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"Rolling Refreshers": A novel approach to maintain CPR psychomotor skill competence☆

Dana Niles[a,*], Robert M. Sutton[b], Aaron Donoghue[a,b], Mandip S. Kalsi[c], Kathryn Roberts[d], Lori Boyle[d], Akira Nishisaki[a,b], Kristy B. Arbogast[e], Mark Helfaer[b], Vinay Nadkarni[a,b]

[a] Center for Simulation, Advanced Education and Innovation, The Children's Hospital of Philadelphia, 34th Street and Civic Center Blvd., Philadelphia, PA 19104, United States
[b] Department of Anesthesiology, Critical Care and Pediatrics, The Children's Hospital of Philadelphia, University of Pennsylvania School of Medicine, 34th Street and Civic Center Blvd., Philadelphia, PA 19104, United States
[c] Department of Anesthesiology, Thomas Jefferson University Hospital, 111 South 11th Street, Philadelphia, PA 19107, United States
[d] Department of Nursing, The Children's Hospital of Philadelphia, University of Pennsylvania School of Medicine, 34th Street and Civic Center Blvd., Philadelphia, PA 19104, United States
[e] The Center for Injury Prevention and Research, The Children's Hospital of Philadelphia, 3535 Market Street, Philadelphia, PA 19104, United States

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ABSTRACT

Objectives: High quality CPR skill retention is poor. We hypothesized that "just-in-time" and "just-in-place" training programs would be effective and well-accepted to maintain CPR skills among PICU staff.
Methods: "Rolling Refreshers", a portable manikin/defibrillator system with chest compression sensor providing automated corrective feedback to optimize CPR skills, were conducted daily in the PICU with multidisciplinary healthcare providers. Providers practiced CPR until skill success was attained, prospectively defined as <3 corrective prompts within 30 s targeting chest compression (CC) rate 90–120/min, CC depth >38 mm during continuous CPR. Providers completing ≥2 refreshers/month (Frequent Refreshers [FR]) were compared to providers completing <2 refreshers/month (Infrequent Refreshers [IR]) for time to achieve CPR skill success. Univariate analysis performed using non-parametric methods. Following actual cardiac arrests, CPR providers were surveyed for subjective feedback on training approach efficacy (5-point Likert scale; 1 = poor to 5 = excellent).
Results: Over 15 weeks, 420 PICU staff were "refreshed": 340 nurses, 34 physicians, 46 respiratory therapists. A consecutive sample of 20 PICU staff was assessed before subsequent refresher sessions (FREQ $n = 10$, INFREQ $n = 10$). Time to achieve CPR skill success was significantly less in FREQ (median 21 s, IQR: 15.75–30 s) than in INFREQ (median 67 s, IQR: 41.5–84 s; $p < 0.001$). Following actual resuscitations, CPR providers ($n = 9$) rated "Rolling Refresher" training as effective (mean = 4.2; Likert scale 1–5; standard deviation 0.67).
Conclusions: A novel "Rolling Refresher" CPR skill training approach using "just-in-time" and "just-in-place" simulation is effective and well received by PICU staff. More frequent refreshers resulted in significantly shorter times to achieve proficient CPR skills.

1. Introduction

Cardiopulmonary resuscitation (CPR) guidelines[1] recommend target values for selected CPR parameters related to rate, depth and release of chest compressions and ventilations, and avoidance of CPR-free intervals. Recent studies on adult patients however show that rescuers adherence to these guidelines is often inconsistent. Out of hospital, chest compressions are not delivered more than half of the time and compressions are too shallow.[2] Additionally, the quality of in-hospital delivered CPR for adult patients is inconsistent and often does not meet guidelines even when performed by well-trained staff.[3] Numerous studies have demonstrated that when high quality CPR is provided to adults, specifically adequate chest compression rate and depth, controlled ventilation, and limited CPR-free intervals, resuscitation outcome is improved.[4–11]

Healthcare providers are required to maintain BLS certifications in an effort to preserve good CPR skills. Yet CPR classes are traditionally taught in an instructor-led classroom-based manner with emphasis on the cognitive aspects of CPR rather than the actual

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* Corresponding author at: Center for Simulation, Advanced Education and Innovation, Room 8NW100, Main Building, The Children's Hospital of Philadelphia, 34th Street and Civic Center Blvd., Philadelphia, PA 19104, United States.
Tel.: +1 215 590 4039; fax: +1 215 590 2969.
E-mail address: niles@email.chop.edu (D. Niles).

