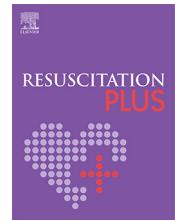


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## Short paper

# Simulation and evaluation of the protective barrier enclosure for cardiopulmonary resuscitation

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## Abstract

**Introduction:** The COVID-19 pandemic has presented a significant challenge for infection prevention and control during airway management in anaesthesia and critical care. The protective barrier enclosure has been described and studied particularly for perioperative anaesthesia use. The potential use of the protective barrier enclosure during cardiopulmonary resuscitation has been poorly explored in the current literature. This work aims to demonstrate the potential of protective barrier enclosure in limiting aerosol dispersion during cardiopulmonary resuscitation delivery.

**Methods:** A proof-of-concept simulation study was conducted to evaluate the protective properties of the protective barrier enclosure during cardiopulmonary resuscitation. Aerosol was simulated using a fluorescent dye trapped within the manikin. Three different methods of cardiopulmonary resuscitation delivery with a protective barrier enclosure applied over the manikin's head were conducted. The first method simulated a chest compression only cardiopulmonary resuscitation, the second method also used chest compressions only, with a face mask fitted on the victim, while the third method, the victim was given chest compression and bag-valve-mask ventilation by two rescuers.

**Results:** In the first method, release of aerosol from the manikin's mouth was observed during chest compression, while in second method, most of the aerosol was trapped within the face mask, with only minor leaking. However, when bag-valve-mask ventilation was delivered, the aerosol leaked out at high speed around the bag-valve-mask seal. No aerosol condensation was found outside of the protective barrier enclosure in all scenes.

**Conclusion:** Protective barrier enclosure may reduce aerosol exposure to the rescuers during out-of-hospital cardiac arrest.

**Keywords:** Protective barrier enclosure, Out-of-hospital cardiac arrest, Aerosol-generating procedure, Cardiopulmonary resuscitation

## Introduction

Cardiac arrest is invariably fatal, if left untreated. Immediate cardiopulmonary resuscitation (CPR) is therefore vital to ensure survival.<sup>1</sup> In the current COVID-19 pandemic situation, there are valid concerns on aerosol generating procedures (AGPs) that may potentially put the responders at risk for infection.<sup>2</sup> Considering that CPR is potentially an AGP, guidelines on CPR for suspected or confirmed COVID-19 patients suggest that responders should use Personal

Protective Equipment (PPE).<sup>3</sup> Poor access to PPE, has been associated with higher risk of COVID-19 infection among frontline health-care providers (HCPs).<sup>4</sup> In an out-of-hospital cardiac arrest (OHCA) situation, access to PPEs may be limited, thus, a decrease in bystander response to OHCA has been reported.<sup>5</sup> Protective barrier enclosures for aerosol containment during various AGPs have been extensively documented, albeit with limited efficacy data.<sup>6</sup> A modified barrier using plastic sheet has been shown to minimized aerosol exposure to HCPs during CPR simulation on a non-intubated manikin.<sup>7</sup> This study aims to demonstrate the function of a manufac-

