BRIEF COMMUNICATION

Learning Gains Derived from a High-fidelity Mannequin-based Simulation in the Pediatric Emergency Department

Tsuen-Chiuan Tsai, Peter H. Harasym,[1] Cheri Nijssen-Jordan,[2] Penny Jennett[1]*

There are limited data on the effectiveness of mannequin-based simulations in pediatrics. This study developed a training program using a high-fidelity child mannequin to simulate critical cases in an emergency department, and examined the learning gains derived from this simulation. Eighteen pediatric residents, as pairs, participated in a high-fidelity simulation pretest, training session and a posttest. The training session, developed based on participants' pretest performance, included videotape review, feedback, and hands-on practice, and focused on the improvement of management skills for shock and tachydyspnea. The pre- and posttest performances were scored for task-specific technical skills and behaviors. The learning gains between the pre- and posttests were significant ($p < 0.001$) for task-specific technical skills (from 64 ± 15% to 93 ± 4%) and behaviors (from 65 ± 18% to 85 ± 12%). This study suggests that high-fidelity simulation can enhance learning about how to manage critical cases in the pediatric emergency department. [*J Formos Med Assoc* 2006;105(1):94–98]

Key Words: mannequin, medical education, pediatric emergency care, simulation

Training competent pediatricians to recognize problems and to apply appropriate management in critical cases is a very important objective. Adult learning theory[1] suggests that the most effective learning occurs when these clinical skills are taught directly during real patient encounters. However, the relative rarity of critical cases and their associated medicolegal problems makes the training of health personnel during real patient encounters practically impossible. Only simulators can offer the opportunity for repeated practice and experimentation in a controlled and safe learning environment, which allows trainees to experience the spectrum of complex procedures with less stress as compared to a real patient encounter. With advances in computerized technology, high-fidelity simulators were developed,[2,3] mostly for adults in the fields of anesthesia, radiology, emergency/critical care medicine, and surgery. However, very little is known about the quality, effectiveness and utility of high-fidelity mannequins in training comprehensive skills in pediatrics.

This study was designed to evaluate a training program that used a high-fidelity child mannequin in a simulated emergency room to educate pediatric residents on the management of critical events. Previously reported mannequin-based simulation examinations[4] were used to determine participants' learning gains derived from the training. Participants' background factors that

Department of Pediatrics, Mackay Memorial Hospital and Mackay Medicine, Nursing and Management College, Taipei, Taiwan, R.O.C., [1]Department of Community Health Science, University of Calgary, and [2]Division of Pediatric Emergency Medicine, Alberta Children's Hospital, Calgary, Alberta, Canada.

Received: October 11, 2004
Revised: December 29, 2004
Accepted: June 7, 2005

***Correspondence to:** Dr. Tsuen-Chiuan Tsai, Department of Pediatrics, Mackay Memorial Hospital, 92, Section 2, Chungshan North Road, Taipei, Taiwan, R.O.C.
E-mail: tsaitc@ms1.mmh.org.tw

might predict their clinical performance during such a mannequin-based simulation were also included in the analysis.

Methods

Subjects

The participants were 18 volunteer pediatric residents at a children's hospital in Canada. There were nine males and nine females with an age range of 24–36 years (mean, 28.1 ± 3.2 years). There were nine pediatric residents in their postgraduate year (PGY)-1, two in PGY-2, four in PGY-3, and three in PGY-4. Based on self-report, their last involvement in cardiopulmonary resuscitation (CPR), if any, was 2 to 34 months previously (median, 12 months). One resident had no previous involvement in CPR. There were five PGY-1 residents who had not taken any Pediatric Advanced Life Support (PALS) courses or training blocks in the emergency department (ED) or intensive care unit (ICU). For others, the duration since their last PALS training ranged from 2 to 24 months (mean, 11.6 ± 6.7 months). The total number of completed blocks of critical event training (ED and ICU) ranged from 0 to 11 (mean, 4.6 ± 4.0 blocks).

Research design

A One-group Pre-experimental Pretest-Posttest Design was used for residents to measure learning gains. The participants, as pairs, first received a 15-minute briefing to gain familiarity with the mannequin and learn about the layout and equipment. A simulation pretest was followed by a 1-hour training session, after which a simulation posttest was given. The pretest cases were: (1) severe asthma with pneumothorax; (2) diarrhea with severe dehydration. The posttest cases were: (1) car crash complication with pneumothorax and chest contusion; (2) insulin dependent diabetes mellitus with diabetic ketoacidosis.

