



Cardiovascular

Bedside chest compression skills: Performance and skills retention in in-hospital trained pediatric providers. A simulation study



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ABSTRACT

Purpose: To assess the effects of a real-time feedback device and refresher sessions in acquiring and retaining chest compression skills.

Methods: Healthcare providers participated in refresher sessions at 3-time points (blocks) over 1-year. At each block, chest compression (CC) skills were assessed on an infant and adult task trainer, in one 2-min trial without feedback (blinded), and up to three 2-min trials with feedback (unblinded). Skills retention over time was explored at three time lags: 1–3, 3–6, >6 months. Data collected included chest compression rate (100–120/min), depth (4 cm for infants and 5 cm for adults), and recoil between compressions.

Results: Among 194 participants, achievement of excellent CC ($\geq 90\%$ of adequate compressions for all parameters) increased with feedback. Linear mixed models found significant ($p < 0.05$) improvement in rate, depth, and recoil. Performance between last unblinded trial in block 1 with the following blinded trial in block 2 significantly decayed in rate on both task trainers irrespective of time passed, while depth and recoil performance were maintained only for infants.

Conclusions: A real-time visual feedback device improved CC skills with better results in infants. Skills decayed over time despite two refresher sessions with feedback.

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1. Introduction

Delivering high-quality cardiopulmonary resuscitation (CPR) is an important determinant of patient outcome after cardiac arrest including long-term survival [1–3]. However, research has demonstrated that the quality of chest compressions (CC) provided by trained healthcare providers during actual cardiac arrest events is poor [1,4–6]. Further, healthcare professionals poorly retain adequate CC skills after basic life support or advanced cardiac life support training. Research has

proved that CPR skills and knowledge quickly deteriorate if not used or refreshed regularly [7–9]. The decay of CPR skills has been identified as a reason for poor CPR quality over the past 30 years [7,10,11].

American Heart Association (AHA) recommends that high-quality CPR should be an educational goal for healthcare providers to close the gap between actual and desired performance [12,13]. Pediatric resuscitation events are uncommon [14,15], which means that a trained provider may not participate in an actual event for months or years after training. Previous studies have demonstrated that refresher/training simulation sessions improve the performance of resuscitation teams [16–18]. As well, providers who are trained with corrective feedback devices have improved performance compared to providers who are trained without them [13]. However, data are limited to plan and implement refresher sessions to accomplish the desired skill performance and retention among providers.

This study was undertaken following our participation in a previous multicentre CPR quality study, which showed that our local CPR quality metrics were sub-par [5,19]. Its goal was to assess the effects of real-time visual feedback and short refresher sessions in acquiring and retaining CPR skills.

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2. Methods

2.1. Study design and setting

The University of Calgary Research Ethics Board approved this prospective, observational study and all participants provided informed consent. A 1-year 4-part CPR quality educational bundle was implemented in the Pediatric Intensive Care Unit (PICU) at Alberta Children's Hospital in Calgary, Alberta, Canada from September 2015 to September 2016. This bundle included 1) replacement of our previous defibrillator with the Zoll R Series® which includes CPR feedback technology (Zoll Medical Corporation, Massachusetts, USA), 2) twice monthly simulated cardiac arrest events, 3) cardiac arrest debriefing sessions, and 4) brief CPR retraining sessions "Rolling refreshers" to staff while working at the bedside [16]. This paper reports data captured during the refresher sessions.

2.2. Participants

All PICU attending physicians, nurse practitioners, registered nurses, respiratory therapists and rotating medical residents were eligible for inclusion. Participants were approached during their working shifts and completed a questionnaire at the beginning of the study to gather demographic and professional-related data. Participants were exempt from basic life support (BLS) provider training over the 1-year course of the study.

