Impact of Simulation Training on Time to Initiation of Cardiopulmonary Resuscitation for First-Year Pediatrics Residents

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Abstract

Background Pediatrics residents have few opportunities to perform cardiopulmonary resuscitation (CPR). Enhancing the quality of CPR is a key factor to improving outcomes for cardiopulmonary arrest in children and requires effective training strategies.

Objective To evaluate the effectiveness of a simulation-based intervention to reduce first-year pediatrics residents' time for 3 critical actions in CPR: (1) call for help, (2) initiate bag-mask ventilation, and (3) initiate chest compressions.

Methods A prospective study involving 31 first-year pediatrics residents at a children's hospital assigned to an early or late (control) intervention group. Residents underwent baseline assessment followed by repeat evaluations at 3 and 6 months. Time to critical actions was scored by video review. A 90-minute educational intervention focused on skill practice was conducted following baseline evaluation for the early-intervention group and following 3-month evaluation for the late-intervention group. Primary outcome was change in time to initiating the 3 critical actions. Change in time was analyzed by comparison of Kaplan-Meier curves, using the log-rank test. A 10% sample was timed by a second rater. Agreement was assessed using intraclass correlation (ICC).

Results There was a statistically significant reduction in time for all 3 critical actions between baseline and 3-month evaluation in the early intervention group; this was not observed in the late (control) group. Rater agreement was excellent (ICC $\geq$ 0.99).

Conclusions A simulation-based educational intervention significantly reduced time to initiation of CPR for first-year pediatrics residents. Simulation training facilitated acquisition of critical CPR skills that have the potential to impact patient outcome.

Editor's Note: The online version of this article contains instructional content, the baseline skills survey, and the experience survey used in this study.

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Introduction

Pediatric cardiopulmonary arrest is a rare event, and timely, high-quality cardiopulmonary resuscitation (CPR) improves outcomes.[1–4] Pediatrics residents have a critical role in initiating life-saving interventions yet have little opportunity to develop or maintain their resuscitation skills.[5–7]

The timely delivery of high-quality CPR is a key dimension of good care, and delays in initiating CPR have a detrimental effect on patient outcome regardless of the quality of resuscitation.[8–12] Pediatrics residents have demonstrated good knowledge of CPR and pediatric advanced life support (PALS), as reflected by high scores on written tests. At the same time, many residents show suboptimal clinical skills in mock code performance.[7,13] The paucity of opportunity to practice these skills makes the application to actual patient care challenging.

Simulation-based training has demonstrated effectiveness in promoting skill acquisition.[14–26] There is growing research in pediatrics evaluating the effect of simulation-based training on the clinical performance of PALS skills during resuscitations.[13,20,22,27–31] Most practicing primary care pediatricians or clinic-based subspecialists are unlikely to perform CPR frequently, and residency training should prepare the pediatrician to appropriately initiate CPR until help arrives. Our study uses standardized simulations to assess first-year pediatrics residents in 3 critical actions of CPR: (1) calling for help, (2) initiation of bag-mask ventilation (BMV), and (3) initiation of chest compressions. Our hypothesis was that a simulation-based educational intervention will reduce residents' time to initiation of CPR.

What was known

Pediatrics residents need to acquire cardiopulmonary resuscitation (CPR) skills, yet opportunities in day-to-day practice are scarce.

What is new

Simulation-based training measured time efficiency gains in 3 critical actions in CPR.

Limitations

Single-site, single-specialty study may limit generalizability. Potential exists for bias in the assignment to the study versus control group. Assessment was focused on time to initiation, not quality of execution of the skills.

Bottom line

Simulation training resulted in time efficiency gains in initiating key components of CPR in first-year pediatrics residents.

