Received: 28 June 2021 | Revised: 10 September 2021 | Accepted: 5 October 2021
DOI: 10.1002/aet2.10702

ORIGINAL CONTRIBUTION

Rapid-cycle deliberate practice improves time to defibrillation and reduces workload: A randomized controlled trial of simulation-based education

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Abstract

Background: The optimal structure of simulation to train teams to perform pediatric advanced life support (PALS) requires further research. Most simulation is structured with an uninterrupted scenario with postsimulation debriefing (PSD). Rapid-cycle deliberate practice (RCDP) is structured with a series of simulations with microdebriefing quickly switching within action targeting specific performance goals.

Objective: The objective was to compare team performance immediately after training, as well as learner workload, for teams trained using either PSD or RCDP.

Methods: In 2018–2019, a total of 41 interprofessional teams of 210 residents and nurses were recruited from 250 eligible participants (84%) and randomized into either arm (RCDP or PSD) teaching the same objectives of resuscitation of a patient in PEA arrest, in the same time frame. The structure of the simulation varied. Demographic surveys were collected before training, the National Aeronautics and Space Administration-Task Load Index (NASA-TLX) was administered immediately after training to assess workload during training and performance was assessed immediately after training using a pulseless ventricular tachycardia arrest with the primary outcome being time to defibrillation.

Results: Thirty-nine teams participated over a 16-month time span. Performance of teams randomized to RCDP showed significantly better time to defibrillation, 100 s (95% confidence interval [CI] = 90–111), compared to PSD groups, 163 s (95% CI = 120–201). The workload of the groups also showed a lower total NASA-TLX score for the RCDP groups.

Conclusions: For team-based time-sensitive training of PALS, RCDP outperformed PSD. This may be due to a reduction in the workload faced by teams during training.

INTRODUCTION

The care of the pediatric cardiac arrest victim requires an interprofessional team to immediately take specific team-based actions, gather information about the patient, share a mental model, and reverse underlying causes.[1] Deviating from guidelines for pediatric advanced life support (PALS) is associated with decreased survival.[2] For expert teams the immediate actions become automatic and they can focus on the steps which require greater adaptability. Team training to improve the care of cardiac arrest patients is necessary.[3]

Studies confirm the benefits of clinical simulation in the development and maintenance of skills for physicians and medical staff;

Supervising Editor: Ting Dong, PhD.

however, certain simulation designs may be more effective than others.[4-9] Traditionally, simulations are designed to allow a participant or group of participants to complete an entire clinical scenario, followed by a reflective debriefing. Postsimulation debriefing (PSD) leads to improved performance.[10-12] In contrast to PSD, rapid-cycle deliberate practice (RCDP) cases are divided into small portions or steps.[13,14] This method also has been shown to improve performance in simulation before versus after training.[13,15,16] Facilitators stop the simulation either when an error or suboptimal action occurs or to highlight and discuss correct actions.

Studies comparing RCDP and PSD show mixed results. This may be from variations in specific methods, level of learner, and topics being taught.[17] In prior comparison studies, teams using PSD progressed through multiple cases before training or during training before assessment and had similar improvement to RCDP.[15] Others have found immediate performance improvement with RCDP compared with PSD for basic life support and neonatal resuscitation training.[18,19]

Cognitive load theory may partially explain the difference in effectiveness between various simulation protocols. This psychoeducational framework posits that working memory is limited and that when working memory is overburdened by high complexity or multiple concurrent tasks, learning is decreased. By reducing the workload required for educational exercises without eliminating essential tasks (reducing extraneous load and optimizing intrinsic load), learning may be fostered.[20]

The primary objective of this study was to compare time to first defibrillation in simulation immediately after RCDP or PSD training. Secondary outcomes measured time to first compression, time to first epinephrine, and workload of teams during RCDP and PSD.

METHODS

Study setting and participants

The study was conducted in the in-situ simulation suite of the emergency department at Texas Children's Hospital, an urban tertiary care hospital, from January 2018 to April 2019.

As part of their pediatric emergency medicine (PEM) rotation, pediatric and emergency medicine residents were required to participate in simulation-based resuscitation training. This training session has been part of our resident rotation and ongoing nurse education and serves to augment the regular PALS certification process. Our group of PEM physicians and PEM nurse educators has developed a set of learning objectives based on American Heart Association guidelines as adapted to our specific institution.[1] Depending on the residency program and postgraduate year, residents were scheduled to have one to three PEM rotations during their residency. On each training day for every PEM rotation, the team included three or four residents and two nurses. The team was randomized to either RCDP or PSD. Roles included team lead, first responder, airway, cardiopulmonary resuscitation (CPR) coach, bedside provider, and recorder. For teams of five, the CPR coach was removed. Teams taught with PSD participated in a single simulation scenario with a single debriefing session. The role that each individual filled was randomized but ensured that a nurse was the recorder and a physician was the lead. All other roles could be filled by either profession. For RCDP, the initial role assignment was also random, but the structure of RCDP encouraged rotation to the other roles in subsequent rounds. Testing case role assignment was determined by the most recent role performed.

Randomization of teams

Randomization.com was used to develop block randomization in blocks of six. Everyone was unaware of that day's randomization until consent had been obtained.

Simulation curriculum design: simulation with PSD

Teams randomized to RCDP or PSD were taught the same topics in the same time frame. For PSD, the training session included one uninterrupted 20-min scenario of an unresponsive child presenting in PEA arrest. The case started with a first responder entering the room, calling for help, and the remainder of the team entering 10 s later. The case began with initiation of CPR, including backboard and monitor placement. It then proceeded through the first pulse-rhythm check including preparation for possible defibrillation, intraosseous (IO) access, and epinephrine administration until the patient had return of spontaneous circulation and required postarrest stabilization and intubation. This was followed by a 40-min reflective debriefing session. PSD was conducted using the Promoting Excellence and Reflective Learning in Simulation (PEARLS) framework with a scripted debriefing.[11] This has been the standard method used by our simulation instructors at our institution. Details of the curriculum are in Appendix S1 (available as supporting information in the online version of this paper, which is available at http://onlinelibrary.wiley.com/doi/10.1002/aet2.10702/full).

RCDP simulation

For the RCDP educational intervention, sessions included multiple rounds of progressively more difficult scenarios with predesigned "hard stops" and "soft stops" with scripted learning points. These cases were published in MedEdPORTAL and adjusted to fit our time constraint of a 1-h session.[21] Teams achieved predefined goals in each round before progressing to the next level of difficulty. Instructors focused on providing direct feedback, using a pause and rewind/restart methodology. Instructors used a debriefing script based on the PEARLS framework.[15] Teams had the opportunity to "rewind" and achieve objectives before moving onto the next round. The sessions taught with RCDP lasted 1 h.

The first round presented an unresponsive child with apnea but with a pulse. The team's objectives were to quickly assess the patient and recognize the need for additional help and a crash cart, apply monitors, and reposition the airway. Once those objectives were achieved, the team moved onto the second round, which was an apneic patient requiring bag-mask ventilation. Subsequent rounds added additional complexity, until the final round which replicated the PSD case. With each round, teams rotated roles, giving everyone a chance to lead.

While debriefing in RCDP was more directive than in PSD, instructors were encouraged to use advocacy and inquiry methods to explore persistent performance gaps. In contrast to RCDP, PSD allowed more time for reflection on individuals' frames and correction of the underlying frame. Even in PSD, instructors would provide direct feedback focusing on choreography of pediatric resuscitation. Both groups had the opportunity to review microprocedures, such as preparing defibrillator and IO placement. In PSD, these skills were taught through explanation and demonstration. During RCDP, individuals could practice these skills in subsequent rounds after being taught. The only differences in debriefing from PSD lay in how much emphasis was placed on direct feedback versus advocacy-inquiry technique and the timing of that feedback.

Instructors and instructor training

A team of two PEM physicians and a nurse taught each day; a research assistant obtained consent and collected data. All educators had more than 2 years of experience teaching the material and had taken simulation instructor training along with train-the-trainer workshops to standardize RCDP and PSD implementation. Mannequin settings were standardized by a preprogrammed simulation in Laerdal learning application (Laerdal Medical).

Study protocol and data collection

After consent, participants completed a demographic survey administered through a Research Electronic Data Capture survey.[22,23] This survey covered prior training and resuscitation experience. Next, instructors conducted an orientation to simulation and the SimJunior mannequin (Laerdal Medical). Then instructors taught for 1 h using RCDP or PSD.

After the training, individuals filled out a survey to rate the workload they experienced during training. The NASA-Task Load Index (NASA-TLX)[24] survey measures six components of workload, three related to the demands of the task faced (mental, physical, and temporal) and three related to the reactions of the individual to the demands (frustration, effort, and performance). Every individual ranked each workload component on a visual analog scale between 1 and 100. The individual ranked the six components in order of contribution to workload, generating a weighted total scale ranging from 0 and 100. While there are no predefined levels for too high or too low workloads, comparisons can be helpful. In general, above 60 is considered to be a high workload, while below 40 is considered low.[25]

After the hour of education and workload survey, the team was then assessed as they completed a simulated uninterrupted test case of a child in cardiac arrest with pulseless ventricular tachycardia (VT). Of note, there was no assessment before the training to avoid introducing repetitive practice into the PSD arm. In contrast with the training, this scenario required defibrillation and use of an antiarrhythmic. This 10-min scenario was video recorded. Key performance metrics were obtained from video review, including time from the first team member's entry into room until time of first chest compression, first defibrillation, and first epinephrine administration. All time measurements were made by one investigator (DSL), who was blinded to the study assignment.