2.3. Refresher/assessment sessions

All refresher sessions involved assessments using two different sizes of task trainers, infant (Laerdal Resusci® Baby QCPR) and adult (Laerdal Little Anne®). Both task trainers were linked to a tablet (Laerdal SimPad®; Stavenger, Norway) that displays CC rate, depth, and recoil so that participants could visualize quality metrics and adjust in real-time. Each participant was initially asked to perform CC for 2 min in a blinded fashion either in the adult or infant task trainer; i.e. the tablet display was hidden from view. They were then asked to perform with the real-time feedback visible to them (i.e. unblinded) either up to three consecutive 2-min trials or until achieving 90% or higher of compressions in target for all CC quality parameters (rate, depth, and full chest recoil). At each assessment, participants randomly performed in the adult or infant task trainer first and after a 10-min break, they were asked to perform in the remaining task trainer. They had the option of stopping at any time if they felt they were too tired to continue.

Adequate CC were defined as: rate of 100 to 120/min for infants and adults, CC depth of at least 4 cm for infants and 5 cm for adults, and provider allowed for full chest recoil between compressions. [13] CC data were downloaded from the tablet, including the percentage of CC in target for rate, depth, and full chest recoil between compressions over the 2-min epochs (blinded and unblinded trials).

For the purpose of assessing the skill retention over time, after completing the first assessment (block 1), participants were invited to participate in retraining sessions (block 2 and block 3). The retraining sessions were scheduled according to individual availability, which resulted in sessions occurring during the following time intervals: between 1 and 3 months, between 3 and 6 months, and over 6 months following the initial training session.

2.4. Outcome measures of the study

Primary outcomes:

- 1) Effect of feedback device on CC performance, measured as the percentage of adequate CC for rate, depth, and chest recoil registered during blinded and unblinded trials (2-min epochs) at three-time points within that 1-year study period (i.e. blocks 1 to 3);

- 2) Proportion of participants achieving overall excellent CC, which is a composite variable that has been used in other CPR studies, [18,20] defined as 90% or higher of compressions in target for all CC quality parameters (rate, depth, and chest recoil); and 3) participants' skills retention over time, obtained by comparing CC performance from the last 2-min trial (unblinded) from the block 1 (baseline) with the blinded for the block 2 (reassessment) at three intervals (time lags): between 1 and 3 months, between 3 and 6 months, and over 6 months.

Secondary outcomes:

- 1) differences in CC performance between infant and adult task trainers, and 2) factors that influence the effect of the real-time visual feedback device on CC performance (including sex, discipline, size of task trainer (infant/adult), block number (study time points), 2-min trials (blinded/unblinded)).

2.5. Statistical analysis

Data were summarized as frequencies (%). Medians and interquartile ranges (IQR) were used as the assumption of normality was not met via the Shapiro-Wilk test.

We used linear mixed models to examine the effect of real-time feedback on CC performance and skills retention between assessments. This method is recommended for repeated measures with missing data and uneven spacing of the repeated measurements [21]. Initial candidate models to investigate the effects of real-time feedback included sex, discipline, size of task trainer, block number, 2-min trials (blinded/unblinded), and two and three-way interactions between task trainer, block and 2-min trials. For the effect of time lag on CC skills retention, we considered sex, discipline, time lag between previous unblinded assessment and blinded reassessment (three groups: 1–3 months, 3–6 months, > 6 months) and the two-way interaction between task trainer and time lag. Participant intercept was included as a random effect, modelled using an identity covariance matrix structure. Non-significant model terms and interactions ($P \geq 0.05$) were iteratively removed. Model fit of the final reduced covariate model with the random effect intercept was compared to the equivalent model with the random effect removed via the log-likelihood chi-square test. A P -value < 0.05 was associated with improved model fit inclusive of the random effect.

Significant differences ($P < 0.05$) in estimated marginal means between blinded and initial unblinded outcome measures stratified by block number and patient were assessed using post-hoc t -tests. Differences between final unblinded assessment of CC outcomes measured in block 1 and subsequent blinded assessment measured in block 2 stratified by time lag and patient were assessed using post-hoc t -tests with Bonferroni adjustment for multiple comparisons (adjusted $P < 0.017$). Additional post-hoc t -tests with Bonferroni adjustment assessed significance (adjusted $P < 0.017$) in measured CC outcomes between the three grouped time lag intervals. Calculated standard errors of the differences were adjusted for correlations between repeated measures of CPR outcomes. All statistical tests were completed using SPSS 19.0 software (IBM, Armonk NY, USA).