Methods

Thirty-one first-year pediatrics residents from a large, urban, tertiary care children's hospital participated from July 2007 through May 2008. All were certified in basic life support (BLS) and CPR 1 month prior to the beginning of the study. We randomized residents based on their clinical schedule into 2 groups: (1) early-intervention group or (2) late-intervention (control) group. Each resident underwent a baseline evaluation followed by repeat evaluations at 3 and 6 months. Our design was a prospective trial using a wait-list control group with the simulation-based educational intervention immediately following baseline evaluation in the early-intervention group and following the 3-month evaluation in the late-intervention group.[32] To capture their increasing clinical exposure, a self-reported experience survey was completed at each evaluation period (provided as online supplemental material).

Our educational intervention consisted of a 90-minute small group (maximum of 9 participants) simulation-based workshop that practiced multiple patient care scenarios with structured feedback focused on CPR and resuscitation skills. The content consisted of assuming the role of first responder and demonstrating appropriate actions, discussing the American Heart Association 2005 *Guidelines for CPR* and the physiology supporting the recommendations, the importance of timely intervention, skill practice with BMV and ancillary airway equipment, the practice of proper technique for chest compressions, and discussion of basic rhythm management as it pertains to defibrillation and use of epinephrine (provided as online supplemental material).[8]

The evaluation consisted of a standardized simulated patient care scenario. Each resident individually participated, with the assistance of a simulated nurse, in 3 different scenarios over the course of 9 months. Prior to each scenario, the resident completed an orientation to the simulator, room, equipment, and medications. The patient history was read outside of the room; the resident then entered the room and intervened as if in a real clinical setting. To help blind the residents to the actions of interest but maintain standardization of examination and management, the scenario at each evaluation period had a unique history, yet in all the scenarios, the patient is found unresponsive in a pulseless electrical activity arrest rhythm (TABLE 1).

All scenarios were conducted in a standardized simulation laboratory and recorded on video for later review. We used a pulse-generating MegaCode Kid manikin and produced monitor outputs using software provided with the SimBaby manikin (Laerdal Medical, Wappingers Falls, NY). Resident participants were blinded to the timed data collection and actions of interest. In both groups, after all 3 critical actions of CPR were initiated, a single instructor (J.C.R.) facilitated application of the advanced PALS protocols as they relate to pulseless arrest (eg, rhythm, defibrillation versus no defibrillation, medications, continuing CPR, endotracheal intubation skills) until arrival of the "code team." In order to blind the residents to the outcome of interest, scenarios continued well after BLS was started and the facilitator addressed additional learning goals. This provided an educational opportunity for the nonintervention group so the experience felt worthwhile to them. There was no instruction on BLS and CPR during the scenario. If a resident did not initiate all 3 critical actions of CPR at 5 minutes, the instructor intervened.

Initiation of CPR was defined by 3 critical actions: (1) calling for help, (2) initiation of BMV, and (3) initiation of chest compressions. The time-to-action data were recorded from the moment the resident entered the room by using video review (2 camera views: side and foot of bed). Data were collected that measured each resident's time to initiate the 3 critical actions of CPR. To assess interrater reliability, a 10% sample was reviewed and timed by a second rater.

The primary outcome measure was the change in time to initiate the 3 critical actions of CPR from baseline to the

