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Effectiveness of a High-Fidelity Simulation-Based Training Program in Managing Cardiac Arrhythmias in Children

A Randomized Pilot Study

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Objectives: Pediatric cardiac arrest is a rare event. Its management requires technical (TSs) and nontechnical skills (NTSs). We assessed the effectiveness of a simulation-based training to improve these skills in managing life-threatening pediatric cardiac arrhythmias.

Methods: Four teams, each composed of 1 pediatric resident, 1 emergency medicine resident, and 2 pediatric nurses, were randomly assigned to the experimental group (EG) participating in 5 video-recorded simulation sessions with debriefing or to the control group (CG) assessed 2 times with video-recorded simulation sessions without debriefing at a 2-week interval. Questionnaires assessed self-reported changes in self-efficacy, stress, and satisfaction about skills. Blinded evaluators assessed changes in leaders' TSs and NTSs during the simulations and the time to initiate cardiopulmonary resuscitation.

Results: After training, stress decreased and satisfaction about skills increased in the EG, whereas it remained the same in the CG ($P = 0.014$ and $P < 0.001$, respectively). There was no significant change in self-efficacy. Analyses of video-recorded skills showed significant improvements in TSs and NTSs of the EG leaders after training, but not of the CG leaders ($P = 0.026$, $P = 0.038$, respectively). The comparison of the evolution of the 2 groups concerning time to initiate cardiopulmonary resuscitation was not significantly different between the first and last simulation sessions.

Conclusions: A simulation-based training with debriefing had positive effects on stress and satisfaction about skills of pediatric residents and nurses and on observed TSs and NTSs of the leaders during simulation sessions. A future study should assess the effectiveness of this training in a larger sample and its impact on skills during actual emergencies.

Key Words: simulation-based training, technical skills, nontechnical skills

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In-hospital cardiac arrest is a rare event in the pediatric population.[1,2] For example, Tibballs et al[1] has observed 20 cardiac arrest in 105,000 admissions during a period of 41 months (1/5000). However, only 25% of children treated for in-hospital cardiac arrests survive to hospital discharge.[2] Children differ from adults as to the cause and pathophysiology of cardiopulmonary arrest,[3] but hospital resuscitation teams are initially designed for the care of adults.[4] Rhythm disorders are one of the causes of cardiac arrest in children. In addition to being rare, rhythm disorders in children have certain characteristics that make their treatment less effective than in adults: they involve specific skills, a high emotional and cognitive load, and the adjustment of drugs dosage related to the weight (need to calculate).[3,5] Health care providers typically have less experience and less comfort with managing these events.

Even clinicians who are knowledgeable and skilled in resuscitation techniques may fail to apply them successfully unless they have an adequately strong belief in their capability.[6] For example, Simon and Sullivan[7] have examined the confidence in performance of pediatric emergency medicine procedures among 117 emergency physicians. Over 25% were uncomfortable with performing certain potentially life-saving pediatric procedures (eg, defibrillation). Clinicians are less likely to initiate and sustain behaviors for which they lack confidence or self-efficacy.[6,8] All this may have an influence on the effectiveness of children resuscitation. In fact, studies showed that the failure of resuscitation is often due to human factors.[9] For example, poor interdisciplinary communication and teamwork seem to be important contributing factors to adverse events in general and in the area in perinatal deaths.[10] It seems that caregivers have a lack of nontechnical skills (NTSs) (eg, self-efficacy, communication, leadership).[11,12]

