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Simulation and education

Low dose- high frequency, case based psychomotor CPR training improves compression fraction for patients with in-hospital cardiac arrest

Ashish R. Panchal[a,*], *Gregory Norton*[a], *Emily Gibbons*[a], *Jeri Buehler*[a], *Michael C. Kurz*[b]

[a] *The Ohio State University Wexner Medical Center, Columbus, OH, United States*
[b] *University of Alabama School of Medicine, Birmingham, AL, United States*

Abstract

Background: High quality cardiopulmonary resuscitation (CPR) is critical to improve survival from cardiac arrest. While low dose- high frequency case-based training enhances CPR skill retention, it is unclear if this training method is feasible in a clinical environment and if it yields improved clinical CPR quality during in-hospital cardiac arrest. We evaluated the implementation of a novel platform providing low dose- high frequency psychomotor CPR training and its impact upon CPR quality.

Methods: The described training platform was launched on two nursing units (60 beds) in a university teaching hospital. Quarterly utilization of the platform was integrated into normal clinical duties of hospital staff. Simulated CPR performance and staff compliance were evaluated pre- and post-intervention. In addition, clinical CPR performance was evaluated for periods of six months before and after four quarters of implementation (median, IQR).

Results: The low dose, high frequency CPR training led to retention of simulated CPR skills (compression rate, depth and fraction) during each quarter exceeding high-quality guideline thresholds. Clinical CPR quality, measured by compression fraction (Pre: 83% (73, 95) and Post: 93% (88, 98), $p < 0.001$) and rate (Pre: 109 (96, 126) and Post: 120 (108, 130), $p = 0.008$) increased significantly following platform implementation. Over the intervention period, program compliance was greater than 97%.

Conclusions: Low dose-high frequency case based psychomotor CPR training is feasible in a clinical setting with high compliance. In two nursing units, this method of training resulted in enhanced CPR skill retention and improved in-hospital clinical CPR quality.

Keywords: Psychomotor training, Cardiopulmonary resuscitation, Education, Compression fraction, In-hospital cardiac arrest

Introduction

Approximately 209,000 patients experience in-hospital cardiac arrest (IHCA) annually in the United States with an overall survival rate of approximately 25%.[1–3] However, there is significant variability in in-hospital survival with adjusted survival rates varying from 12.3% to 22.7% (bottom and top decile) with a 42% difference in odds of survival between similar hospital facilities.[4,5] The exact cause of this large variation in survival has not been clearly delineated, though, one specific cause may be the quality of cardiopulmonary resuscitation (CPR) provided.[6] Parallel variability among in-hospital CPR delivery has been observed with high quality CPR playing a significant role in positive patient outcomes.[7–13] Such variability suggests the consistent provision of high quality CPR to IHCA patients is critical.

As outlined by Meaney in 2013, identifying barriers to high quality CPR is essential to improve resuscitation performance.[6] While most providers retrain in CPR every two years, evidence indicates CPR

* Corresponding author at: 760 Prior Hall, 376 West 10th Avenue, Columbus, OH, 43210, United States.
E-mail address: ashish.panchal@osumc.edu (A.R. Panchal).

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skills degrade within three to six months of training without regular practice opportunities.[14–18] Many providers lack the opportunity to perform CPR, in training and clinical situations, resulting in critical CPR skills degradation.[19] One emerging strategy to maintain CPR skill competency is the use of low dose-high frequency case based simulation training for providers.[19,20] Using this method, including simulation training sessions at 3 month regular intervals, CPR skills retention by providers doubled.[20] It is unclear if this training is feasible and effective in a clinical in-hospital environment for long term CPR training and skills retention. In addition, whether utilizing this training method yields improved CPR quality during clinical IHCA events.

We sought to evaluate the feasibility and compliance with a novel low dose-high frequency case based mobile psychomotor CPR training platform in an in-hospital setting replacing standard basic life support (BLS) recertification. We evaluated: (1) the effectiveness of low dose-high frequency CPR training for maintenance or improvement of CPR skills, (2) participant compliance with these training methods, and (3) CPR performance during clinical IHCA following the implementation of this CPR training.

