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Opening the discussion on a closed intubation box

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ABSTRACT

Background: Airway management for patients with COVID-19 poses a significant infection risk to clinicians. As such, some providers have adopted the “COVID intubation box”, a cuboid barrier which separates the clinician from the airway. While this device has limitations, there is promising evidence on its effectiveness.

Aim: To summarize the history, evidence, and limitations of the popular intubation box design. Furthermore, we share our modified design and experiences from airway simulations.

Methods: Using our prototyping and validation facilities, our team designed and iteratively improved our device to arrive at a final design. The expert panel, consisting of anesthesiologists, infection control staff, and emergency clinicians, trialed the device using airway simulation mannequins and provided feedback.

Results: Our final device features a dome shape, increased height, wider arm port diameter, additional side port for assistants, and drapes to reduce viral escape. Feedback from simulations was overall positive, especially noting that the height and arm port diameter facilitated arm motion within the box. The infection control team preferred the unique dome shape for safe disinfection.

Conclusion: Our intubation box overcomes several challenges and criticisms of the popular intubation box. This device is an important harm reduction tool for clinicians during this COVID-19 pandemic.

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1. Introduction

The management of coronavirus disease 2019 (COVID-19) poses unique challenges and risks to healthcare workers around the world. Troubling data from China and Europe estimates that up to 5–10% of cases are healthcare workers who constitute frontline efforts against this virus [1]. Viral transmission is especially high during aerosol generating manoeuvres of airway management, such as preoxygenation, tracheal intubation, suctioning, bag-mask ventilation, extubation [2]. As such, anesthesia, intensive care, and emergency department providers who perform tracheal intubation face significant risk of transmission which warrants special attention and effective solutions. Furthermore, prolonged aerosol stability of viral particles, global personal protective equipment (PPE) shortage, and correlation between disease and exposure to high viral load exacerbate the risk of transmission related to airway management [3–5].

1.1. Current solutions

One creative solution to mitigate these risks was first published by Dr. Lai and his medical team in Taiwan [6]. Their original “aerosol box” involves a clear 40x50 × 25 cm plastic box placed over the patient’s head, with two 10 cm holes for arms to access the airway. During intubation and extubation, aerosolized viral particles may be contained within this semi-closed box, thereby reducing risk to the intubator, assistants, and aerosolization to the patient’s environment. In fact, a study simulating laryngoscopy of a mannequin and expelled fluorescent dye showed that this type of barrier greatly reduced exposure to the laryngoscopist [7]. Therefore, this tool - combined with simulation training and appropriate PPE - affords an extra layer of protection for healthcare workers and has been recommended by authors and guidelines as a form of engineering control [8].

Since the original design, the device has gained popularity with several groups developing their own variations featuring similar
cuboid shape, two arm holes, and clear plastic material [9,10]. However, major criticisms of this tool include limited access in a difficult airway scenario, restricted arm motion, difficulty intubating with a raised head-of-bed, and lack of access for assistants. Depending on the height of the intubator, the cuboid design could even impair their line of sight or present glare from overhead lighting. If heavier materials are used for stability, the box can be cumbersome to remove in a difficult airway scenario or may even fall off the table and injure the patient. Furthermore, the box’s perpendicular edges and corners are more difficult to clean which renders the device a possible fomite for transmission. Designs that were meant to be flat-packed for shipping may have exposed crevices at the joints that can also be difficult to clean [10]. These challenges may limit the practicality and adoption of this tool. However, we believe that this device is an important harm-reduction tool and with adequate training, can greatly reduce viral load exposure for intubator.

2. Methods

To address the above challenges, our team has re-designed the COVID intubation box in collaboration with our hospital’s Department of Radiation Oncology, Anesthesia, Emergency Services Department and Infection Prevention and Control (IPAC) Team. We created several designs in-hospital with input from the radiation oncology team with experience in custom moulds, and the final prototypes were manufactured with industry assistance. As we had access to clinical areas to perform clinical validation and simulation, we were able to iteratively improve the design through a prototyping and evaluation strategy. The expert panel, consisting of anesthesiologists, infection control staff, and emergency clinicians, conducted full end-to-end dry-runs using airway simulation mannequins to mimic the clinical use of the device [10]. With each iteration, clinician feedback was captured in order to achieve a final design. We present here the details of our design, rationale for modifications, and our local simulation and patient experiences.