Studies suggested that, for best clinical outcomes, it is important to give training in both technical skills (TSs) (eg, knowledge and skills related to medical expertise) and NTSs (eg, communication, leadership) to health care teams.[11,13] These NTSs are often addressed in crisis resources management (CRM) courses intended to help prevent and manage difficulties during medical care.[14] Crisis resources management principles are designed to deal with an acute crisis and to focus the attention on factors, which might improve patient safety (eg, call for help early, exercise leadership, communicate effectively).[15] Simulation-based training has been recommended as a method to train teams in learning these skills for pedagogical and patient safety reasons, and the use of this tool is increasing across the world.[14,16,17] To prepare medical residents to stressful events, a growing number of programs have integrated high-fidelity simulation in training.[16,18–20] The simulation allows maintaining a high level of skills by recreating infinitely serious and infrequent clinical situations. The advantages are to provide controlled environment (no risk for patient), contextual and interactive learning, repetitive practice, standardization of teaching with a range of task difficulty level, and immediate feedback and debriefing.[21,22] Debriefing is a reflective feedback process in which learners are encouraged to discuss strengths and weaknesses of their performance.[23] This process has been found to be critical for the success of experiential learning in simulation.[24,25] However, studies are needed to determine how to use simulation training and debriefing with the most efficient way and to provide a better understanding of the advantages of this type of training.[14,22,26]

Our aim was to assess the effectiveness of a high-fidelity simulation-based training with debriefing about TSs and NTSs in managing children with cardiac arrhythmias in nurses and residents working in pediatric and emergency medicine. Objectives were to measure (1) the self-reported changes in perceived stress,

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self-efficacy, and satisfaction about their skills among all nurses and residents; (2) the changes in recorded TSs (eg, clinical knowledge) and NTSs (eg, leadership) of the leaders during simulation sessions assessed by 3 blinded evaluators; and (3) the time to initiate cardiopulmonary resuscitation (CPR) (eg, initiate bag-mask ventilation).

METHODS

Design and Participants

The study took place at the Pediatric Simulation Center, Pediatric Department, Liège University Hospital–NDB, Belgium. Four teams of participants, each composed of 4 members (1 pediatrician resident, 1 emergency medicine resident, 1 pediatric nurse working in the ward, and 1 pediatric nurse working in the pediatric emergency department), were created on a voluntary basis among the staff of pediatric and emergency medicine departments of the hospital. These 4 teams were randomly divided into 2 groups based on their working rota (as a matter of practical organization of the training sessions): the experimental group (EG) and the
AQ4 control group (CG) ~~(see Fig. 1)~~. The EG participated in a regular high-fidelity simulation-based training composed of 5 simulation sessions with debriefing. We assessed the self-reported changes in perceived stress, self-efficacy, and satisfaction about skills with questionnaires before and after this training program for all participants, and 3 blinded evaluators assessed the changes in TSs and NTSs of the leader of the simulation by comparing between the videos of the first and fifth simulation sessions. The CG did not participate to the training program and was assessed 2 times with questionnaires and with 2 video-recorded simulation sessions without debriefing (with an interval of 2 weeks between the 2 sessions at least). The CG had a debriefing after these 2 assessment times. Changes in the EG were compared with the changes in the CG. The institutional review boards (research ethics committee) of the Liège University Hospital, Belgium, approved the study (number B707201318537). Each participant provided a written consent to participate.