Sample size calculation and statistical analysis

Our primary outcome was predefined as time to first defibrillation. Based on pilot data from a prior study of PEM fellows[15] we calculated a sample size of 16 teams based on an estimated average time to defibrillation of 140 s with an improvement of 30 s and a standard deviation of 30 s. Using a two-sided tail with alpha of 0.05 and beta of 0.20, this yielded an estimated sample size of 16 in each arm.[26,27]

Planned secondary analysis included the time to compressions and time to first epinephrine. Finally, the workload of each group of teams as measured by NASA-TLX (total and subscore) was measured and compared between the groups.

Demographic data were checked for normalcy using the Shapiro-Wilk test. Categorical comparisons were calculated using Pearson chi-square test or the Fisher exact test if any value was <5. Continuous variables were analyzed using the Mann-Whitney or Kruskal–Wallis test. A p-value <0.05 was defined as statistical significance. All analyses were conducted using the Statistical Package for the Social Sciences, version 25 (IBM Corp.).

Institutional review board statement

This study was approved by institutional review board at our institution. The research and education were funded internally from our institution. Prior to the start of the day, a research assistant obtained verbal consent from all participants. If any member declined consent, the educational session continued but study data were not collected.

RESULTS

Participants

In total 250 participants were eligible for training and had been scheduled for training. As outlined in Figure 1, 21 were taught on days alongside PEM fellows and these days were not randomized

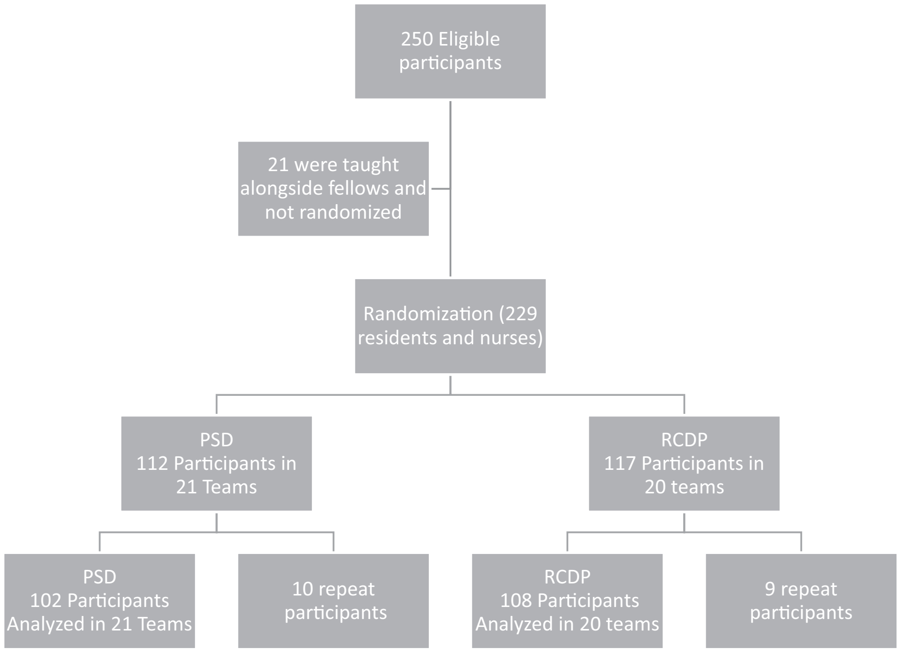

FIGURE 1 Flow of participants through study: 250 recruited, repeat participants were allowed to participate in teams, but their responses to workload questions was not included in analysis. PSD, postsimulation debriefing; RCDP, rapid-cycle deliberate practice

into this study; 19 residents returned for a second round of training. While their workload and survey data were excluded from analysis, the teams to which they were assigned were included (Figure 1). There were 20 RCDP groups and 21 PSD groups. There were no significant differences between clinical experience of the individuals or groups. There was variation in size between groups, but the variation in size was equivalent between the groups (Table 1).

Clinical performance

There was a significant difference in time to first defibrillation: RCDP averaged 100 s (95% CI = 90–111) and PSD averaged 163 s (95% CI = 120–201; Figure 2). There was no significant difference in time to first compression: RCDP averaged 18 s (95% CI = 16–21 s) and PSD averaged 19 s (95% CI = 16–22 s). There was one team in each arm that never gave epinephrine within 10 min. Excluding those, average time to epinephrine showed overlap of 95% CIs: RCDP 251 s (95% CI = 218–284 s) and PSD 321 s (95% CI = 282–361 s).

Workload

RCDP had a lower frustration subscore (3.7 vs. 8.9; $p < 0.001$) and weighted total score (63.7 vs. 69.4; $p = 0.02$) when compared to PSD. There were no significant differences in the other subscores (Figure 3).

We conducted a post hoc analysis of team size and workload (Table 2). There was no significance when looking at all team members. Examining just the team lead's workload, there was a significant reduction their workload for teams of more than six members compared to teams with five members.

DISCUSSION

After training, RCDP groups defibrillated 1 min faster than PSD groups. While teams in both arms reported high workloads through the NASA-TLX,[25] RCDP had lower NASA-TLX workloads as compared to PSD. This reduction in workload along with an improvement in performance is consistent with our hypothesis.

The difference in time to first defibrillation was clinically important. The average time of RCDP was about 1 min faster than those trained with PSD. Time to defibrillation was chosen as our primary outcome since there was a connection shown between time to defibrillation and survival for adults with in-hospital cardiac arrest.[28] For adults and infants less than 1 year of age, this remains the goal according to American Heart Association's Get with the Guidelines.[29] For children, Hunt et al.[30] investigated if there was a similar association between time to defibrillation and survival and did not find a link. The impact of this research remains unclear. While no association of time to defibrillation and survival was found, most cases of shockable rhythms did receive electricity in less than 2 min. An accompanying commentary argues that rapid defibrillation in children should still be encouraged.[31]

While the training sessions did not require defibrillation, both PSD and RCDP curricula did teach choosing the correct dosage for defibrillation and charging the defibrillator before the rhythm was analyzed. The only additional steps required during the testing case were recognition of VT, the need for defibrillation, and pushing the button.

Our findings are in line with existing research on RCDP, which has shown improved performance of teams.[15,17,18,32-35] This project showed that time to defibrillation was shorter when teams were trained using RCDP compared with PSD. Prior studies on training residents the skill of defibrillation show that simulation can improve this skill and suggestions have been made to integrate defibrillation

TABLE 1 Demographic differences between randomized groups (N = 210)

	PSD, n = 102 (48.6%)	RCDP, N = 108 (51.4%)	p-value
Current role in ED			
Categorical pediatric residents	34 (33.3)	34 (31.5)	0.86
EM resident	23 (22.5)	21 (19.4)	
Other combined resident (Med-Peds, Ped-Neuro, etc.)	11 (10.8)	15 (13.9)	
RN	34 (33.3)	38 (35.2)	
Current year in training (for residents)			
PGY-1	6 (8.8)	4 (5.7)	0.67
PGY-2	50 (73.5)	50 (71.4)	
PGY-3	11 (16.2)	13 (18.6)	
PGY-4	1 (1.5)	3 (4.3)	
Estimate of real codes	5.0 (2.0–10.0)	3.0 (1.75–10.0)	0.28
Is PALS certificate up to date			
No	3 (2.9)	7 (6.5)	0.33[a]
Yes	99 (97.1)	101 (93.5)	
Previous exposure to simulation training			
No	5 (4.9)	4 (3.7)	0.74[a]
Yes	97 (95.1)	104 (96.3)	
Previous leader in simulated code			
No	32 (31.4)	33 (30.6)	0.90
Yes	70 (68.6)	75 (69.4)	
Teams with CPR coach	PSD teams, n = 21	RCDP teams, n = 20	
	14 (66)	13 (65)	0.91

Note: Data are reported as n (%) or median (IQR).

Abbreviations: IQR, interquartile range; PALS, Pediatric Advanced Life Support; PSD, postsimulation debriefing; RCDP, rapid-cycle deliberate practice.

[a]Fisher's exact test was utilized when any cell value was less than 5.

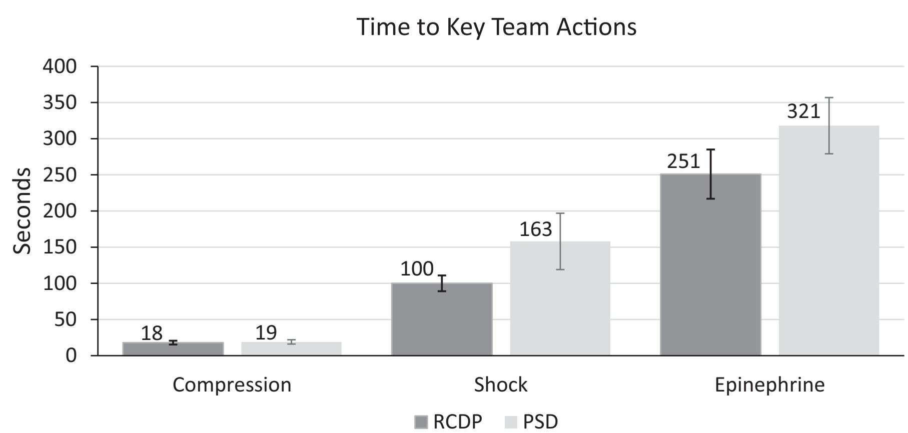

FIGURE 2 Time to actions for each arm. Lists time for RCDP and PSD arms for seconds for first compression, first defibrillation, first dose of epinephrine. Statistical significance for time to first shock. PSD, postsimulation debriefing; RCDP, rapid-cycle deliberate practice

training within basic life support courses as we have done here.[36] What has not been shown before is that RCDP is superior to PSD to train teams in the complex choreography needed to rapidly perform CPR and prepare for and deliver defibrillation.

