High-Fidelity Simulation Enhances Pediatric Residents’ Retention, Knowledge, Procedural Proficiency, Group Resuscitation Performance, and Experience in Pediatric Resuscitation

abstract

OBJECTIVE: The goal of this study was to assess the effect of high-fidelity simulation (HFS) pediatric resuscitation training on resident performance and self-reported experience compared with historical controls.

METHODS: In this case-control study, pediatric residents at a tertiary academic children’s hospital participated in a 16-hour HFS resuscitation curriculum. Primary outcome measures included cognitive knowledge, procedural proficiency, retention, and self-reported comfort and procedural experience. The intervention group was compared with matched-pair historical controls.

RESULTS: Forty-one residents participated in HFS training with 32 matched controls. The HFS group displayed significant initial and overall improvement in knowledge ($P<.01$), procedural proficiency ($P<.05$), and group resuscitation performance ($P<.01$). Significant skill decay occurred in all performance measures ($P<.01$) with the exception of endotracheal intubation. Compared with controls, the HFS group reported not only greater comfort with most procedures but also performed more than twice the number of successful real-life pediatric intubations (median: 6 vs 3; $P=.03$).

CONCLUSIONS: Despite significant skill decay, HFS pediatric resuscitation training improved pediatric resident cognitive knowledge, procedural proficiency, and comfort. Residents who completed the course were not only more proficient than historical controls but also reported increased real-life resuscitation experiences and related procedures.

INTRODUCTION

The Accreditation Council for Graduate Medical Education requires pediatric training programs to certify competency in critical care procedures and emergency situations. The Review Committee for Pediatrics defines specific procedural competencies that programs must document for each resident physician. Historically, residents have gained resuscitation experience in the emergency department, ICUs, inpatient wards, and via the Pediatric Advanced Life Support (PALS) course. However, most residents finish training with inadequate knowledge and proficiency with critical care skills. Surveys of pediatric residents reveal that large percentages have never led a resuscitation event, and program directors perceive that many fail to achieve procedural competence. The PALS course is insufficient in ensuring a resident’s prolonged mastery of resuscitation skills. With duty hour restrictions limiting exposure to critically ill patients,
incorporating adjunctive educational methods is essential. Simulation has the potential to measure and improve residents’ resuscitation skills, procedural proficiency, comfort, teamwork, and communication. High-fidelity simulation (HFS) uses computerized, interactive, lifesized pediatric manikins that offer realistic patient responses. HFS is gaining acceptance in medical training because of its safety, reproducibility, and ease of simulating critical events, and some studies have suggested that simulation is superior to traditional experiential training. As such, the standard practice of “see one, do one, teach one” may be evolving into “see one, simulate many, do one competently, and teach everyone.”

Few studies have measured pediatric residents’ retention after HFS training. The objectives of the current study were to: (1) evaluate the effectiveness of HFS training on cognitive knowledge and observed performance; (2) assess long-term retention by retesting the following academic year; (3) assess the effect of retention interval on skill decay of cognitive knowledge and observed performance; and (4) compare cognitive knowledge, observed performance, comfort, and self-reported real-life experience between residents who complete HFS training versus historical residents with no previous simulation training.

METHODS

Study Design/Study Population

This study was conducted between August 2008 and February 2011. Participants were pediatrics and medicine-pediatrics residents during their first (postgraduate year [PGY]-1) through third (PGY-3) year at the Medical University of South Carolina, a 173-bed quaternary care hospital with ~22,000 pediatric emergency department visits, 700 PICU patients, and 1000 NICU patients per year. Residents complete 5 months of training in the pediatric emergency department, 3 months in the NICU, and 1 month in the PICU with 2 months of PICU cross-cover. Residents participate in the Pediatric Medical Emergency Team and Mayday response teams when on-call on the wards and PICU rotations. All participants completed PALS and Neonatal Resuscitation Program training before starting their residency and before study participation.

This study was approved as exempt research by the institutional review board of the Medical University of South Carolina, and informed consent was therefore not required.