3. Results

3.1. Participant characteristics

Overall, 194 resuscitation team members were enrolled. Table 1 shows participant baseline characteristics stratified by discipline. The median age of participants was 31.5 years (IQR: 28, 38 years) and they had a median of 4 years of experience (IQR: 2, 9.75 years) in their current positions.

Table 1
Demographic and professional characteristics of study participants.

Characteristics frequency (%)	Discipline frequency (%)				Summary n = 194
	Registered nurses	Respiratory therapists	Physicians/nurse practitioners	Residents ^a	
	n = 95 (49)	n = 52 (26.8)	n = 13 (6.7)	n = 34 (17.5)	
Sex					
Female	89 (93.7)	38 (73.1)	10 (76.9)	20 (58.8)	157 (80.9)
Male	6 (6.3)	14 (26.9)	3 (23.1)	14 (41.2)	37 (19.1)
Years of experience ^b					
< 5	46 (56.8)	24 (60)	3 (33.3)	26 (96.3)	99 (63.1)
5–15	18 (22.2)	14 (35)	6 (66.7)	1 (3.7)	39 (24.8)
> 15	17 (21)	2 (5)	–	–	19 (12.1)
Last BLS course taken ^b					
< 6 months	24 (30.4)	18 (48.6)	2 (20)	20 (71.4)	64 (41.6)
7–12 months	44 (55.7)	13 (35.1)	1 (10)	5 (17.9)	63 (40.9)
1–2 years	11 (13.9)	6 (16.2)	2 (20)	3 (10.7)	22 (14.3)
> 2 years	–	–	5 (50)	–	5 (3.2)
CPR on manikin within 2 years ^b					
Yes	78 (97.5)	36 (97.3)	8 (80)	23 (92)	145 (95.4)
No	2 (2.5)	1 (2.7)	2 (20)	2 (8)	7 (4.6)
CPR on real patients within 2 years ^b					
Yes	35 (45.5)	20 (54.1)	9 (90)	9 (36)	73 (49)
No	42 (54.5)	17 (45.9)	1 (10)	16 (64)	76 (51)

^a Comprised of residents of Pediatrics, Anesthesia, Emergency, Respiriology, Neurology, and Pediatric Emergency Medicine.

^b Loss of data due to incomplete questionnaires.

At the end of the study, 95 (49%) participants completed one assessment, 67 (34.5%) completed two and 32 (16.5%) completed all three assessments. The time lag between the first two assessments, for the 99 participants who completed two or three of them was: 40 participants (40.4%) completed them between 1 and 3 months, 38 participants (38.4%) between 3 and 6 months, and 21 participants (21.2%) in longer than 6 months. Fig. 1 shows the number of participants per block per discipline. Table 2 displays the number of participants per trial.

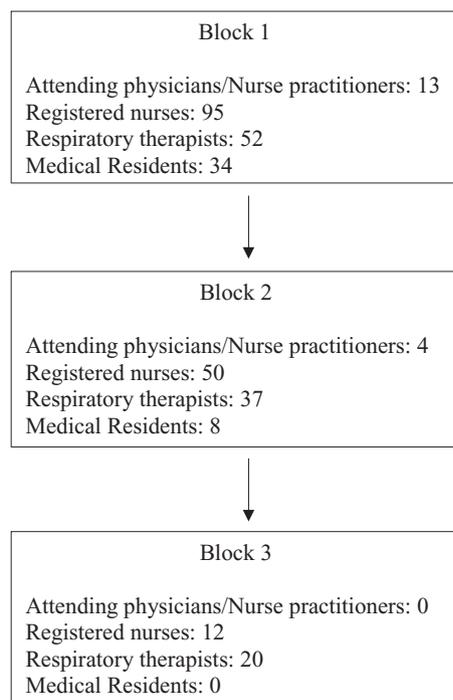


Fig. 1. Flow diagram of number of participants per block and their discipline. Note: Staff workflow issues, including short rotations for some residencies and leaves among staff, determined the drop-out in the study.