For our secondary outcome of a weighted NASA-TLX score, there is a statistically significant reduction from 69.4 to 63.7. Both of these scores are in the highest percentile of reported scores compared against other studies.[25,37-39] While there are studies comparing workload of different clinical or simulated tasks under different conditions,[37-42] this is the first study that we know of using workload inventories to compare different curricula.

The major contributor to the difference in overall NASA-TLX scores was the frustration subscore. This is consistent with the findings from Chancey's qualitative analysis that suggested the RCDP method provides a safe environment to learn material in small chunks. By quickly moving between practice and feedback, RCDP

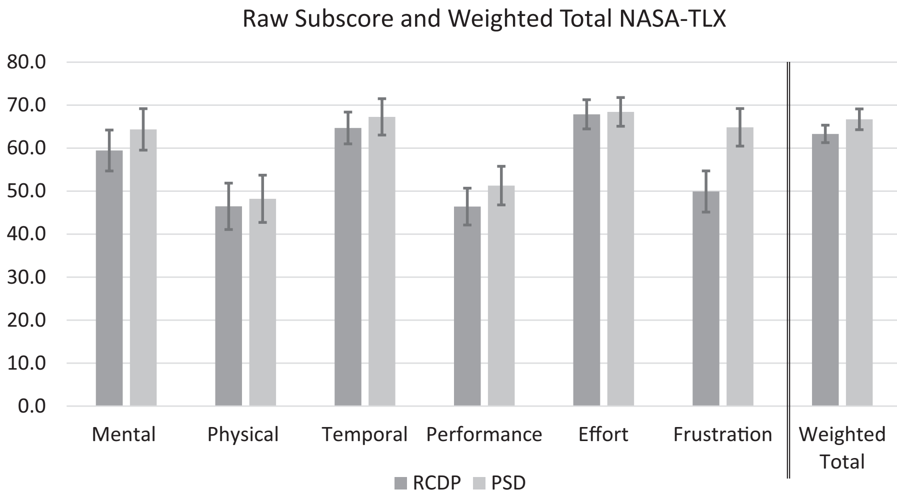

FIGURE 3 Mean raw subscores and weighted totals for NASA-TLX for RCDP and PSD groups. Frustration subscore and weighted total showed statistical significance. Error bars show 95% CIs. NASA-TLX, National Aeronautics and Space Administration-Task Load Index; PSD, postsimulation debriefing; RCDP, rapid-cycle deliberate practice

TABLE 2 Average Workload score by team size

	Small teams (five)	Large teams (six or more)	*t*-test *p*-value
All team members ($N = 210$)	57.1 (±12.8)	56.9 (±11.8)	0.90
Team lead only ($n = 32$)	69.4 (±8.0)	61.6 (±8.5)	0.02

Note: Data are reported as mean (±SD). There were 41 teams total, but only 32 leaders included in study since some team leaders' data were unavailable.

gives learners a chance to make a mistake, learn how to perform a skill correctly, and then practice performing the skill. Learning skills as they are needed and then being given a chance to use those new skills can be viewed as less frustrating.[43] The frustration for PSD likely came from attempting to perform actions that they knew were needed but were unlikely to have performed in clinical practice. Debriefings after simulation covering all issues requires remembering the entire scenario and these little errors during debriefing and never getting a chance to practice perfectly. This dedication of attention to many events has been hypothesized to increase workload.[43] In contrast with dealing with skills as they arise, this method requires time to discuss how errors early in the simulation affected perceptions and physiologic changes later in the simulation.

The workload of the team leaders was reduced in teams that included a CPR coach. While this is a post hoc analysis, this is consistent with a prior study by INSPIRE investigators.[37] Likely the dedication of an extra member of the team to serve as a monitor of compression depth, rate, and recoil takes away some of the tasks that are normally carried by the team leader. This effect is not seen when examining all members of the team.

There was no significant difference in time to first compression. Time to first defibrillation requires more steps and team interaction than initiating compressions and relies on actions of only the first responder without team work. In our testing scenario, time to first compression measured time for the first responder to check for a response, call for help, check for a pulse, and start compressions did not require a complex team-based choreography. This type of action was unlikely to be affected by the change in simulation structure. Both groups were able to perform this skill well under the recommended 1-min time limit proposed by Get with the Guidelines.[29] Since both teams did very well on this metric of initiating chest compressions quickly, detecting a significant difference between them is difficult.

For time to first epinephrine there was a suggestive difference in means between the groups, but the CIs of the two groups overlapped. It is not clear why this did not show a similar difference as defibrillation; however, the time to epinephrine depends on many factors which introduces variability into the measurement of team-based training methods. For example, some of the teams delayed initial defibrillation to focus on drawing up and administering epinephrine. It is difficult to tease apart these variations during data collection.

Ideally, we would like to have the teams taught by different simulation methods return and see if the difference in time to defibrillation was maintained. Instead of having entire teams return, we did have individuals return and measured their performance as team leaders. Separately, data comparing delayed performance of residents as team leaders have been reported.[44] Similar results were found on delayed performance by Swinger et al.[33] This improved leadership at a later simulation strengthens the evidence that given a certain amount of time for simulation training, the repeated practice in RCDP may be a better structure of simulation compared with a single simulation with more time spent on PSD.

Limitations

This study was conducted at a single institution limiting ability to generalize results. Similarly, different levels of experience of residents and nurses may change outcomes. We cannot comment on the superiority of RCDP over PSD for overall resuscitation quality. Also, individuals in the PSD arm only practiced in a single role. They were tested in that same role. This should maximize the performance of that team in testing, but it is unclear whether cross-training in multiple roles is partially responsible for improvements in team performance. In contrast to other studies,[15,18,45] we limited PSD to a single simulation with debriefing. This limits conclusions from our study that RCDP is superior to PSD to cases where only a single scenario takes place. Further research is needed to compare RCDP with PSD when more time and repetitions are possible.

Team makeup and size varied from day to day, but the groups in each arm had a similar distribution of sizes. This variation may have impacts on the effectiveness of the curriculum, but should have similar effects in each arm. While NASA-TLX is widely used and helpful to examine total workload during a task, it is not designed to separate out intrinsic, extrinsic, and germane loads.

CONCLUSIONS

Teams trained using rapid-cycle deliberate practice were faster to defibrillate and demonstrated less frustration and workload. Further work may be conducted to separate out the different kinds of workload during education, how changes in frequency or duration of education and integration into a residency curriculum affects learner outcomes, and how clinical behaviors and patient outcomes are affected by training. Next, work on feasibility of integrating rapid-cycle deliberate practice into required life-support courses should be done.

For team-based time-sensitive simulations like defibrillation as part of pediatric advanced life support, teams trained with rapid-cycle deliberate practice outperformed those trained with postsimulation debriefing. This correlated with a reduction in workload of teams during training.

CONFLICT OF INTEREST

The authors have no potential conflicts to disclose.