Training Curriculum

The HFS training program used a 16-hour pediatric resuscitation course (Appendix 1), split into two 8-hour days separated by 2 weeks. The curriculum was developed at the Emergency Medicine Foundation and the American College of Emergency Physicians Teaching Fellowship Program (August 2000–March 2001; Dallas, Texas) and was reviewed by fellowship faculty to ensure that it met the standards of the Instructional System Design model for educational instructional development. The course was piloted in 2001 and 2002, and the results were published previously. The pilot course was revised for use with HFS in 2008. The learning objectives, evaluation procedures, and instructional strategy were based on 2005 American Heart Association pediatric resuscitation guidelines.

Eight to 10 courses were given each academic year to ensure that all residents were trained. Groups consisted of 6 residents with 2 instructors. The curriculum director performed instruction and assessment with assistance from the pediatric chief residents and a pediatric nurse practitioner. Courses were videotaped and reviewed by the curriculum director to ensure interobserver consistency. The HFS curriculum consisted of online didactics, surveys, cognitive knowledge assessment, hands-on manikin training, and procedural knowledge assessment (SimBaby; Laerdal Medical, Stavanger, Norway). On day 1, participants were trained in procedural proficiency and group resuscitation by using deliberate repetitive practice until mastery was achieved. Mastery was defined as error-free performance. On day 2, additional practice was provided to achieve a high degree of overlearning. Overlearning was defined as deliberate overtraining of skills past the set criterion performance level of mastery.

Data Collection/Outcome Measures

Participants were enrolled as PGY-1 or PGY-2. Appendix 2 lists the performance measures analyzed. Cognitive knowledge of pediatric resuscitation was assessed by using a 50-question multiple choice examination. Observed performance (procedural proficiency and group resuscitation performance) was assessed through direct observation by using structured checklists, which consisted of discrete observable critical actions that were dichotomously scored as “performed correctly” or “not performed correctly.” Summative performance was scored as the percentage of critical actions correctly performed. Group performance was...
assessed during a standardized patient scenario of pulseless arrest and evaluated teamwork and patient management skills. The selection of procedural proficiency skills (Appendix 2, Part II) to be trained and tested was based on the 2006 Pediatric Residency Review Committee’s “Table of Technical and Therapeutic Procedures.”45 Skills that were listed as training requirements (the resident should master the performance of or be developing skill with the procedure) were emphasized. The content of the cognitive knowledge test and the structured observed checklists was based on 2005 American Heart Association guidelines for PALS.44 Self-reported comfort and real-life experience with resuscitation skills were assessed by using a confidential survey. A 7-digit Likert scale (from “significantly uncomfortable” to “significantly comfortable,” with a “neutral” mid-scale) was used for self-reported comfort levels.

Performance measures were assessed before initial training (time 1) and immediately posttraining (time 2). Retesting (time 3) occurred the following academic year before retraining. Self-reported experience was assessed at times 1 and 3. Primary outcome measures included initial improvement (time 1 to time 2), skill decay (time 2 to time 3), and overall improvement (time 1 to time 3). Retention interval was defined as the time interval between times 2 and 3. Retention was defined as the absolute performance at time 3 compared with time 2. Skill decay was defined as the decrease in performance from time 2 to time 3. The effect of retention interval on skill decay was assessed by comparing study participants who retested at ≤12 months after initial training versus those who retested at >12 months. Correlation between self-reported comfort and real-life experience was analyzed in the intervention group.

### Historical Control Group

To account for the confounding factor of residency training on knowledge and skill retention, residents who participated in the HFS curriculum (ie, the intervention group) were compared with historical residents who did not participate (ie, the control group) by using a matched-paired cohort study. Matching was based on years of training. The control group was tested with the same performance measures (Appendix 2) in the same HFS environment as the intervention group. A subgroup analysis was performed in which PGY-2 control residents were compared with PGY-2 intervention residents and PGY-3 controls with PGY-3 intervention residents. Comparisons of cognitive knowledge, observed performance, comfort levels, and self-reported real-life experiences were assessed between groups. This comparison occurred at time 3 for the intervention group to determine the effect of the HFS course on retention.

### Power

The study was implemented to augment the procedural and resuscitation training curriculum in a pediatric residency program. As such, all residents were required to participate in the study. A retrospective power analysis was performed. The study was powered to detect at least a 3.25-point difference in procedural assessment scores at time 1 and time 2 with an α of .05 and 95% power. Assumptions used were normal distribution of scores and a historical SD for the scores of 5.3 points.46

### Statistical Analysis

Descriptive statistics were calculated for cognitive knowledge, procedural proficiency, and group resuscitation performance at times 1, 2, and 3 for the intervention group. Similar control group statistics were collected. Correlation coefficients were generated to assess the relationship between self-reported comfort and experience levels in the intervention group.

