Effectiveness of "Resuscitation Cover All" in Minimizing COVID-19 Transmission to Health-Care Workers during Cardiopulmonary Resuscitation

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Abstract

Introduction: Coronavirus disease 2019 (COVID-19) is a highly contagious disease transmitted by contact, droplets, and aerosols. Front line health-care workers (HCWs), particularly emergency physicians and acute care providers, are vulnerable to being exposed while treating their sick patients. Despite appropriate personal protective equipment use, HCW gets infected, suggesting the need for multiple layers of protection such as barrier devices. **Methods:** We aimed to determine the effectiveness of our novel "Resuscitation Cover All"(RCA) in reducing the exposure of HCW to simulated respiratory particles and its feasibility during cardio pulmonary resuscitation (CPR). This was a pilot simulation-based study. Five CPR simulation sessions were performed in Standard and RCA protocols, individually. Exposures through contact, droplets, and aerosols were simulated using a standardized volume of liquid detergent. Under Wood's lamp illumination, exposures of participants were compared between the protocols. Rate and depth of chest compressions, time taken to intubate, interruptions in CPR, and first-pass success were analyzed. **Results:** Overall mean exposure in standard protocol was 4950.4 ± 1461.6 (95%confidence interval [CI]:3135.7–6765.2) sq.pixels and RCA protocol was 2203.6 ± 1499.0 (95%CI: 342.4–4064.9) sq.pixels ($P = 0.019$). In standard, chest compressor had the highest exposure of 3066.6 ± 1419.2 (95%CI: 2051.3–4081.9) sq.pixels followed by defibrillator assistant 1166.4 ± 767.4 (95%CI: 617.4–1715.4) sq.pixels. Chest compressor of RCA had reduced exposure compared to that of standard ($P < 0.001$). Hands were the most frequently exposed body part. Airway manager of RCA had no exposure over head and neck in any session. No significant difference in CPR performance metrics was observed. **Conclusion:** This pilot simulation-based study shows that the novel RCA device could minimize the exposure of HCW to simulated respiratory particles during CPR. Also, it might not alter the high-quality CPR performance metrics. We need more real-life evidence.

Keywords: Aerosol box, aerosol-generating procedure, barrier device during resuscitation, health-care worker infection, personal protective equipment

INTRODUCTION

During the coronavirus disease 2019 (COVID-19) pandemic, health-care workers (HCW) are at higher risk of infection than the general population. The World Health Organization (WHO) Pan American Regional Office in Washington, DC, reported that 570,000 HCWs were infected and 2500 died due to COVID-19.[1] A systematic review which included 97 studies of COVID-19 among HCW stated that one-tenth of the total HCW had been infected with severe acute respiratory syndrome coronavirus 2. Among HCW, 5% was the pooled prevalence of severe COVID-19 and 0.5% had fatal outcomes. The fatal outcome was attributed to exposure to multiple cases and high viral load from sick patients.[2] Infected HCW may further diminish the capacity of already overburdened health-care system in a pandemic.

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In 2014, the WHO developed a guideline for infection prevention and control of epidemic-and pandemic-prone acute respiratory infections in healthcare. The guideline strongly recommended using appropriate personal protective equipment (PPE) as determined by risk assessment (according to the procedure and suspected pathogen).[3] The main route of COVID-19 transmission is through droplet and contact, though other routes are also possible.[4] For COVID-19, recommendations for PPE are gloves, masks, goggles or faceshields, and long-sleeved gowns with N95 respirators recommended over masks for aerosol-generating procedures (AGPs), consistent with the WHO 2014 guideline.[5,6] Centers for Disease Control and Prevention (CDC) recommends that nonsterile, disposable patient isolation gowns, which are used for routine patient care in health-care settings, are appropriate for use by HCW when caring for patients with suspected or confirmed COVID-19. If there is a medium to high risk of contamination, CDC recommends isolation gowns that claim moderate to high barrier protection.[7]