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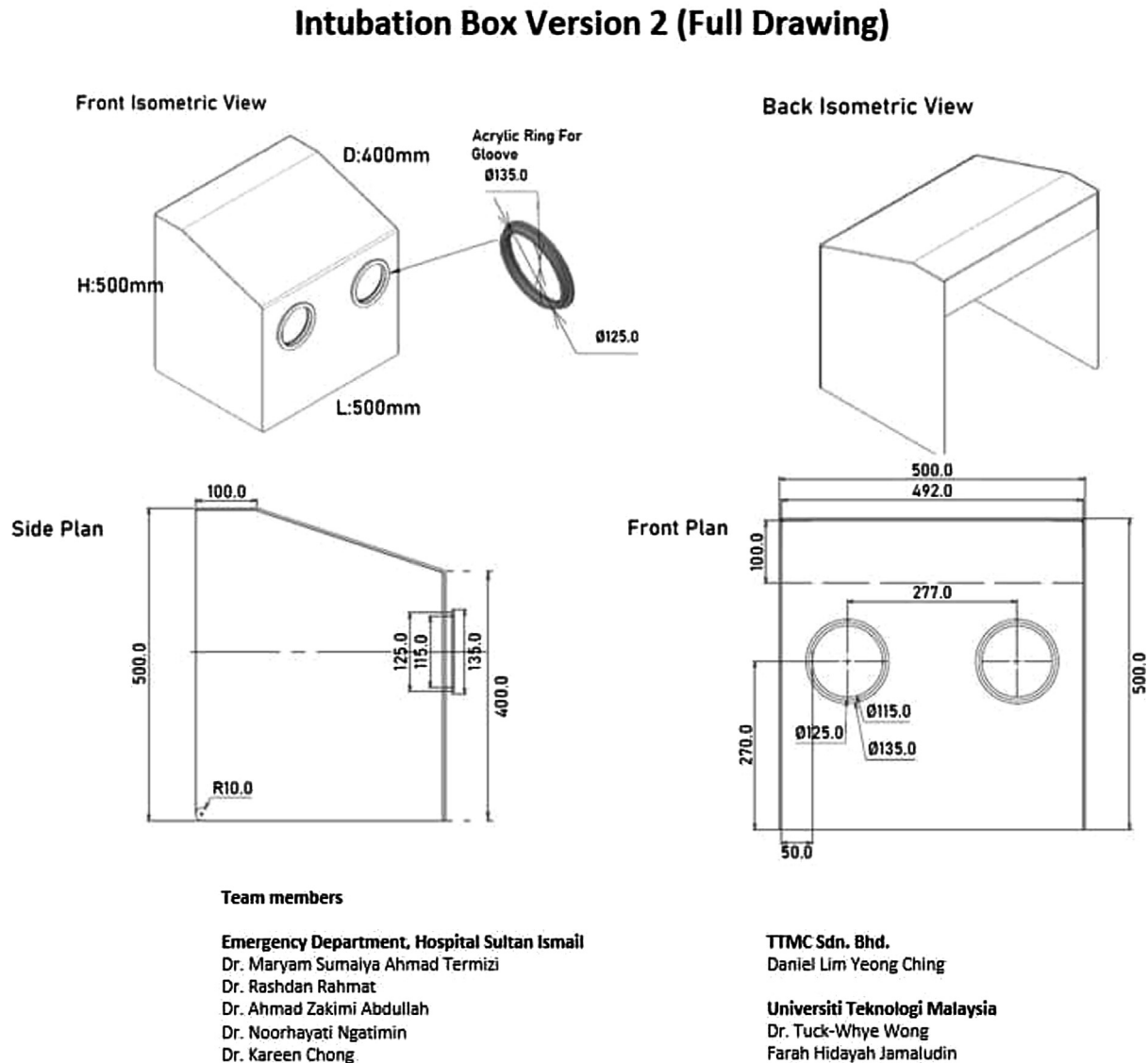
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**Fig. 1 – The design of the Protective Barrier Enclosure**

tured protective barrier enclosure in containing aerosol dispersion during different situations of CPR delivery. It is hypothesized that the protective barrier enclosure may reduce aerosol exposure to the CPR responder.

## Methods

Aerosol dispersion during chest compression and artificial ventilation of a CPR procedure was studied using an adult-manikin (Brad CPR Manikin, Simulaids). Simulated aerosol was produced through the ultrasonication of a pyrene-based fluorescent dye using an ultrasonic-humidifier. The aerosol produced was trapped and channeled to a siphon pump fixed within the manikin. The outlet pipe of the siphon pump was placed through the manikin's mouth. Compression of the siphon pump during chest compression released the aerosol accordingly.






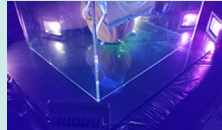



A simulation was performed depicting an adult experiencing OHCA prompting CPR. Three different methods of CPR delivery with

a protective barrier enclosure (Fig. 1) applied over the manikin's head were conducted (See video). The first method simulated the victim being rescued using chest compression only. The second method also used chest compressions only, however, here a face mask was fitted on the victim. In the third scene, the victim was given chest compression and bag-valve-mask (BVM) ventilation by two rescuers. Video footages were recorded using slow motion videography. After a 40 min simulation, each scene was illuminated with ultraviolet light to visualize condensed fluorescent aerosol. This simulation-based study does not require ethical approval.

