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Effectiveness of Four-Decontamination Techniques on Bacterial Growth on CPR Manikins after Use in a CPR Course

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Empirical Research

Effectiveness of Four-Decontamination Techniques on Bacterial Growth on CPR Manikins after Use in a CPR Course

Rachel K. Katch, David C. Berry

Abstract

The American Red Cross and American Heart Association are strong advocates of preventing disease transmission during cardiopulmonary resuscitation (CPR) training by promoting careful and consistent manikin decontamination. Because CPR is taught worldwide, identifying low-cost, efficient, and effective means of decontamination is imperative. **Objective:** Determine the degree of contamination on CPR manikins after routine use, and evaluate the efficacy of four disinfecting methods to reduce bacterial growth. **Design:** Descriptive laboratory. **Setting:** CPR class; microbiology laboratory. **Subjects** Forty-eight Actar 911™ CPR manikins (Armstrong Medical Industries, Lincolnshire, IL). **Main Outcome Measure(s):** Dependent variable was bacterial colony growth (count); independent variable was treatment group. Colony growths too numerous to count defaulted to a minimum 300 threshold (standard laboratory protocol). Data was analyzed with descriptive statistics and a repeated-measures ANOVA (group X time [initial, post-24, post-disinfected swab]) set a priori at 0.05. **Results:** A repeated-measures ANOVA revealed no significant main effect for interaction or group on mouth or chest plate swabs. Results showed a significant main effect for time on chest plate ($F2,88=12.1;p<0.001$) and mouth ($F1.14,50.2=7.2;p=0.02$) bacterial colony counts. Chest plate decreased bacterial growth from post-24 (72.8±84.9) to post-disinfected (12.2±44.6). Mouth decreased bacterial growth from initial swabbing (4.3±5.7), to post-24 (3.0±6.6), to post-disinfected (0.5±1.1). **Conclusions:** If unsanitized, CPR manikins are possible vectors for bacterial growth. Clorox Disinfecting Wipes™, 1:10 bleach-to-water solution and 70% isopropyl alcohol were low cost, efficient, and effective decontamination methods; UVC-light's effectiveness requires further research. Athletic trainers and educators can use these results to appropriately select disinfecting agents to reduce the risk of opportunistic bacterial growth on CPR manikins.

INTRODUCTION

With advanced research in modern medicine, most infectious bacterial strains can simply be cured with antibiotics; however, due to inappropriate use of the medication, antibiotics have helped create bacterial diseases that are resistant to treatment (Neu, 1992). Bacteria are microscopic, single-celled, and inhabit all types of environments, including: (1) soil, (2) seawater, and (3) on the bodies of other organisms (Centers for Disease Control and Prevention, 2016a). They can be classified by their shape, which includes, but is not

limited to: (1) spherical, (2) rod-like, (3) spiral, or (4) comma-shaped (Centers for Disease Control and Prevention, 2017; Black, 1990). Although many bacteria have been found beneficial (e.g., aiding in digestion), some are capable of producing infectious disease on humans who come into contact with the infectious bacteria (e.g., MRSA, strep throat, tuberculosis, etc.) (Centers for Disease Control and Prevention, 2016a; Centers for Disease Control and Prevention, 2017). In addition to bacteria, viruses are also infectious agents that replicate within the cells of living hosts. Both bacteria and viruses are transmitted through different mediums including, but not limited to: (1) air-droplets (e.g., respiratory route of transmission), (2) direct contact (e.g., physical contact between the infected person and susceptible person), and (3) indirect contact (e.g., contact occurs through contaminated surfaces or objects) (Centers for Disease Control and Prevention, 2014; Verelst, Willem, & Beutels, 2015). Unlike against bacteria, antibiotics are ineffective against viruses (Centers for Disease Control and Prevention, 2016a).

Each year in the United States, at least two million people become infected with bacteria that are resistant to antibiotics, and at least 23,000 people die annually as a direct result of these infections (Centers for Disease Control and Prevention, 2013). Additionally, many more people die from illnesses complicated by infection from an antibiotic-resistant bacteria (Centers for Disease Control and Prevention, 2013). In addition to these infections, viruses such as seasonal influenza affect 5%-20% of the population and account for upwards of 49,000 deaths annually (Centers for Disease Control and Prevention, 2016b). Bacterial and viral infections occur everywhere; however, data shows that most occur in the general population or community, specifically in healthcare settings (e.g., hospitals, emergency response training, etc.) (Centers for Disease Control and Prevention, 2013). Therefore, the selection of approved disinfectants together with the use of appropriate cleaning materials is an imperative step to assure a high level of safety and efficacy for the disinfection process (Diab-Elschahawi et al., 2010).