Wilcoxon signed rank tests and paired t tests were used to test differences between cognitive knowledge, procedural proficiency, or group resuscitation performance of the intervention group when appropriate. Repeated analysis of variance was completed to assess within-subject effects of the intervention group. All statistical calculations were performed by using SAS version 9.3 (SAS Institute, Inc, Cary, NC).

### RESULTS

#### Participants

Forty-one pediatrics and medicine-pediatrics residents were enrolled in the intervention group. The mean length of completed residency training at the time of initial HFS training and retesting was 11.2 months and 23.5 months, respectively. The median retention interval (time 2 to time 3) was 12 months (range: 2–24 months). Thirty-two matched-pair historical control residents (mean length of training: 23.9 months) were selected for comparison at time 3. Table 1 compares demographic characteristics of the intervention and control groups.

### Effect of Initial Training, Skill Decay, and Overall Improvement

Tables 2, 3, and 4 show the effectiveness of HFS training on initial improvement, overall improvement, retention,
and skill decay. Baseline proficiency in all skills (time 1) was poor despite previous PALS training. The median time between PALS training and initial HFS training was 10 months (mean: 11.2 months). There was significant initial training was 10 months (mean: 11.2 months) between PALS training and initial HFS training. The median time between times 2 and 3. Data are the mean percentage scores of correct answers on 50-question cognitive knowledge examination. Median of 12 months (range: 2–24 months) between times 2 and 3.

TABLE 1 Study Participant Demographic Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Historical Control Group (n = 32); August 2008 to May 2009</th>
<th>Intervention Group (n = 41); July 2009 to February 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>15 (47)</td>
<td>17 (41)</td>
</tr>
<tr>
<td>Female</td>
<td>17 (53)</td>
<td>24 (59)</td>
</tr>
<tr>
<td>Age, y, mean (median)</td>
<td>30.6 (29.1)</td>
<td>30 (28.9)</td>
</tr>
<tr>
<td>PGY-2, n (%)</td>
<td>17 (53)</td>
<td>18 (44)</td>
</tr>
<tr>
<td>PGY-3, n (%)</td>
<td>15 (47)</td>
<td>23 (56)</td>
</tr>
<tr>
<td>Months of training at time of testing, mean (median)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PGY-2</td>
<td>19 (20)</td>
<td>16.6 (17)</td>
</tr>
<tr>
<td>PGY-3</td>
<td>30 (31)</td>
<td>29 (29)</td>
</tr>
<tr>
<td>Cumulative</td>
<td>23.9 (21.5)</td>
<td>23.5 (24)</td>
</tr>
<tr>
<td>Combined medicine-pediatrics residents, n (%)</td>
<td>5 (15.6)</td>
<td>4 (9.7)</td>
</tr>
<tr>
<td>Recertified in PALS, n (%)a</td>
<td>10 (31)</td>
<td>13 (32)</td>
</tr>
</tbody>
</table>

Demographic characteristics cited for the Intervention Group are at the time of retesting (time 3). Demographic characteristics cited for the Historical Control Group are before any HFS training. The χ² analysis showed no statistical differences in demographic measurements of intervention and historical control groups (P > .05).

a All participants completed initial PALS training before PGY-1 and before any testing or HFS training. Some of the study subjects had recertified in PALS (ie, taken PALS a second time) before testing. All residents who had recertified were PGY-3.

Compared with controls, the intervention group reported greater comfort and more actual experience with pediatric resuscitations and procedures. Comfort levels were significantly higher for all skills except resuscitation of shock requiring fluid resuscitation, evaluation and management of dysrhythmias, and bag-valve-mask ventilation with and without chest compressions (Table 8). The intervention group reported more successful real-life intubations than controls (median: 6 vs 3; P = .03) and more experience with resuscitation of pulseless arrest (median: 1 vs 0; P = .02). Experience with respiratory failure approached but did not attain significance (median: 4 vs 3; P = .06).

