Short Communication

Intubator Performance and Contamination with the Use of Barrier Enclosure Devices: Results from a Simulated COVID-19 Resuscitation

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Submitted 28 July 2020; revised 6 October 2020; editorial decision 3 December 2020; revised version accepted 23 December 2020.

Abstract

Introduction: Medical institutions are using barrier enclosure devices during intubation procedures and other aerosol-generating medical procedures without evidence of their effectiveness or usability, potentially compromising patient care, and provider safety. Our objective was to determine the degree of protection offered by these devices and explore other usability factors for two popular barrier systems.

Methods: A simulated trial comparing an intubation box, a frame and plastic tarp system, and unprotected intubation was performed in an academic emergency department. Ten emergency physicians were recruited to participate. Our primary outcome was the degree of contamination from secretions measured by average surface area exposed to phosphorescent material. Secondary outcomes included: laryngoscopy time and time to barrier application, unsuccessful intubation attempts, and usability ratings for each system. Descriptive statistics were reported for all variables of interest and a linear mixed model was used to analyze contamination and laryngoscopy time. Usability was captured through electronic questionnaires using a five-point Likert scale.

Results: Contamination was more prevalent with the box, compared to the frame and tarp, and no device, however, this did not achieve statistical significance (13.2% versus 8.1% versus 12.2%, $P = 0.17$). A barrier system delayed intubation when compared to using no system (no system = 24.4 s [95% CI 17.3–27.5], frame = 54.4 s [95% CI 13.8–95.0], box = 33.8 s [95% CI 21.4–46.1], $P = 0.02$). In assessing usability, 30% of users preferred the use of a box barrier, 40% of users preferred the frame, and 30% would not use either in future intubation.
Conclusions: Compared to no barrier protection, an intubation box enclosure offers limited additional protection. A frame and tarp system reduces exposure at the expense of visibility and operator comfort. Finally, barrier systems do not appear to have a clinically significant impact on airway management.

Keywords: aerosols; bioaerosolsexposure assessment; penetration through PPE; PPE

Introduction

Front-line healthcare workers are at a high risk of exposure to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (Tran et al., 2012), the cause of coronavirus disease (COVID-19). During resuscitation, providers often perform aerosol-generating medical procedures (AGMP); prior experience has identified endotracheal intubation as a leading AGMP responsible for occupationally acquired infection due to the worker’s proximity to the patient’s oro-nasopharynx, which potentially contains high viral loads (Zou et al., 2020).

Global supply of personal protective equipment (PPE) have come under strain during this pandemic, and to minimize COVID-19 transmission, protected intubation systems, such as barrier boxes and plastic sheet devices, have been introduced (Canelli et al., 2020; Matava et al., 2020). However, the level of protection conferred by these devices has not been extensively studied and there is limited data on their protective and operating characteristics (Kearsley, 2020). As such, we sought to evaluate each systems’ performance during emergency airway management.

Methods

Barrier systems and simulation set-up

Two enclosure systems commonly used for protection against COVID-19 (Fig. 1) were locally procured. One is a transparent box (polycarbonate or acrylic) with two holes used for airway management and the other a rigid frame (polymer or metal) with clear plastic draped over. Both systems are placed over a supine patient covering the head, neck, and chest during intubation. Our box (40 cm × 50 cm × 50 cm) was made of clear polycarbonate panels with an open side facing the end of the bed. The frame system was built to have a metal frame (30 cm × 68 cm × 74 cm) with clear plastic draped on top, which slides under the mattress at the head of the bed. The two sides were secured to the stretcher, and the operator side was left free to allow for airway manipulation underneath the sheet.

A mannequin (Laerdal SimMan ALS) with standard airway anatomy was modified with a pressurized oxygen gas system to create a burst of phosphorescent droplets and aerosols during the scenario, activated prior to laryngoscopy. A reservoir was situated in the oropharynx that contained 5 ml of water with 2 g of phosphorescent powder (particle size 1–5 μm);
GloGerm Company, Moab, Utah (Glo Germ Company). This reservoir was connected to wall-supplied oxygen pressurized to 50 psi. During airway manipulation, the pressurized system was activated, dispersing the contents of the reservoir through the nares as described in Dharamsi (2020).

Simulation testing
A simulation scenario (Dharamsi, 2020) was performed in an urban academic emergency department in Toronto, Ontario. Participants were recruited using an electronic invitation distributed to emergency department staff and selected on first-come-first-serve basis. Participants were oriented to the device and simulation environment and were randomly paired. They performed mock trials with direct and video laryngoscopes, and all chose the CMAC 3 video-laryngoscope (Model 8401Hx, KARL STORZ SE & Co. KG, Tuttlingen, Germany) as it is the most commonly employed video device in our practice setting, and the preferred intubation method based on institutional policy.