Since bacterial infections do present a possible threat to life, organizations such as the American Red Cross (Washington, DC) and American Heart Association (Dallas, TX) believe it is critical to prevent the spread of infectious disease during cardiopulmonary resuscitation (CPR) training and that manikins should be decontaminated carefully and consistently (American Red Cross, 2011). Since the 1960's when the American Heart Association developed programs to teach the general public in providing CPR, there have been numerous decontamination techniques from which first aid and CPR instructors can choose to sanitize surfaces; however, there is a paucity of literature on whether any of these techniques are safe and/or effective to use on CPR manikins (American Heart Association, 2017; Corless, Lisker, & Bukheit, 1992). Presently, the American Red Cross and American Heart Association estimate that annually they train a combined total of more than 21 million people worldwide on techniques such as performing CPR, utilizing an automated external defibrillator (AED), and providing first aid (American Red Cross, 2014). Alone, the American Heart Association and American Stroke Association trained more than 19 million people world-wide in CPR in 2015-2016 (American Heart Association, 2016). Thus, the implications to decrease infectious disease transmission via CPR manikins during CPR training are imperative.

The decontamination agents examined in this study include: (1) ¼ cup bleach to one-gallon water solution, (2) 70% isopropyl alcohol wipes, (3) Clorox Disinfecting Wipes® (The Clorox Company, Oakland, CA), and (4) ultra violet-C light (Germguardian™, Mentor, OH). Bleach is a solution of sodium hypochlorite and water that historically has been very effective in killing microorganisms (Jordan, DiCristina, & Lindsay, 2006; de Oliveira et al., 2011; Rutala & Weber, 1997). It can enter microbial cells, where it reacts with many cellular components, destroying them and killing the cell (Centers for Disease Control and Prevention, 2016a). Isopropyl alcohol is also an effective decontaminant that is bactericidal, tuberculocidal, fungicidal, and virucidal but does not destroy bacterial spores (Hendry, Conway, & Wothington, 2012; Keen, Austin, Huang, Messing, & Wyatt, 2010; Hudson, 1984). The 70% isopropyl alcohol works by denaturizing proteins and inhibiting the production of metabolites essential for rapid cell division (Centers for Disease Control and Prevention, 2016a). Thirdly, Clorox Disinfecting Wipe® ingredients include a combination of ammonium chlorides and isopropyl alcohol (quaternary ammonium

compound) (Clorox), while the mode of decontamination includes inactivation of energy-producing enzymes, denaturation of essential cell proteins, and disruption of the cell membrane (Centers for Disease Control and Prevention, 2016a; Department of Environmental Health and Safety, 2008). Clorox® claims its product is an effective medium for decontamination (Clorox, 2017); however, little research on the wipes, specifically, has been conducted (Greatorex et al., 2010). Lastly, UVC-light uses UV-radiation, which is a form of non-ionizing radiation characterized by wavelength and frequency (Andersen, 2006). The mechanism of germicidal action involves chemical reactions facilitated by UV-radiation (Andersen, Bånrud, Bøe, Bjordal, & Drangsholt, 2006). Although literature has shown UVC-light to be an effective decontaminant in health care settings (Andersen, Bånrud, Bøe, Bjordal, & Drangsholt 2006; Kac et al., 2007; Nerandzic, Cadnum, Eckart, & Donskey, 2012), its efficacy is still under investigation due to its variability and inconsistent decontamination (Centers for Disease Control and Prevention, 2016a; McLeod et al., 2013).

Because all four of these cleaning agents have been shown to be effective in decontaminating bacteria and/or viruses, we aimed to answer which is the most effective method to properly decontaminate CPR manikins after use in a normal college level CPR course to limit possibly pathogenic bacteria and communicable disease transmission. This aim falls under the prevent and prepare Chain of Survival Behaviors by recognizing there are risks and hazards that individuals need to be aware of to mitigate contact with these potentially pathogenic bacteria, and providing the most effective techniques for decontamination.