Correlation Between Resident Comfort and Experience

Significant moderately positive correlations (r = 0.3–0.7 with P < .05) existed between comfort levels and self-reported real-life experience with most pediatric resuscitation skills in the intervention group. The only exceptions were with chest compressions (r = 0.18), intraosseous needle insertion (r = 0.17), and termination of resuscitation (r = 0.26). Endotracheal intubation success displayed a strong correlation (r = 0.72) between comfort and self-reported experience.

DISCUSSION

This study contributes to the field of pediatric simulation research in several aspects. Primarily, the results add to the existing body of research that simulation training has positive effects on resuscitation education.
It demonstrated that an HFS pediatric resuscitation curriculum not only significantly improved residents’ cognitive knowledge and procedural proficiency but also increased their self-reported frequency of performing resuscitation skills in actual clinical practice. To achieve these results, the study design that was used differed in approach compared with many previous studies. The inclusion of the historical control group addressed the possible confounder of traditional experiential training on retention and the possibility of the Hawthorne effect (the notion that the observed performance of participants may be influenced by the fact that they knew they were being observed). Using the historical control group was advantageous compared with a pre-/post- study design in that both the intervention and control groups were subjected to the Hawthorne effect. Thus, the fact that intervention residents demonstrated greater proficiency in cognitive knowledge and observed performance, higher levels of comfort, and more actual experience with pediatric resuscitations and procedures than the control group could be attributed to the intervention alone. Although a randomized controlled study would be superior to the use of historical controls, using a control group with traditional training alone was considered to be unethical given the positive preliminary results of simulation on both resuscitation performance and procedural proficiency.

Before this study, research investigating the long-term effects of simulation training on pediatric residents’ retention of knowledge and procedural skills yielded variable results. The current study demonstrated that skill decay occurs despite the novel modality of HFS but found that retention varied based on the skills that were assessed. Group resuscitation performance deteriorated to a greater degree than cognitive knowledge, and both declined more than procedural proficiency. Some skills decayed more significantly than others (ie, cardioversion/defibrillation versus endotracheal intubation) and could warrant more frequent retraining. These observations may represent the underlying complexity of group dynamics as well as highlight the effect of frequency of exposure in clinical practice. The degree of skill decay was unchanged when comparing retention intervals of ≤12 months versus >12 months, which implies that the decrease in performance occurred soon after training but then remained relatively static for the range of retention intervals (2–24 months). Because this study was not designed to determine the optimal retraining interval to minimize clinically significant skill decay, further research is needed in this area.

### TABLE 3 Effectiveness of HFS Training on Individual Procedural Proficiency: Initial Improvement, Skill Decay, and Overall Improvement

<table>
<thead>
<tr>
<th>Variable</th>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length-based resuscitation tape</td>
<td>91% (89–93)</td>
<td>100% (99–100)</td>
<td>97% (95–98)</td>
</tr>
<tr>
<td>Intravenous needle insertion</td>
<td>72% (65–78)</td>
<td>98% (97–99)</td>
<td>92% (90–94)</td>
</tr>
<tr>
<td>Bag-valve-mask ventilation with and</td>
<td>77% (73–82)</td>
<td>97% (95–99)</td>
<td>92% (90–94)</td>
</tr>
<tr>
<td>without compressions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endotracheal intubation</td>
<td>80% (75–85)</td>
<td>97% (95–99)</td>
<td>95% (93–97)</td>
</tr>
<tr>
<td>Cardiopulmonary resuscitation</td>
<td>54% (46–62)</td>
<td>91% (88–93)</td>
<td>84% (80–88)</td>
</tr>
<tr>
<td>Defibrillation</td>
<td>66% (58–75)</td>
<td>95% (92–97)</td>
<td>90% (88–93)</td>
</tr>
<tr>
<td>Overall mean (95% CI)</td>
<td>73% (68–78)</td>
<td>96% (95–97)</td>
<td>92% (90–93)</td>
</tr>
</tbody>
</table>

Data are percentage of critical actions performed on a structured checklist. Median of 12 months (range: 2–24 months) between times 2 and 3.