Cardio pulmonary resuscitation (CPR) is an AGP as it involves a set of interventions such as chest compressions, positive pressure ventilation, establishment of an advanced airway, drug delivery and defibrillation.[8,9] Individual role of chest compression or defibrillation in aerosol generation cannot be reliably identified.[10] CPR on COVID-19 patients carries higher risk of exposure to HCW.[11,12] The International Liaison Committee on Resuscitation' COVID-19 consensus statement suggested several modifications to airway management during cardiac arrest which included donning of PPE (goggles, faceshield, N95facemask, gloves, coverall/gowns, headcover, and shoe cover), minimizing number of rescuers, using a viral filter, highly skilled airway manager to ensure best chance of first-pass success, use of video laryngoscopy, pausing chest compressions during airway intervention and ensuring adequate cuff pressure to prevent leaks.[13] The American Heart Association updated Advanced Cardiac Life Support guidelines in its 2020 COVID-19 interim guidance and recommended considering resuscitation appropriateness, prioritizing intubation at the earliest possible opportunity and if delayed intubation, to consider supraglottic airway or bag-mask device with filter and tight seal.[14] The European Resuscitation Council guidance suggested to defibrillate shockable rhythms rapidly before starting chest compressions, if a donned HCW with defibrillator was readily available.[15]

CPR, being a high-stress event, may cause lapse in infection control practices and be an important reason for a breach in the barrier of the PPE. Giwa*etal*. Estimated that atleast 10% of HCW in Italy would be infected despite using PPE.[16] In Italy, higher infectivity, and death rates among HCW were attributed partly to inadequate PPE, including problems with the global supply chain.[17] The mismatch in demand and supply chain of PPE led to alternative ways to protect HCW. One such means was the barrier-enclosure device, which is usually made using plastic sheets on a structured framework or a transparent acrylic glass.[18] Barrier-enclosure devices have

been suggested to limit the spray of respiratory particles during airway interventions.[19] A meta-analysis compared various barrier-enclosure systems (aerosol boxes, plastic drapes, etc.) for use during airway procedures in COVID-19 patients.[20] The "aerosol box" was criticized for being bulky, heavy to carry and position in emergency settings and for being rigid restricting the hand movements. Barriers that use plastic sheets were preferred for its versatility and flexibility.[21] Azhar *et al*. Concluded that an aerosol box may significantly reduce exposure but with increased intubation time and reduced operator's mobility and visibility.[22]

Using a barrier device during CPR brings in various crucial factors such as time to setup the device, ease of access to the patient for performing chest compressions, defibrillation, and airway management. We designed a novel barrier device for the purpose of minimizing exposure of HCW during CPR of COVID-19 patients and named it "Resuscitation Cover All"(RCA). The objectives of this pilot study were to determine the effectiveness of RCA device in minimizing the exposure of HCW to simulated respiratory particles and its feasibility during CPR.

METHODS

The study was conducted at the Department of Emergency Medicine of a Tertiary Care Teaching Hospital in South India. We built a simple, cost-effective barrier device for use during CPR of suspected or confirmed COVID-19 patients. The skeletal model of the device was designed using poly vinyl chloride pipes so as to lay over the patient, spanning from head to foot. The entire length of the device was six feet and split into two templates of three feet each, one for upper body and the other for lower body [Figure 1a and b]. A transparent plastic sheet was spread over the templates and glued to the pipes. The plastic sheet on cranial side of the upper body template had two circular ports through which a clinician's hands can access the patient's airway [Figure 1b]. The plastic sheet on caudal aspect of the upper body template was left to hang freely by its sides, so that an assistant can lift the plastic sheet to provide external defibrillation or to assist with intubation, if necessary. The free-lying plastic sheet of upper body template would overlap that of lower body template. Total cost of the device was 2500 Indian rupees (34USdollars). We named our novel barrier device as RCA [Figure 1b].