METHODS

Subjects

The subjects included 48 Actar 911™ CPR manikins (Armstrong Medical Industries, Lincolnshire, IL) used by students in two college Basic Life Support (BLS) CPR (American Red Cross) courses. All manikins were deemed to be in proper working order prior to the start of each class. Students enrolled in the courses detached the chest plates and prepared a set of lungs designed for the manikins. During a 50-minute educational intervention (i.e., CPR for adults), students utilized

standard precautions (i.e., use of nitrile gloves and resuscitation mask) while performing chest compressions and rescue breaths.

Study Design

The study consisted of two phases. Phase one employed a prospective design to determine the prevalence of bacterial contamination on the CPR manikins at a single point in time. Phase two used a repeated measures design to evaluate the efficacy of recommended cleaning practices in reducing levels of bacterial contamination identified on CPR manikins in phase one. Approval was granted by the University's Human Subjects Institutional Review Board.

Materials

Standard swabbing and quantitative plating methods, as described in Bailey & Scott's Diagnostic Microbiology (Forbes, Sahm, & Weissfeld, 2007), were followed for all samples. Sample planting occurred using prepared oxoid dehydrated culture media (i.e., Remel™ Blood Agar [Tryptic Soy Agar (TSA) with 5% Sheep Blood]) (Thermo Scientific; Lenexa, KS). Cultured media were placed in an incubator (Scienceware®; Bel-Art Products, Wayne, NJ), and were monitored and maintained at 37 ˚C (98.6°F).

Procedure

Data collection was comprised of two phases. Due to the limited number of available manikins, and to ensure adequate power (.80 or greater) and a medium effect 0.5 or larger, phase one and phase two were initially completed using 24 manikins and then repeated one week later on another 24 manikins for a total sample size of 48 (24 per group). The three-time points included: (1) initial swab (phase one), post-24 swab (phase two), and (3) post-decontamination swab (phase two).

Phase One

The manikins were decontaminated using Clorox Disinfecting Wipes® prior to undergoing the 50-minute educational intervention (i.e., CPR course) following manufacturer's recommendations. At the conclusion of the educational intervention, the chest plates were detached, the lungs were removed, and the manikins were collected using standard precautions (i.e., gloves). All manikins were labeled and aseptically swabbed and planted on the TSA with 5% Sheep Blood (SBA) plates

using standard medical lab science procedures. Sites for individual swabbing included the area around the mouth and on the chest plate between the nipples. The inside of the lungs and masks were not swabbed due to the study focusing on manikin decontamination. Lungs are one-time use items and should be replaced on subsequent training, while masks should stay in the possession of the same individual during training. All plates were then incubated for 24 hours. To simulate realistic storage, the manikins were returned to the storage cabinet for 24 hours to begin phase two.

Phase Two

After 24 hours, manikins were removed from the storage cabinet using standard precautions (i.e., gloves) and were again swabbed, planted (SBA), and incubated for 24 hours. The manikins were then randomized into four treatment groups and disinfected with either: (1) 1:10 bleach-to-water solution (bleach [made 10 minutes before disinfection in a new spray bottle]), (2) 70% isopropyl alcohol (isopropyl alcohol), (3) Clorox Disinfecting Wipes® (wipes), or (4) UVC-light (UVC). Disinfection procedures (e.g., time for disinfection, cleaning technique) followed the specific manufacturer's recommendations when applicable. The two researchers responsible for the manikin decontamination reviewed and practiced each procedure prior to data collection to ensure consistency. Manikins in the bleach and isopropyl alcohol groups were disinfected by completely applying the disinfecting solutions onto the chest and mouth by means of sterile gauze using a zig-zag pattern across the chest and an internal-to-external pattern in the mouth. The surfaces were then allowed to sit undisturbed for one minute before any remaining solution was wiped dry with a sterile gauze pad using aseptic techniques, per Clorox® bleach and isopropyl alcohol manufacturer's recommendations. Manikins in the wipes group were disinfected by applying the solution onto the chest and mouth using a zig-zag pattern across the chest and an internal-to-external pattern in the mouth, ensuring all surfaces were covered. The solution was then allowed to sit undisturbed for four minutes before any remaining solution was wiped dry using aseptic techniques, per Clorox® manufacturer's recommendations. Lastly, manikins in the UVC group were disinfected by waving the wand approximately one inch above the surface of both the chest and mouth for 20 seconds, making sure to cover all surface areas, per the UVC manufacturer's recommendations. After disinfection, all manikins were swabbed, planted on the SBA, and incubated again for 24 hours. After incubation, all plates were evaluated for colony counts and appearance according to standard operating procedures derived from Bailey & Scott's Diagnostic Microbiology textbook (Forbes, Sahm, & Weissfeld, 2007).