3.2. Chest compression performance

The medians of the percentage of compressions in target for rate, depth, and recoil were >90% for most of the trials and in both sizes of task trainers (Table 2). However, in blinded trials, lower medians and wider IQR were observed. The variability observed in blinded trials was less in the unblinded trials with real-time feedback. Medians >90% were achieved for rate performance in all unblinded trials in both task trainers. For depth performance however, two unblinded trials had medians below the 90% (block 2, trial 3 and block 3, trial 2). Recoil was in target during all three blocks, blinded and unblinded trials, in both sizes of task trainers. A greater number of unblinded trials were required for participants to achieve the quality target in the adult task trainer.

Table 3 summarizes the percentage of participants who achieved overall excellent CC. The lowest performances were seen in blinded trials compared to unblinded ones in each block, especially with the adult task trainer.

3.3. Linear mixed model in the analysis of the effect of real-time feedback on performance rate, depth and recoil

The final mixed model identified block number ($F = 3.240$, $P = 0.040$) and trial ($F = 355.129$, $P < 0.001$) as significant covariates in the prediction of rate performance (log likelihood $\chi^2 = 25.515$, $df = 1$, $P < 0.001$). Estimated marginal means for unblinded CC rate performances were significantly ($P < 0.05$) improved within all blocks compared to initial blinded results in both task trainers. Block number (i.e. study time point) and 2-min trial were significant covariates to predict rate performance (Table 4).

A significant improvement in depth was observed in unblinded trials in block 1 ($P < 0.05$) for infants. Although not statistically significant, the use of real-time feedback improved infant depth performance in relation to blinded performance in blocks 2 and 3. Statistically significant ($P < .05$) performance improvement occurred in all blocks using real-time feedback for the adult task trainer (Table 4). The significant covariates to predict depth performance identified in the final mixed model (log likelihood $\chi^2 = 55.576$, $df = 1$, $P < 0.001$) were: sex ($F = 4.993$,

Table 2

Percentage of chest compressions in target for rate, depth and recoil using infant and adult task trainers in blinded and unblinded real-time feedback assessment trials. Blocks 1–3 refer to study time points within the 1-year study period.

Number of participants/trial ^a		Compression rate (Percentage in target) Median (IQR: P25, P75)		Compression depth (Percentage in target) Median (IQR: P25, P75)		Compression recoil (Percentage in target) Median (IQR: P25, P75)	
Infant	Adult	Infant	Adult	Infant	Adult	Infant	Adult
Block 1							
Blinded		73	87.5	100	73	99	100
194	194	(23, 97)	(31, 98)	(98, 100)	(8, 100)	(90, 100)	(96, 100)
Unblinded trial 1		96	99	100	96	100	100
194	194	(92, 99)	(93, 100)	(99, 100)	(89, 100)	(99, 100)	(99, 100)
Unblinded trial 2		97	99	100	92	100	100
35	50	(89, 100)	(91, 100)	(100, 100)	(76, 97)	(90, 100)	(98, 100)
Unblinded trial 3		96	95.5	100	90	100	99.5
11	18	(88, 99)	(87, 99)	(98, 100)	(65, 94)	(96, 100)	(97, 100)
Block 2							
Blinded		91	94	100	96	100	100
98	99	(41, 99)	(51, 100)	(100, 100)	(35, 100)	(99, 100)	(99, 100)
Unblinded trial 1		96.5	99	100	99	100	100
98	99	(95, 99)	(97, 100)	(100, 100)	(92, 100)	(100, 100)	(100, 100)
Unblinded trial 2		96.5	99	100	96	99.5	100
8	19	(94, 100)	(97, 100)	(99, 100)	(90, 100)	(98, 100)	(100, 100)
Unblinded trial 3		100	94	100	86	100	100
1	3						
Block 3							
Blinded		92	79	100	93	100	100
31	32	(40, 99)	(22, 98)	(97, 100)	(22, 100)	(99, 100)	(93, 100)
Unblinded trial 1		96	99	100	98	100	100
31	31	(94, 100)	(96, 100)	(99, 100)	(87, 100)	(99, 100)	(99, 100)
Unblinded trial 2		98	97.5	100	70.5	100	100
6	6	(92, 99)	(93, 99)	(96, 100)	(51, 90)	(99, 100)	(98.5, 100)
Unblinded trial 3		-	-	-	-	-	-

IQR: interquartile range.