Methods

Study design

This evaluation is a prospective before-after intervention study following the launch of a novel low dose high frequency case based mobile psychomotor CPR training platform which replaced our standard BLS recertification (Resuscitation Quality Improvement [RQI], American Heart Association, Dallas, Texas). The study was conducted at a tertiary care medical centre where simulation-based CPR training and clinical CPR performance of in-hospital clinical staff was routinely measured. Subjects included staff members (nurses and patient care associates PCAs) assigned to clinical duty in two hospital floors where the platform was launched in place of traditional bi-annual CPR training that these staff members must complete. This study was provided exemption as a quality improvement project by the institutional review board at The Ohio State University Wexner Medical Centre.

Intervention

The case based psychomotor mobile CPR training platform was launched in the in-hospital setting October 2014 and monitored through October 2015 on two cardiology hospital floors (non-ICU) in a tertiary care medical centre (Fig. 1). The simulation stations were placed in the nursing units with training activities integrated into normal clinical duties. Each quarter, participants were required to perform different activities to enhance baseline CPR training. The four quarter activities were:

Quarter 1: baseline basic life support training (combined training of compressions and respirations

Quarter 2: separate focused training of compressions and ventilations

Quarter 3: separate focused training of compressions and ventilations

Quarter 4: training focused on combined one rescuer performance of compressions and ventilations

These training activities were purposely selected and designed to confirm behavioural skills development of both compressions and ventilation separately (Quarters 2 and 3) and then to build on these experiences in a combined compression and ventilation exercise (Quarter 4). Subjects were required to achieve a passing score for each activity, per the standards set by the platform. If participants did not pass, skills stations are programmed to provide feedback on skills so that participants can remediate and complete the exercise. Through this mechanism, all clinical staff on the target floors were retrained in CPR quarterly with feedback provided at each session. This was done over a one year time period. Simulation data (i.e. rate of compressions and ventilations, etc.) was collected by the psychomotor station using a cloud-based, turn-key learning and training management system (American Heart Association, Dallas, TX and Laerdal Medical, Stavanger, Norway). Simulation data was analysed for all participants who completed four quarters of the psychomotor station training.

Clinical data collection

As part of the program deployment, an *a priori* decision to evaluate in-hospital clinical CPR quality metrics both before (Pre-RQI) and after

Fig. 1 – Image of the Resuscitation Quality Improvement™ (RQI) system.

(Post-RQI) implementation was made. Pre-RQI was defined as a 6-month period without RQI implementation while Post-RQI was defined as a 6-month period following completion of four quarters of RQI training. As part of the normal quality improvement activities at the medical centre, clinical CPR metrics are collected from clinical defibrillators (Stryker formerly PhysioControl, Redmond, WA) for all cardiac arrests in-hospital. Continuous ECG and impedance recordings were available from each IHCA case and evaluated using proprietary software (CODE-STAT-10, Stryker, Redmond, WA) (Fig. 2). The software automatically evaluates and annotates compression reports from each IHCA event. Each report was then manually reviewed to confirm and correct report annotations as appropriate and record CPR performance. Compressions were evaluated per minute epoch of cardiac arrest event. Compression fraction was defined as the total time with chest compressions divided by interval of time measured.[6] This data was de-identified and stored in a cardiac arrest database for review by the resuscitation committee at the medical centre.

Outcome measures

Real world feasibility and performance of the case-based psychomotor CPR training station was assessed through evaluations of: (1) the effectiveness of low dose-high frequency CPR training for maintenance or improvement of CPR skills in place of a certification course, (2) participant compliance with these training methods, and (3) CPR performance during clinical IHCA following the implementation of this CPR training (both Pre-RQI and Post-RQI). Outcomes variables for each were defined *a priori*. Data on compression and ventilation performance, specifically compression depth (mm), rate (compressions/min), adequate release (%), ventilation rate (breaths/min), and tidal volume (ml)[6] from the psychomotor simulation station was collected. Compliance with the psychomotor station was evaluated over one year, monitoring whether participants were able to successfully complete the activity during each assigned quarter. Finally, clinical CPR metrics from clinical IHCA events in the targeted clinical settings were obtained from the quality improvement dataset and evaluated for compression fraction and compressions/min during the Pre-RQI period (January–June 2014) and the Post-RQI period (completion of 4 quarters of training) (January–June 2016).