Training and Materials

The high-fidelity simulation sessions with debriefing were aimed to develop TSs (eg, to recognize a sick child) and NTSs
AQ5 (eg, leadership). They used interactive baby and junior manikins (SimBaby and SimJunior; Laerdal Medical, Norway) and placed them in a realistic clinical environment (emergency medicine department) for monitoring. The subjects participated in 5 clinical scenarios on arrhythmia (ie, arrhythmia due to hypovolemia, drug intoxication, hyperkalemia, drowning, or hypoxia). The order of the scenarios was randomly assigned and differed from 1 team to another to avoid contamination between the teams. A pediatrician and a pediatric intensive care cardiac specialist had prepared all scenarios. The scripts included the initial clinical vignette, vital signs, patient weight, laboratory values, and anticipated changes in the clinical status, including how and when the decompensation should occur (eg, in the fourth minute of scenario, the patient will progress to asystole), and provided answers to the measures taken by the participants (eg, the patient returned to sinus rhythm when adrenaline is administered). To maintain realism, participants had few interactions with evaluators, who were in a control room, which was separated from the emergency room by a glass. At the beginning of the simulation program, participants undergo familiarization to the simulation room (explanation of the simulation progress and the principles of nonjudgment, as well as familiarization with the manikin and the environment). Each 15-minute scenario begun with the emergency medicine nurse who would call an emergency medicine resident for help. Then, they were provided with pediatric colleagues' support if appropriate to the scenario (eg, senior doctor, nurse). A video relay to the debriefing room provided the possibility to do video-assisted debriefing. During the video-assisted debriefing, the facilitator choose some sequences showing good and bad NTs and TSs to reinforce good practice, to reflect on their practice, and to learn from mistakes. A 30- to 40-minute structured debriefing based on the model by Rudolph et al[27] and led by 2 experienced facilitators who attended an EuSim Simulation Instructor Course (1 physicians and 1 nurse) followed the scenarios. Debriefing allowed participants to reflect on actions taken in the scenario and discuss them within the team. It included the following steps: a reactions phase in which trainees "blow off steam", a description phase, an analysis phase in which the instructor and trainees discuss and analyze trainees' performance, and a summary phase in which each trainee phrase their take-home message.[28]

Assessment

Assessment of Self-Reported Changes

All participants gave socioprofessional data (age, sex, profession, year of specialization for residents). They also completed 3 questionnaires: a perceived stress questionnaire, a self-efficacy questionnaire (before each simulation session), and a satisfaction questionnaire (after each simulation session).

- Perceived stress questionnaire (available in Appendix 1, http://links.lww.com/PEC/xxx). A 5-item visual analog scale (VAS) ranging from 0 (very stressful) to 10 (not at all stressful) assessed perceived stress in emergencies (eg, communicating with parents in emergencies). Cronbach α coefficient was 0.69.
- Self-efficacy questionnaire adapted from Levy et al[29] (available in Appendix 1, http://links.lww.com/PEC/xxx). A 12-item questionnaire scored on a 6-point Likert scale from 1 (very low) to 5 (excellent) (and 0 for "not applicable") assessed self-efficacy about the use of TSs (4 items, eg, to recognize a patient in cardiopulmonary arrest) and CRM NTSs (8 items, eg, call for help). Cronbach α coefficient was 0.87 for TSs and 0.77 for NTSs.
- Satisfaction questionnaire (available in Appendix 1, http://links.lww.com/PEC/xxx). A 5-item VAS ranging from 0 (not at all satisfied) to 10 (totally satisfied) assessed the trainee satisfaction about their general skills used in the simulation session (3 items: managing the clinical case, coordinating tasks of the team, and control on their own stress) and about their communication (2 items: communication with patients and communication with parents). Cronbach α coefficient was 0.71 for general skills and 0.84 for communication skills.

Assessment of Changes in TSs and NTSs of the Leaders During Simulation

These changes were measured with the 26-item validated grid of Grant[30,31] including 2 parts: first, NTSs based on CRM principles (leadership and communication; 12 items) and second, TSs (ABCD approach, knowledge and clinical skills; 14 items). Each skill was scored on a 4-point Likert scale from 0 (not executed/not observed) to 3 (systematically well executed), with a possibility to score "item not pertinent for the scenario." This tool allows evaluating clinical performance and leadership skills of the leaders during simulated pediatric crisis situations. The interrater reliability coefficient is excellent, as demonstrated by an overall intraclass correlation coefficient of 0.91 (95% confidence interval, 0.88-0.93).[31] Three experts in the field of pediatric emergency medicine trained to use the grid analyzed the videos.

These 3 assessors were blinded to the distribution of the groups or their status as pretraining or posttraining.

Time to Initiate CPR

Initiation of CPR was defined by 1 critical action, the bag-mask ventilation. The time-to-action data were recorded from the moment the first resident entered the room by using video review. Data were collected that measured time to initiate this critical action of CPR.