Incubation

All uninoculated materials (i.e., SBA, swabs) were kept closed, and therefore sterile, up until the time of sampling. Exposure of the uninoculated media to the environment was for the shortest time possible (1–2 minutes) and aseptic technique was utilized at all times according to standard microbiological techniques. All samples were incubated within four hours of sampling and were incubated at 37°C (98.6°F) overnight in ambient air.

Identification

Two investigators trained in medical lab sciences (using Bailey & Scott's Diagnostic Microbiology [Forbes, Sahm, & Weissfeld, 2007]) collected the samples and analyzed the number of colony forming units (CFUs) on each plate. Although the raters were not specifically blinded to which phase each plate was from, the assessment process involved a simple objective count of colonies that adhered to standard microbiological techniques. The microbiological analysis involved quantization of each colony from the initial swab, post-24 hour, and post-decontamination plates, according to standard operating procedures. Colony counts that were too numerous to count were defaulted to a value of 300. Identification of colony growth on initial swabs was not evaluated; however, post-24 hour and post-decontamination colonies were further identified to determine whether they were pathogenic, normal flora, or an environmental contaminant, when applicable, but were not the focus of this study. Basic identification techniques used included gram stain, catalase, and coagulase tests.

Data Analysis

We utilized IBM's Statistical Package for the Social Sciences (version 19, IBM., Somers, NY) to calculate descriptive statistics for the dependent variable, bacterial colony count. The independent

variable was treatment group. Colony counts and bacteria type were recorded in hard copy format before being transferred to Microsoft Excel and then to SPSS. We calculated repeated-measures analyses of variance (ANOVA) for the bacterial colony count for the chest plate and mouth swabs (group X time [initial, post-24, post-decontamination swab]). Any post-hoc analysis was completed using a pairwise comparison with a Sidak correction. The level of significance (P < .05) was set a priori for all statistical analyses.

RESULTS

A total of 144 plates from the 48 manikins (initial swab, n=48; post-24 swab, n=48; post-disinfected swab, n=48) were sampled, and descriptive statistics were calculated (Table 1 and 2). Mauchly's test indicated that the assumption of sphericity had been violated ($X2$ (2)=10.0, p=.007), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε=.828). The repeated measures ANOVA revealed no significant main effect for interaction or group on mouth or chest plate swabs. Results did reveal a significant main effect for time for chest plate ($F2,88$=12.1, p<0.001) and mouth ($F1.14,50.2$=7.2, p=0.02) bacterial colony counts (Table 3 and 4).

Pairwise comparison demonstrated decreased chest plate bacterial growth post-24 (72.8±84.9) to post-decontamination (12.2±44.6) (Table 1). Chest plate post-disinfected showed no bacterial growth in 0% of UVC, 10.4% of wipes, 18.8% of bleach, and 22.9% of isopropyl alcohol plates (Table 3). The pairwise comparison revealed decreased mouth bacterial growth from initial swabbing (4.3±5.7) to post-24 (3.0±6.6) to post-decontamination (.5±1.1) (Table 2). Mouth plate post-decontamination showed no bacterial growth on 58.3% of UVC, 83.3% of wipes, 83.3% of the bleach, and 75% of isopropyl alcohol plates (Table 4).

For both the chest and mouth post-disinfected plates a majority of organisms were normal flora; however, any significant opportunistic bacteria found on post-24 hour plates were eliminated during the decontamination process (Figures 1a-d).

Clorox Disinfecting Wipes®
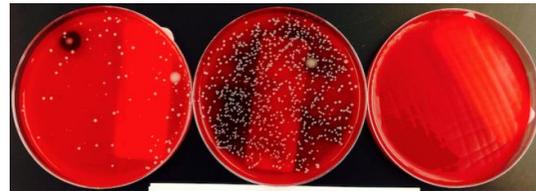
UVC-Light

1:10 Bleach Solution

70% Isopropyl Alcohol

Figures 1a-d. Bacterial colony growth from initial swab (left), post-24-hour swab (middle), and post-disinfection (right). Plates should be read left to right (i.e., left, middle, and right).