3. Results

3.1. Design

The final design aimed to address the main concern associated with the cuboid shape, which is that seams, edges, and joints are more difficult to disinfect and present a transmission risk (Fig. 1). As such, a single sheet of polyethylene terephthalate glycol (PET-G) was thermoformed into a curved dome shape without abrupt corners. In this process, the sheet is heated, shaped over a custom designed mould, and then cooled to its final form. This allowed us to create the curved shape, which was approved by our IPAC team for ease of disinfection and reuse of the device. Furthermore, a single curved sheet of 0.47 cm thick PET-G dramatically reduces the mass of the dome, thereby limiting the risk of the unit tipping. Line of sight and glare issues were also resolved with the curved shape.

In order to improve the restricted arm movement—another key criticism—we increased the device height from our initial 48.3 cm to 55.9 cm, the width to 50.8 cm (standard operating room table has 55.9 cm width), and depth to 38.1 cm. These dimensions provide more room to maneuver arms and airway equipment without colliding with the internal walls. Also, the arm ports were upsized from 10.2 cm in Dr. Lai’s original prototype to 12.7 cm, to accommodate for greater arm movement and varying body habitus of the intubator. Granted, while this theoretically increases the risk of viral particles escaping the intubation box, clear adhesive can be easily used to cover any redundant hole while preserving flexibility of movement (see Fig. 2). Finally, the broader base compared to the narrower dome lowers the center of gravity, thereby increasing stability and preventing the lightweight device from being knocked over. In the operating room where a narrow table may increase fall risk, attaching standard armboards to the table provides further stability.

Finally, a unique feature of our design is the addition of a third arm port to accommodate an airway assistant (e.g., handling a stylet or passing equipment). If not used, this port can be easily sealed off with a disposable cover such as adhesive dressing or plastic wrap to further reduce the risk of escaping viral particles (Fig. 2). Similarly, the caudal end of the box can be sealed off with a disposable drape.

3.2. Simulation and feedback

The device was tested on an adult airway mannequin in different intubation scenarios, including a standard intubation with one and two providers, an elevated head of bed which is often used to optimize hypoxemic patients, and a troop pillow which may be used for obese patients with potentially difficult airways [11]. Bag-valve-mask ventilation was performed using a self-inflating bag with the addition of a high-efficiency particulate air filter and inline quantitative end-tidal carbon dioxide detector. Intubations were

![Fig. 1. Image and schematic of dome shaped intubation box](image)
Caption: Panel A - photograph of curved dome with clear drape covering the caudal end. Panel B - side view showing assistant side port. Panel C - front view showing arm ports and dimensions.
performed with direct laryngoscopy (standard Macintosh 3 and 4 blades), videolaryngoscopy (GlideScope), stylet and bougie (Cook Medical Frova intubating catheter 14 Fr x 70 cm) introducers, as well as manual inline cervical stabilization by an assistant to simulate trauma scenarios [12].

Feedback from airway providers was overall positive. Both direct laryngoscopy and videolaryngoscopy were trialed and had similar first-pass success for intubation without major issues. Compared to the cuboid design, the dome shape helped to overcome some of the glare and line of sight issues, as there were no edges to obscure the view. The increased height and larger arm ports permitted better arm motion and manipulation of airway tools including the bulky bag-valve-mask with HEPA filter and carbon dioxide detector. The side arm port received positive feedback for allowing an assistant to pass airway equipment, manipulate an intubating stylet, or hold the tracheal tube. Some perioperative providers stated that they would prefer to use this device on extubation in order to reduce exposure if patients cough on emergence from anesthesia.