Statistical Analysis

Baseline time 0 data were compared between groups (EG and CG) on self-reported data, and on recorded TSs and NTSs to test for initial equivalency of groups using *t* tests for independent samples. Multivariate analyses (analysis of variance [ANOVA]) were calculated regarding time of assessment to compare the 2 groups for questionnaires scores, recorded TSs and NTSs, and time to start CPR. Interrater reliability between experts was established using the intraclass correlation coefficient (2-way mixed). Fleiss[32] had described values from 0.40 to 0.75 as "fair to good." All statistical test were 2-tailed, and a *P* value less than 0.05 was considered statistically significant. The analyses were performed with SPSS Version 21.0.[33]

RESULTS

Baseline Results

Mean (SD) age of participants was 33 (10.8)years. There were 4 men and 12 women. Residents were in their first or second year. The comparison between EG and CG groups at baseline showed no significant differences for self-reported variables (perceived stress, self-efficacy, satisfaction), excepted for the stress in communicating with a patient ($t = -2.897$; $P = 0.012$) that was higher in the EG than in the CG, and for TSs and NTSs of the leaders assessed by experts.

Self-Reported Changes After Training for All Participants

Repeated measures ANOVA on time of evaluation were performed for each questionnaire.

Regarding perceived stress (see Table 1), the analysis indicated a time effect (F = 7.046; $P = 0.019$) and a group by time interaction effect (F = 7.88; $P = 0.014$): perceived stress in emergency situations decreased in the EG after training and remained the same in the CG. Regarding self-efficacy, the analysis indicated no significant effect of time and no interaction between group and time: in both groups, participants already had a high mean of self-efficacy at baseline. Regarding satisfaction, the analysis revealed change over time for satisfaction about communication (F = 9.15; $P = 0.009$) and group by time interaction effects for satisfaction about general skills (F = 19.18; $P = 0.001$) and about communication skills (F = 10.42; $P = 0.006$): satisfaction about their skills increased in the EG after training and remained the same in the CG. T1

Changes in TSs and NTSs of the Leaders During Simulation Sessions After Training

Acceptable interrater reliability was obtained for the validated grid of Grant performance ratings: $r = 0.66$ ($P = 0.009$) for part 1 (leadership and communication skills) and $r = 0.61$ ($P = 0.019$) for part 2 (knowledge and clinical skills). Repeated measures ANOVA on time of evaluation showed a group by time interaction effect for leadership and communication skills (F = 5.691, $P = 0.038$) and for knowledge and clinical skills (F = 6.842, $P = 0.026$): leaders in the EG have improved these

TABLE 1. Perceived Stress, Self-Efficacy, and Satisfaction Among EG and CG Before (T0) and After Training (T1), and ANOVA With Repeated Measures on Time of Evaluation