### TABLE 4 Effectiveness of HFS Training on Group Resuscitation Performance: Initial Improvement, Skill Decay, and Overall Improvement

<table>
<thead>
<tr>
<th>Variable</th>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teamwork</td>
<td>62% (53–72)</td>
<td>98% (96–99)</td>
<td>82% (76–87)</td>
</tr>
<tr>
<td>Patient management</td>
<td>55% (50–60)</td>
<td>95% (93–96)</td>
<td>67% (71–73)</td>
</tr>
<tr>
<td>Overall mean (95% CI)</td>
<td>57% (51–64)</td>
<td>95% (94–97)</td>
<td>73% (68–78)</td>
</tr>
<tr>
<td>Initial improvement (time 1→time 2)</td>
<td>38% (32–44)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skill decay (time 2→time 3)</td>
<td></td>
<td>–22% (17–27)</td>
<td></td>
</tr>
<tr>
<td>Overall improvement (time 1→time 3)</td>
<td></td>
<td>16% (9–22)</td>
<td></td>
</tr>
</tbody>
</table>

Data are percentage of critical actions performed on a structured checklist. Median of 12 months (range: 2–24 months) between times 2 and 3.

### TABLE 5 Comparison of Intervention and Historical Control Groups: Cognitive Knowledge Scores

<table>
<thead>
<tr>
<th>Score</th>
<th>Control (n = 32)</th>
<th>Intervention (n = 41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (95% CI)</td>
<td>58% (54–61)</td>
<td>74% (71–77)</td>
</tr>
<tr>
<td>Median (P value)</td>
<td>56%</td>
<td>74% (P &lt; 0.0001)</td>
</tr>
</tbody>
</table>

Data are percentage scores of correct answers on a 50-question cognitive knowledge examination. Testing for the intervention group occurred at time 3, the academic year after they had taken the HFS course (median: 12 months; range: 2–24 months).
There were several limitations to the current study. Baseline performance scores for the control group were not collected because the study was started during their second year of residency. Baseline assessments of control and intervention groups at the start of residency training would have controlled for differences due to inherent cognitive and procedural competence. Although cognitive knowledge testing, self-reported comfort levels, and real-life experience were collected in a blinded and confidential manner, the observed performance measures (procedural proficiency and group resuscitation performance) were unblinded. The lack of blinded assessors may have favored finding a difference, despite the use of structured checklists. The intervention group’s familiarity with the testing content from the previous year may have accounted for their improved performance compared with controls. However, the independent measures of self-reported real-life experience and comfort levels support the inference that residents are more comfortable attempting procedures during actual resuscitation events after completing simulation training, a necessary prerequisite for proficiency.

Another limitation is that this study was conducted at a single academic institution with a relatively small number of participants. A multicenter trial with a larger cohort would provide greater validity. Scenarios also included only resident trainees; including multidisciplinary caregivers would allow a more realistic environment in which to assess team performance.

This study did not include the use of validated measurement tools to assess...

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### TABLE 6 Comparison of Intervention and Historical Control Groups: Individual Procedural Proficiency

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control (n = 32)</th>
<th>Intervention (n = 41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length-based resuscitation tape</td>
<td>90% (88–93)</td>
<td>97% (95–98)</td>
</tr>
<tr>
<td>Intraosseous needle insertion</td>
<td>66% (60–72)</td>
<td>92% (90–94)</td>
</tr>
<tr>
<td>Bag-valve-mask ventilation with and without compressions</td>
<td>76% (72–81)</td>
<td>92% (90–94)</td>
</tr>
<tr>
<td>Endotracheal intubation</td>
<td>82% (77–88)</td>
<td>95% (93–97)</td>
</tr>
<tr>
<td>Cardioversion</td>
<td>49% (40–58)</td>
<td>84% (80–88)</td>
</tr>
<tr>
<td>Defibrillation</td>
<td>59% (50–68)</td>
<td>90% (88–93)</td>
</tr>
<tr>
<td>Overall mean (95% CI)</td>
<td>70% (66–75)</td>
<td>92% (90–93)</td>
</tr>
<tr>
<td>Median (P)</td>
<td>72%</td>
<td>94% (P &lt; .0001)</td>
</tr>
</tbody>
</table>

Data are percentage of critical actions performed on a structured checklist. Testing for the intervention group occurred at time 3, the academic year after they had taken the HFS course (median: 12 months; range: 2–24 months).