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psychomotor skills of delivering a chest compression or rescue breath.[12–14] No study has demonstrated that didactic instruction regarding CPR theory will improve CPR quality.[15] Proficiency performing CPR psychomotor skills is variable after traditional BLS education, but overall poor. Retention of CPR skills is problematic with poor performance 3–6 months posttraining.[16–18] Inadequate time to practice skills on a manikin has been implicated as a specific cause of poor skill acquisition.[18]

Recent modifications of defibrillator technology using a force sensor and accelerometer (Philips MRx/Q-CPR) can provide real-time audiovisual feedback on the rate, depth, and quality of chest compressions (CC) during CPR. To implement these new monitor–defibrillators and in an attempt to "train to excellence", we instituted a novel program of frequent bedside refresher psychomotor training ("Rolling Refreshers"). We hypothesized that frequent "just-in-time" and "just-in-place" training (defined as a training session conducted directly prior to a potential intervention and at/near the site of the potential intervention) would be effective and well-accepted to maintain high quality CPR skills among bedside Pediatric ICU healthcare first responders.

2. Methods

2.1. Study design

This prospective, observational study was approved by the Institutional Review Board at the Children's Hospital of Philadelphia in the 45 bed tertiary care Pediatric ICU (PICU). Data collection procedures were completed in compliance with the guidelines of the Health Insurance and Portability and Accountability Act to ensure subject confidentiality. Written informed consent was waived since all data collected were de-identified.

2.2. Equipment and training

A commercial monitor/defibrillator system (Heartstart MRx/Q-CPR, Philips Healthcare, Andover, MA) was implemented in the PICU and utilized for this study which was equipped with a chest compression sensor with a force transducer/accelerometer which records and provides real-time audiovisual corrective and directive feedback in accordance with current AHA quality targets: CC depth $\geq$38 mm, rate 90–120 CC/min, pauses of <15 s, and residual leaning force between compressions of <2.5 kg (as pre-set by the manufacturer). Data are stored internally in the defibrillator for later review and analysis. Data included chest compression rate (average rate/min and actual number of chest compressions delivered/min), depth (mm), force (kg), and type and time of audiovisual feedback prompts.

In addition to standard defibrillator training received by all providers in the PICU, the multidisciplinary bedside healthcare providers (physicians, nurses, respiratory therapists) caring for the 5 most critically ill patients (as subjectively identified by the clinical teams managing the PICU), those at highest risk of suffering a cardiac arrest, were "Refreshed" everyday. The "Rolling Refresher" cart was rolled to the patient bedside and, led by a certified BLS instructor, each provider practiced CPR according to American Heart Association (AHA) Guidelines with real-time automated directive and corrective feedback until skill success was attained. The "Rolling Refresher" cart consisted of a Resusci Annie (Laerdal Medical, Stavanger, Norway) manikin and MRx/Q-CPR defibrillator setup on a $33''H \times 26''W \times 45''D$ utility cart (Figure 1). These sessions were brief (<5 min), focused entirely on the psychomotor aspects of CPR, and specifically tailored to the questions and capabilities of the bedside providers.

Figure 1. "Rolling Refresher" cart outside patient room.

2.3. CPR quality parameters

Consideration was given to uniform reporting of chest compression quality,[19] hence chest compression quality targets were prospectively defined as follows: rate 90–120 CC/min, depth $\geq$38 mm, and release of force applied to the chest to less than 2.5 kg between compressions. Skill success was defined prospectively as 30 s of chest compressions with less than 3 feedback prompts.

In order to assess the effect of greater exposure to refreshers on CPR performance, a consecutive sample of PICU healthcare providers were assessed before subsequent refresher sessions. Providers were selected successively over the course of one day without bias to duration of employment, previous training, or previous participation in actual resuscitations. Providers were then divided into two groups based on the number of refreshers they had completed. Those who completed $\geq$2 refreshers/month (Frequent Refreshers [FREQ]) were compared to providers that completed <2 refreshers/month (Infrequent Refreshers [INFREQ]) for time to achieve CPR skill success.

In addition, after actual cardiac arrest resuscitations, CPR providers were asked to provide subjective feedback on Rolling Refresher efficacy (5-point Likert scale; 1 = poor to 5 = excellent).