TABLE 1 **Standardized Simulation Scenarios**

Parameter	Scenario
Standardized orientation	Oriented to the room, equipment (oxygen, airway supplies, length-based dosing tape, code cart), medications, and location of the code button.
	Oriented to the simulator: breath sounds, heart tones, pulses, monitor (ECG, pulse oximetry, BP)
Unique history read outside of the room	
Baseline	7-year-old boy admitted last night for dehydration secondary to poor oral intake from chicken pox. He has been febrile overnight.
3-Month	7-year-old boy with short-gut syndrome admitted yesterday with a fever. He has been afebrile since admission and doing well. His blood culture has not grown in over 24 hours, and he is on antibiotics. He has been receiving TPN overnight.
6-Month	7-year-old boy admitted overnight with a presumed diagnosis of dehydration secondary to gastroenteritis. He received a bolus of 40 ml of normal saline per kg and has been on two-times maintenance IV fluids.
Standardized history read outside of the room	A floor nurse urgently calls you into the room for help after the patient is found unresponsive
Standardized physical examination and ECG rhythm	The patient is unresponsive, apneic, and pulseless. ECG rhythm on monitor shows PEA with a rate in the 70s; pulse oximetry without waveform; BP is undetectable
Cause of PEA (not revealed until the resident completes the scenario)	
Baseline	Unrecognized septic shock caused by group-A *Streptococcus* infection
3-Month	Unrecognized hyperkalemia due to an error in constituting TPN
6-Month	Unrecognized myocarditis with fluid over-resuscitation

Abbreviations: ECG, electrocardiogram; BP, blood pressure; IV, intravenous; PEA, pulseless electrical activity; TPN, total parenteral nutrition.

3-month evaluation in the early-intervention group compared to that in the late-intervention (control) group. The change in time was analyzed by comparing Kaplan-Meier curves, using the log-rank test with a P value $\leq .05$. To provide a measure of central tendency, medians with intraquartile ranges were calculated. Because median data will not account for those who never completed the critical actions, we compared Kaplan-Meier curves to determine statistical significance. Interrater reliability was assessed using intraclass correlation (ICC). The clinical experience surveys were compared using the χ^2 statistic with a P level $\leq .05$. Data were analyzed using Stata version 10.1 software (StataCorp LP, College Station, TX).

The Children's Memorial Hospital Institutional Review Board approved this study, and all participants signed informed consent agreeing to video recording of sessions.

Results

At baseline, there were no significant differences between the groups in medical school and clinical experience, previous simulation training, and participation in mock codes. There also were no significant differences between the groups at all 3 evaluation periods regarding their experience hearing or reading about resuscitation skills. There were some differences between the groups reported in observing and participating in resuscitation skills at the 3- and 6-month evaluations (TABLE 2).

Each resident participated in 3 different individual simulation scenarios, for a total of 93 evaluations. The primary outcome measure (change in time from baseline to the 3-month evaluation) was analyzed separately for all 3 critical actions of CPR. In the early-intervention group there was a statistically significant reduction in the time to call for help ($P < .01$), initiation of BMV ($P < .04$), and initiation of chest compressions ($P < .01$). This was not seen in the call for help ($P = .16$), BMV ($P = .18$), and chest compressions ($P = .28$) in the late-intervention (control) group. The differences between each group's time to initiation of chest compressions at each evaluation period are illustrated in the FIGURE.

Median times to the critical actions of CPR are shown in TABLE 3. Rater agreement for each of the 3 critical actions was excellent with an ICC ≥ 0.99.

Discussion

Our study demonstrates the efficacy of simulation training in reducing time to initiation of CPR for first-year pediatrics residents. Using an objective time-based measure to evaluate individual resident's performance with a late-intervention group to control for clinical experience

TABLE 2 **Comparison of Clinical Experience Between Early- and Late-Intervention Groups**