### TABLE 7 Comparison of Intervention and Historical Control Groups: Group Resuscitation Performance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control (n = 32)</th>
<th>Intervention (n = 41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teamwork</td>
<td>56% (45–66)</td>
<td>82% (76–87)</td>
</tr>
<tr>
<td>Patient management</td>
<td>54% (49–59)</td>
<td>67% (71–73)</td>
</tr>
<tr>
<td>Overall mean (95% CI)</td>
<td>54% (47–60)</td>
<td>73% (68–78)</td>
</tr>
<tr>
<td>Median (P)</td>
<td>47%</td>
<td>74% (P &lt; .0002)</td>
</tr>
</tbody>
</table>

Data are percentage of critical actions performed on a structured checklist. Testing for the intervention group occurred at time 3, the academic year after they had taken the HFS course (median: 12 months; range: 2–24 months).

### TABLE 8 Median Comfort Scores for Intervention and Historical Control Groups

<table>
<thead>
<tr>
<th>Critical Pediatric Resuscitation Skills</th>
<th>Control (n = 29)*</th>
<th>Intervention (n = 41)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>The ability to both lead and participate in the resuscitation of a critically ill pediatric patient</td>
<td>3.5</td>
<td>5.0</td>
<td>.002</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>5.0</td>
<td>6.0</td>
<td>.008</td>
</tr>
<tr>
<td>Shock</td>
<td>5.0</td>
<td>6.0</td>
<td>.14</td>
</tr>
<tr>
<td>Pulsatile arrest (asystole or pulseless electrical activity)</td>
<td>2.0</td>
<td>4.5</td>
<td>.002</td>
</tr>
<tr>
<td>Bradycardia with hypotension</td>
<td>4.0</td>
<td>4.0</td>
<td>.004*</td>
</tr>
<tr>
<td>Dysrhythmias (supraventricular tachycardia and ventricular fibrillation)</td>
<td>3.0</td>
<td>5.0</td>
<td>.08</td>
</tr>
<tr>
<td>Bag-valve-mask ventilation with and without chest compressions</td>
<td>5.0</td>
<td>6.0</td>
<td>.06</td>
</tr>
<tr>
<td>Endotracheal intubation</td>
<td>3.0</td>
<td>5.0</td>
<td>.03</td>
</tr>
<tr>
<td>Intraosseous needle insertion</td>
<td>3.0</td>
<td>5.0</td>
<td>.0001</td>
</tr>
<tr>
<td>Synchronized cardiovascular and asynchronized defibrillation</td>
<td>2.0</td>
<td>4.0</td>
<td>.0001</td>
</tr>
<tr>
<td>Selection and dosing of drug regimens used for rapid sequence induction for intubation</td>
<td>2.0</td>
<td>3.0</td>
<td>.33</td>
</tr>
<tr>
<td>Correct selection of pediatric resuscitation equipment and drug-dosing using the length-based pediatric resuscitation tape</td>
<td>5.0</td>
<td>6.0</td>
<td>.0002</td>
</tr>
<tr>
<td>The discussion and decision regarding termination of resuscitation efforts</td>
<td>2.0</td>
<td>3.0</td>
<td>.05</td>
</tr>
</tbody>
</table>

Comfort scores were assessed by using the Likert scale of comfort: 1 = significantly uncomfortable; 2 = moderately uncomfortable; 3 = minimally uncomfortable; 4 = neutral; 5 = minimally comfortable; 6 = moderately comfortable; 7 = significantly comfortable. Wilcoxon signed rank sum 2-sample test was used to test for differences in the distribution of scores.

* Comfort and experience survey data from 3 control participants who took an incompatible version of the survey were excluded from analysis.

* Rare but can occur where medians are the same but the Wilcoxon rank sum is still significant, based on the overall distribution of scores.
resident performance, which remains a universal limitation of simulation research. However, increasing evidence suggests that valid and reliable assessments of procedural skills may be achieved by using simulation, and the data support the use of structured checklists. The individual and group procedural skill checklists used in this study were based on the 2005 American Heart Association guidelines for PALS, giving them a degree of content validity. However, formal validation of the observed structured checklists was not performed, thus limiting the construct validity of our performance measures. To minimize interobserver variability, the curriculum director oriented all instructors and directly observed or reviewed the participants’ videotaped recordings. The lack of validated measurement instruments that are discriminatory, reproducible, and reliable (interobserver and intraobserver) is a major focus of the multidisciplinary simulation research networks. The Examining Pediatric Resuscitation Education Using Simulation and Scripting and the Patient Outcomes in Simulation Education collaborative groups are currently assessing the development and validation of scoring tools, which may facilitate a standardized approach across institutions.