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REFERENCES

1. de Caen AR, Berg MD, Chameides L, et al. Part 12: Pediatric advanced life support. *Circulation*. 2015;132(18 suppl 2):S526-S542. https://.doi.org/10.1161/cir.0000000000000266
2. Wolfe HA, Morgan RW, Zhang B, et al. Deviations from AHA guidelines during pediatric cardiopulmonary resuscitation are associated with decreased event survival. *Resuscitation*. 2020;149:89-99. doi: 10.1016/j.resuscitation.2020.01.035
3. Cheng A, Magid DJ, Auerbach M, et al. Part 6: Resuscitation education science: 2020 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2020;142(16_suppl_2). doi: 10.1161/cir.0000000000000903
4. Andreatta P, Saxton E, Thompson M, Annich G. Simulation-based mock codes significantly correlate with improved pediatric patient cardiopulmonary arrest survival rates*. *Pediatric Critical Care Medicine*. 2011;12(1):33-38. doi: 10.1097/pcc.0b013e3181e89270
5. Cook DA, Hatala R, Brydges R, et al. Technology-enhanced simulation for health professions education. *JAMA*. 2011;306(9). doi: 10.1001/jama.2011.1234
6. Shapiro MJ, Morey JC, Small SD, et al. Simulation based teamwork training for emergency department staff: does it improve clinical team performance when added to an existing didactic teamwork curriculum? *Qual Saf Health Care*. 2004;13(6):417-421.
7. Hunt EA, Walker AR, Shaffner DH, Miller MR, Pronovost PJ. Simulation of in-hospital pediatric medical emergencies and cardiopulmonary arrests: Highlighting the importance of the first 5 minutes. *PEDIATRICS*. 2008;121(1):e34-e43. doi: 10.1542/peds.2007-0029
8. McGaghie WC, Issenberg SB, Petrusa ER, Scalese RJ. A critical review of simulation-based medical education research: 2003–2009. *Medical Education*. 2010;44(1):50-63. doi: 10.1111/j.1365-2923.2009.03547.x
9. McGaghie WC, Barry IS, Cohen ER, Barsuk JH, Wayne DB. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? A meta-analytic comparative review of the evidence. *Acad Med*. 2011;86(6):706-711.
10. Rudolph JW, Simon R, Dufresne RL, Raemer DB. There's no such thing as "nonjudgmental" debriefing: a theory and method for debriefing with good judgment. *Simul Healthc*. 2006;1(1):49-55.
11. Eppich W, Cheng A. Promoting excellence and reflective learning in simulation (PEARLS): development and rationale for a blended approach to health care simulation debriefing. *Simul Healthc*. 2015;10(2):106-115.
12. Brett-Fleegler M, Rudolph J, Eppich W, et al. Debriefing assessment for simulation in healthcare: development and psychometric properties. *Simul Healthc*. 2012;7(5):288-294.
13. Hunt EA, Duval-Arnould JM, Nelson-McMillan KL, et al. Pediatric resident resuscitation skills improve after "Rapid Cycle Deliberate Practice" training. *Resuscitation*. 2014;85(7):945-951. doi: 10.1016/j.resuscitation.2014.02.025
14. Perretta JS, Duval-Arnould J, Poling S, et al. Best practices and theoretical foundations for simulation instruction using rapid-cycle deliberate practice. *Simul Healthc*. 2020;15(5):356-362.
15. Lemke DS, Fielder EK, Hsu DC, Doughty CB. Improved team performance during pediatric resuscitations after rapid cycle deliberate practice compared with traditional debriefing: a pilot study. *Pediatr Emerg Care*. 2019;35(7):480-486.
16. Sullivan NJ, Duval-Arnould J, Twilley M, et al. Simulation exercise to improve retention of cardiopulmonary resuscitation priorities for in-hospital cardiac arrests: a randomized controlled trial. *Resuscitation*. 2015;8:6-13.
17. Taras J, Everett T. Rapid cycle deliberate practice in medical education – a systematic review. *Cureus*. 2017;9(4):e1180.
18. Magee MJ, Farkouh-Karoleski C, Rosen TS. Improvement of immediate performance in neonatal resuscitation through rapid cycle deliberate practice training. *J Grad Med Educ*. 2018;10(2):192-197.
19. Hunt EA, Duval-Arnould JM, Chime NO, et al. Integration of in-hospital cardiac arrest contextual curriculum into a basic life support course: a randomized, controlled simulation study. *Resuscitation*. 2017;114:127-132.
20. van Merriënboer JJ, Sweller J. Cognitive load theory in health professional education: design principles and strategies. *Med Educ*. 2010;44(1):85-93.
21. Doughty C, Welch-Horan T, Hsu D, et al. Rapid cycle deliberate practice pediatric simulation scenarios. *MedEdPORTAL*. 2015. doi:10.15766/mep_2374-8265.10134
22. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--A metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377-381. doi:10.1016/j.jbi.2008.08.010

23. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: building an international community of software platform partners. *J Biomed Inform*. 2019;95:103208.
24. Hart SG. Nasa-Task Load Index (NASA-TLX); 20 years later. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. 2006;50(9):904-908. doi: 10.1177/154193120605000909
25. Grier RA. How high is high? A meta-analysis of NASA-TLX Global Workload Scores. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. 2015;59(1):1727-1731. doi: 10.1177/1541931215591373
26. Hulley SB, Cummings S, Browner W, Grady DG, Newman TB. Designing Clinical Research. Wolters Kluwer, Lippincott Williams & Wilkins; 2013:73.
27. Chow SC, Jun S, Wang H, editors. *Sample Size Calculations in Clinical Research*. 2nd ed. Chapman & Hall/CRC; 2008.
28. Patel KK, Spertus JA, Khariton Y, et al. Association between prompt defibrillation and epinephrine treatment with long-term survival after in-hospital cardiac arrest. *Circulation*. 2018;137(19):2041-2051.
29. Get with the Guidelines Resuscitation Fact Sheet. American Heart Association. 2017. Accessed August 29, 2021. https://www.heart.org/idc/groups/heart-public/@private/@wcm/@hcm/@gwtg/documents/downloadable/ucm_434082.pdf
30. Hunt EA, Duval-Arnould JM, Bembea MM, et al. Association between time to defibrillation and survival in pediatric in-hospital cardiac arrest with a first documented shockable rhythm. *JAMA Netw Open*. 2018;1(5):e182643.
31. Topjian A. Shorter time to defibrillation in pediatric CPR. *JAMA Network Open*. 2018;1(5):e182653.
32. Yan DH, Slidell MB, McQueen A. Rapid cycle deliberate practice simulation curriculum improves pediatric trauma performance. *Simul Healthc* 2020 [online ahead of print]. doi:10.1097/SIH.0000000000000524
33. Swinger ND, Rutledge C, Gaither S, Youngblood AQ, Zinkan JL, Tofil NM. Rapid cycle deliberate practice improves and sustains paediatric resident PALS performance. *BMJ Simul Technol Enhanc Learn*. 2020;6(5):257-261. doi: 10.1136/bmjstel-2019-000483
34. Cory MJ, Colman N, McCracken CE, Hebbar KB. Rapid cycle deliberate practice versus reflective debriefing for pediatric septic shock training. *Pediatr Crit Care Med*. 2019;20(5):481-489.
35. Wing R, Tsao HS, Toomey V, et al. Excellence in Communication and Emergency Leadership (ExCEL): pediatric first 5 minutes workshop for residents. *MedEdPORTAL*. 2020;16:10980.
36. Jeffers J, Eppich W, Trainor J, Mobley B, Adler M. Development and evaluation of a learning intervention targeting first-year resident defibrillation skills. *Pediatr Emerg Care*. 2016;32(4):210-216.
37. Tofil NM, Cheng A, Lin Y, et al. Effect of a cardiopulmonary resuscitation coach on workload during pediatric cardiopulmonary arrest: a multicenter, simulation-based study. *Pediatr Crit Care Med*. 2020;21(5):E274-E281.
38. Tofil NM, Lin Y, Zhong J, et al. Workload of team leaders and team members during a simulated sepsis scenario. *Pediatr Crit Care Med*. 2017;18(9):e423-e427.
39. Brown LL, Lin Y, Tofil NM, et al. Impact of a CPR feedback device on healthcare provider workload during simulated cardiac arrest. *Resuscitation*. 2018;130:111-117.
40. Weinger MB, Reddy SB, Slagle JM. Multiple measures of anesthesia workload during teaching and nonteaching cases. *Anesth Analg*. 2004;98(5):1419-1425.
41. Mazur LM, Mosaly PR, Hoyle LM, Jones EL, Marks LB. Subjective and objective quantification of physician's workload and performance during radiation therapy planning tasks. *Pract Radiat Oncol*. 2013;3(4):e171-e177. doi:10.1016/j.prro.2013.01.001
42. Abe T, Dar F, Amnattrakul P, et al. The effect of repeated full immersion simulation training in ureterorenoscopy on mental workload of novice operators. *BMC Med Educ*. 2019;19(1):1-9.
43. Chancey RJ, Sampayo EM, Lemke DS, Doughty CB. Learners' experiences during rapid cycle deliberate practice simulations: a qualitative analysis. *Simul Healthc*. 2019;14(1):18-27.
44. Won SK, Doughty CB, Young AL, et al. Rapid cycle deliberate practice improves retention of pediatric resuscitation skills compared with postsimulation debriefing. *Simul Healthc*. 2021 [onine ahead of print]. doi:10.1097/SIH.0000000000000568
45. Patricia K, Arnold J, Lemke D. Rapid cycle deliberate practice: application to neonatal resuscitation. *MedEdPORTAL*. 2017;13:10534.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Lemke DS, Young AL, Won SK, et al. Rapid-cycle deliberate practice improves time to defibrillation and reduces workload: A randomized controlled trial of simulation-based education. *AEM Educ Train*. 2021;5:e10702. doi:10.1002/aet2.10702

Rapid Cycle Deliberate Practice Improves Retention of Pediatric Resuscitation Skills Compared With Postsimulation Debriefing

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Introduction: Rapid cycle deliberate practice (RCDP) for teaching team-based resuscitation is associated with similar improvements in immediate performance as compared with postsimulation debriefing (PSD). Limited studies compare skill retention between these 2 modalities. Our objective was to compare retention of team leader performance in residents trained with RCDP versus PSD.
Methods: This was a cluster-randomized trial comparing RCDP and PSD from January 2018 to April 2019. Pediatric and emergency medicine residents participated in simulation-based pediatric resuscitation education, and teams were randomized to undergo either RCDP or PSD. Each participant's team leader performance was assessed 1 to 12 months after training via a simulated cardiac arrest. The primary outcome was time to defibrillation. Secondary outcomes included overall team leader performance and time to chest compressions.
Results: Thirty-two residents (90.6% pediatrics, 9.4% emergency medicine) met inclusion criteria (16 RCDP, 16 PSD). Of the 32 residents, 40% returned in 1 to 3 months, 25% 3 to 6 months, 16% 6 to 9 months, and 19% 10 to 12 months. Participants in RCDP had more than 5 times the odds of achieving defibrillation versus those in the PSD group (odds ratio = 5.57, 95% confidence interval = 1.13–27.52, $P = 0.04$). The RCDP group had a higher mean Resident Team Leader Evaluation score (0.54 ± 0.19) than the PSD group (0.34 ± 0.16, $P < 0.001$).
Conclusions: This study shows significant differences in subsequent performance in the team leader trained with RCDP and suggests that RCDP may improve retention of pediatric resuscitation skills compared with PSD. Future studies should focus on best applications for RCDP with attention to knowledge and skill decay.
(*Sim Healthcare* 00:00–00, 2021)

Key Words: Simulation, pediatric, resuscitation, rapid cycle deliberate practice, resident education.