2.4. Data analysis

A Microsoft Windows based software program, Q-CPR Review (Laerdal Medical, version 2.1.0.0, Stavanger, Norway), was used for the initial examination and analysis of chest compression data. Standard descriptive summaries (mean and standard deviation for parametric variables, median and interquartile range for non-parametric variables) of CPR quality parameters (rate, depth, leaning) were calculated during refresher sessions. Univariate analysis was performed using non-parametric methods (Wilcoxon rank-sum, STATA 8.0, STATA Corporation, College Station, TX). A p-value less than 0.05 was considered statistically significant.

3. Results

Over the course of 15 weeks, 420 "Refresher" sessions were conducted in the PICU. Refreshers were completed by nurses 340 times, physicians 34 times, and respiratory therapists 46 times. All were previously trained and certified in basic life support according to the

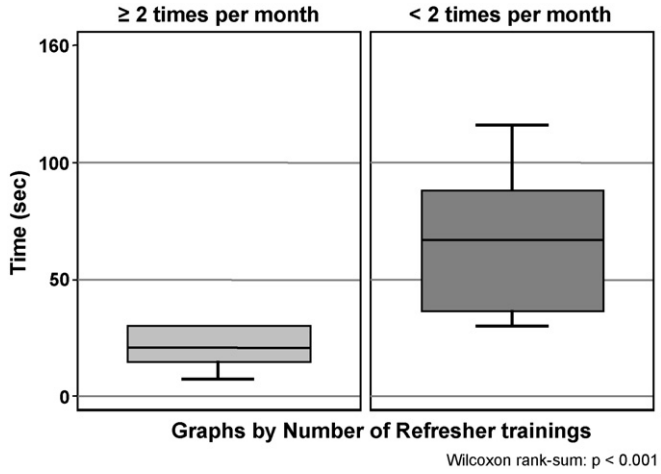

Figure 2. Box plot diagram demonstrating time to achieve chest compression skill success per group.

AHA standards according to hospital policy. Individual participation frequency ranged from 0 to 15 refresher sessions.

A consecutive sample of 20 PICU staff was assessed over the course of one day before subsequent refresher sessions. Of those 20, 10 subjects had been previously refreshed ≥2 times/month (FREQ) and 10 subjects had been refreshed <2 times/month (INFREQ).

Figure 2 displays the time (s) to obtain skill success. Time to achieve CPR skill success in those refreshed ≥2 times/month (FREQ, median 21 s, IQR: 15.75–30 s) was significantly less then those that refreshed <2 times/month (INFREQ, median 67, IQR: 41.5–84 s) ($p < 0.001$ by Wilcoxon rank sum test).

Following actual cardiac arrest resuscitations, the healthcare providers involved in delivering chest compressions ($n = 9$) reported having been previously "Refreshed" a median of one time (IQR: 1–5) and rated "Rolling Refresher" training as effective (mean 4.2 on a Likert scale of 1 = poor to 5 = excellent; standard deviation 0.67).

4. Discussion

Our study demonstrates that a 'just-in-time' and 'just-in-place' educational program aimed at optimizing psychomotor skill performance during CPR is feasible and was well-accepted by participants. Our data also suggest that healthcare providers who underwent these sessions more frequently displayed better skill performance during subsequent assessments, as measured by our set of prospective criteria for manikin skill success.

Our novel sessions were brief (<5 min), focused entirely on the psychomotor aspects of CPR and the specific needs of the bedside provider. Targeted towards the bedside healthcare providers of the children subjectively identified at highest risk of impending cardiac arrest, our objective was to refresh the skills of those providers to prepare them to deliver the best CPR possible in the event of an arrest. With audiovisual feedback turned on, providers repeating multiple refresher training sessions were noted to adjust towards optimal chest compressions significantly faster than providers completing less than 2 refresher training sessions/month. Furthermore, the healthcare providers involved in delivering chest compressions during actual resuscitations valued the efficacy of this novel education method.