	EG		CG		Time Effect	Group × Time Effect
	T0, Mean (SD)	T1, Mean (SD)	T0, Mean (SD)	T1, Mean (SD)	F (*P*)	F (*P*)
Perceived stress in emergencies (VAS: stressful [0] to not stressful [10])						
Managing a patient in cardiopulmonary arrest	2.8 (1.8)	6.2 (2.0)	2.8 (2.0)	4.3 (2.5)		
Communicating with a patient	3.9 (1.8)	6.1 (1.9)	6.6 (1.8)	5.5 (1.9)		
Communicating with parents	4.2 (2.2)	6.6 (2.0)	6.2 (2.3)	6.3 (2.4)		
Coordinating the tasks of the team	4.1 (1.8)	7.1 (2.5)	6.4 (2.5)	5.2 (2.6)		
Feeling of control	5.2 (2.4)	7.1 (1.3)	5.7 (1.7)	6.0 (1.1)		
Total	4.0 (1.3)	6.6 (1.7)	5.5 (0.5)	5.5 (1.7)	**7.046 (0.019)**	**7.880 (0.014)**
Self-efficacy (Likert: not confident [0] to very confident [5])						
TSs	4.0 (1.0)	4.3 (0.3)	3.7 (0.5)	3.8 (0.2)	0.70 (0.417)	0.11 (0.748)
NTSs	3.4 (0.7)	4.0 (0.7)	3.3 (0.5)	3.6 (0.2)	4.49 (0.054)	0.73 (0.408)
Satisfaction about skills used in simulation (VAS: not satisfied [0] to totally satisfied [10])						
Managing the clinical case	4.5 (1.6)	8.1 (1.1)	5.8 (1.4)	4.5 (1.7)		
Coordinating tasks of the team	4.4 (1.4)	7.8 (1.7)	6.1 (2.5)	4.5 (2.1)		
Controlling my own stress	6.7 (2.1)	8.6 (1.0)	7.4 (2.1)	6.6 (1.7)		
Subtotal	5.2 (1.1)	8.2 (0.9)	6.4 (1.7)	5.2 (1.7)	3.64 (0.077)	19.18 (0.001)
Communicating with parents and relatives	3.2 (2.2)	7.5 (1.2)	4.6 (2.7)	4.9 (2.4)		
Communicating with patient	3.3 (1.4)	7.2 (1.3)	4.8 (2.5)	4.2 (1.7)		
Subtotal	3.2 (1.1)	7.3 (1.1)	6.4 (1.7)	4.6 (1.8)	9.15 (0.009)	10.42 (0.006)
Total	4.4 (1.0)	7.8 (0.8)	5.7 (1.1)	5.0 (1.5)	**11.73 (0.004)**	**28.99 (<0.001)**

skills after training, while these skills remained the same in the CG (see Table 2). Specifically, the leaders in the EG had improved 4 items among leadership and communication skills (items 1, 2, 4, and 5: "Resident clearly identifies he/she will lead the resuscitation, delegates roles and responsibilities appropriately to team members, uses effective closed loop communication, manages team resources appropriately among team members") and 5 items among knowledge and clinical skills (items 5, 6, 12, 13, and 14: "Resident asks for initiation of appropriate initial breathing support and ensures effectiveness, identifies need for and obtains appropriate airway interventions as required, chooses interventions according to appropriate PALS algorithm, orders appropriate investigations, asks for assessment of neurological status or secondary survey once stabilization of ABC's complete"), but not in the CG.

Changes in the Time to Initiate CPR

There was no significant group by time interaction effect; the comparison of the evolution of the 2 groups concerning the time to initiate CPR was not significantly different between the first and last simulation sessions. However, between the first and last simulation sessions, the EG showed a small reduction in the time to initiate CPR (mean = 47 and mean = 40, respectively), whereas the CG showed a substantial increase in the time to initiate CPR (mean = 39 and mean = 94, respectively).

DISCUSSION

Our pilot study aimed to assess the effectiveness of a high-fidelity simulation-based training with debriefing about TSs and NTSs in managing children cardiac arrhythmias among nurses and residents working in pediatric and emergency medicine. Objectives were to measure self-reported changes in perceived stress, self-efficacy and satisfaction about their skills among all participants, and changes in several recorded TSs and NTSs of the leaders during simulation sessions. We compared the results of an EG (receiving a regular simulation-based training) to a CG, each group composed of 4 residents and 4 nurses. Our study has shown that this training program had a significant positive impact on (1) self-reported perceived stress and satisfaction about the skills used during the simulation sessions of all participants and (2) TSs and NTSs of the leaders during the simulation sessions. However, there were no significant changes in self-reported self-efficacy and in the time to start CPR.

First, perceived stress (eg, stress about communicating with parents) in emergency situations decreased in the EG after training, whereas it remained the same in the CG. This result is important when we consider that the reality of cardiac arrest being less common in pediatrics places residents and nurses at risk of being hesitant and highly anxious when such events do arise.[34] An emergency situation is a stressful experience for health care workers, and perceived stress may interfere with their decision-making abilities and performance.[35] Particularly, feeling overwhelmed by stress may cause cognitive impairment, potentially leading to loss of concept on how to deal with an emergency situation, which in turn further increases stress.[35] For example, Hunzicker et al[35] have shown a significant negative correlation between the overall perceived stress during a simulated CPR and hands-on time (hands-on time defined as duration of uninterrupted chest compressions and defibrillation in the first 120 seconds after the onset of the cardiac arrest), indicating that more stress was associated with less hands-on time.