Pediatric resuscitations are rare yet life-threatening events that require a coordinated and effective team performance. Simulation, when compared with traditional clinical education, has been shown to improve performance as well as technical and nontechnical skills.[1] Multiple studies have demonstrated the value of simulation-based medical education (SBME) to enhance education and to improve patient outcomes.[2–4] Simulation-based medical education that incorporates deliberate practice and mastery learning has been associated with improved learning outcomes, compared with SBME methods that did not include these features.[5–8] Research on these 2 features has focused on individual skills. For team-training simulation, the tradition has been scenario-based simulation with postsimulation debriefing (PSD).[9] A potential weakness of the PSD design is that it is not conducive to long-term retention of skills.[10,11] As a result, there is a risk that these skills will not be applied when required. This is especially important for cardiac arrest, when interventions, such as defibrillation and initiation of cardiopulmonary resuscitation (CPR), are time-sensitive and directly affect patient outcomes.[12]

Rapid cycle deliberate practice (RCDP) is an SBME model for team-based training that is structured to quickly rotate from learner practice and expert feedback to achieve repeatable performance of a criterion standard choreography while providers use verbal scripts to improve communication during time-sensitive situations.[13] Multiple forms of debriefing strategies are used including ongoing coaching, advocacy inquiry, and plus delta.[13–15] Teams are allowed enough time to practice these skills correctly until mastery is achieved.

A qualitative study from our group analyzed learners' experiences during RCDP simulation and found it to be well received by learners who reported increased confidence and decreased cognitive load.[16] We hypothesized that a similar effect would be seen when skills were tested several months after initial training and that individuals taught with RCDP would have improved skill acquisition and retention.

Previous studies have also shown that RCDP improves learner performance and that it may be at least as effective as

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The authors declare no conflict of interest.

This study is attributed to the Section of Emergency Medicine, Department of Pediatrics, Baylor College of Medicine.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.simulationinhealthcare.com).

DOI: 10.1097/SIH.0000000000000568

PSD in teaching complex resuscitation team skills in the short term.[13,15,17] However, there are limited data comparing the retention of pediatric resuscitation skills acquired by these 2 modalities. The relative importance of reflective learning and deliberate practice for resuscitation performance has not been clearly defined, and different structures of simulation need to be compared.

The aim of our study is to determine whether future performances of residents acting as team leaders of pediatric resuscitation scenarios are better after training with RCDP simulation compared with residents trained through PSD simulation with time to defibrillation serving as the primary outcome.

METHODS

Design

This was a cluster-randomized trial comparing the effect of RCDP and PSD education on follow-up performance in simulation.

Study Setting and Participants

The study was conducted in the in situ simulation suite of the emergency department at an urban, tertiary care children's hospital from January 2018 to April 2019.

Institutional board approval (Reference #H-41413) was obtained before the start of enrollment.

As part of their pediatric emergency medicine (PEM) rotation, pediatric and emergency medicine residents participated in simulation-based resuscitation training and had the opportunity to enroll in the study. If a participant did not consent to the study, simulation training continued that day, but the team's data were not collected or used. Depending on the residency program and postgraduate year, residents were scheduled to have 1 to 3 PEM rotations during their residency. On each training day for every PEM rotation, a team was formed comprising 3 to 4 residents and 2 nurses. The team was randomized to either RCDP or PSD. Two PEM faculty simulation instructors and 1 nurse educator led these training sessions. All educators were trained to teach both RCDP and PSD. They completed an instructor course as well as an additional workshop for RCDP to teach this specific curriculum. There was ongoing monitoring of instructors by the experts who taught the workshops to ensure consistency, and feedback was provided to the instructors. Roles included team lead, first responder, airway, CPR coach, bedside provider, and recorder. For teams of 5, the CPR coach was removed because this role is not always available in every resuscitation, whereas all the other roles are critical to every code.

After completion of their initial training session, every resident who returned during the study period, on a subsequent PEM rotation, was eligible for enrollment in this study. Learners excluded from this study were those who failed to complete the entire simulation protocol and those whose video recording could not be used because they were either improperly recorded or missing critical information. In addition, although they were part of the intervention and initial training session, our returning nurses were excluded from this study.

Randomization.com was used to develop a scheme with equal numbers of groups in each arm for blocks of 6 teams. In addition to randomization to the type of training, the roles of each member of the team were also randomized. The research assistant was unaware of that day's randomization until consent had been obtained. Once consent was obtained, the research assistant determined to which preassigned type of training that the group was randomized.

Simulation Curriculum Design

Simulation With PSD

Teams randomized to RCDP or PSD training and debriefing were taught the same topics in the same timeframe. In the PSD group, the training session included 1 uninterrupted 20-minute scenario of an unresponsive child presenting in pulseless electrical activity (PEA) arrest. The case started with the first responder entering the room with the remainder of the team arriving 10 seconds after the call for help. The case proceeded through basic life support, monitor placement, intraosseous (IO) access, and epinephrine administration until the patient had return of spontaneous circulation and required postarrest stabilization with intubation and treatment of shock. This was followed by a 40-minute reflective debriefing session. Instructors used a scripted debriefing including choreography and learning objectives (see Doc, Supplemental Digital Content 1 http://links.lww.com/SIH/A654, which demonstrates RCDP and PSD teaching scenarios). Debriefing for traditional simulation was conducted using the PEARLS (Promoting Excellence and Reflective Learning in Simulation) framework with a scripted debriefing.[18]

Rapid Cycle Deliberate Practice Simulation

Participants in RCDP engaged in a 1-hour teaching session with predetermined learning objectives. The session included multiple rounds of progression of the same scenario in rapid sequence with predesigned “hard stops” and “soft stops” with scripted learning points. Learners achieved predefined goals in each round before progressing to the next level of difficulty. Instructors focused on debriefing with direct feedback, using a pause and rewind/restart methodology.

In RCDP, feedback was interspersed throughout the simulation and was short and concentrated on team actions that had just been performed. With each round, team members rotated roles, giving everyone a chance to be the team lead. With predefined goals in place, learners had the opportunity to rewind before a key action or entirely restart the scenario and achieve those goals before moving onto the next round. For example, the first round presented an unresponsive child with apnea but with a pulse. The team's objectives were to quickly assess the patient and recognize the need for additional help and a crash cart, apply monitors, and reposition the airway. Once those objectives were achieved, the team moved onto the second round, an apneic patient requiring bag-mask ventilation. The third round was of a pulseless patient requiring quick recognition and initiation of chest compressions. The fourth round required placement of a backboard, pads, step stool, and charging the defibrillator to the appropriate energy setting in an effort to reach the first pulse and rhythm check in a coordinated way. Once the team identified the rhythm as PEA, the fifth round required access via IO placement and administration of epinephrine. The final round required pulse and rhythm checks every 2 minutes, multiple doses of epinephrine, the switching of compressors, and mental modeling by the team leader who directed adjunctive therapies for the treatment of shock until the patient achieved return of spontaneous circulation. The objectives and skills expected for this final round of RCDP were the same as those for the PSD scenario (see Doc, Supplemental Digital Content 1 http://links.lww.com/SIH/A654, which demonstrates RCDP and PSD teaching scenarios).

Although the technique of debriefing in RCDP is more directive than in PSD, instructors were encouraged to use advocacy and inquiry methods to explore persistent performance gaps in both types of simulation.[19] In contrast to RCDP, the PSD model allowed more time for reflection on individuals' frames and sought to correct the underlying frame through feedback during an active discussion. Even in the PSD simulations, instructors would provide direct feedback focusing on actions and, specifically, on ideal choreography of pediatric resuscitation. Moreover, both groups had the opportunity to review microprocedures, such as IO placement, manipulating the defibrillator, which included review of shockable rhythms, and drawing up epinephrine; however only the RCDP group was allowed to deliberately practice these skills. Both RCDP and PSD used a blended approach to debriefing using the PEARLS framework and a debriefing script.[18] The differences in debriefing techniques lay in how much emphasis was placed on direct feedback versus advocacy inquiry technique, as well as the timing of that feedback. Rapid cycle deliberate practice debriefing used the technique of direct feedback more than advocacy inquiry, whereas PSD debriefing allowed more time for reflective advocacy inquiry over direct feedback.