This was a nonblinded, pilot simulation study using a CPR mannequin (Laerdal, United States). The participants were 2nd-and 3rd-year postgraduate Emergency Medicine residents. Participation was voluntary and the residents were enrolled after obtaining informed consent. We explored the ways of HCW exposure through contact, droplet, and aerosol spread during CPR. House hold liquid detergent (SurfExcel, Hindustan Unilever Limited, India) was used as a cost-effective to fluorescent dye. To simulate contact transmission, 5 ml of liquid detergent was painted on mannequin before the beginning of scenarios. To simulate cough reflex and spray

of respiratory droplets, an infusion tubing was placed at the mannequin's oropharynx and was intermittently squirted with 5 ml liquid detergent during CPR. To simulate aerosols, 2 ml of liquid detergent mixed with 2 ml of water was delivered by a nebulizer with the nebulizer tube placed at the oropharynx through out CPR. To avoid false positives or false negatives under Wood's lamp illumination, we opted for black-colored PPE. We tailored our economical PPE using the black plastic bags of biomedical waste management at our hospital [Figure 1c]. To enact CPR on the mannequin, we had a team of three members with their roles designated as a chest compressor, an airway manager, and a defibrillator assistant. All of them were attired in black-colored PPE. We had three observers to assess each one of them. These observers monitored the rate and depth of chest compressions, time to intubate, and duration of interruption in CPR.

In Scenario 1 (standard protocol), the chest compressor initially checked for a carotid pulse on the mannequin to identify cardiac arrest and immediately began chest compressions. Droplets and nebulized aerosols were simulated during CPR. The airway manager performed video laryngoscopy (Tuoren Video Laryngoscope) and intubated with on going chest compressions. Artificial manual breathing unit ventilation was provided after intubation. After two minutes of CPR Cycle 1, defibrillation was provided by the defibrillator assistant and compressions were resumed immediately by the chest compressor. CPR Cycle 2 was done for two minutes, through out which droplet and aerosols were simulated using liquid detergent. After completing Scenario 1, the team members were examined under Wood's lamp illumination. They were photographed from

all four directions, after which they changed to a new set of black-colored PPE to enact Scenario 2.

In Scenario 2 (RCAprotocol), the chest compressor initially checked for a carotid pulse to identify cardiac arrest. Then, the team members placed the RCA device on the mannequin. The chest compressor began chest compressions, and the rest of the sequence was similar to the standard protocol. After completing Scenario 2, the team members were photographed from all four directions under Wood's lamp illumination [Figure 2]. Five sessions of two cycled (4 min) CPR were simulated in standard protocol and RCA protocol individually.

We used Nikson D5500 digital camera with AF-P 18–55mm lens. Camera settings including ISO and shutter speed were set "auto" to capture images for both standard and RCA protocol. The illuminated areas in photographs were quantified by measuring square pixel units of the intensity of illumination using ImageJ software (version 1.46r), a Java-based software developed at the National Institute of Health, Bethesda, Maryland, United States [Figure 3]. The exposure of HCW in standard protocol was compared to that of RCA protocol to evaluate the effectiveness of RCA. The feasibility of RCA during CPR was measured by comparing CPR performance metrics such as rate and depth of chest compressions, time taken to intubate, first-pass success, and duration of interruption in CPR.

Data analysis

Convenient sampling technique was used, and a sample size of 5 (5 simulation sessions in Standard and RCA protocol, individually) was chosen as it was a pilot study. Data were analyzed using SPSS software version 20.0, manufactured by

Figure 1: (a) RCA model with red arrows pointing toward the junction of upper and lower templates.(b) RCA placed on mannequin showing cranial end circular ports.(c) Team members attired in black-colored self-tailored PPE

Figure 2: (a) Chest compressor of standard protocol photographed from different directions.(b) Chestcompressor of RCA protocol photographed from different directions

IBM Corp, New york, USA. The distribution of continuous variables such as exposure in terms of count (squarepixels) in teammembers, chest compression rate per minute, time taken to intubate in seconds and duration of interruption in CPR in seconds were tested for normality using Kolmogorov–Smirnovtest and expressed in terms of mean with standard deviation or median with interquartile range based on the normality. The distribution of categorical variables was expressed in terms of frequencies and percentages. The Chi-square test or Fisher's exact test was used to look for a significant difference in categorical variables between groups. The independent student's *t*-test or Mann–Whitney *U*-test was used to look for a significant difference in continuous variables between groups. All statistical analyses were carried out at 5% level of confidence and $P < 0.05$ was considered statistically significant.