^a The number of participants decreased per trial within each block as participants achieved the goal of 90% of compressions in target or stopped because of fatigue.

$P = 0.027$: overall estimate males = 90.27 (95% CI: 85.79–94.74), females = 84.91 (95% CI: 82.49–87.33), block number ($F = 5.339$, $P = 0.005$), trial ($F = 171.237$, $P < 0.001$), size of task trainer ($F = 214.076$, $P < 0.001$) (i.e. significantly greater depth in infant than adult), and the interaction between trial and size of task trainer ($F = 65.218$, $P < 0.001$).

Statistically significant ($P < 0.05$) improvements in unblinded CC recoil estimated marginal means were limited to block 1 for both task trainers (Table 4). Although not statistically significant, real-time feedback improved recoil performance within blocks 2 and 3 for infants and adults. Mixed model analysis to predict recoil performance identified sex ($F = 9.049$, $P = 0.003$; overall estimate males = 92.63 (95%

Table 3

Proportion of participants achieving overall excellent CPR, better than 90% of chest compressions performed in target for rate, depth, and recoil.

Block	Trial	Frequency (%)	
		Infant	Adult
1	Blinded	54/194 (28.9)	33/194 (17.6)
	Trial 1	149/194 (78.8)	122/194 (65.6)
	Trial 2	23/35 (65.7)	23/50 (46)
2	Blinded	7/11 (63.6)	4/18 (22.2)
	Trial 1	45/98 (46.4)	27/99 (27.3)
	Trial 2	90/98 (91.8)	73/99 (73.7)
3	Blinded	7/8 (87.5)	15/19 (78.9)
	Trial 1	1/1 (100)	1/3 (33.3)
	Trial 2	15/31 (48.4)	8/32 (25)
3	Blinded	25/31 (80.6)	21/31 (67.7)
	Trial 1	5/6 (83.3)	2/6 (33.3)
	Trial 3	-	-

Table 4

Estimated marginal means from linear mixed model analysis to predict performance of chest compressions rate, depth, and recoil using infant and adult task trainers between blinded and unblinded real-time feedback assessment trials.

Skill	Block	Trial	Estimated marginal means (95% CI)	
			Infant	Adult
Rate	1	Blinded	60.86 (56.96–64.76)	67.73 (63.84–71.62)
		Unblinded	93.63* (89.75–97.51)	93.16* (89.25–97.07)
	2	Blinded	69.07 (63.69–74.44)	72.83 (67.51–78.16)
		Unblinded	94.47* (89.12–98.82)	95.78* (90.46–101.10)
	3	Blinded	67.34 (58.02–76.85)	63.25 (53.98–72.52)
		Unblinded	93.27* (83.86–102.29)	92.26* (82.85–101.68)
Depth	1	Blinded	90.78 (87.25–94.31)	58.02 (54.50–61.54)
		Unblinded	98.22* (94.71–101.73)	88.75* (85.21–92.29)
	2	Blinded	94.00 (89.16–98.84)	69.32 (65.14–74.73)
		Unblinded	98.48 (93.66–103.29)	92.47* (87.67–97.26)
	3	Blinded	90.22 (81.82–98.63)	65.77 (57.50–74.05)
		Unblinded	96.84 (88.43–105.24)	86.80* (78.39–95.20)
Recoil	1	Blinded	87.70 (85.59–89.80)	90.48 (88.38–92.58)
		Unblinded	97.91* (95.82–100.00)	98.65* (96.54–100.76)
	2	Blinded	97.87 (94.99–100.75)	94.57 (91.71–97.42)
		Unblinded	98.47 (95.60–101.33)	99.04 (96.19–101.89)
	3	Blinded	96.47 (91.48–101.47)	94.45 (89.53–99.36)
		Unblinded	98.96 (93.96–103.95)	98.75 (93.76–103.75)

CI: Confidence Interval.

* Significant improvement ($P < 0.05$) in Chest Compressions outcome between blinded and unblinded estimated marginal means as compared per block.