Study Protocol and Data Collection

After obtaining informed consent, a brief orientation to simulation and the SimJunior mannequin (Laerdal Medical; Stavenger, Norway) was provided. Teams of residents and nurses participated in a 1-hour training simulation focusing on resuscitation of a child with PEA, using either RCDP or PSD based on randomization. After the teaching scenario, the team completed a test case of a child in ventricular fibrillation cardiac arrest, requiring initiation of CPR, defibrillation, and administration of epinephrine.

Participants returned for a second simulation day on a subsequent PEM rotation, as determined by their residency schedule, ranging from 1 to 12 months after their initial training session. Before the start of this session, participants completed a demographic survey administered through Research Electronic Data Capture (REDCap), a secure institutional database.[20] This survey queried each learner's level of training, type of residency, whether they were pediatric advanced life support (PALS) certified, and estimated number of real-life resuscitations attended. They were tested individually on a pulseless ventricular tachycardia (PVT) arrest case before the start of their second day of simulation training. These individuals were tested in the team lead role. This case was scripted and preprogrammed with 3 confederates (2 PEM faculty, 1 nurse) playing the other roles (1 person to give bag-mask ventilation, 1 person to perform CPR, and another to assist with all other tasks; see Doc, Supplemental Digital Content 2 http://links.lww.com/SIH/A655, which contains the retention test scenario). These confederates performed bedside tasks based on the team leader's directions. Performance data for participants were measured in real time by study coinvestigators using a stopwatch and recorded on an encrypted spreadsheet, and the cases were video recorded. The initial call for help was for an unresponsive and apneic child for which bag-valve mask was initiated. Resuscitative efforts would reveal that the child is also in PVT arrest requiring defibrillation. This case lasted 3 minutes or until a shock was delivered. Two different defibrillators were used during the study. Most participants were trained and tested with the Zoll-R Series defibrillator (Zoll Medical Corporation, Chelmsford, MA), which replaced all the Lifepak 20 defibrillators (Physio-Control, Redmond, WA) across the institution in March 2018. Because of the switch, several participants were tested with a different defibrillator than the one with which they were trained.

Video recordings were used to evaluate resident team leader performance. Five coinvestigators served as video reviewers. One blinded reviewer (S.K.W.) confirmed the times recorded in real time to chest compressions and time to defibrillation for all cases to minimize bias and ensure consistency; the start time was determined by the beginning of a verbal prompt given by the nurse upon each participant's entry into the room in response to the call for help. In addition, each team leader performance was assessed by 2 of the 5 reviewers for each video recording; their respective scores were recorded as Resuscitation Team Leader Evaluation (RTLE) 1 and RTLE 2 for each case. Each reviewer was given a number 1 through 5. For every 10 videos, every combination of 2 of the 5 reviewers was used so that each video was reviewed twice and each reviewer was assigned to 4 videos. Reviewers were blinded to study group allocation of the participants.

The RTLE is a validated tool that assesses elements of team leader competency in pediatric resuscitation, and each participant was scored using a modified RTLE.[21] The original tool includes 26 items, 12 that evaluate leadership and communication and 14 that evaluate knowledge and skills. Because of the brief length of the test case in our study, the application of the full-length tool was limited as several items could not be applied or adequately measured. Therefore, a priori, the study coinvestigators limited the components of this scoring tool to those that could be assessed in the 3-minute test case, before data collection and analysis (see Doc, Supplemental Digital Content 3 http://links.lww.com/SIH/A656, REDCap Survey). The reviewers together evaluated every component of the original RTLE and determined whether it could be applied to the brief test case. Together, they adjusted elements of the RTLE to fit the test case and reached an agreement on the grading of every component.

Outcomes

The primary outcome was time to defibrillation in a pediatric cardiac arrest case by participants, previously trained in either RCDP or PSD simulation, in the team lead role at delayed follow-up. Secondary outcomes included time to chest compressions and team leader performance based on the modified RTLE.[21]

Statistical Analysis

Using data from a prior study,[22] we estimated time to defibrillation to be approximately 110 seconds. We wanted the power to detect a difference of 30 seconds between teams, so we calculated the mean of the populations to be approximately 110 and 140 and a standard deviation of 30. Using a 2-tailed α value of 0.05 and a β value of 0.2, we calculated a sample size of 16 per arm via https://www.stat.ubc.ca/~rollin/stats/ssize/n2.html.

Differences between the 2 study groups and learner demographics were assessed using the Pearson χ^2 test for categorical variables and the Mann-Whitney test for skewed, continuous data. If any of the categorical variables included a value of less than 5, the Fisher exact test was used. Frequencies, column percentages, medians, interquartile ranges, and *P* values were reported.

To determine the odds of achieving defibrillation in the intervention group, an odds ratio (OR) with a 95% confidence interval (CI) and a *P* value was calculated. A time-to-event analysis (Kaplan-Meier curve/log rank *P* value) using 1 minus survival for time-to-shock was also conducted to show the proportion of those who achieved defibrillation for the 2 groups. If the teams did not reach defibrillation by 3 minutes (stopping point), they were censored (contributed time without an event).

The distributions of the continuous outcome variables were normal, so independent *t* tests were used to determine time differences. Power, means, standard deviations, and *P* values for each outcome were reported.

Lastly, to determine the reliability of the independent scores generated from video viewing, an intraclass correlation coefficient (ICC) analysis was conducted to find the agreement between 2 raters. A 1-way random model for absolute agreement using single measures was chosen. For this analysis, the ICC, 95% CIs, and *P* values were reported. Statistical significance was defined as a *P* value of less than 0.05. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS), Version 25 (IBM Corp, Armonk, NY).

RESULTS

Participants

Two hundred sixty-four residents were eligible to participate in this study. Once enrolled, they were randomized as a group to receive either RCDP (n = 127) or PSD (n = 137) on their initial simulation day. We expected a significant percentage of enrolled participants to be lost to follow-up because of the nature of residents' schedules during the study period. Some residents rotated through PEM once and never returned for a subsequent session. Most pediatric residents rotate through PEM twice a year in their second year (ranging 1–-11 months between rotations). Our study was aligned with our residents' schedules; thus, most participants could not be captured in our study period, which began in the middle of the academic year. After a variable washout period of 1 to 12 months since the initial assessment, 36 residents returned for a second simulation day during the study period and met inclusion criteria. Four residents were excluded because of either video recording failure or technical error during the case where the incorrect rhythm was displayed on the monitor. Ultimately, data from 32 residents (90.6% pediatrics, 9.4% emergency medicine) were analyzed for this study. Within the follow-up period of 1 to 12 months, 21 residents returned within 6 months (9 RCDPs, 12 PSDs) and 11 residents returned between 6 and 12 months (7 RCDPs, 4 PSDs). More specifically, 40% returned in 1 to 3 months, 25% 3 to 6 months, 16% 6 to 9 months, and 19% 10 to 12 months. For both study groups, pediatric residents were the majority (Fig. 1).

Learner characteristics are presented (Table 1). There were no significant differences between baseline characteristics (training program, year of training, prior simulation lead, and

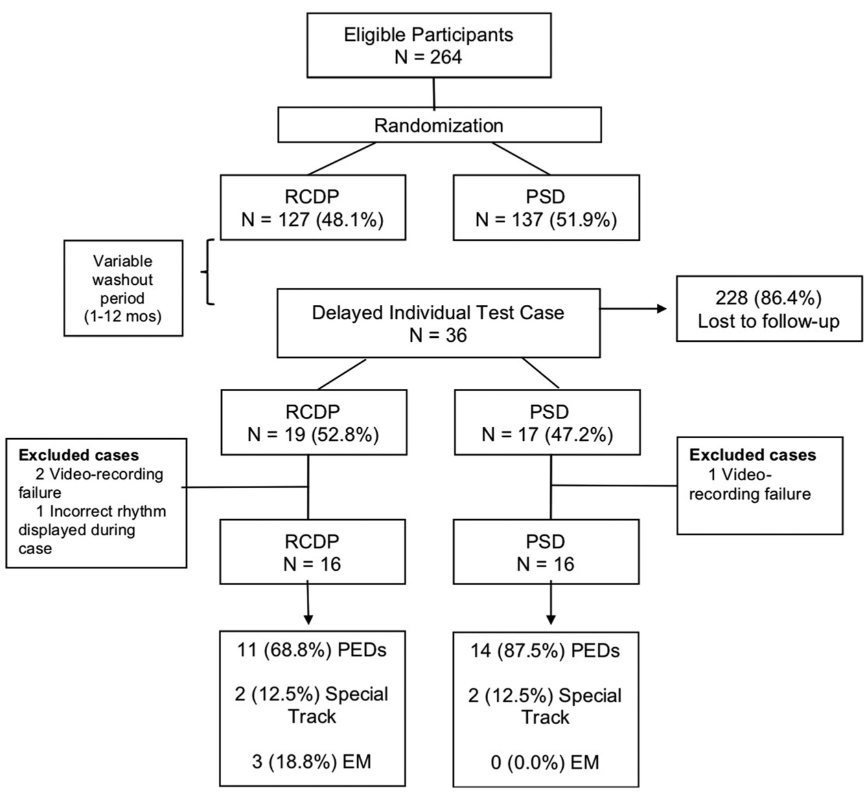

FIGURE 1. Flow of study.