Statistical analysis

Data was analysed with Stata® 14 (StataCorp. 2015, College Station, TX). Descriptive statistics (medians) with interquartile ranges were calculated. Simulation data from the psychomotor station was evaluated for (1) performance of separate compressions and ventilation skills and (2) comparison of the separate skills to a combined compression and ventilation exercise. A Wilcoxon rank sum test was used to compare performance of participants between quarters 2 and 3 to evaluate for skill attainment of separate compression skills and ventilation skills. Quarters 2 and 4 were compared to evaluate potential difference between simulation activities done separately (compressions and ventilations-Quarter 2) to the combined compression and ventilation exercise (Quarter 4). A Wilcoxon rank sum test was done to compare clinical compression data (compression fraction and compression rate) Pre-RQI to Post RQI.

Results

The mobile case-based psychomotor CPR training platform was launched in October 2014. The total number of participants for the two nursing floors was 155 individuals which increased from the original enrollment of 140 individuals due to staff turnover and addition during the study period. All participants who started in the study completed all four quarters of training. The median age of participants was 37.8 (95% CI: 36–39.7). The majority of the participants were female (72.9%). Clinical staff composition was 29% patient care associates (unlicensed providers) and 71% nurses (licensed LPN or RN).

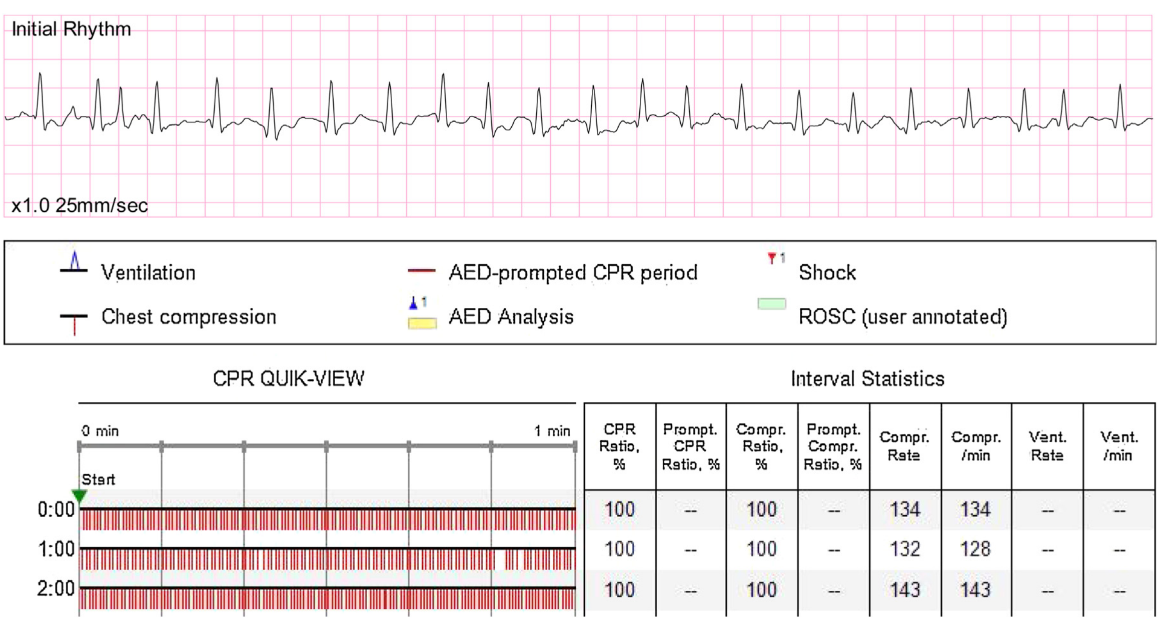

Fig. 2 – Image of the data provided by the physio control data entry system, CODE-STAT. Every compression given within the study time frame was recorded and evaluated.

Table 1 – Program compliance over the four quarters of the year. Lack of compliance was due primarily to medical leave exemptions with 1 participant who did not complete the training per quarter.

Quarter number	Total participants	Incomplete (n)	Complete (n)	Compliance (%)
Quarter 1 10/01/14 – 12/31/14	140	4	136	97.14%
Quarter 2 01/01/15 – 03/31/15	144	4	140	97.22%
Quarter 3 04/01/15 – 06/30/15	150	1	149	99.33%
Quarter 4 07/01/15 – 09/30/15	155	3	152	98.06%

Table 2 – Maintenance of CPR skills using the psychomotor stations. Participants performed separate compression and ventilation skills in Quarters 2 and 3. Data presented as median and interquartile ranges (IQR).