Second, our pilot study showed that the satisfaction (measured just after the simulation sessions) about their skills used during simulation (eg, coordinating tasks of the team, managing the clinical case) increased in the EG after training, whereas it remained the same in the CG. This result confirmed another study having evaluated a simulated-based team-training program (about collaboration, communication, task management, teamwork, and leadership) in a multidisciplinary pediatric team. This study has also found a significant increase in posttest scores for perceived collaboration and satisfaction about care decisions at the end of the simulation sessions.[36] As for Jankouskas et al,[36] our results suggested that the participation in a high-fidelity simulation-based training with debriefing about TSs and NTSs increased perceived satisfaction about their skills used during simulation in managing children cardiac arrhythmias.

Third, there was no significant effect on self-confidence contrary to a previous study by our team.[37] On one hand, as participants already had high self-confidence at baseline (between 3.3 and 4 on a scale with 5 points), it could be hypothesized that a significant increase in the scores was not possible. On the other hand, this questionnaire could be too general as it assessed the self-confidence that a person could have in general in handling a child cardiac arrest, in comparison with our satisfaction questionnaire that assessed directly the actions carried out in the simulation sessions. For example, Figueroa et al[38] had assessed confidence in specific roles during the scenarios after a simulation-based training course (after cardiac surgical emergency scenarios). This study showed an increasing in confidence in the roles of team leader, advanced airway management, and cardioversion/defibrillation during crisis scenarios.[38] In the same way, self-confidence was defined and assessed as the "belief in your ability to competently perform ultrasound-guided central venous insertion on a real patient with a reasonably high chance of success in the study of Thomas et al[39] after a simulation-based training for pediatric residents. Considering these other studies, our measure of self-confidence was obviously too general to obtain an effect after the training.

Fourth, regarding the skills evaluated by experts, acceptable interrater reliability was obtained for the validated grid of Grant et al.[30] Results showed that the leaders in the EG improved their recorded TSs (knowledge and clinical skills) and NTSs (leadership and communication skills) after training, whereas these skills remained the same in the CG. Other studies have shown that simulation can improve pediatric resident performance during resuscitations.[40] However, there are little data available in the literature looking at resuscitation team leadership skills in pediatrics.[40] For example, Gilfoyle et al[19] showed that residents were able to acquire resuscitation team leadership skills following a simulation-based intervention on the principles of CRM and Jankouskas et al[36] showed that multidisciplinary team participation in a CRM program increased observed teamwork skills. So our pilot study suggested that the participation in a high-fidelity simulation-based training with debriefing about TSs and NTSs increased observed TSs and NTSs in children cardiac arrest simulation sessions.

Fifth, the comparison of the evolution of the 2 groups concerning the time to initiate CPR was not significantly different between the first and last simulation sessions, although there was a reduction in the EG and a substantial increase in the CG. We can assume that a larger sample could have led to a significant result like in the study of Ross et al.[41] Sufficient statistical power is required to show that there is indeed a difference between 2 groups. The power partly depends on the number of subjects included. As the number of subjects is important, the test is more powerful. Especially when the desired effect is small, it is necessary to include a large number of patients. This kind of results is very important considering that the chance of survival is greater the sooner CPR is initiated in these cases.