RESULTS

Eight participants were enrolled in this study. A total of 10 simulation sessions, divided into two protocols of five sessions each, were conducted. Each simulation session lasted for four minutes, to constitute two cycles of CPR. Over all mean exposure in standard protocol was 4950.4 ± 1461.6 (95% confidence interval [CI] 3135.7–6765.2) sq.pixels and RCA protocol was 2203.6 ± 1499.0 (95%CI: 342.4–4064.9) sq.pixels ($P = 0.019$). In standard, chest compressor had the highest exposure (3066.6 ± 1419.2[95% CI: 2051.3–4081.9] sq.pixels) followed by defibrillator

Figure 3: Quantification of illuminated areas of exposure using Image J software

assistant (1166.4 ± 767.4[95%CI: 617.4–1715.4] sq.pixels). The median time taken to intubate was 24.0 ± 14.4 (95% CI: 13.7–34.3) seconds in standard and 30.0 ± 20.4 (95%CI: 15.4–44.6) seconds in RCA protocol ($P = 0.458$).

Table 1 compares the HCW exposure and CPR performance metrics between the Standard and RCA protocols. Chest compressor of RCA had lower exposure compared to that of standard ($P < 0.001$). Airway manager of RCA had some what higher exposure compared to standard ($P = 0.443$). Figure 4 depicts the frequencies of body parts exposed in our simulation study. In standard protocol, the most frequently exposed body part was the team members' gloved hands. Airway manager of RCA did not exhibit any exposure on the head and neck, despite the mean exposure being higher than standard.

The CPR performance metrics between the two protocols were almost similar. CPR cycle 2 of RCA was no different from Standard, considering the median rate of chest compressions. Correct hand placement and adequate depth of chest compressions were observed in all simulation sessions. All intubations were successful in Standard, but one was esophageal intubation in RCA protocol. CPR was not interrupted beyond 10s to perform intubation in any protocol. A qualitative group discussion was done with study participants at the end of sessions on the feasibility of RCA. Airway managers conveyed no difficulty with hand movements during laryngoscopy with RCA in place. Visualization of vocal cords was little difficult due to the squirted liquid detergent on the RCAs plastic sheet. Chest compressors conveyed that maintaining hand position was little difficult with RCA inplace. Defibrillator assistant conveyed little difficulty in delivering shock, as he should lift the plastic sheet every time to access mannequin. Majority of the participants conveyed that RCA was feasible to use with adequate training.

DISCUSSION

In our pilot-simulation study, we noticed that HCW exposure to simulated respiratory particles was minimized using RCA. The RCA device did not alter the CPR performance metrics. The exposure to simulated respiratory particles was higher in chest compressor, followed by defibrillator assistant and airway manager. Multiple studies have used similar methods for

Table 1: Comparison of exposure of team members and cardiopulmonary resuscitation performance metrics between the protocols (*n*=5)

Parameters	Standard protocol (95% CI)	RCA protocol (95% CI)	*P*
Overall mean exposure in square pixel of the team members	4950.4±1461.6 (3135.7-6765.2)	2203.6±1499.0 (342.4-4064.9)	0.019
Mean exposure of chest compressor in square pixel	3066.6±1419.2 (2051.3-4081.9)	635.4±571.4 (226.6-1044.2)	<0.001
Mean exposure of airway manager in square pixel	717.4±425.3 (413.1-1021.7)	860.2±388.7 (582.1-1138.3)	0.443
Mean exposure of defibrillator assistant in square pixel	1166.4±767.4 (617.4-1715.4)	708.0±573.1 (298.1-1117.9)	0.148
Median rate of chest compressions per minute in cycle 1 of CPR (IQR)	108 (25)	84 (23)	0.060
Median rate of chest compressions per minute in cycle 2 of CPR (IQR)	89 (18)	88 (13.5)	0.834
Mean duration of interruption in CPR in seconds	18.3±12.4 (9.5-27.1)	21.2±7.4 (15.9-26.6)	0.533
Mean time taken to intubate in seconds	24.0±14.4 (13.7-34.3)	30.0±20.4 (15.4-44.6)	0.458