CI: 89.99–95.27), females = 96.88 (95% CI: =95.45–98.31)), block number ($F = 9.500$, $P < 0.001$), trial ($F = 26.185$, $P < 0.05$) and the interaction between block number and trial as significant covariates (log likelihood $\chi^2 = 26.476$, $df = 1$, $P < 0.001$). Recoil was less susceptible to improving with feedback but the baseline measurements of recoil were greater than rate and depth and so less room for improvement in this skill.

3.4. Participants' skills retention

CC rate performance significantly degraded from the final unblinded trial (i.e. with feedback device) in block 1 (baseline) to blinded results in block 2 using both infant and adult task trainers. Significantly (P -adjusted < 0.017) lower rate performance was associated with all time lag intervals (Table 5). Time lag was a significant covariate that predicted rate ($F = 33.565$, $P < 0.001$; log likelihood $\chi^2 = 4.089$, $df = 1$, $P = 0.043$).

CC depth performance was maintained for infant task trainer irrespective of the time passed between unblinded and the subsequent blinded trial. Participants did not retain depth performance on the adult task trainer with significantly (adjusted $P < 0.017$) lower blinded performance at all time lag intervals (Table 5). Mixed model analysis identified time lag ($F = 11.069$, $P < 0.001$), simulated patient ($F = 55.491$, $P < 0.001$) and their interaction ($F = 5.584$, $P = 0.001$) as significant covariates of depth performance prediction (log likelihood $\chi^2 = 6.156$, $df = 1$, $P = 0.013$).

Statistically significant reductions (adjusted $P < .017$) in recoil performance were noted on the adult task trainer between baseline and time lags of 1–3 months and > 6 months. Performance was significantly higher (adjusted $P < .017$) at a time lag of 3–6 months compared to 1–3 months (Table 5). Mixed model recoil prediction was significantly affected by time lag ($F = 4.815$, $P = 0.003$; log likelihood $\chi^2 = 8.360$, $df = 1$, $P = 0.001$). Recoil performance was maintained irrespective of time lag interval for the infant task trainer.

4. Discussion

In this study, the percentage of participants who performed over the expected goal of 90% of compressions in target was low, especially in

Table 5

Estimated marginal means from linear mixed model analysis to predict chest compressions rate, depth and recoil performance using infant and adult task trainers as a function of time lag between final block 1 unblinded (baseline) and initial blinded block 2 trials.

Skill	Time lag (months)	Estimated marginal means (95% CI)	
		Infant	Adult
Rate	Baseline	96.57 (91.36, 100)	97.52 (92.41, 100)
	1–3	66.36 ^a (57.46, 75.26)	77.6 ^a (69.10, 86.12)
	3–6	68.94 ^b (60.77, 77.11)	71.18 ^b (63.22, 79.14)
	> 6	78.43 ^c (67.95, 88.92)	71.19 ^c (60.70, 81.68)
Depth	Baseline	98.57 (93.98, 100)	92.91 (88.42, 97.40)
	1–3	95.63 (87.84, 100)	72.1 ^a (64.69, 79.61)
	3–6	94.45 (87.29, 100)	69.5 ^b (62.59, 76.56)
	> 6	94.67 (85.48, 100)	74.18 ^c (64.99, 83.64)
Recoil	Baseline	99.29 (97.45, 100)	99.40 (97.60, 100)
	1–3	98.22 (95.10, 100)	92.41 ^{a,d} (89.42, 95.39)
	3–6	97.62 (94.75, 100)	96.9 ^d (94.16, 99.75)
	> 6	98.11 (94.43, 100)	93.96 (90.28, 97.63)

Significant difference (adjusted $P < 0.017$) between

^a baseline outcome and time lag of 1–3 months.

^b baseline and time lag of 3–6 months.

^c baseline and time lag of >6 months.

