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Manoj H. Iyer, MD*
Nasir Hussain, MD, MSc*
Amar Bhatt, MD*
Adam A. Dalia, MD, MBA†
Michael Essandoh, MD, FASE*,[1]
*Department of Anesthesiology, Division of Cardiothoracic and Vascular Anesthesia, Ohio State University Wexner Medical Center, Columbus, OH
†Department of Anesthesiology, Pain Medicine, and Critical Care, The Massachusetts General Hospital, Harvard Medical School, Boston, MA

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A Portable Negative Airflow Box to Control Exposure for Aerosol-Generating Procedures During Coronavirus Disease 2019 (COVID-19) Pandemic

To the Editor:

SINCE the World Health Organization declared coronavirus disease 2019 (COVID-19) as a pandemic,[1] several articles have demonstrated the high risk of exposure to severe acute respiratory syndrome coronavirus 2 that healthcare personnel face when involved in aerosol-generating procedures. Bag-mask ventilation, tracheal intubation, and extubation represent risky procedures for anesthesiologists because of the exposure to a higher concentration of aerosols, possibly because of the greater viral load of this virus in the upper airway secretions.[2] According to the National Institute for Occupational Safety and Health (NIOSH), controlling this type of risk requires implementing a hierarchy of controls that provides effective and feasible solutions to reduce hazards (eg, decreasing exposure to respiratory droplets and aerosols).[3]

Because elimination and substitution (the most effective NIOSH strategies) are not yet available, hospitals worldwide have shielded healthcare workers (HCWs) mainly by improving personal protective equipment (PPE)[4]; however, more effective containment measures. Such as administrative and engineering controls (ECs), surprisingly have been overlooked.

This omission can be secondary to the difficulty of setting up negative-pressure rooms in due time, and at the Hospital Universitario San Ignacio (Bogota, Colombia) in affiliation with Pontificia Universidad Javeriana, we faced this difficulty, and therefore we aimed to redesign the original "aerosol box"[5] into a negative-pressure microenvironment (Table 1) in an effort to produce an interim EC measure during the crisis.

Table 1
Comparison Between the Aerosol Box and the Portable Negative Airflow Box

Characteristics	Dr. Hsien Yung Lai's Aerosol Box	San Ignacio Portable Negative Airflow Box
Size	L: 40 cm H: 50 cm W: 50 cm	Wider and taller (L: 43 cm; H: 53 cm; W: 53 cm) that fits larger patients
Shape	Cuboid design	Cuboid design with sloping side for the intubator to reduce refractive errors and improve operator ergonomics
Access ports for arms	2, just for the operator	6 ports (2 on each side) with wider access for assistance When not in use, sliding doors keep these ports sealed
Independent access port for anesthesia circuit and/or others*	No	Yes
Material	Transparent acrylic	Transparent acrylic
Negative pressure box	No	Yes
Isolation	No	Yes
Risk of aerosol leak	High	Very low

* Oxygen cannula, Venturi mask system, or suction tube.

Engineer Control: Applying Principles to the Aerosol Box (Fig 1)

Isolation

Clear plastic (1 m × 1.5 m) is hermetically attached through synthetic gutters. This plastic has a "T-shirt- like" opening for the head of the patient to access the box and is resealable to decrease particle dispersion when removing the box. Six circular ports for arm access, each with a diameter of 15 cm, provide versatility for using this box in other settings where the arrangements of ventilator connections vary; moreover, when the box is not in use, sliding doors keep these ports sealed. In addition, each port has external flanges to firmly attach disposable long-arm veterinary gloves and maintain the hermetic seal when working inside the box. There is an additional port at the bottom, with a small sliding door for the anesthetic breathing circuit, which can be sealed when not in use.

Ventilation

A suction tube (pressure −150 mmHg) is taped inside, exhausting air to a closed canister with a hypochlorite solution located outside the box. In compliance with NIOSH, this suction removes the hazard at the source and increases air exchange within the sealed acrylic box, decreasing the load of airborne contaminants even while the box is removed.