	Quarter 2 (IQR)	Quarter 3 (IQR)	P value
Compression depth (mm)	52.0 (50, 55)	52.0 (51, 55)	0.33
Compressions with Adequate depth (%)	97 (94, 99)	97 (94, 99)	0.77
Compressions with Adequate release (%)	99 (98, 99)	99 (99, 100)	0.26
Compression rate (cpm)	108 (103, 115)	109 (102, 113)	0.10
Compressions with Adequate rate (%)	83 (55, 95)	82 (65, 98)	0.76
Tidal Volume (ml)	526 (476, 569)	509 (461, 582)	0.76
Ventilation Rate (bpm)	11 (10, 12)	11 (10, 12)	0.27
Breaths with Adequate ventilations (%)	91 (83, 100)	91 (84, 100)	0.66

Participants were enrolled, and psychomotor skill activities were included in the normal workflow of the medical units. The compliance of participants to completion of the quarterly activities is noted in Table 1. For quarters 1 through 4, compliance was high (greater than 97%) with lack of compliance being primarily due to appropriate medical leave exemptions. Per quarter, there was one different delinquent participant.

During each quarterly activity, participants received simulation training with the goal of achieving a set passing score to confirm skills acquisition. To assure that trainees maintained skills in subsequent training sessions, the quality of simulated CPR provided by participants when compression and ventilation skills were trained separately was evaluated (Table 2). Between Quarters 2 and 3, there were no difference in compression (depth, rate, release) or ventilation (tidal volume, rate) skill attained using the psychomotor skills station.

Table 3 demonstrates simulation skills performance when compressions and ventilations were trained separately (Quarter 2) or combined in one exercise (Quarter 4). In this evaluation, psychomotor station data demonstrated increased compressions with adequate rate (Quarter 2: 83% to Quarter 4: 90%, $p = 0.01$). However, there was a decreased tidal volume (Quarter 2: 526 ml to Quarter 4: 478.5 ml, $p = 0.004$), ventilation rate (Quarter 2: 11 bpm to Quarter 4: 6 bpm, $p < 0.001$) and breaths with adequate ventilations (Quarter 2: 91% to Quarter 4: 66%, $p < 0.001$). There was no significant difference in compression depth or rate and no clinically significant change in the compressions with adequate release.

Clinical compression data from in-hospital cardiac arrest cases treated before (Pre-RQI) and after (Post-RQI) were evaluated (Table 4). A total of 20 in-hospital cardiac arrest events occurred on the two nursing floors during the study period (Pre-RQI: 11; Post RQI: 9) with a total of 19,943 compressions performed. Compression fraction improved Pre-RQI to Post RQI from 83% to 93%, respectively ($p < 0.001$). In contrast, compressions per minute increased Pre-RQI to Post RQI (Pre: 109 and Post: 120, $p = 0.008$).

Table 3 – Comparison of psychomotor skill assessments when participants performed skills separately (compressions and ventilations) and combined (Quarter 2 vs Quarter 4). Data presented as median and interquartile ranges (IQR).

	Quarter 2 (IQR)	Quarter 4 (IQR)	P value
Compression depth (mm)	52 (50, 55)	52 (50, 55)	0.43
Compressions with adequate depth (%)	97 (94, 99)	96 (93, 98)	0.16
Compressions with adequate release (%)	99 (99, 99)	99 (99, 100)	0.038
Compression rate (cpm)	109 (103, 115)	108 (104, 112)	0.28
Compressions with adequate rate (%)	83 (55, 95)	90 (75, 97)	0.01
Tidal volume (ml)	526 (476, 569)	478.5 (391, 527)	0.004
Ventilation rate (bpm)	11 (10, 12)	6 (5, 6)	<0.001
Breaths with adequate ventilations (%)	91 (83, 100)	66 (50, 83)	<0.001

Table 4 – Comparison of clinical CPR quality pre-RQI vs post-RQI (median, IQR). Participants had improved compression fractions and increased compressions per minute.

	Pre-RQI	Post-RQI
Cardiac arrest events	11	9
Total compressions performed	6038	13905
Compression fraction (%)	83 (73, 95)	93* (88, 98)
Compressions rate (comp/min)	109 (96, 126)	120* (108, 130)

* $p < 0.05$.