^d Significant difference (adjusted $P < 0.017$) between adult recoil measurements at 1–3 months and 3–6 months.

blinded trials. Therefore, we concur with other authors in that trained healthcare providers struggle to provide high-quality CPR [5,22]. We demonstrated that a real-time feedback device improved performance for rate, depth, and recoil in both sizes of task trainers in the 3-time points measured. As well, a greater percentage of providers achieved the goal of overall excellent CPR using real-time feedback. This study proved the value of knowing the percentage of participants providing CC according to the guidelines for CC rate, depth, and full recoil, along with the percentage of compressions in target to better assess the skills of providers.

These findings concurred with previous studies that have reported a statistically significant increase in the percentage of CC within AHA guideline with a feedback device [13]. In general, visual feedback helps rescuers attain adequate rate, depth, and recoil [5,23–25]. Feedback devices with continuous auditory feedback have been found by others to be more effective than visual feedback for compression rate in infant and adults, but not for depth performance [26,27]. Considering that participants in this study achieved the expected rate using visual feedback but not the expected depth with the adult task trainer, it is unlikely that the type of feedback used limited the improvement. In addition, feedback devices prevent CPR skills from deteriorating while compressing over time [28,29]. However, in our study, refresher sessions did not prevent the CC skills from deteriorating in the long term.

Unlike two previous studies [30,31], where training using a feedback device also improved CC skills retention over time; we found a decline in these skills irrespective of the time passed between two assessments. Research has documented the loss of ability to compress within adequate guideline starting at 3 months after training [7,16,17,32,33]. However, our results showed decay of skills in a shorter time (1–3 months). The different study designs may explain this difference, particularly the set times for reassessment.

Sutton et al. found that the skills are better retained after two previous trainings and with the use of a live instructor [18]. Oermann et al. confirmed that short monthly trainings maintain or improve nursing students' CPR skills over a year period [17]. Our results support the need for >2 training sessions as we saw no rate and depth performance retention when comparing just 2 of them. Our results could not support any adequate interval for retraining, but the feasibility of offering short refresher sessions monthly should be explored, considering the low rate of cardiac arrest in pediatric units, and the rapid decay of the skills among participants. As recommended by Perkins, creative methods to increase staff involvement need to be in place [12].

The decline observed was significantly greater using an adult task trainer. Providers retained the skills to compress to the guidelines for CC depth and recoil on an infant task trainer, but not on an adult one. We are aware of no reports of simulations comparing retention of skills on adult versus infant manikins over time. Badaki-Makun et al. demonstrate that performance deteriorates similarly in 10-min sessions on an adult and infant manikin and the overall work needed to compress is similar in both [34]. However, our results showed how a greater number of participants were required to compress on the adult task trainer in the subsequent trials 2 and 3 because they did not achieve the goal of 90% of adequate CC. Pediatric providers are less accustomed to adult size patients in real life so this may have impacted their performance with the adult task trainer. Future studies may help elucidate if this is a reproducible result.

4.1. Study limitations

This study has several limitations. First, we were unable to assess the chest compression skills at the designed 3-time points for a major percentage of the participants due to drop-out seen. However, we collected sufficient data to assess the level of their bedside skills and applied statistical methods to overcome the issues regarding missing data.

Second, the measured performance may be influenced by several situations: participants learned from their performance at the baseline (first 2-min) blinded assessment, as they were aware of their results when they finished, this learning may account for some improvement seen at unblinded trials. Participants were working their regular shifts and participated in the assessments when they had time, but fatigue or focus on their patients could have distracted them to fully perform. Most of the providers were exempt from BLS provider courses over the project length but they may have been part of actual events. As part of the educational bundle described above, some of them participated in at least one simulated resuscitation event. Furthermore, the performance in simulated patients may not be the same in a real patient, and these skills should be assessed to fully understand the skills of PICU resuscitation team members.

5. Conclusions

Bedside CPR skills of trained in-hospital providers were poor at baseline but improved with real-time visual feedback. Two refresher sessions using feedback did not prevent skills to decay over time, especially on an adult task trainer. Therefore, a better performance is expected in infants than in adults. This study revealed what to expect from providers' performance on any given day after training, emphasizing utilization of feedback devices both for training purposes and real patient care. Short rolling refresher trainings should be implemented regularly to overcome poor performance and decay of CPR skills.

Conflict of interest

None

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