During the simulations, the participants took turns acting as the primary physician who performed all the required clinical tasks, and they were rated only when acting as the primary physician. During the training session, the instructor reviewed the videotapes with the residents, and gave feedback based on their performance on the pretest. Participants were asked to repeat poorly performed tasks.

Instruments

We used a full-scale, high-fidelity child mannequin (PediaSIM®; Medical Education Technologies Inc, Sarasota, FL, USA). The simulation and rating instrument, with the performance attributes of task-specific technical skills (T) and behaviors displayed (B), have been described in a prior report.[4] In this study, T and B scores were expressed as a percentage. Pre- and posttest simulations were videotaped and rated by three independent raters. During the training session, the instructor reviewed the videotapes of the pretest simulation with the residents, and provided feedback based on participants' pretest performance. Participants were asked to repeat poorly performed clinical tasks on the mannequin. The computerized simulation could be restarted for any necessary part with the equipment being used as teaching aids.

Data analysis

Multiple analysis of variance (MANOVA)[5] with repeated measures was used to examine whether differences between pre- and posttest mean scores were significant. The dependent variables were the clinical performance scores (T and B). The level of significance was set at 0.05. Spearman's rank order correlation was used to determine the relationship between participants' background and their clinical performance. The background variables included: age, PGY, last experience involving CPR (in months), duration since last PALS training (in months), total blocks completed on critical care, and participants' confidence level about their performance during the simulation. The confidence level was derived from the sum score of six 5-point questions (Appendix). One-way MANOVA was used to determine the significance of differences in simulation performance between males and females.

Table 1. Descriptive statistics of 18 residents' clinical performance scores before and after mannequin-based training (pretest/ posttest)

	Technical skill (%)			Behavior (%)		
	Mean ± SD	Min	Max	Mean ± SD	Min	Max
Pretest	64 ± 15	42	90	65 ± 18	32	89
Posttest	93 ± 4	86	97	85 ± 12	57	98

SD = standard deviation; Min = minimum; Max = maximum.

Results

Learning gains derived from mannequin-based training session

Descriptive statistics of pre- and posttest scores in the 18 residents are shown in Table 1. Pretest T and B scores were 64 ± 15 and 65 ± 18, respectively, while corresponding posttest scores were 93 ± 4 and 85 ± 12, respectively. MANOVA with repeated measures revealed a significant improvement from the pretest to posttest scores ($p < 0.001$). Posttest T scores improved more than posttest B scores.

Factors related to clinical performance during simulation

The regression summary (Table 2) revealed that only duration since the residents' last involvement in performing CPR could predict posttest B scores ($p = 0.02$, with coefficient of –0.63). The duration since last CPR exposure could predict posttest behavior performance, meaning the shorter the duration, the better the performance. MANOVA revealed no significant difference in simulation performance between males and females ($p = 0.09$).

Discussion

In this study of learning gains derived from mannequin-based simulation in a pediatric ED, the posttest performance scores were significantly higher than the pretest scores. The pretest/posttest difference was considered to represent the learning gains derived from the mannequin-based training session that included feedback and repeated practice. It was assumed that the learning gains were not from increased familiarity with the simulation itself because all the participants were familiar with the simulation before pretest. Further, a previous study reported that familiarity or comfort with the simulation environment had little or no effect on performance.[6] The posttest was delivered immediately after the training session, thus, the pre- to posttest score difference represented short-term learning gains derived from the training session. Long-term learning retention was not examined in this study.