TABLE 1. Learner Demographics (N = 32)

	PSD (n = 16, 50.0%), n (%)	RCDP (n = 16, 50.0%), n (%)	P
Training program			
Categorical pediatrics	14 (87.5)	11 (68.8)	0.19
Emergency medicine	0 (0.0)	3 (18.9)	
Pediatric specialty tracks	2 (12.5)	2 (12.5)	
Year of training			
PGY1	1 (6.3)	1 (6.3)	1.00
PGY2	15 (93.8)	15 (93.8)	
PALS certified	16 (100.0)	16 (100.0)	*
Prior simulation experience	15 (93.8)	15 (93.8)	1.00†
Prior simulation lead experience	12 (75.0)	15 (93.8)	0.33†
Actual codes attended	3.0 (2.0, 3.75)	3.0 (2.0, 8.75)	0.82†

*Cannot be calculated.
†Fisher's exact test was used when any cell value was less than 5.
‡P value calculated using the Mann-Whitney test.
PGY: postgraduate year.

number of codes attended) and study groups. All participants were PALS certified throughout the study period.

Performance

Significantly more members of the intervention group achieved defibrillation within 3 minutes: 81.3% in the RCDP group versus 43.8% in the PSD group. Therefore, the RCDP group had more than 5 times the odds of reaching defibrillation than those in the PSD group (OR = 5.57, 95% CI = 1.13–27.52, P = 0.04; Table 2). When using a time-to-event analysis, the percentages to defibrillation increased at a higher rate in the RCDP group than the PSD group (log rank P = 0.02; Fig. 2). Further analysis was done to assess skill retention in 3-month intervals and found our results to be inconclusive (see Table, Supplemental Digital Content 4 http://links.lww.com/SIH/A657, which demonstrates performance data in 3-month increments since time of training).

All participants in both study groups initiated CPR during the test case. The RCDP group required less time than the PSD group to initiate compressions (22.75 seconds vs. 35.00 seconds, respectively; Table 3), but this difference was not statistically significant (P = 0.07). For the modified RTLE, the RCDP group had a higher score than the PSD control group (0.54 vs. 0.34, respectively, P < 0.001; Table 3).

Interrater Reliability

To assess interrater reliability, ICCs were calculated for both RTLE 1 and RTLE 2 scores. Interrater reliability had excellent agreement, having a significant correlation of 0.88 (95% CI = 0.77–0.94, P < 0.001).

DISCUSSION

Educational Significance

Our study found that individuals who were previously trained in pediatric resuscitation skills using RCDP were more likely than those trained using PSD to defibrillate within 3 minutes of cardiac arrest. In addition, RCDP was associated with an improvement in time to chest compressions and team leader performance, but this was not statistically significant.

In previous research, RCDP has been shown to be at least as effective as PSD in imparting immediate knowledge and skills.[23] However, there are limited data comparing the long-term retention of skills acquired by these 2 modalities of SBME, and the current data comparing these 2 teaching methods are limited and inconclusive.[24] Hunt et al[13] showed that RCDP improves the time-sensitive "first 5-minute" performance of resident learners and introduced the concept of providing direct feedback paired with repetitive and deliberate practice. Rapid cycle deliberate practice was associated with key measures of resuscitation quality, including improved times to CPR and defibrillation, but without direct comparison to PSD. Lemke et al[15] built upon these initial findings and directly compared RCDP with PSD simulation methods. Their study showed improvement in team performance after RCDP sessions, which was similar to the improvement seen after a PSD session. Their study also demonstrated a significantly greater improvement for human factors (establishing roles, closed-loop communication, shared mental model, mutual respect, knowledge sharing, constructive intervention, work distribution, and appropriate disposition) with RCDP compared with PSD simulation. In addition, another study by Cory et al[25] showed that although both RCDP and PSD were effective in training residents in the management of septic shock, RCDP was superior immediately after training; there was no difference on follow-up assessment 3 to 4 months after initial training.

It is possible that repetition with deliberate practice enhances memory consolidation, a key to skill retention. A large meta-analysis comparing SBME with deliberate practice versus traditional clinical education found superiority in SBME with deliberate practice as a teaching model for acquiring specific clinical skills.[7] Similarly, RCDP mirrors the learning in these studies and emphasizes repetitive practice over reflective debriefing.

Our findings are consistent with and build upon those of previous studies by examining skill retention over time. While residents were taught pediatric resuscitation skills based on a case of PEA, they received training on the defibrillator that would allow them to be successful on a subsequent test that included a potentially more challenging algorithm in a case of PVT. Despite the difference in training and testing scenarios, our data suggest that RCDP may be more effective than PSD at solidifying learned skills and creating muscle memory for time-sensitive choreographed events.

The timing and quality of resuscitation matter when caring for critically ill patients. In cardiac arrest, the delivery of appropriate defibrillation for a shockable rhythm is crucial. The PALS guidelines continue to emphasize immediate CPR and early defibrillation in pediatric cardiac arrest as soon as a shockable rhythm is recognized, with the goal of maximizing the chance of return of spontaneous circulation.

Our results reflect the beneficial effects of RCDP as a teaching modality, as more residents trained with RCDP were achieving critical actions faster and having measurably better

TABLE 2. Odds of Achieving Defibrillation Within 3 Minutes by Study Group (N = 32)

	Shock, n (%)*	Did Not Shock, n (%)*	OR	95% CI	P
PSD	7 (43.8)	9 (56.3)	5.57	1.13–27.52	0.04
RCDP	13 (81.3)	3 (18.8)			

*Row percentages are provided.
PSD, postsimulation debriefing (control).

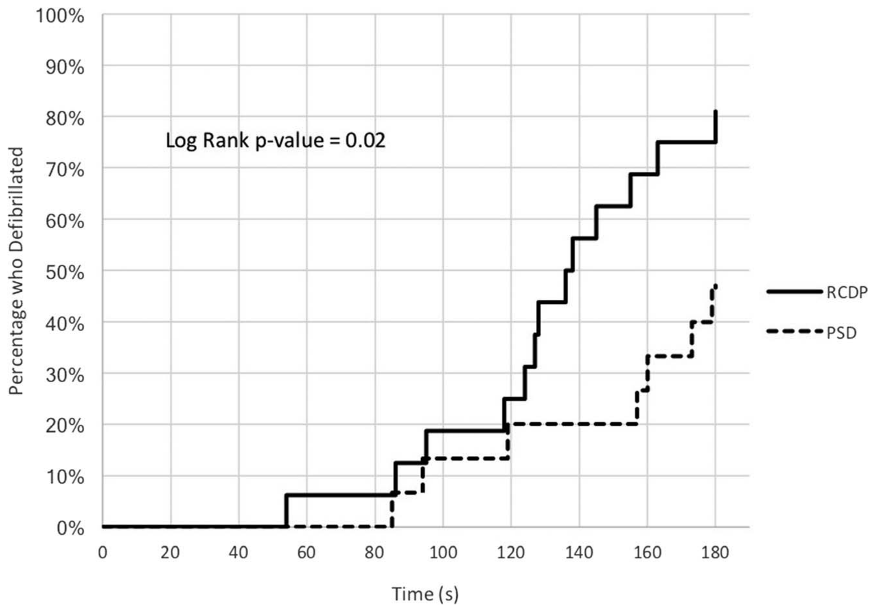

FIGURE 2. Kaplan-Meier curve of time elapsed from onset of pulseless VT to defibrillation. Rapid cycle deliberate practice showed a higher rate of increase in percentages to defibrillation than PSD. VT, ventricular tachycardia.

team performances than those taught using the traditional debriefing model. One possible explanation for this difference is that the cognitive load is lower during RCDP than in PSD. In RCDP, participants receive real-time feedback in digestible portions and in smaller time increments, followed by an opportunity to practice deliberately and accomplish specific tasks.[16] The deliberate practice is key to creating an effective connection between behavior improvements. This also allows for a more meaningful understanding of one's actions, which may further improve retention. Possibly, one of the most beneficial effects of RCDP is that the technique reflects Kolb experiential learning theory, an educational theory in which much of medical training is modeled after. It includes a 4-step cycle of concrete experience, reflective observation, abstract conceptualization, and active experimentation. When these steps are done sequentially as they are in RCDP, it is intended to truly solidify learning.[26]

This is in contrast to PSD in which general and specific feedback is given all at once without an immediate opportunity to implement behavioral change through deliberate practice. Attempts to recall specific circumstances that need improvement may not be successful, and some aspects of the feedback may become less effective. The other difference is how much time is spent on different aspects of pediatric resuscitation. Our RCDP residents spent more time practicing initial actions of pediatric resuscitation at the expense of less time on actions farther down the algorithm; residents in the PSD group spent more time performing or discussing subsequent actions.

The cohort of instructors who taught both RCDP and reflective debriefing sessions received formal training in both methods of debriefing and used scripted debriefs for both. However, these instructors may have varied in their individual teaching styles and delivery of feedback, arguably making our results more generalizable because we then captured a real-life application of the educational interventions, rather than their use under purely laboratory conditions. Moreover, despite having multiple video reviewers, the ICCs for resident team leader performance scores had excellent agreement.