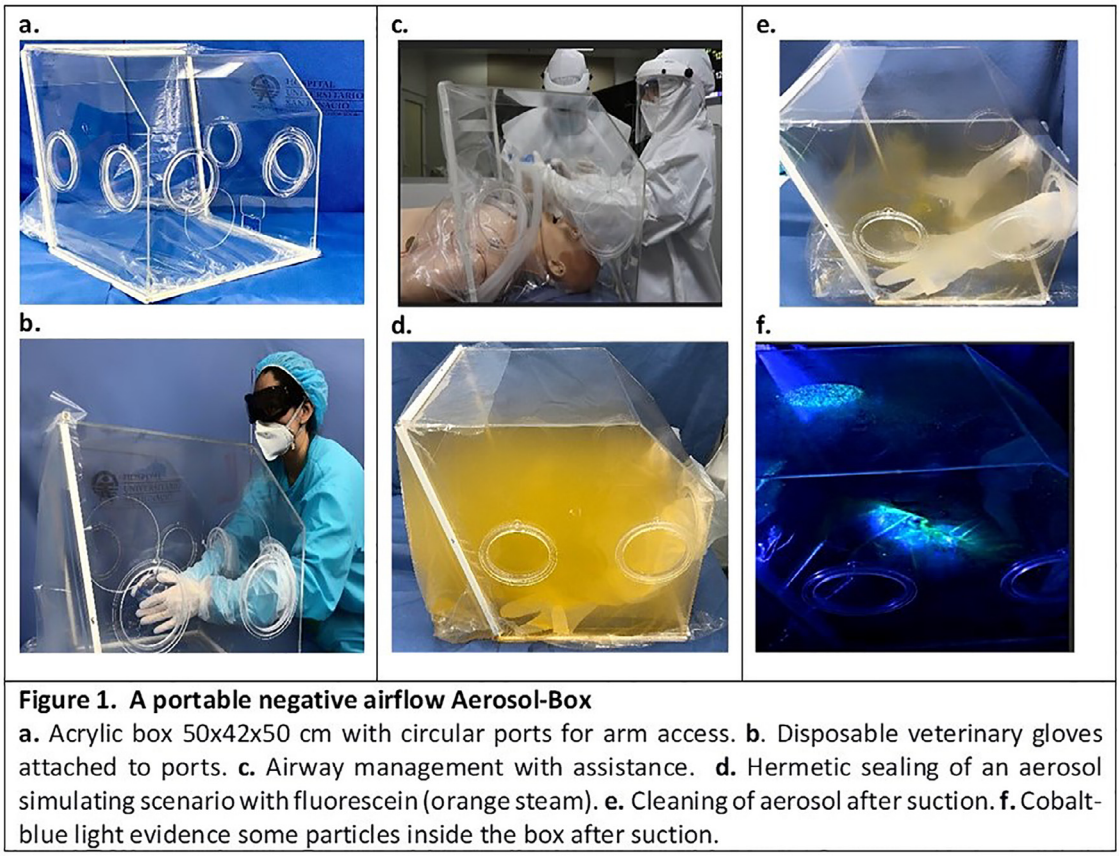

Figure 1. A portable negative airflow Aerosol-Box
a. Acrylic box 50x42x50 cm with circular ports for arm access. **b.** Disposable veterinary gloves attached to ports. **c.** Airway management with assistance. **d.** Hermetic sealing of an aerosol simulating scenario with fluorescein (orange steam). **e.** Cleaning of aerosol after suction. **f.** Cobalt-blue light evidence some particles inside the box after suction.

Fig 1. A portable negative airflow aerosol box. (A) Acrylic box 50 cm × 42 cm × 50 cm with circular ports for arm access. (B) Disposable veterinary gloves attached to ports. (C) Airway management with assistance. (D) Hermetic sealing of an aerosol-simulation scenario with fluorescein (orange steam). (E) Cleaning of aerosol after suction. (F) Cobalt blue light evidence of some particles inside the box after suction.

Simulation Laboratory

Fluorescein Test

Using concentrated (orange) nebulized fluorescein (Bio Glow; HUB Pharmaceuticals, Plymouth, MI), we tested for leaks and aerosol dispersion within the box, and with diluted liquid fluorescein (green), we tested for droplets spread under cobalt blue light. The clearance of the nebulized solution and evidence of orange particles within the suction tube attest for clearance of particles through negative pressure. Both tests demonstrated visual containment for aerosols and droplets (Fig 1, *D-F*).

Simulation Scenarios

We performed multiple high-fidelity simulated tracheal intubations using a conventional laryngoscope (#3 Macintosh blade) and video laryngoscope (King Vision; Ambu, Columbia, MD, and Storz; Karl Storz SE & Co, Tuttlingen, Germany). We also performed several simulated extubations and scenarios requiring endotracheal tube disconnections from the anaesthesia breathing circuit (eg, transport to intensive care unit, head or neck surgery requiring removal of the box) to test maneuvers, such as the use of clamps for endotracheal tube or faster ways of resealing the head opening to decrease aerosolization of enclosed particles when removing the box. We found simulation to be the cornerstone for anesthesiologists and other staff involved in airway management to accept and become more comfortable with the device. From these experiences, we developed and improved checklists to ensure availability of tools within the aerosol box to reduce the number of times ports are opened during airway manipulation. Even though this was a challenging process because of time constraints and a feeling of changing rules, it was and still is presented as an alternative for airway management; therefore, the criterion of the specialist is not at stake.