In summary, our training showed a positive impact in the EG at 2 levels of the Kirkpatrick's 4-level model used for evaluation of

TABLE 2. TSs and NTSs Among EG and CG Before (T0) and After Training (T1)

	EG		CG		Time Effect	Group × Time Effect
	T0, Mean (SD)	T1, Mean (SD)	T0, Mean (SD)	T1, Mean (SD)	F (*P*)	F (*P*)
Part 1. Leadership and communication skills						
1. Resident clearly identifies he/she will lead the resuscitation	0.5 (0.5)	1.5 (0.8)	0.7 (0.5)	0.7 (0.5)	**5 (0.049)**	**5 (0.049)**
2. Resident delegates roles and responsibilities appropriately to team members	1.7 (0.8)	2.3 (0.8)	1.8 (0.4)	1.7 (0.5)	1.8 (0.209)	**5 (0.049)**
3. Resident maintains control of leading the resuscitation	2.0 (0)	2.7 (0.5)	1.8 (0.4)	1.8 (0.4)	4 (0.073)	4 (0.073)
4. Resident uses effective closed loop communication	1.5 (0.8)	2.0 (0.9)	1.7 (0.8)	1.0 (0.6)	0.09 (0.765)	**4.62 (0.057)**
5. Resident manages team resources appropriately among team members	1.8 (0.4)	2.3 (1.0)	1.8 (0.8)	1.2 (0.4)	0.12 (0.734)	**5.98 (0.035)**
6. Resident verbalizes thoughts and summarizes progress periodically for benefit of the team	1.5 (1.1)	2.2 (1.0)	1.3 (1)	1.7 (0.5)	2.37 (0.155)	0.26 (0.619)
7. Resident asks for and acknowledges input from team	1.7 (0.8)	1.8 (0.8)	1.8 (1.0)	1.8 (0.8)	0.17 (0.687)	0.17 (0.687)
8. Resident reassesses and re-evaluates situation frequently	2.2 (0.7)	2.5 (0.8)	2.0 (0.9)	2.0 (0.6)	1 (0.341)	1 (0.341)
9. Resident avoids fixation errors	1.7 (0.5)	1.8 (0.7)	1.3 (0.8)	1.5 (0.5)	0.35 (0.570)	0 (1)
10. Resident refrains if possible from active participation	1.2 (0.8)	2.5 (1.2)	0.7 (0.5)	0.8 (0.4)	6.64 (0.028)	4.02 (0.073)
11. Resident shows anticipation of future events by asking for preparation of equipment of medication not yet needed	1.7 (0.8)	1.7 (0.5)	1.5 (0.5)	1.3 (0.5)	0.29 (0.599)	0.29 (0.599)
12. Resident asks for appropriate help early and shows awareness of own limitations	1.3 (0.8)	1.8 (1.0)	1.3 (0.5)	1.3 (0.8)	1 (0.341)	1 (0.341)
Total	1.6 (0.5)	2.1 (0.6)	1.5 (0.5)	1.4 (0.3)	3.08 (0.110)	**5.69 (0.038)**
Part 2. Knowledge and clinical skills						
1. Resident obtains preliminary history quickly or designates other to do so	1.7 (0.8)	2.3 (0.5)	2.0 (0.6)	2.0 (0.6)	2.5 (0.145)	2.5 (0.145)
2. Resident obtains full set cardiorespiratory monitoring and full set of vitals promptly	1.7 (0.8)	1.5 (1.1)	1.8 (0.8)	1.3 (0.5)	2.1 (0.177)	0.53 (0.485)
3. Resident obtains assessment of airway patency and protection	2.0 (0.6)	1.8 (0.4)	1.5 (0.5)	1.5 (1.0)	0.17 (0.687)	0.17 (0.687)
4. Resident obtains assessment of breathing	1.8 (0.7)	2.0 (0.6)	1.5 (1.2)	1.0 (0.6)	0.32 (0.583)	1.29 (0.282)
5. Resident asks for initiation of appropriate initial breathing support and ensures effectiveness	1.5 (0.5)	2.2 (1.0)	1.3 (0.5)	1.2 (0.4)	3.46 (0.092)	**9.62 (0.011)**
6. Resident identifies need for and obtains appropriate airway interventions as required	1.8 (1.0)	2.3 (1.0)	1.8 (0.8)	1.3 (0.5)	0 (1)	**6 (0.034)**
7. Resident ensures adequacy of airway and breathing after each intervention	1.8 (0.8)	1.5 (1.0)	2.0 (0.9)	1.0 (0.9)	4.71 (0.055)	1.18 (0.304)
8. Resident asks for assessment of pulses and perfusion	1.3 (0.5)	2.0 (0.9)	1.8 (0.8)	1.5 (0.5)	0.26 (0.619)	2.37 (0.155)
9. Resident asks for initiation of chest compressions when appropriate and ensures adequacy of compressions	2.2 (0.8)	2.5 (0.5)	1.8 (0.8)	1.3 (0.5)	0.09 (0.765)	2.36 (0.156)
10. Resident ensures timely appropriate vascular access	2.5 (0.8)	2.5 (0.5)	2.2 (0.4)	1.7 (0.8)	0.56 (0.473)	0.56 (0.473)
11. Resident verbally identifies cardiac rhythm on monitor and reassesses rhythm and pulse appropriately after each intervention	1.0 (1.1)	1.5 (0.5)	1.0 (0.6)	2.0 (0.6)	**19.29 (0.001)**	2.14 (0.174)
12. Resident chooses interventions according to appropriate PALS algorithm	1.8 (0.4)	2.5 (0.5)	1.5 (0.8)	1.3 (0.5)	1.8 (0.209)	**5 (0.049)**
13. Resident orders appropriate investigations	1.5 (0.5)	1.7 (0.5)	1.7 (0.5)	1.0 (0.6)	3.46 (0.092)	**9.62 (0.011)**