CI: Confidence interval, RCA: Resuscitation cover all, CPR: Cardiopulmonary resuscitation, IQR: Interquartile range
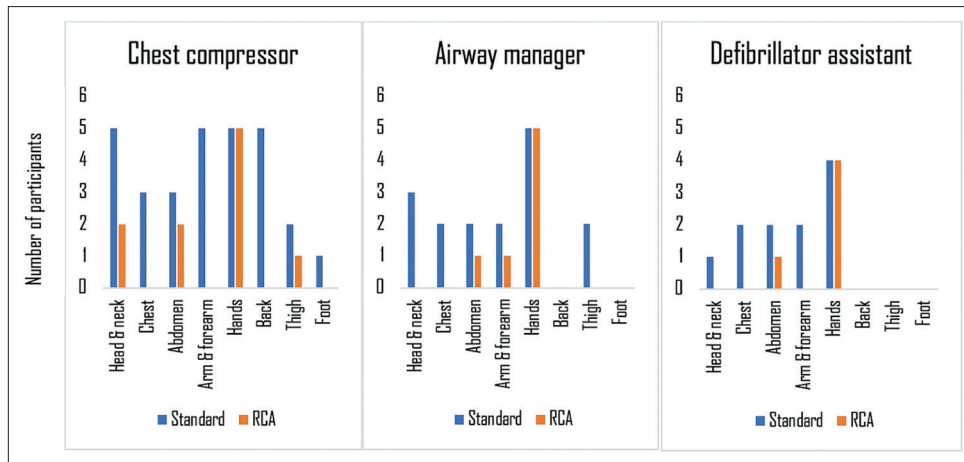
Figure 4: Comparison of frequencies of body parts exposed between the protocols

assessing droplet and aerosol spread by using fluorescence dye and then quantifying the area of distribution.[19,20,23,24] Liquid detergent was used in this study as a cost-effective alternative to fluorescent dye. However, the validity of liquid detergent to simulate respiratory particles is unknown. We found more than hundreds of tiny detergent droplets of varied sizes dispersed widely on PPE of HCW [Figure 2a and b]. Because of the varied size and wider pattern of droplet dispersion, the exposure could not be appropriately quantified by measuring body surface area. Hence, we used Image J software, a computer vision-based image processing analysis, which has been found to be more accurate in quantifying granular and/or particulate materials of varying sizes and shapes.[25]

The exposures of chest compressor, airway manager and defibrillator assistant of standard protocol were compared with those of RCA protocol. Among the team members of Standard protocol, chest compressor had the highest exposure followed by the defibrillator assistant. Hands were the most frequently exposed body part of all team members. This might be because of direct contact with the mannequin. Chest compressor of RCA had lower exposure compared to the standard ($P < 0.001$). There was a huge difference in overall exposure of team members between both the protocols ($P = 0.019$). This indicates that RCA could minimize the exposure of HCW to simulated respiratory particles during CPR. The airway manager's mean exposure in RCA protocol was some what higher than that of standard. This might be explained by the need for hand placement through cranial end ports inside the RCA device where in the respiratory particles might possibly be concentrated because of the lesser dispersion with RCA in place. On the contrary, it is important to highlight that the airway manager had no head-and-neck exposure in any session of RCA protocol. This observation signifies that exposure through droplet and spread could also be minimized by RCA. A small sample simulation study by Canelli *et al.* Using fluorescent dye demonstrated that an aerosol box during intubation limited the contamination.[19] Paroya *et al.* Proposed that draping a patient's mouth and nares during manual chest compressions minimized the risk of HCW exposure.[26]