Challenges During Clinical Use

Surgical Scenarios

Once the simulation stage was completed, we started using the aerosol box, with asymptomatic patients admitted for elective surgery, and eventually for suspected and confirmed COVID-19 patients scheduled for emergency surgery.

Before entering the operating room, we explain the use of the box to the patient and proceed to use it if the patient agrees; when considered appropriate, the patient can be sedated to improve the tolerance and comfort within the box. We have found it paramount to have adequate and continuous communication with the patient and the airway team during these circumstances to ensure the success and safety of the procedure.

We have been able to successfully perform endotracheal intubations with conventional laryngoscopes and video laryngoscopes, rescue face-mask ventilation, awake intubations for fullstomach, and awake extubations without a significant increase of time during these maneuvers.

The surgical site determines the feasibility of leaving the box in place during a procedure; when the surgical procedure is below the upper thorax, such as during appendectomies, laparoscopic cholecystectomies, or femoral or tibial osteosynthesis, it is feasible to leave the box in place during the surgery and avoid disconnecting the breathing circuit during removal of the box. For head and neck surgeries, the use of the box as a barrier is balanced with the need for disconnecting the circuit during its removal.

Acknowledging that extubation presents a less-controlled scenario for anesthesiologists, with a higher risk of exposing other staff and anesthesiologists to aerosols (eg, lack of neuromuscular relaxation, cough reflex, spontaneous ventilation), we favor the use of the box during extubation and during the subsequent recovery time, especially for symptomatic patients. We have found it useful during this time for the purpose of suctioning airway secretions, delivering bronchodilators via a nebulizer, and allowing for high-flow oxygen therapy for a short time while maintaining a closed environment within the box. Although we have not been presented with reintubation scenarios, they remain a possibility within the box because the laryngoscope or videolaryngoscope, the face mask, the suction tube, and the wire remain inside the box; a quick opening of 1 port to introduce a new endotracheal tube can be foreseen as a flaw.

To date the box has not been used in patients with anticipated difficult airway; however, using a video laryngoscope, as described earlier, is a possibility as is using other equipment required for intubation (eg, laryngeal mask, intubation bougie, stylet).

Other Scenarios

Other scenarios include intubations of suspected or confirmed COVID-19 patients in the intensive care unit, providing cardiopulmonary resuscitation for patients lying supine, and providing a barrier for awake patients during regional anesthesia. Recently, some pediatric ear-nose-throat surgeons have started using the box during high-risk aerosol-generating procedures, such as tonsillectomies, and while changing tracheostomy tubes; however, we acknowledge that they could benefit from other modifications in size and shape to fit their needs better during the procedure.

As we described earlier, this device was modified to provide an alternative for safer airway management during the COVID-19 crisis, and its use is up to the anesthesiologist's preference; the portability of the box allows for its rapid removal in a non-anticipated difficult airway or in any situation that presents a potential safety threat to the patient.

Caveats or Limitations

Use of Fiber Bronchoscope

From simulation scenarios, we observed that the box does not provide easy access for the fiber bronchoscope. Therefore, it has a limited value in case of an anticipated difficult airway that requires the use of fiber bronchoscope. A modification to the upper side of the box would be necessary to fit this purpose.

Time for Preparing the Box for an Emergency Surgery or Intubation

It takes about 5- to- 7 minutes to assemble the box; therefore, we have a stock of boxes sealed and ready to be used.

Waste Generation

Although the box is reusable, the materials used to achieve isolation (eg, gloves and plastic) are disposed of after their use, which is not environmentally friendly. Nurses are in charge of these disposals and require minimal but highly relevant training in the removable of the plastics to avoid the risk of cross-infection. In the simulation laboratory, we teach our team how to assemble and dispose of the plastics adequately.

Changing the Patient's Position

Several surgeries require that the position of the patient be changed. Although some anesthesiologists have managed to maintain the box in place while changing the position of the patient (mainly lateral recumbent in thoracic surgery), it is a challenging maneuver. In some patients, the box needs to be removed.

