continues to grow. The responsible pathogen, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), measures approximately 0.125 μm, and is transmitted through respiratory droplets or via aerosols (airborne).2–4 Droplet transmission occurs with close contact (<1 m), when particles (ranging in size from 0.5 to 0.10 μm) are expelled into the ambient air while talking, coughing, or sneezing.2–4 Airborne transmission (particles <0.5 μm) can occur under specific circumstances when aerosol-generating procedures are performed (eg, endotracheal intubation, tracheostomy, endoscopy, cardiopulmonary resuscitation).3,4 These fine particles may remain suspended in the air or drift away on air currents,2–4 thereby increasing the potential for transmissibility of SARS-CoV-2 in suboptimally ventilated surroundings.

Respiratory failure in COVID-19 patients with prolonged endotracheal intubation may require a tracheostomy and percutaneous endoscopic gastrostomy (PEG) tube placement to facilitate recovery.5 These procedures are considered high risk for generating aerosols.3,4 Large viral loads are often present in saliva, oral, and nasal mucosa, and pulmonary secretions of COVID-19 patients.5,7 Performing such procedures increases the risk of exposure to SARS-CoV-2 among surgeons, nurses, and anesthesia providers in the operating room (OR).8 To enhance health care provider safety, we designed, simulated, and implemented a portable, continuous negative pressure, operative field barrier system. Using equipment readily available in most hospitals, the purpose of this system is to facilitate the safe performance of high-risk aerosol-generating procedures. We describe the use of this system in a case of combined open tracheostomy and PEG tube placement in a patient. Signed Health Insurance Portability and Accountability Act authorization and appropriate informed consent were obtained.

CASE DESCRIPTION

A 59-year-old man with prolonged respiratory failure due to COVID-19 was scheduled for elective open tracheostomy and PEG tube placement. The patient was transported from the intensive care unit (ICU) using a protective canopy to decrease the risk of aerosolization in the event of an unplanned disconnect from mechanical ventilation. The procedures were performed on the ICU bed to minimize the risk of ventilator circuit disruptions. The operative field barrier was built using spring clamps, plastic arches, transparent sterile plastic sheets, and drape clamps. Plastic arches were placed over the bed and secured using spring
clamps. The patient was draped and prepared in a standard fashion. A transparent sterile plastic sheet was then placed on top of the plastic arches. This sheet was secured with drape clamps leaving a space gap between the bed and the sheet for the surgeons to reach into the operative field. Continuous negative pressure was created using a commercially available surgical waste management system (Neptune 3; Stryker Corporation, Kalamazoo, MI). A 7/8th-inch hose was connected to the smoke evacuation port with the tip placed in close proximity to the incision site for the tracheostomy. Before implementation in the clinical setting, the negative pressure environment was validated using a smoke evacuation model in the simulation laboratory (Supplemental Digital Content, Video 1, http://links.lww.com/AACR/A399) and in the OR during a maxillofacial surgery. A standard open tracheostomy was performed without complications (Figure 1). While the head of the patient was still under the protective canopy, a second 7/8th-inch tubing was placed to create a continuous negative pressure environment while manipulating the upper airway during endoscopy. Transillumination of the stomach on the abdominal wall was achieved without difficulty and PEG tube placement was performed without any complications (Figure 2).

DISCUSSION
Combined open tracheostomy and PEG tube placement under a continuous negative pressure operative field barrier can be performed safely and successfully. The system created by the transparent sheet, in conjunction with continuous negative pressure, allowed the OR personnel to have an extra layer of protection from droplets and aerosols while performing the tracheostomy, endoscopy, gastrostomy, and during insufflation of the stomach, without compromising the surgical view. The gap between the transparent sheet and the bed allowed for good mobility and range of motion for the surgeons. Instruments were also easily handed under the plastic sheet to the surgeons. Performing an endoscopy under the protective canopy with continuous negative pressure additionally decreased the surgeon’s and anesthesia provider’s risk of exposure to contaminated droplets as well as aerosols. Furthermore, maneuverability of the endoscope was not restricted, and a safe, yet expeditious, PEG tube placement was achieved without difficulty.