Limitations

This study had several limitations. First, the return test case was designed to include 3 confederates with the learner serving as team lead. However, in 4 cases, the instructor team did not have a third confederate to assist, either because of scheduling conflicts or functionally because 1 instructor had to operate the computer for the simulation. Of those 4 cases, 3 of the learners had received simulation training with RCDP and only 1 with reflective debriefing. This may have altered the performance of the team lead, as the learner might have been occupied by tasks that they normally would not be responsible for if a third teammate were present. Secondly, there was some variability in team members for the initial training session, with some teams comprising of 5 and others 6 learners. Depending on the size of the team, some teams did not have a learner participant as a CPR coach, which may have altered the dynamics and choreography of the team. In addition, there was an institution-wide switch in defibrillators, from Physio-Control Lifepak 20 defibrillators to the Zoll R Series, which took place in March 2018, 2 months into our study. This switch affected 9 participants (28%), as they were tested using a defibrillator with which they were not initially trained. They were, however, evenly distributed between the 2 groups

TABLE 3. Comparison of Study Groups and Outcomes Using the Independent *T* Test

	PSD, n	PSD, Mean (SD)	RCDP, n	RCDP, Mean (SD)	*P*
Time to shock, s	7	138.14 (38.42)	13	126.85 (33.59)	0.50
Washout period, mo	16	4.23 (3.17)	16	5.99 (3.73)	0.16
Time to CPR, s	16	35.00 (23.12)	16	22.75 (9.83)	0.07
RTLE (1) score	16	0.34 (0.16)	16	0.54 (0.19)	<0.001

(5 RCDPs, 4 PSDs). Another limitation lies in the modified RTLE tool for team leader performance, because modification may affect its validity. Furthermore, the amount of time spent leading the team was less for individuals who achieved defibrillation earlier because the scenario ended once defibrillation was performed. However, our study showed that the RCDP group performed significantly better than the PSD group based on their RTLE scores. Although this study was not powered to compare RTLE and defibrillation times, future research studies should seek to understand how team leader performance affects outcomes. Moreover, this study tested team leadership. Most of the residents in the PSD group kept their assigned roles throughout the simulation and therefore did not receive the chance to be team lead, whereas RCDP gave residents the opportunity to rotate roles and thus practice in real team as team lead. This may suggest that the benefit seen in RCDP lies more in rotating the learners and offering first-hand experience than from the difference in training structure itself. Lastly, although the initial simulation education came in the form of team-based training, the follow-up testing focused on individual performance. Therefore, the first and second time points could not be directly compared for each individual, thus raising the question if retention is truly measured. Future studies could directly compare individual scores before and after a period in which decay of knowledge and skills might occur.

Future Directions

Future studies should focus on best applications for RCDP and its effectiveness with varying levels of learners and differing content. Rapid cycle deliberate practice should be tested against PSD after integration into the PALS curriculum. These should also assess knowledge and skill decay. In addition, research is needed to determine whether the benefits observed from RCDP are translated to clinical practice, resulting in clinically significant improvement in resuscitation performance and ultimately survival in children.

CONCLUSIONS

A skill is not considered truly learned until retention and/or transfer of that particular skill is demonstrated. This study demonstrated a significant difference in performance metrics in team leaders who were previously trained with RCDP compared with PSD. Residents trained using RCDP were more likely to achieve defibrillation faster and perform more effectively as team leader than those trained using PSD debriefing methods. Rapid cycle deliberate practice may be a superior method for training teams when choreographed and time-dependent actions are required. Such an advantage should encourage wider adoption and study of RCDP, which may provide better learning outcomes for trainees and improved clinical outcomes for patients.

ACKNOWLEDGMENTS

The authors thank all of our educators who made this study possible: Kiyetta Alade, MD, MEd, RDMS; Brian Bassham, MD; Corrie Chumpitazi, MD, MS; Charlyn Davis, MSN, RN, CPEN, CPN; Erin Henkel, MD; Kim Little, MD, MEd; Shyama Kamat, MD; Faria Pereira, MD; Natalie Pham, MSN, RN, CPEN, CPN; Nadia Villarreal, BSN, RN, CPEN, SANE-P; and Elizabeth Wuestner, MSN, RN, CPEN.

REFERENCES

1. Savoldelli GL, Naik VN, Park J, Joo HS, Chow R, Hamstra SJ. Value of debriefing during simulated crisis management: oral versus video-assisted oral feedback. *Anesthesiology* 2006;105(2):279–285.
2. Cook DA, Hatala R, Brydges R, et al. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. *JAMA* 2011;306(9):978–988.
3. Shapiro MJ, Morey JC, Small SD, et al. Simulation based teamwork training for emergency department staff: does it improve clinical team performance when added to an existing didactic teamwork curriculum? *Qual Saf Health Care* 2004;13(6):417–421.
4. Hunt EA, Walker AR, Shaffner DH, Miller MR, Pronovost PJ. Simulation of in-hospital pediatric medical emergencies and cardiopulmonary arrests: highlighting the importance of the first 5 minutes. *Pediatrics* 2008; 121(1):e34–e43.
5. Issenberg SB, Mcgaghie WC, Petrusa ER, et al. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. *Med Teach* 2005;27:10–28.
6. Ericsson KA. Deliberate practice and acquisition of expert performance: a general overview. *Acad Emerg Med* 2008;15:988–994.
7. McGaghie WC, Issenberg SB, Cohen ER, et al. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? A meta-analytic comparative review of the evidence. *Acad Med* 2011;86:706–711.
8. Ericsson KA. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. *Acad Med* 2004;79(Suppl 10):S70–S81.
9. Rudolph JW, Simon R, Dufresne RL, et al. There's no such thing as "nonjudgmental" debriefing: a theory and method for debriefing with good judgment. *Simul Healthc* 2006;1:49–55.
10. Hunt EA, Vera K, Diener-West M, et al. Delays and errors in cardiopulmonary resuscitation and defibrillation by pediatric residents during simulated cardiopulmonary arrests. *Resuscitation* 2009; 80(7):819–825.
11. Cooper S, Libby J. A review of educational issues in resuscitation training. *J Clin Nurs* 1997;6(1):5–10.
12. Perretta JS, Duval-Arnould J, Poling S, et al. Best practices and theoretical foundations for simulation instruction using rapid-cycle deliberate practice. *Simul Healthc*. Oct 2020;15(5):356–362.
13. Hunt EA, Duval-Arnould JM, Nelson-McMillan KL, et al. Pediatric resident resuscitation skills improve after "rapid cycle deliberate practice" training. *Resuscitation* 2014;85(7):945–951.
14. Sawyer T, Eppich W, Brett-Fleegler M, Grant V, Cheng A. More than one way to debrief: a critical review of healthcare simulation debriefing methods. *Simul Healthc* 2016;11(3):209–217.
15. Lemke DS, Fielder EK, Hsu DC, Doughty CB. Improved team performance during pediatric resuscitations after rapid cycle deliberate practice compared with traditional debriefing: a pilot study. *Pediatr Emerg Care* 2019;35(7):480–486.
16. Chancey RJ, Sampayo EM, Lemke DS, Doughty CB. Learners' experiences during rapid cycle deliberate practice simulations: a qualitative analysis. *Simul Healthc* 2019;14(1):18–28.
17. Welch-Horan T, Doughty C, Hsu D, et al. Randomized controlled trial of rapid cycle deliberate practice simulation versus traditional simulation for teaching pediatric resuscitation skills to resident physicians. Abstracts to be presented at the 16th annual international meeting on simulation in healthcare: January 16th–20th, 2016 San Diego, CA. *Simul Healthc* 2015;10:470.
18. Eppich W, Cheng A. Promoting Excellence and Reflective Learning in Simulation (PEARLS): development and rationale for a blended approach to health care simulation debriefing. *Simul Healthc* 2015;10(2):106–115.
19. Cheng A, Hunt EA, Donoghue A, et al. Examining pediatric resuscitation education using simulation and scripted debriefing: a multicenter randomized trial. *JAMA Pediatr* 2013;167:528–536.
20. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research Electronic Data Capture (REDCap)—a metadata-driven

methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009;42(2): 377–381.

21. Grant EC, Grant VJ, Bhanji F, Duff JP, Cheng A, Lockyer JM. The development and assessment of an evaluation tool for pediatric resident competence in leading simulated pediatric resuscitations. *Resuscitation* 2012;83(7):887–893.

22. Welch-Horan T, Doughty C, Hsu D, Fielder E, Pereira F, Little-Wienert K, Kaziny B, McManemy J, Lemke D. Comparing rapid cycle deliberate practice and traditional debriefing for resident training. *International Pediatric Simulation Symposia and Workshops*. Vienna, Austria, 2014.

23. Magee MJ, Farkouh-Karoleski C, Rosen TS. Improvement of immediate performance in neonatal resuscitation through rapid cycle deliberate practice training. *J Grad Med Educ* 2018;10(2):192–197.

24. Taras J, Everett T. Rapid cycle deliberate practice in medical education—a systematic review. *Cureus* 2017;9(4):e1180.

25. Cory MJ, Colman N, McCracken CE, Hebbar KB. Rapid cycle deliberate practice versus reflective debriefing for pediatric septic shock training. *Pediatr Crit Care Med* 2019;20(5):481–489.

26. Fewster-Thuente L, Batteson TJ. Kolb's experiential learning theory as a theoretical underpinning for Interprofessional education. *J Allied Health* 2018;47(1):3–8.