Conclusion

This redesigned device presents as an alternative to compensate for the lack of more suitable EC in our local context, enhancing the barrier between HCWs and hazards, such as droplets and aerosols,[6] with a keen focus on limiting aerosols dispersion. We believe that this new device overcomes some limitations mentioned by other authors,[7,8] and highlights the importance of allowing training time for staff involved with airway management. We also acknowledge that additional studies are needed to evaluate which combination of PPE and EC provides the best control for minimizing contamination and infectious risks for HCWs. This essential finding can assist in determining barriers and PPE to be used when reestablishing the operating room workflow in many institutions.

Conflict of Interest

None.

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Jennifer Cárdenas-Mancera, MD
Lina Valencia-Arango, MD, MSc
Juan Camilo Segura-Salguero, MD
Lorena Díaz-Bohada, MD, MSc
Department of Anaesthesia, Hospital Universitario San Ignacio, Javeriana University School of Medicine, Bogota, Colombia

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Epicardial Echocardiography—A Plausible Alternative Cardiac Imaging Technique in COVID-19 Pandemic

To the Editor:

Coronavirus disease 2019 (COVID-19), because of its high infectivity rate, created havoc across the globe.[1] Healthcare workers are the most affected community, having high mortality across the world. Severe acute respiratory syndrome coronavirus 2 enters cells through angiotensin- converting enzyme-2 receptors, which are expressed mostly in lung and intestines.[2] So, the virus load is increased in aerodigestive tract secretions. Any procedure involving the aerodigestive tract causes aerosolization, which increases the risk of direct and cross-contamination among healthcare workers.[3] Transesophageal echocardiography (TEE), being an aerodigestive tract procedure, commonly is used in cardiac surgery to evaluate the heart and its associated structures.

Even though various techniques and maneuvers are suggested in recent literature to reduce aerosolization during TEE usage, the risk of infection still persists.[4] The TEE probe remains in contact with the aerodigestive tract secretions, posing a potential contamination risk to healthcare workers handling the TEE probe for imaging as well as during disinfection. Usage of a protective sleeve over the TEE probe may not avoid the virus exposure completely. Moreover, a protective sleeve over the TEE probe makes the maneuver of the probe more difficult to acquire images and also compromises the image quality. Hence, the American Society of Echocardiography recommends an alternate method for TEE to be used whenever possible in COVID-19 patients.[5]

Epicardial echocardiography (E-echo) is not an uncommon imaging modality in perioperative cardiac settings. E-echo is well known to produce high-quality images, especially of the anterior cardiac structures compared to TEE.[6-8] In addition to it, epiaortic echocardiography gives more valuable information about aortic diseases perioperatively.[9] E-echo can be performed easily by using a transthoracic probe or TEE probe (Fig 1-3).

Advantages of E-echo and epiaortic echocardiography over TEE in the midst of COVID-19 pandemic are as follows:

1. There is no aerosolization with E-echo/epiaortic echocardiography.
2. Usually, E-echo has been performed with a protective cover over the probe, which eliminates the direct contact of the probe with patients' body fluids. Thus, decontamination of the probe is simple and easy to perform. Further, it reduces the virus exposure to healthcare workers significantly compared to TEE.
3. Except for a transparent cover over the echocardiography machine while using it for suspected/confirmed COVID-19 cases, no special preparation is needed. So, there is no significant change in image quality.

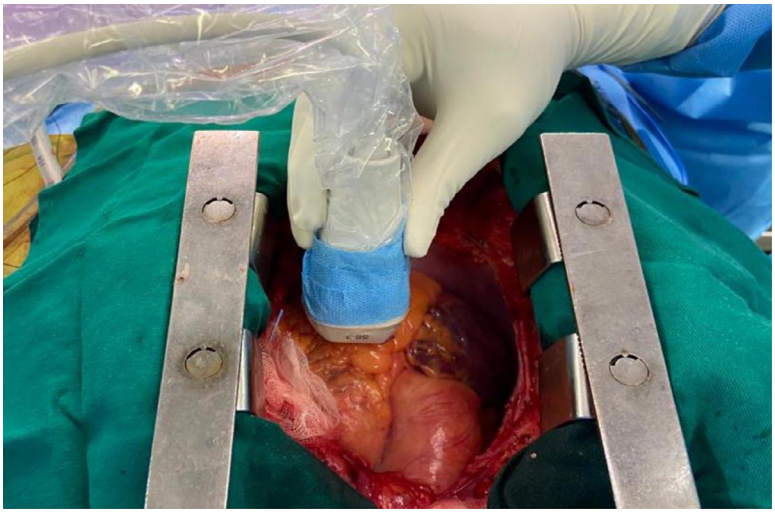

Fig 1. Echo probe covered with sterile sleeve placed over epicardium.