Discussion

In this analysis of a single site, prospective before/after study of IHCA, we observed excellent compliance and improvement in simulated CPR performance. Furthermore, the clinical performance of CPR improved when measured after completion of 1 year of psychomotor platform CPR training. Our results were consistent across other observed settings[16,17,19,20] and consistent with other literature regarding adult learning and performance frequency based competency and spaced training.[18] Our data originates from the first application of this novel platform in a clinical environment on an inpatient setting with the goal to replace a basic life support certification course. These observations support the use of this platform to maintain competency and improve CPR performance in clinical inpatient settings without the need for a certification course.

The use of increased frequency training has previously demonstrated improved CPR performance and skills retention.[20] Sutton et al. demonstrated that "booster" session training improved retention of CPR skills. In this setting, the simulated performance of "excellent CPR" increased from 26% to 65% when trained with automated feedback only.[20] Further, CPR skills were retained in subsequent assessments over a 6 month period. Similar success was also noted in frequent, short (6 min) monthly CPR training.[19] The data from this study builds on these previous evaluations with retention of skill quality after quarterly refreshers (Table 3). Participants maintained quality CPR over the course of one year through bolus training which led to improved clinical chest compression fraction Pre RQI to post RQI. Further, this study also details the effect of training type (separate versus combined skills) on CPR quality. During combined compression and ventilation exercises, psychomotor training participants demonstrated improved compression quality with a concurrent decrease in the quality of ventilation performance (Table 4). This is probably due to a greater focus being placed on compression quality rather than on ventilations by the simulation-based feedback system acknowledging the importance of chest compressions on outcome.[11,12]

Another specific advantage in the use of psychomotor stations is the high compliance with training due to the integration of training with normal clinical activities. This is a novel approach to CPR competency-based training which has not previously been described since this methodology replaces basic life support refresher courses. The design and structure of this intervention directly led to the high compliance rates of greater than 95%. This is since the follow up mechanism used to maintain staff compliance is the same as that used for other unit-based training common on these hospital floors. Using the already developed infrastructure to leverage competency-based training and proficiency maintenance may be essential to assure high quality in-hospital CPR.

Improving in-hospital cardiac arrest outcomes depends on the performance of high quality CPR.[6,12,21] However, in the hospital setting, staff working in non-critical care units may face cardiac arrest events infrequently and may not be prepared to provide high quality CPR leading to high variability in CPR performance.[7,8] In this evaluation, we demonstrated that CPR training through low dose- high frequency case based psychomotor stations is feasible and may improve in-hospital clinical chest compression performance and skills retention. Though compression fraction was improved, the compression rate was noted to be elevated post training. The cause of this is unclear however, previous work has demonstrated that higher compression rates by providers is not uncommon.[21,22] Further, it has been demonstrated that likelihood of return of spontaneous circulation is highest at compression rates of 125/min [22] but greatest survival to hospital discharge was associated with rates from 100−120.[11] With this in mind, future work will be directed at improving chest compression rate for in-hospital arrests as part of the training program.

Limitations

Though this study does demonstrate improvements in chest compression performance, there are several limitations to the study which need to be considered. First, as is common for provider training, all training and assessments of participants were conducted on a simulant and CPR performance on humans may be different. Also, CPR conducted at the psychomotor stations was performed for brief periods of time whereas during clinical cardiac arrest events, providers may be required to perform CPR for sustained time periods and thus quality may differ due to provider burnout. Further, the clinical data from this study evaluates hospital staff on two units of a hospital and thus may not be generalizable to other populations. We were also not able to differentiate which provider was performing CPR at a specific minute during the course of a code due to the number of individuals who arrive from the floor to perform CPR. Therefore, we looked at the staff as a whole to improve the global CPR quality of the 2 units. It is also possible that other factors could have contributed to the improved performance like the release of the 2015 American Heart Association Guidelines or individualized external training. Finally, this evaluation was not powered to evaluate clinical survival or neurological outcomes from in-hospital cardiac arrest. Further research is necessary to understand the effect of RQI on in-hospital cardiac arrest morbidity and mortality.

Conclusions

Low dose-high frequency case based psychomotor CPR training is a feasible method for enhancement of CPR skill retention with high compliance rates in the in-hospital setting. Further, this competency-based training model led to improved in-hospital clinical CPR quality. Further research is necessary to evaluate skill retention and the effect of RQI on in-hospital cardiac arrest morbidity and mortality.

Conflicts of interest

None declared.

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