Table 1. Chest Plate Mean and Standard Deviation of Bacterial Growth Via Treatment.

Group	Initial Swab*	Post 24-Hour Swab*	Post-Cleaning Swab*
1:10 Bleach-to-Water Solution	35.50 ± 21.03	66.33 ± 79.58	0.58 ± 1.24
Clorox Disinfecting Wipes®	119.66 ± 101.06	88.25 ± 88.44	6.91 ± 19.91
UVC-Light	44.50 ± 56.75	70.41 ± 84.21	41.58 ± 82.66
70% Isopropyl Alcohol	67.58 ± 67.47	68.41 ± 100.17	0.08 ± 0.28
Total	66.81 ± 73.51	72.83 ± 84.99	12.29 ± 44.63

* Mean ± SD

Table 2. Mouth Plate Mean and Standard Deviation of Bacterial Growth Via Treatment.

Group	Initial Swab*	Post 24-Hour Swab*	Post-Cleaning Swab*
1:10 Bleach-to-Water Solution	4.58 ± 4.62	2.00 ± 1.80	0.41 ± 1.16
Clorox Disinfecting Wipes®	7.58 ± 9.02	1.50 ± 1.50	0.16 ± 0.38
UVC-Light	2.50 ± 4.40	5.91 ± 12.37	0.75 ± 1.28
70% Isopropyl Alcohol	2.75 ± 1.54	2.83 ± 4.28	0.66 ± 1.43
Total	4.35 ± 5.77	3.06 ± 6.67	0.50 ± 1.12

* Mean ± SD

DISCUSSION

Literature has shown a link between potentially pathogenic bacterial contamination and bacterial infection when humans come into contact with infectious bacteria (Craft, 2015; Dodd et al., 2016; American Red Cross, 2011). With CPR being taught worldwide, the chances of bacterial infection due to contaminated manikins is a potential problem. The results of our study indicate that, if un-sanitized, CPR manikins are a potential source of bacterial transmission. The majority of isolated bacterial species identified were normal flora, therefore unlikely to pose a bacterial infection risk; however, any number of bacteria or viral pathogens could pose a threat to elderly or immunocompromised individuals who may come into contact with a manikin during training.

Based on our results, no significant differences were noted between the treatment groups. However, the wipes, isopropyl alcohol, and bleach solution demonstrated greater bacterial destruction, especially on the chest plate, when compared to UVC. This finding coincides with other studies proclaiming the efficacy of all three techniques (Jordan, DiCristina, & Lindsay, 2006; de Oliveira et al., 2011; Centers for Disease Control and Prevention, 2016a; Rutala & Weber, 1997; Hendry, Conway, & Worthington, 2012; Keen,

Table 3. Post-Cleaning Total Colony Count at the Chest.

Group	Colony Count											
	0		1-10		11-25		25-50		51-100		>300*	
	n	%	n	%	n	%	n	%	n	%	n	%
1:10 Bleach-to-Water Solution	9	18.8	3	6.2	0	0	0	0	0	0	0	0
Clorox Disinfecting Wipes®	5	10.4	6	12.6	0	0	0	0	1	2.1	0	0
UVC-Light	0	0	4	8.4	3	6.2	4	8.3	0	0	1	2.1
70% Isopropyl Alcohol	11	22.9	1	2.1	0	0	0	0	0	0	0	0
Total	25	52.1	14	29.3	3	6.2	4	8.3	1	2.1	1	2.1

*Too numerous to count.

Table 4. Post-Cleaning Total Colony Count at the Mouth.

Group	Colony Count											
	0		1		2		3		4		5	
	n	%	n	%	n	%	n	%	n	%	n	%
1:10 Bleach-to-Water Solution	10	20.8	1	2.1	0	0	0	0	1	2.1	0	0
Clorox Disinfecting Wipes®	10	20.8	2	4.2	0	0	0	0	0	0	0	0
UVC-Light	8	16.7	1	2.1	2	4.2	0	0	1	2.1	0	0
70% Isopropyl Alcohol	8	16.7	3	6.2	0	0	0	0	0	0	1	2.1
Total	36	75	7	14.6	2	4.2	0	0	2	4.2	1	2.1

Austin, Huang, Messing, & Wyatt, 2010; Greatorex et al., 2010) under different conditions. These decontaminants are also more readily available and cost-effective than UVC to the wide range of professions and consumers utilizing decontamination methods in daily work and life. However, decontamination techniques like the bleach solution are not convenient, leave a residual taste/smell, and stain equipment and clothing (American Red Cross, 2011). This then leads to decreased decontamination compliance and may increase the risk of bacterial disease transmission between individuals. In addition, the wipes must sit for a minimum of four minutes before being wiped dry. In a fast pace environment, compliance with these directions may be overlooked, again increasing an individual's risk of bacterial contamination.