Surgical waste management systems are typically composed of 2 different pumps: a surgical fluid suction pump and a separate smoke evacuator pump. Using the smoke evacuator 7/8th-inch port allows the creation of a negative pressure environment with an airflow of 33 cubic feet per minute when set to 100% power per the manufacturer. The use of in-line ultra-low particulate air (ULPA) filters remove 99.99% of particles 0.1 μm or larger from the surgical field, compared to the high-efficiency particulate air filters (HEPA), that have a filtration performance of 99.97% of particles >0.3 μm. ULPA filters have a life span of 80 hours and do not need to be replaced with each new patient. While data regarding their utility in patients with COVID-19 remain sparse, the effectiveness of such filters in sequestering particles that are the same size or smaller than SARS-CoV-2 has been previously demonstrated.

Wall vacuum and standard surgical fluid suction are designed to pull liquids and operate on the principle of water lift (ie, maximum suction pressure generated). On the other hand, smoke evacuators operate on the principle of airflow (ie, volume of air moved through the vacuum).
Paulsen\textsuperscript{14} reported that wall vacuum outlets found inside the OR generate approximately 114–121 L/min of airflow depending on the wall connector that is used. When a wall suction regulator is placed in line, the flow decreases to approximately 80 L/min. Airflow decreases even further after adding cannisters, tubing, and suction devices, assuming there are no physical kinks in the system.\textsuperscript{14} Conversely, surgical waste management systems generate a negative airflow of approximately 935 L/min.\textsuperscript{14} Surgical waste management systems generate higher negative airflow compared to wall suction, with significantly fewer opportunities for mechanical obstruction.

Negative pressure operative fields, like the one we have described, can be created easily using low-cost equipment readily available in most hospitals. They may significantly reduce the risk of exposure and cross contamination of SARS-CoV-2 in high-risk aerosol-generating procedures in and outside the OR environment. It is important to note that the transparent plastic sheet used in this barrier system should not be tucked in, otherwise the force generated by the suction device causes the setup to collapse. By keeping the transparent plastic sheet loosely draped over the operative areas allows for ambient air to be constantly sucked in without causing any movement or disruption of the barrier creating the negative pressure environment. And although we used a very specific type of suction device that is highly reliable and commonly available in our ORs, it may be possible to achieve the same effect with other types of continuous suction. However, we have not validated these alternative methods and cannot verify their effectiveness. Moreover, we did not assess whether the use of an ULPA or HEPA filter-equipped continuous negative pressure system alone would completely mitigate the risk of viral transmission. Indeed, during the case, all health care providers strictly adhered to the airborne precaution guidelines, recommended by the Centers for Disease Control and Prevention (CDC) as well as the Food and Drug Administration (FDA)\textsuperscript{41,11}; all individuals used appropriate personal protective equipment (eg, N95 respirators, eye protection, gowns, and gloves)\textsuperscript{15} and the OR followed the recommended airborne contaminant removal protocol (minimum of 12 air changes per hour).\textsuperscript{4,11} Additionally, the patient was transported with a secured airway, inside a protective hood, and under full neuromuscular blockade to minimize the risk of aerosolization. Finally, the use of a continuous negative pressure operative field should be used with caution in emergency situations so that it does not delay appropriate care. With greater institutional experience, our assembly time dropped from an initial 6–8 minutes to approximately 2–3 minutes. The system has been used in over 100 patients with no resulting delays in care. Furthermore, the setup can be dismantled within seconds by removing the drape clamps that secure the transparent sheet to the plastic arches to allow for direct access to patients.

In COVID-19 patients with prolonged endotracheal intubation who require a tracheostomy and the PEG tube placement, limiting exposure to aerosols during these procedures is a critical step in reducing risk to health care providers. We present the use of a portable, continuous negative pressure operative field barrier for this combined procedure using standard equipment readily available in most ORs and hospitals. In conjunction with evidence-based precautions recommended by the CDC and FDA, continuous negative pressure operative fields may significantly reduce the risk of viral transmission to OR personnel and health care providers.

DISCLOSURES

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Contribution: This author helped conceptualize the report, draft the initial manuscript, and review and revise the manuscript and approved the final manuscript as submitted and agreed to be accountable for all aspects of the study.
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