The CPR performance metrics were similar in both the protocols. In RCA protocol, the median rate of chest compressions in CPR Cycle 1 was 24 compressions per minute lesser, probably explained by the initial time taken to place the RCA device on the mannequin before initiating chest compressions. No difference in median rate of chest compressions in CPR cycle 2 clarifies that RCA might not hinder performing high-quality chest compressions. The median duration of interruption in CPR in RCA protocol was 3 s longer than standard because of the additional time taken to displace the plastic sheet to defibrillate. In RCA protocol, the average time taken to intubate was 6 s longer and one intubation was misplaced into the esophagus. This might be explained by the reduced visibility because of the squirted and nebulized liquid detergent on the plastic sheets. Furthermore, our team members were not familiar with RCA. Such hindrances could be over come by adequate training of the HCW with RCA. A single-center, prospective, noninferiority, randomized controlled trial in surgical patients under going general anesthesia looked at the effect of a barrier device on time to intubate. They found that the mean time taken to intubate (TTI) with out barrier device was 42s (CI19.2–64.8) and with barrier device was 52s (CI26.1–78). The difference in mean TTI was 10.1s (CI-∞to14.9).[27]

In our literature search, we could not find any barrier device for the sole purpose of performing CPR on COVID-19 patients. Our novel RCA device is intended to minimize HCW exposure as well as be more clinician-friendly during crucial times such as CPR. The advantages of our RCA device are cost-effectiveness, lightweight, convenient to use, quick fit over the mannequin, transport-friendly, and able to be removed rapidly particularly in emergency situations (loss of airway, vomiting, etc.,). It ensures adequate view of the patient's airway and allows good hand movements of the Airway manager as well as the Assistant. It is a split device, so it can be handled easily during positioning in emergency settings as well as during removal, cleaning, and storage. We also aim at providing a solution for the concerns about secondary aerosolization upon barrier removal. After achieving return of spontaneous circulation, the patient may be transported along with the RCA device to

a COVID isolation negative pressure room, and later, RCA may be removed. The plausible disadvantage is that respiratory particles may be propelled toward the airwaymanager, in case adequate seal is not maintained at the cranial end circular ports.

The strengths of this study were cross-overdesign, black-colored PPE, cost-effective framework of RCA, and team of residents well trained in CPR. The study had some weaknesses such as small sample size and use of liquid detergent which was not equivalent to respiratory particles. To organize a real study in future, exposure may be simulated using a harmless virus to assess the effectiveness of RCA and exposure may be measured using a standardized technique. We still need trials and simulation studies with more participants to obtain more information on this barrier device. Consensus on simulation of exposure and assessment of outcomes is urgently needed. We also need more real-life evidence.

What this study adds ?

Barrier device is an adjunct to the current infection control PPE practices for COVID-19 and does not substitute appropriate PPE. Barrier device during CPR has not been investigated. Our novel RCA device could minimize the exposure of HCW during CPR. With adequate training of HCW, ergonomics of CPR would be enhanced. While protecting HCW from exposure, our RCA simultaneously permits access from all sides, better maneuverability, and visualization through the transparent plasticsheets, making it feasible for use during CPR. This pilot-simulation study offers very low-certainty evidence that the novel RCA barrier device may provide better protection to HCW during CPR in addition to standard PPE.

Limitations

This nonblinded pilot simulation study was limited by the small sample size. Results cannot be paralleled to a dynamic ED setting to resuscitate COVID-19 patients in cardiac arrest. Liquid detergent was used instead of fluorescent dye for cost-effectiveness. There were inherent limitations to the extent to which we were able to simulate droplet a nd aerosol generation during CPR. Our simulation methods cannot be merely extrapolated to the virulent viral particles' velocity and trajectory. Another limitation was that tiny, aerosolized particles might have been missed under Wood's lamp illumination. Exposure quantified by square pixels might not be too accurate measurement. There liability of the unit of measurement in square pixel units of the intensity is unknown.

Conclusion

CPR in COVID-19 patients poses the risk of virus transmission to HCW. In simulated settings, the novel "RCA" device could minimize the exposure of HCW to respiratory particles generated during CPR. Once the learning curve is achieved, the ergonomics of CPR would be enhanced. Before recommending for wide spread clinical use, further validation randomized controlled studies are required to demonstrate the efficacy and feasibility of the device during CPR of COVID-19 cardiac arrest victims.

Conflicts of interest

There are no conflicts of interest.

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