Although studies support the use of UVC as a disinfectant (Andersen, Bånrud, Bøe, Bjordal, & Drangsholt, 2006; Kac et al., 2007; Nerandzic, Cadnum, Eckart, & Donskey, 2012), there have also been studies that question its efficacy as well (Centers for Disease Control and Prevention, 2016a; McLeod et al., 2013). In regards to decontamination of the manikins' chest plate with UVC, our conclusion agrees with the latter research (Centers for Disease Control and Prevention, 2016a; McLeod et al., 2013). Based on our results, decontamination of the manikins' mouth with UVC suggests that this procedure may be viable; however, bacterial colony count on the manikins' mouth was significantly less than the chest plate, making the chest plate a greater risk for bacterial transmission. UVC's effectiveness requires further research as potentially pathogenic bacteria still existed on post-decontaminated chest plates. Possible causes that could denote the variances in UVC's efficacy include: (1) differences among brands used between studies, (2) differences in light source size, (3) distance between wand and surface, and (4) time UVC is contacting the surface.

In addition to the above discrepancies, destruction of molecular chains requires a dose of UVC that is

matched to the type of organism; this dose is the germicidal wavelength of 253.7 nm (Andersen, Bånrud, Bøe, Bjordal, & Drangsholt, 2006). As the genetic structure of bacteria or viruses is exposed to UVC, it will be destroyed; however, the success of surface disinfection depends greatly on the consistency of the material to be disinfected (Andersen, Bånrud, Bøe, Bjordal, & Drangsholt, 2006). In general, UVC rays must directly strike the microorganism to achieve lethal destruction (Andersen, Bånrud, Bøe, Bjordal, & Drangsholt, 2006). If the organism is hidden below the surface of a material or is not in the direct path of UVC rays, it will not be destroyed (Andersen, Bånrud, Bøe, Bjordal, & Drangsholt, 2006). Although UVC leaves no residue in the indoor environment and the newer-style units are not subject to temperature limitations, UVC may have destructive effects over time by fading colored paints and fabrics on materials such as plastic and vinyl (Andersen, Bånrud, Bøe, Bjordal, & Drangsholt, 2006).

When performing CPR for the professional rescuer or healthcare provider, participants are required to be in physical contact with the manikin. During the educational intervention, the participant's hands are placed on the chest between the nipples while providing 30 compressions, and a resuscitation mask is sealed over the mouth and nose when providing two ventilations following standard CPR protocols (American Red Cross, 2011). Although universal precautions (i.e., gloves, resuscitation mask) are utilized with all participants, possible contaminants from surrounding surfaces (i.e., floor, CPR mats, college books/notebooks) could serve as vectors for contamination onto the manikin's chest plate. This would explain why the manikins' chest plate colony count was higher than the mouth.

When performing the required ventilation skills, saliva from the participant may have accumulated on the manikins' face from either direct, indirect, or air-droplet transmission, creating another source of possible bacterial contamination. However, use of the resuscitation masks during our educational intervention is the likely explanation as to why there was a reduced bacterial colony count around the mouth due to the mask's one-way valve. Another possible explanation for the discrepancy in the bacterial colony counts between the chest and mouth is the usage of plastic lungs. The lungs are attached under the chest plate and through the