CONCLUSIONS

Pediatric residents who participated in a HFS resuscitation course demonstrated long-term improvement and retention in cognitive knowledge, procedural proficiency, and group resuscitation performance compared with the historically matched cohort with only standard residency training. Residents who participated in HFS training reported an increase in comfort and real-life experience with resuscitations and procedures compared with historical controls. Because significant skill decay occurs over time, retraining is needed to maintain high proficiency standards.

REFERENCES

22. Overly FL, Sudikoff SN, Shapiro MJ. High-fidelity medical simulation as an assessment tool for pediatric residents’


APPENDIX 1 Pediatric Resident Simulation Training Curriculum

Day 1
A. Overview of course (15 minutes)
B. Precourse survey of self-reported comfort and experience (10 minutes)
C. Baseline cognitive knowledge assessment (30 minutes)
D. Baseline assessment of observed performance (individual procedural proficiency and group resuscitation performance) by using structured observed checklists (3 hours)
E. Instructor demonstration of individual procedural skills followed by deliberate repetitive practice by learner until mastery (4 hours)

Day 2
A. Educational HFS scenario practice incorporating overtraining of individual and group resuscitation skills to provide high degree of overlearning (4 hours)
B. Retesting of observed performance measures (3 hours)
C. Retesting of cognitive knowledge (30 minutes)
D. Postcourse survey of comfort and course feedback (10 minutes)

Online resources
A. Lectures/presentations
   1. Introduction to the Basics of Pediatric Resuscitation
   2. Pediatric Airway Management and Recognition of the Critically Ill Child
   3. Rapid Sequence Induction for Intubation
   4. Cases in pediatric resuscitation (2-month-old sudden infant death syndrome case, 3-year-old with hypoglycemia)
B. Procedural demonstrations
   1. Bag-valve-mask ventilation with and without compressions
   2. Intraosseous procedure
   3. Intubation procedure
   4. Defibrillation and cardioversion procedure
C. Interactive cases
   1. 2-year-old near-drowning in pulseless arrest
   2. Pediatric trauma
D. Assigned readings
   1. Basic life support (BLS) and PALS update
   2. Emergency airway management
   3. Managing the death of a child in the emergency department
E. Practice questions
APPENDIX 2 Performance Measures

I. Cognitive knowledge of pediatric resuscitation
II. Individual procedural proficiency
   1. Length-based resuscitation tape
   2. Intraosseous needle placement
   3. Bag-valve-mask ventilation with and without chest compressions
   4. Endotracheal intubation
   5. Cardioversion
   6. Defibrillation
III. Group resuscitation performance of pulseless arrest
   1. Teamwork
      Assigning clear team roles and responsibilities
      Closed-loop communication
      Knowledge sharing
      Constructive intervention
   2. Patient management
      Prompt identification of pulseless arrest
      High-quality cardiopulmonary resuscitation
      Effective coordination of resuscitation procedures
      Return of spontaneous circulation
IV. Comfort and experience with critical pediatric resuscitation skills
   1. The ability to both lead and participate in the resuscitation of a critically ill pediatric patient
   2. Resuscitation of respiratory failure requiring airway management
   3. Resuscitation of shock requiring fluid resuscitation
   4. Resuscitation of pulseless arrest (pulseless electrical activity or asystole)
   5. Resuscitation of bradycardia with hypotension
   6. Evaluation and management of selected dysrhythmias (supraventricular tachycardia and ventricular fibrillation)
   7. Performance of bag-valve-mask ventilation with and without chest compressions by using properly sized equipment and proper technique
   8. Performance of endotracheal intubation by using properly sized equipment and technique
   9. Performance of intraosseous needle insertion by using properly sized equipment and technique
  10. Performance of synchronized cardioversion and asynchronous defibrillation of unstable cardiac dysrhythmias
  11. Selection of dosing of drug regimens used for rapid sequence induction for intubation
  12. Correct usage of length-based resuscitation tape
  13. Termination of resuscitative efforts
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