Each pair performed the scenario with (i) no barrier, (ii) with the frame, (iii) with the box wearing personal protective equipment (gown, gloves, face mask, and shield). The order was randomized to account for improvements with repetition. The pair took turns leading the airway management while the other was an airway assistant. All actions were observed and timed by a study author (M.B.Y., D.T., J.C.) on a standardized data collection sheet:
1. Enter the room.
2. Apply the barrier apparatus.
3. Deliver 6 breaths by bag valve mask (BVM) with two-person technique (the leader holds the mask on with both hands while the assistant squeezes the bag).
4. Leader performs video-laryngoscopy to intubate the patient (pressurized system is activated).
5. BVM is attached to the endotracheal tube to deliver six breaths.

Participants were then illuminated with ultraviolet light to qualify the deposition of phosphorescent liquid which was recorded on paper using a standard burn diagram. The apparatus was removed by authors (M.B.Y., D.T., J.C.) and decontaminated using water and hydrogen peroxide.

The primary outcome was the degree of contamination. This outcome measure was captured using a standard reference body surface burn diagram and the ‘Rule of Nines’ (typically used to quantify the surface area of a burn in an adult victim). Degree of contamination was measured by marking printed diagrams with affected areas and calculating the percentage of the total and average body-surface area (TBSA) exposed to Glo Germ material after each trial run. The percentage of TBSA was estimated to the nearest quarter of that zone (e.g. if a marker landed on the anterior right chest, it would be estimated as 4.5%). The degree of head and neck exposure was reported descriptively, using a previously published methodology (Feldman et al., 2020). Secondary outcomes included: laryngoscopy time (end of step 3 to step 5), barrier application time (step 1), unsuccessful intubation attempts (which we defined as >60 s of laryngoscopy without successfully passing the endotracheal tube through the vocal cords) and usability of each system. Usability assessments were captured through an electronic survey and reported descriptively using a five-point Likert scale. Descriptive statistics were calculated for all variables of interest. The outcomes of TBSA and laryngoscopy time were analyzed using linear mixed models in relation to the type of barrier applied. The models treated subjects as a random effect. The model adjusted means and their associated 95% confidence intervals (CI) reported. All analyses were carried out using SAS Version 9.4 (SAS Institute, Cary, NC, USA).

Results
Ten emergency physicians (three females, seven males) performed each scenario (n = 30 trials), representing a range of experience (average years in practice 8.7 ± 4.0 [min 2 years (resident), max 16 years in practice]) and height (min = 5’5”, max = 6’4”).

Contamination & operator safety
The average TBSA percent exposure per participant for the box was 20.8%, the plastic frame 10.9%, and unprotected 18.1% (Fig. 2). However, there was no significant difference when reviewing adjusted TBSA (12.2% [95% CI 7.9–16.5] for no device, 13.2 [95% 8.9–17.5] for the box, and 8.1% [95% 3.8–12.4] for the frame, P = 0.17). Head and neck exposure was only observed in unprotected and box intubations, which was not significantly different (P = 0.99). Qualitative observations demonstrated that the box conferred the higher risk of exposure to the neck and upper torso area.

Operator efficiency
Trials without a barrier (average 22.4 s [95% CI 17.3–27.5]) were faster when compared to using the frame (54.4 s [95% CI 13.8–95.0]) and the box (33.8 s [95%
There was no statistical difference between the frame and the box (difference = 20.6 [95% CI –27.6–69.1], \( P > 0.05 \)). The box was applied faster than the frame (11.7 s [95% CI 6.8–16.7] versus 21.9 s [16.9–26.9], \( P < 0.01 \)). There was one unsuccessful intubation attempt when using the frame.

Usability
All participants responded to our survey. The frame was ranked higher than the box for basic airway maneuvers (e.g. oral airway insertion and BVM use) (3.1 versus 2.6) and cooperation with the assistant (3.6 versus 3.1). Intubation was reported slightly easier with the box compared to the frame (3.1 versus 3.0). Users felt the frame conferred more protection from secretions compared to the box (4.3 versus 3.9). In selecting a future device, 30% would use the box, 40% would use the frame, and 30% said neither. Unstructured feedback reflected advantages to the frame in permitting equipment manipulation and a greater sense of protection. The box was described as being easier to set up, and the clear polycarbonate was easier to see through compared to the plastic tarp.