mouth to provide an airway (Figures 2a-b). A pair of small flaps at the mouth end of the plastic lungs are folded over the manikins' mouth, in essence creating a secondary barrier, especially to air-droplets.
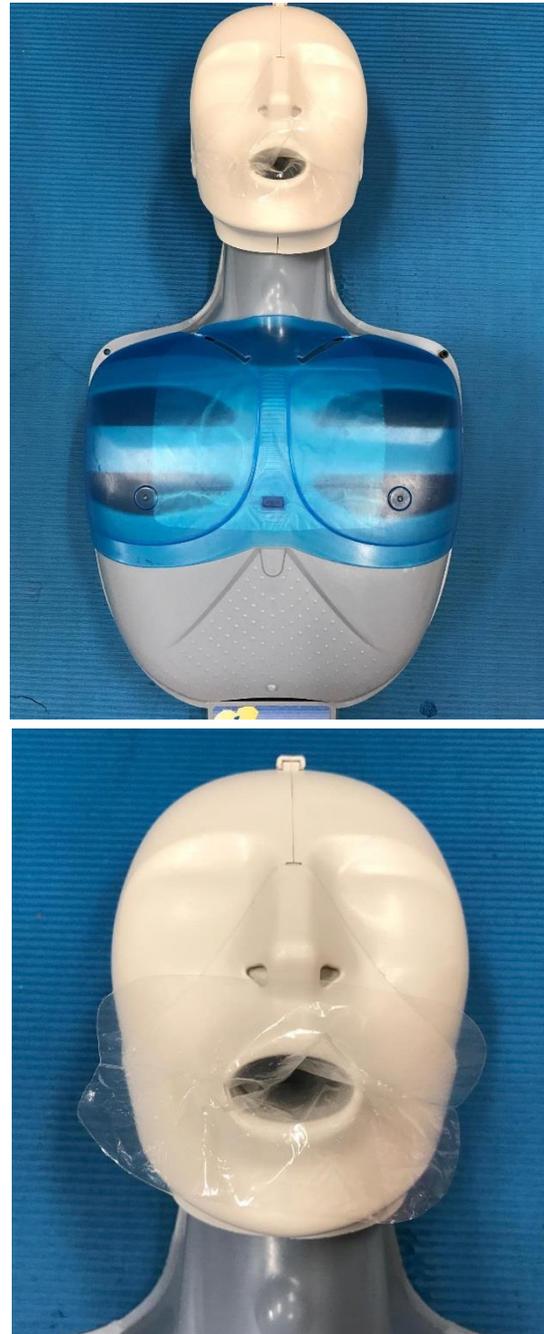
Figures 2a-b. Placement illustration of the plastic lungs in the Actar 911™ CPR manikins prior to use in a CPR course.

Limitations

Possible limitations of the study include: (1) cross-contamination during storage, (2) differences in swabbing technique between the two microbiologists, and (3) differences in individual researcher's sanitation technique. During our storage phase of the study, manikins were placed collectively in a storage cabinet for 24-hours after the initial swab. This storage technique was used to simulate realistic storage, but it also allows for bacterial cross-contamination that could possibly alter the data. The second limitation regarding differences in swabbing technique could also possibly cause data disparities (i.e., bacterial colony growths). Although researchers followed standard laboratory protocols during the swabbing procedure, individual sources of human error can occur by inconsistently swabbing each plate with the same technique. Finally, the third limitation involves differences in individual sanitation procedure. Two researchers randomly disinfected each manikin following the specific manufacturer's recommendations when applicable; however, decontamination technique between the two individuals could slightly differ, possibly causing data discrepancies. This statement holds true especially with UVC, as there are many possible decontamination inconsistencies that could denote variance in its efficacy as previously stated.

Implications for Field

During the duration of a CPR for the professional rescuer/healthcare provider course where precautions (i.e., gloves and resuscitation mask) are used, there are many possible routes for bacterial contamination onto CPR manikins. If left un-sanitized, the manikins are possible vectors for infectious bacterial growth and transmission between course participants. Healthcare providers and educators can use our results to appropriately select decontamination agents to reduce the risk of infectious bacterial growth on CPR manikins and prevent the spread of infectious bacterial contamination between CPR-course participants worldwide, especially if the instructor does not require the use of universal precautions (i.e., nitrile gloves, face-shields, or resuscitation masks).

CONCLUSION

Even when precautions (i.e., gloves and resuscitation mask) are used, CPR manikins after use in a CPR course have been shown to be vectors for pathogenic bacteria. Direct skin-to-manikin contact with the chest and mouth during skills (i.e., chest compressions, ventilations) could possibly cause an increase in bacterial contamination along with an increased chance of infectious disease transmission between participants. Thus, bacterial decontamination after the conclusion of every course session is imperative. Our results suggest that the wipes, bleach, and isopropyl alcohol are effective means of decontamination and are readily available for use by healthcare providers. In contrast, UVC's effectiveness still requires further research as pathogenic bacteria still existed on post-disinfected plates, and there are many discrepancies in proper technique that can denote variance in its decontamination effectiveness.

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