Performance enhancement was more prominent in task-specific technical skills compared with behavior. This finding indicates that mannequin-based training is more efficient in improving task-

Table 2. Summary of Spearman's rank order correlations (r) for pretest /posttest technical skill (T) and behavior (B) scores based on participants' background*

	Pretest				Posttest			
	T		B		T		B	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Age	–0.05	0.84	0.03	0.89	0	0.99	0.30	0.23
PGY	0.28	0.26	0.32	0.20	0.33	0.18	0.23	0.35
CPR	–0.01	0.96	–0.09	0.73	0.05	0.85	–0.46	0.05
PALS	–0.29	0.30	–0.04	0.88	0.32	0.25	–0.26	0.36
Tblock	0.33	0.18	0.23	0.36	0.12	0.63	0.24	0.33
Confidence	0.32	0.20	0.33	0.17	0.28	0.27	0.35	0.15

**Background factors were: age (in years); PGY (postgraduate year in years); CPR = last involvement with cardiopulmonary resuscitation in months; PALS = last attendance of pediatric advanced life support course in months; Tblock = total number of blocks completed on critical care; Confidence = participants' self-confidence levels.*

specific skills than practice behavior. From the perspective of the taxonomy of learning i.e. cognitive learning, skill learning and affective learning,[7] the development of skills can only be attained through diligent practice, evaluation and feedback, while behavior in an affective domain (a further level) must be experienced through utilizing learners' analytical, critical and synthesis thinking abilities. This study demonstrated the different learning gains between the "psychomotor" and "affective" learning domains.

The degree of simulation realism is closely related to the initial investment and operational expenditure on the mannequin system. If the mannequin and setting were to be made more realistic, the associated cost would also have to increase proportionally. The acquisition cost for such a high-fidelity mannequin has been reported to exceed $250,000, with an annual maintenance fee varying from $10,000 to $167,250.[6,7] These reports suggest that the expense of high-fidelity mannequins based on the quality and the effectiveness of the simulation training is considered necessary in some institutions. Although no conclusion regarding cost versus benefit could be drawn on the system used in this study, our observations support that a high-fidelity mannequin-based simulation is valuable in the enhancement of learning.[4] High-fidelity mannequin-based simulation may increase confidence in the ability to deal with real patient encounters. According to the encoding specificity hypothesis in human memory,[8] the more real the experiences obtained by physicians in a simulated ED setting, the more likely they will be applied in the real world. In addition, the importance of saving lives should not be determined entirely on the basis of cost versus benefit. Gaba and DeAnda noted that "no industry in which human lives depend on the skilled performance of responsible operators has waited for the unequivocal proof of the benefits of simulation before embracing it".[9]

Regarding the correlation of participants' background with simulation performance, none of the background factors (i.e. age, gender, total number of blocks taken on critical care, PGY, the last involvement with CPR, number of completed blocks of PALS, self-confidence level) significantly predicted clinical performance. This indicates that seniority and prior traditional training does not guarantee better clinical performance, as has been previously reported.[9,10] Physicians were usually not aware of incorrect aspects of their own performance. The rarity of such critical cases may explain the lack of correlation with performance across the four PGY. Appropriate management of critical emergency situations should be based on sound medical knowledge, and achieved by feedback given on direct observation plus repeated practice. In this study, the lack of performance discrimination of the posttest T score could be explained by a post-training ceiling effect, as almost all the residents achieved excellent performance after the training session.

This study has shown that the use of high-fidelity simulation can enhance learning specific to managing critical cases in a pediatric ED. The learning gains were mainly derived from the training session, and not from repeated exposure to the simulation. The results of this study also suggest that the training session can be successfully delivered to more than one trainee because acting as an assistant during the simulation did not decrease the learning gains.

Acknowledgments

The authors gratefully acknowledge the Shock Trauma Air Rescue Society (STARS) in Calgary, Canada, Mike Lamacchia, Dr. M.J. Betzner, Dr. B. McLeod, Dr. J. Baumber, Tony Nijssen, and the pediatric residents in Alberta Children's Hospital for their contributions to this study.

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Appendix

Questions on participants' confidence about their performance during the simulation

(Strongly disagree: 1, disagree: 2, neutral: 3, agree: 4, strongly agree: 5)

1. I felt I made correct actions during the simulation.	1	2	3	4	5
2. I found my knowledge basis was adequate to the simulation task.	1	2	3	4	5
3. I showed leadership during the simulation.	1	2	3	4	5
4. I communicated clearly and specifically with the patient's family and/or my assistant during the simulation.	1	2	3	4	5
5. I used all available sources of help effectively during the simulation.	1	2	3	4	5
6. I was able to remain free from environmental distractions during the simulation.	1	2	3	4	5