## Results

Release of massive and randomly dispersed aerosol from the manikin's mouth was observed during chest compression in scene 1. When the face mask was applied, most of the aerosol was trapped within the mask, with only minor leaking. However, when BVM ventilation was delivered, the aerosol leaked out at high speed around

**Table 1 – Summary of simulated scenes conditions and corresponding UV fluorescence images.**

Simulated Situations	Scene1 One Rescuer Chest Compression Only Victim without Face Mask	Scene 2 One Rescuer Chest Compression Only Victim with Face Mask	Scene 3 Two Rescuers Chest Compression Artificial Ventilation
Scene Overview			
Aerosol Generating Condition			
UV Illumination	Barrier Left Edge View		
			
	Barrier Right Edge View		
			
	Victim Chest View		
			

the BVM seal, creating turbulence. The condensed aerosol accumulated in the form of fluorescent droplets on areas-in-contact. Using ultraviolet light, a uniform accumulation of aerosol was revealed within the boundary of the protective barrier enclosure in scene 1. Similar results were observed in scene 3, however the overall amount of condensed droplets was lower. The BVM was also stained with fluorescent droplets. Notably, with the face mask applied in scene 2, fewer aerosol droplets were observed, and they were mostly limited to the victim's head area. No aerosol condensation was found outside of the protective barrier enclosure in all scenes. The summary of the simulations is depicted in [Table 1](#)

## Discussion

According to the European Resuscitation Council guidelines, in the current pandemic, willing and able lay rescuers should at least perform

chest compression after recognition of an OHCA.<sup>4</sup> Even in the health-care setting, CPR is considered an AGP which may put HCPs at risk.<sup>8</sup> The minimum droplet-precaution PPE during CPR are gloves, apron, surgical mask and eye/face protection, while the minimum airborne-precaution PPE are gloves, gown, N99 or N95 facemask, eye/face protection, or alternatively powered air purifying respirators (PAPRs).<sup>4</sup> Tracheal intubation, or insertion of a second-generation supraglottic airway device (SGA) is encouraged in the presence of a trained airway manager, to reduce the risk of infection during ventilation with less aerosol generation compared to facemask ventilation.<sup>9,10</sup>

Findings of this study indicate that the current recommendations for CPR may not entirely prevent the risk of exposure since aerosol leakage was evident in particular when a BVM, but also, to a lesser extent, when a surgical face mask was applied to the manikin. Protective barrier enclosure was found to improve the protection against risk of contact with aerosol substantially and may be beneficial in a limited PPE situation. Hence, protective barrier enclosure may be

recommended during AGPs, especially when artificial ventilation is unavoidable. A similar conclusion was drawn by Canelli and coworkers on use of protective barrier enclosure during intubation in a limited PPE access situation.<sup>11</sup> Another simulation study presented the potential benefit of a protective barrier enclosure for the protection of HCPs during intubation, thus underscoring its possible utility for similar procedures such as CPR.<sup>12</sup>

However, it is conceivable that the protective barrier enclosure limits access to the patient and therefore increase the time to deliver life-saving care. The protective barrier enclosure has been shown in manikin simulations to increase the time for intubation.<sup>13,14</sup> Airway management difficulty, patient injury, compromise of PPE integrity, lack of evidence, lack of cleaning standards and exposure to higher concentration of viral aerosols are valid concerns of the protective barrier enclosure use.<sup>15,16</sup> Nevertheless, during OHCA, the accessibility of protective barrier enclosure may decrease delivery time of CPR, as it may reduce the hesitation of potential responders.

In our study, the pattern and amount of aerosol simulated may not reflect accurately the conditions in the actual situation. The study did not include simulations in the absence of protective barrier enclosure. Use of standard PPE in any case remains of utmost priority during CPR delivery and the protective barrier enclosure remains as an adjunct for extra protection against aerosol exposure. The number of people at the scene shall also be limited to essential personnel only. Post-CPR delivery, standard disinfection procedures of the scene and the protective barrier enclosure should be performed. Simulation training may help rescuers familiarize themselves with the use of protective barrier enclosure and the practical challenges of a smaller resuscitation team.

## Conclusions

The use of protective barrier enclosure in a situation with limited PPE or in combination with PPE may reduce aerosol exposure to the CPR provider in OHCA cases.

## Conflicts of Interest

The authors of this study declare to have no conflict of interest.

## Acknowledgements

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.resplu.2021.100180>.

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