3.3. Bio-burden and disinfection

As part of the simulation, we qualitatively assessed the effectiveness of the intubation box in preventing contamination. Fluorescent dye (GloGerm, Utah) was sprayed cephalad from the position of the mannequin’s mouth towards the intubator and arm ports, mimicking the direction of cough [13]. Ultraviolet light revealed no contamination of the intubator’s gown except for parts of the gown and gloves which were inside the box. This supports the findings of Canneli et al. [7]. Furthermore, the device was assessed by our local IPAC team and deemed suitable for cleaning with hospital-approved disinfectant wipes. The dome shape without any edges or corners was preferred for ease of disinfection. Notably, the contaminated box should be carefully handled and any removable plastic wrap or adhesive should be properly disposed of between uses.

4. Discussion

This paper describes our unique design and construction of the intubation box. Our airway simulations with various intubation techniques received positive feedback from clinicians for ease of use and infection control experts for ease of cleaning. Our qualitative bio-burden test with fluorescent dye shows minimal contamination beyond the barrier, akin to previous data on the effectiveness of such an intubation box [7]. Ultimately, we believe this device has potential to decrease infection risk to the intubator in conjunction with PPE, reduce cumulative viral exposure to nearby personnel and surfaces, provide some protection in resource-limited settings without proper PPE capacity, and limit viral spread during extubation.

4.1. Limitations

While there is convincing evidence that this device provides a physical barrier for droplet transmission—thereby reducing viral load to the operator—it may not fully protect from aerosols generated from airway management, which is one of the main concerns in tracheal intubation [2,7]. Therefore, airway operators must continue to wear appropriate PPE. Nonetheless, the intubation box serves to reduce the bio-burden on clinicians’ PPE and skin, while protecting nearby surfaces and personnel which may otherwise be exposed to viral particles many metres away [14]. Another area for careful consideration is that all intubation barriers may contain a high viral concentration in a relatively enclosed space, which necessitates careful removal of the device to prevent inadvertent spread of fomites. Finally, while our design improves flexibility, this device still imposes some restriction to the operator’s arm motion, which could impair successful airway management. Our study did not directly compare time and outcomes with and without the device. Therefore, if intubation is expected to be difficult, the patient has poor respiratory reserve, or initial attempts with the intubation box are unsuccessful, operators must be prepared to abandon the device. Nonetheless, we believe the intubation box still has value in protecting airway clinicians, especially in straightforward intubations or elective settings (e.g., perioperative).

5. Conclusion

Airway management presents significant risk to healthcare
workers during this viral pandemic. In addition to proper PPE, other harm reduction tools must be considered to protect clinicians during airway management. We believe this intubation box has great potential to decrease the risk of transmission and should be part of the clinician’s armamentarium for airway management. By sharing our designs and experiences, we aim to advance the discussion on how anesthesia, intensive care, and emergency medicine providers can better protect themselves while providing safe patient care. Future research includes trialing this device for airway management in real patients in various clinical settings and stages of illness, as well as quantifying viral loads on clinicians’ PPE with and without this device.

Outstanding questions

- Does this intubation box improve clinical outcomes by reducing infection rates amongst healthcare workers?
- Does this intubation box reduce quantitative viral load on clinicians’ personal protective equipment and skin?
- Are there differences in time-to-intubation and rates of successful intubation between using the intubation box, other physical barriers (e.g., clear drape over airway only), or no additional barrier devices?

Glossary

- **Aerosol generating procedure**: Medical procedures (e.g., intubation, suctioning, bag-mask ventilation) that induce microscopic airborne particles (‘aerosol’) that can remain in the air or even travel short distances. If inhaled, aerosols containing viruses can lead to infection.
- **Viral Load**: Measure of the amount of virus found in bodily fluids, mucus membranes, or any surface. Greater viral load exposure to clinicians may increase the risk of infection, thereby justifying this intubation box which may reduce viral load exposure.
- **High-efficiency particulate air filter (HEPA)**: A portable filter attached between the patient and ventilation equipment to trap viral particles generated during exhalation.

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Declaration of competing interest

None.

**CRediT authorship contribution statement**

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