Continued next page

TABLE 2. *(Continued)*

	EG		CG		Time Effect	Group × Time Effect
	T0, Mean (SD)	T1, Mean (SD)	T0, Mean (SD)	T1, Mean (SD)	F (*P*)	F (*P*)
14. Resident asks for assessment of neurological status or secondary survey once stabilization of ABC's complete	0.5 (0.5)	2.3 (0.8)	0.5 (0.5)	0.8 (0.8)	**13.85 (0.004)**	**6.64 (0.028)**
Total	1.7 (0.3)	2.1 (0.5)	1.6 (0.4)	1.4 (0.3)	0.34 (0.571)	**6.84 (0.026)**

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such training interventions[42]: the attitudes learning level (change in self-assessment of stress and satisfaction about skills used) and the behavioral level (change of observed TSs and NTSs). The differences between the 2 groups could be attributed to the lack of debriefing in the simulation sessions of the CG. Savoldelli et al[25] have previously shown that individuals who do not undergo any form of debriefing demonstrate no improvement in CRM. Although many studies conclude that debriefing is key for simulation learning, there are very few data on what happens during debriefing. Based on a content analysis of debriefings, Boet et al[43] have hypothesized that the effectiveness of team debriefing could be attributed to either feedback (from an instructor, team members, or a video review) or reflection (on their own performance or general principles of CRM). Research should aim to identify which factors are most important for effective debriefing. Additional evidence is also needed to determine if this type of training improves management of real-life critical events (the patient outcome level of the Kirkpatrick model).[40] Only a few studies have focused on the effect on patient outcome. The results are often contradictory; some have shown the positive effects on patients[44] and others not.[45] Larger-scale studies might be necessary to demonstrate an effect of simulation-based team training.[14]

Our pilot study had limitations. First, we had only 16 participants for the self-rated part and only 4 participants were assessed in the video. Our future goal is to offer this kind of training to all residents of the medical school by integrating it into their curriculum. Second, the questionnaire about self-confidence was too general to measure an effect of the training. The lack of results on self-confidence could also show that the impact of the training did not generalize beyond simulation sessions. Finally, posttraining assessment took place just after training; it would have been interesting to propose a follow-up assessment at 3 or 6 months.

In conclusion, our high-fidelity simulation-based training with debriefing about TSs and NTSs in children cardiac arrhythmias among nurses and residents working in pediatric and emergency medicine had a significant positive impact on perceived stress, satisfaction about skills, and observed TSs and NTSs. A future study should assess the effectiveness of this training in a larger sample and its impact on skills during actual emergencies.

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