Events/Skills Performed on Patients	Group	NICU						Younger than 8 Years						8 Years and Older					
		Observed			Performed			Observed			Performed			Observed			Performed		
		B	3M	6M	B	3M	6M	B	3M	6M	B	3M	6M	B	3M	6M	B	3M	6M
Code/resuscitation	Early	7	8	10	4	7	10	7	5	**8**	1	2	**7**	14	3	3	5	2	2
	Late	3	3	9	3	4	7	2	5	**1**	1	1	**0**	10	3	2	3	0	1
BMV (total)	Early	7	8	10	5	**8**	10	5	3	**8**	0	0	1	13	1	1	7	0	0
	Late	5	4	12	5	**2**	11	3	3	**1**	1	1	0	11	3	2	6	1	1
BMV (during code)	Early	6	7	9	3	**6**	6	4	3	**7**	0	0	0	7	1	1	1	0	0
	Late	3	2	9	1	**2**	7	4	3	**1**	1	0	0	8	3	2	1	0	1
Endotracheal intubation (total)	Early	7	8	10	4	**7**	9	5	0	2	2	0	0	10	0	1	5	0	0
	Late	6	5	12	4	**4**	10	3	1	0	2	1	0	10	2	2	9	2	2
Endotracheal intubation (code)	Early	6	8	9	3	**6**	5	2	0	2	0	0	0	6	0	1	0	0	0
	Late	5	3	9	1	**1**	6	1	1	0	0	0	0	5	2	1	1	0	0
Chest compressions	Early	4	3	8	0	1	2	2	1	1	0	0	0	12	0	1	3	0	0
	Late	3	3	8	0	1	1	3	3	1	2	2	0	8	1	2	2	0	0
Defibrillation/ cardioversion	Early	0	0	0	0	0	0	1	1	1	0	0	0	7	0	0	1	0	0
	Late	0	0	0	0	0	0	2	1	0	0	0	0	7	1	1	1	0	0

Abbreviations: B, baseline; NICU, neonatal intensive care unit; 3M, 3-month evaluation; 6M, 6-month evaluation; BMV, bag-mask ventilation.
Number of residents in each group having had experience at each evaluation period (since the previous evaluation period).
Early-intervention group n = 16; late-intervention group n = 15.
No statistically significant differences noted, except bolded data indicates less reported experience in the late-intervention group ($P \leq .05$).

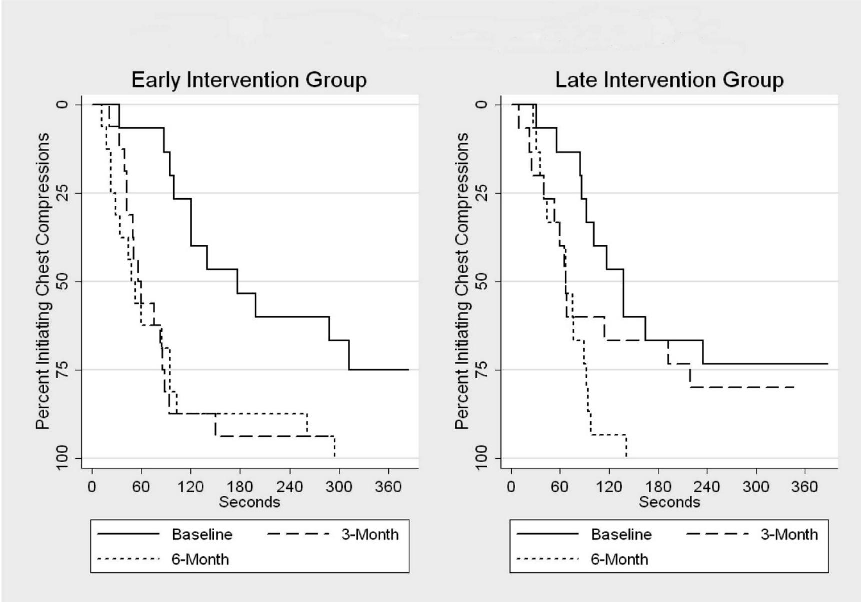

FIGURE **Time to Initiation of Chest Compressions**

allowed us to evaluate the impact of our educational intervention.

An important finding was the reduction in time to initiation of chest compressions. At baseline, most residents took more than 2 minutes to initiate chest compressions in a pulseless patient, and 25% never initiated compressions. This finding is similar to those in a study of pediatrics residents participating in mock codes in which 66% failed to start compressions within 1 minute of pulselessness, and 33% never started compressions.[6] Our study demonstrated that the early-intervention group significantly reduced the time to initiation of compressions, and all members of this group started compressions.