An increase in the quality of chest compressions has been previously reported with a one-time basic life support (BLS) refresher training in nurses.[20] Not surprisingly, greater self-confidence, recent BLS training and recent performance of CPR during actual cardiac arrest were among the determinants associated with better quality BLS. Sutton et al. demonstrated that using a Voice Advisory Manikin (VAM) with corrective audio feedback can improve the initial skill acquisition of one-rescuer pediatric BLS skills in lay providers when compared to high quality individualized human instruction.[21] The mechanism of improved CPR skill competence in Sutton's study may have been related to faster acquisition of skill proficiency with the corrective audio feedback. Nonetheless, multiple studies suggest that chest compression quality continues to be sub-optimal after CPR training and could be contributing to the poor performance in clinical practice.[16–18,22]

The quality of actual CPR has been shown to be poor in adult cardiac arrest resuscitation attempts and the importance of high quality CPR for improved survival suggests a critical need for novel methods to improve the quality of CPR. Two possible targets for improving CPR psychomotor skill delivery are (1) directive and corrective audiovisual feedback and monitoring of CPR quality during resuscitation attempts, and (2) novel bedside educational programs that bring the teaching to the bedside where the care is provided in a frequent, just-in-time manner. We have termed the latter "Rolling Refreshers".

Data obtained from quality assurance of our clinical cardiac arrest resuscitations suggests that the quality of CPR delivered was very good and exceeded the chest compression quality reported in adult studies.[2,3,5,23] The chest compression data from cardiac arrest resuscitations in our institution demonstrate an adequate compression rate 57% of the time, adequate depth 73%, and no flow time approximately 10%.[23] In contrast, adult studies report an adequate compression rate only 31% of the time, adequate depth 63%, and no flow time approximately 50%.[3] Only modest improvement in the quality of CPR during in-hospital cardiac arrest was found with audiovisual feedback[4,24] but without a pre-emptive Rolling Refresher strategy.

Importantly, despite the departure from routine certification practice and the increase in bedside responsibilities, healthcare providers valued the efficacy of this novel education method. After participating in actual cardiac arrest resuscitations, CPR providers rated the efficacy of the Rolling Refresher training program a 4.2 (Likert scale: 1 = poor, 5 = excellent, standard deviation 0.67).

Since implementing the Rolling Refresher program, over 2200 sessions have now been conducted in the PICU and Emergency Department and continue to be well-accepted by individual staff members. Several staff have completed more than 25 refresher training sessions. Our goal is to improve the quality of CPR by assuring that front-line staffs for at-risk patients are confident and competent to deliver excellent quality CPR.

5. Limitations

There are several limitations to this study. A small, consecutive sample was used to confirm the effectiveness of frequent refresher training in the provider's competence in CPR. We attempted to analyze the actual clinical performance of the trained staff; however, the resuscitation events were infrequent to achieve this purpose. This was originally designed as a quality improvement check, and should be confirmed in a larger, randomized study sample across multiple units. Also, the psychomotor skill testing was conducted on manikins. We cannot confirm that the improved quality of chest compressions provided during refreshers on manikins will translate to performance during actual cardiac arrest compressions or that this is generalizable to other settings and institutions.

Objective ICU predicted patient mortality scoring systems were not utilized during this study. Instead, the 5 most critically ill patients, those at highest risk of suffering a cardiac arrest, were subjectively identified by the clinical teams managing the PICU. Due to this subjective selection, we cannot determine if there was potential for self-selection, which deserves further clarification in a future study.

In addition, we had to arbitrarily select a cut-off for the definition of Frequently Refreshed (>2 refreshers/month) vs. Infrequently Refreshed (<2 refreshers/month) providers. Future studies to clarify the dose–response relationship for refresher training to maintain CPR skill competence are necessary. Our initial study thus suggests feasibility and efficacy of a "Rolling Refresher" program in our single institution setting. Much work remains to address effectiveness and efficiency of such a program in generalized settings.

6. Conclusions

A novel "Rolling Refresher" bedside CPR skill training approach using "just-in-time" and "just-in-place" education is effective and well received by PICU staff despite bedside responsibilities and time constraints. Participation in ≥2 refreshers/month resulted in significantly shorter duration to achieve proficient CPR skills on manikins. Bedside providers delivering CPR during actual cardiac arrests rated the Rolling Refresher method as highly effective. CPR performance during actual cardiac arrest resuscitations exceeded reported quantitative metrics of CPR quality in adult patients suggesting a positive effect of "Rolling Refresher" training. Further study is needed to determine timing, intensity, frequency and types of psychomotor refresher CPR training to maintain effective CPR provider competence.

Conflicts of interest

The authors acknowledge the following potential conflicts of interest. Dana Niles, Vinay Nadkarni and Robert Sutton receive grant support from the Laerdal Foundation for Acute Care Medicine. Vinay Nadkarni receives unrestricted grant funding from NIH and Medical Education Technologies, Inc.

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