Discussion
We compared barrier enclosure devices to standard airway management during the performance of AGMP. While enclosure systems take time to set-up, our study demonstrated how these systems can reduce the airway operator’s risk of exposure without a clinically significant impact on their ability to intubate. The frame and tarp system showed the lowest contamination rates and was the only one to protect from head and neck exposure. This has been described by other authors (Brown et al., 2020; Cubillos et al., 2020; Francom et al., 2020), and suggests that a closed system may offer better protection. The metal frame system had 7% less average

Figure 2 Contamination burn diagram showing the distribution of the phosphorescent Glo Germ™ liquid at the end of the simulation. Each color represents a specific participant’s exposure and contamination (image adapted from https://commons.wikimedia.org/wiki/File:Lund-Browder_chart-burn_injury_area.PNG, accessed 28 April 2020).
TBSA exposure compared to control and 10% less than the box system (without achieving statistical significance), which we hypothesize could be related to the four-sided coverage this system provides. These findings are consistent with recent literature suggesting plastic sheet systems represent a low-cost, pragmatic, and effective way in protecting providers during high-risk procedures (Allen et al., 2021; Brown et al., 2020; Jain, 2020).

Furthermore, plastic sheet systems move towards complete isolation of the provider from air contaminants, which is in line with more effective and desirable control measures outlined in universally accepted basic principles in occupational hygiene (Occupational Hygiene Training Association, 2017). On the contrary, box devices which open caudally (towards the patient’s feet) at best segregate the user from potentially infectious aerosols but present more opportunities for transmission to other providers in the room. In keeping with the hierarchy of effectiveness for control measures, this has been demonstrated in comparative studies (Brown et al., 2020; Gore et al., 2020; Ibrahim et al., 2020) showing increased contamination of providers as a result of particles escaping through the open caudal face of box systems relative to enclosed plastic sheet systems.

Few investigators have evaluated these devices, with limited focus on efficiency or usability (Canelli et al., 2020; Cubillos et al., 2020; Francom et al., 2020; Jazuli et al., 2020; Matava et al., 2020). These issues were highlighted by participants in our study who preferred systems with improved usability despite concerns of visibility and set-up time. Although the box was applied quicker with faster intubation times, participants indicated that the frame provided better maneuverability, self-reported protection, and was the preferred system for future use. Interestingly, approximately 30% of our participants elected not to use a barrier system for their next intubation procedure. This highlights the need to prioritize human factors and design elements in future studies and consider these alongside the degree of protection conferred. Without procedural and protection considerations, these devices will not be successfully integrated into healthcare environments. Focusing on usability only may lend providers to have a false sense of security, and likewise, adopting systems which focus solely on provider protection may compromise the delivery of patient care.

Limitations
Our study is limited by a small number of participants, with varying degrees of airway skills. While each participant used fresh PPE, donning and doffing standards adherence was not assessed. We used secretions from a mannequin that acts a biological surrogate, and without restrictions to the application of an enclosure (e.g. a combative patient). Additionally, our estimations of TBSA exposed may under or over-estimate the true degree of provider contamination. The scenario used describes a deteriorating patient, which does not represent all clinical presentations of COVID-19. Finally, we did not measure the volume or size of droplets, although the particle size used is similar to SARS-CoV-2 (Matava et al., 2020).

Conclusion

While existing measures exist to protect physicians during AGMP, to our knowledge, this is the first study to compare efficacy, efficiency, and usability between two barrier enclosures. Our study highlights physician priorities during protected intubation and provides insight into the use of enclosures in clinical settings. These systems demonstrate promise in offering an added layer of protection to physicians without impacting ease of airway management. Further research should include usability and human factors considerations with a degree of protection in order to maximize adoption.

Acknowledgments

The authors would like to thank a local volunteer group, in Toronto, Canada (https://www.covidbox.org/) for donating their aerosol box. They prepared a flat-packed aerosol box designed and professionally manufactured from a polycarbonate material, assembled with zip-ties. Klick Health also provided models of an intubation box for the initial user testing.

The authors would also like to acknowledge contributions of our nurse educators (Emma Gaylord and Sarah McDermid-Flabbie), Emergency Medicine physicians (Dr Joel Puetz, for assembling the metal frame prototypes, Dr Derrick Chang, for testing the prototypes), Roger Chow and all the participant volunteers.

Funding

This work was supported by an unrestricted grant from the University Health Network and Mount Sinai Hospital Academic Fund Plan, Toronto, Canada.

Declaration of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
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