The goal of our intervention was to reduce both the time to initiation of CPR and the variation in performance among the members of the first-year resident cohort. We wanted to improve the performance of the entire group and help poorly performing residents initiate CPR in a timely fashion. We used Kaplan-Meier survival curves to more accurately capture the performance of residents who may

TABLE 3 **Median Time to Critical Actions of CPR**

Group	Median Time to Event in Seconds (Intraquartile Range)		
	Baseline	3-Month Evaluation	6-Month Evaluation
Early-intervention group			
Call for help	119 (37–168)	35 (16–65)	24 (14–61)
Bag-mask ventilation	46 (26–69)	29 (16–39)	21 (15–41)
Chest compressions	177 (100–300)	58 (43–88)	51 (26–95)
Late-intervention group (Control)			
Call for help	122 (24–300)	52 (23–152)	48 (29–61)
Bag-mask ventilation	41 (32–93)	33 (28–60)	25 (18–39)
Chest compressions	138 (87–300)	67 (40–220)	67 (40–92)

The simulation-based intervention took place between baseline and the 3-month evaluation for the early-intervention group and between the 3- and 6-month evaluations for the control. This is indicated by the double line between cells.

never have initiated the action and evaluate the effect of our intervention in reducing performance variation for the entire group (illustrated by more vertical/steeper curve). The intraquartile range of median times also narrowed after the intervention, reflecting this decrease in performance variation. By focusing our study on first-year residents, we were able to understand the effect of our educational intervention on a relatively naïve group of learners with fewer confounding clinical and educational experiences. Furthermore, we felt demonstrating timely initiation of CPR was crucially important for a first-year resident who would be a likely first hospital responder to a critically ill child.

The chance of survival is greater the sooner CPR is initiated in a pulseless patient; few studies have focused on individual performance in terms of time to initiation of CPR.[27,30,33–35] Andreatta et al[36] showed a positive correlation between increased frequency of resident participation in mock code training sessions and increased survival rates for hospitalized pediatrics patients who experienced a cardiopulmonary arrest. Simulation provides the opportunity to train individuals in the care of rare but life-threatening events in a standardized manner.

All resident participants were certified in BLS and CPR at the same time, 1 month prior to participating in the study, and we believe most would start CPR in a timely fashion. However, when patients are in a more complex hospital environment, trainees may be distracted from the basics of providing high-quality CPR.

Our investigation has several limitations. Both groups had similar baseline clinical and educational experiences; however, the groups reported at the 3-month evaluation some differences in experience, with 81% of the early-intervention group having completed a neonatal intensive care unit rotation by the 3-month evaluation compared to only 47% of the late-intervention group. In addition, our study was conducted in a single institution with a limited number of participants. The assignment of residents to the intervention and control groups was not randomized but based on schedule and availability. Our outcome of interest was the change in time to initiation of the 3 critical actions of CPR, but we did not examine the quality of those interventions. Finally, our study was not able to assess whether the gains in our interventions were sustainable.

Future research should examine the quality of CPR performance, the challenges to providing timely CPR in a complex hospital environment, and the optimal timing for ongoing educational efforts.

Resources needed for this intervention include the cost of 1 instructor and 1 staff member to set up the equipment and run the simulator. Each session ran 90 minutes plus 30 minutes of setup and breakdown, resulting in 2 hours per session times 6 sessions for a total of 12 hours. At $150 an hour, the cost (excluding faculty time) is estimated at $1,800, while faculty time costs vary by specialty and academic role. Residents accepted the simulation training and expressed thanks for the opportunity to practice, improve, and reduce some of their anxiety caring for critically ill children.

Conclusion

A simulation-based educational intervention significantly reduced time to initiation of CPR for first-year pediatrics residents. Residents improved their time to initiation of chest compressions with greatly decreased performance variation. Simulation training facilitated the acquisition of these critical skills that impact patient outcome, and this type of educational strategy is feasible for pediatrics residency programs.

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