

**Simulation Training as a Mechanism for Procedural and Resuscitation
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Simulation Training as a Mechanism for Procedural and Resuscitation Education for Pediatric Residents: A Systematic Review

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KEY WORDS

education, pediatrics, simulation, resident

ABBREVIATIONS

ACGME: Accreditation Council for Graduate
Medical Education

AV: audiovisual

LP: lumbar puncture

MeSH: Medical Subject Headings

OSCE: observed structured clinical examination

PALS: Pediatric Advanced Life Support

PGY: postgraduate year

PIV: peripheral intravenous

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abstract

BACKGROUND: Pediatric residents often finish their training lacking sufficient procedural proficiency and resuscitation experience in the care of critically ill children. Simulation is gaining favor in pediatric residency programs as a modality for procedural and resuscitation education. We reviewed the literature assessing simulation and its role in pediatric resident training.

METHODS: We conducted a Medline and PubMed search of simulation training in pediatric resident education from January 2007 to July 2012.

RESULTS: Eight studies were included and divided into simulated procedural assessments and simulated resuscitation scenario assessments. The studies varied widely in their approach and analysis, and they yielded mixed results.

CONCLUSIONS: Although some studies show the merits of simulation in the procedural and resuscitation training of pediatric residents, more research is needed to assess the effectiveness of simulation as an educational tool. Goals of future simulation research should include creation of validated assessment tools and applying skills learned to patient care outcomes.

As pediatric residency programs nationwide adapt to duty hour requirements mandated by the Accreditation Council for Graduate Medical Education (ACGME), many challenges persist in ensuring a trainee's competency.¹ The ACGME requires pediatric training programs to evaluate and certify specific core competencies, including competency in critical care procedures and emergency situations.² Historically, pediatric residents have gained much of their experience in resuscitation through direct patient exposure in the emergency department, ICUs, and inpatient wards, and via participation in a standardized Pediatric Advanced Life Support (PALS) course.³⁻⁵ However, it is now recognized that despite current educational methods, most pediatric residents finish their training without attaining sufficient knowledge and experience in the care of critically ill children and lack adequate critical care procedural skills.⁵⁻¹⁰ Pediatric program directors perceive that many residents fail to achieve procedural competence by the end of training, and surveys of pediatric residents found that large percentages of postgraduate year (PGY) 3 residents had never led a resuscitation event.^{6,11,12} In addition, the PALS course is insufficient in ensuring that pediatric residents have prolonged mastery of resuscitation skills, as retained knowledge of the details of PALS algorithms decreases significantly over the 12 months after the course.¹³⁻¹⁹

As residents' experiential training faces time restrictions, the implementation of adjunctive educational methods is critical. One promising educational modality

is the use of simulation training, which utilizes computerized, interactive, life-sized pediatric manikins that can be programmed to provide realistic patient responses based on the actions of resident trainees. These manikins offer realistic anatomic features and clinical functionality, including lifelike airway and breathing patterns, palpable pulses, ability to place intravenous/intraosseous needles, and realistic response to cardioversion/defibrillation.

Simulation has been used to measure residents' baseline aptitude with resuscitation skills and procedural performance, and it has also been shown to be a reliable tool for improving residents' medical knowledge, procedural proficiency, comfort, communication/teamwork, and teaching skills.²⁰⁻²⁶ Pediatric residents have been shown to favor simulated mock resuscitation scenarios compared with didactic lectures and oral examinations, and simulation has been used as an effective adjunct to improve cognitive performance in PALS training sessions and in teaching the Neonatal Resuscitation Program.^{23,27,28} Simulation has begun to gain widespread acceptance in medical training because of the safety of the environment, reproducibility/standardization of content, and the ease of simulating critical events.²⁹ Some studies have even suggested that simulation-based training is superior compared with traditional experiential training in assuring proficiency of specific resuscitation skills.³⁰ 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."³¹

Because duty hour restrictions may further limit pediatric residents' experiential training by decreasing their

exposure to critically ill patients, it is of paramount importance to implement adjunctive educational means to ensure a trainee's competency. This article offers a review of current pediatric simulation literature and highlights the potential benefits of formal implementation of simulation training into a pediatric residency program.

METHODS

A literature search was performed to identify articles relevant to simulation research for pediatric residency training. Two reviewers (with the assistance of a reference librarian) performed a search with Medline and PubMed to identify articles relevant to simulation training use in pediatric residency programs. We used the following combinations of medical subject heading (MeSH) terms and key words: (1) "Patient Simulation" [MeSH] OR patient simulation OR "Manikins" [MeSH] OR manikin; (2) "Internship and Residency" [MeSH] OR resident* OR intern*; and (3) "Pediatrics" [MeSH] OR pediatric*. The asterisk symbol was used after key words resident, intern, and pediatric to also search alternate endings. The Boolean "AND" statement was used to combine MeSH term and key word groupings to refine the search results to the most applicable citations. These initial abstracts were reviewed and analyzed for inclusion.

Inclusion criteria included the following: (1) utilization of simulation as an intervention with measured outcomes; (2) English language; (3) accessible full text; and (4) articles published in peer-reviewed journals from January 2007 to July 2012. References from relevant articles were then explored, and appropriate citations were also reviewed and included. Articles that did not include pediatric residents were

excluded. The quality of the study was not a factor in the inclusion/exclusion criteria to allow initial capture of all pertinent studies. Independent application of the inclusion and exclusion criteria was performed for each article, with discussion and consensus being obtained when discrepancies arose. As part of the review, the literature was divided into those articles that included simulated procedural assessments and those that included simulated resuscitation scenario assessments.

RESULTS

The search produced 65 citations, of which 25 full-text articles were reviewed after the initial screening of abstracts. Eight articles met criteria for inclusion in this review. Four were prospective observational or interventional studies, 3 were randomized controlled or crossover trials, and 1 used a longitudinal, mixed-methods design. Table 1 provides the specific characteristics of the studies reviewed that included simulated procedural assessments. Table 2 provides the specific characteristics of the reviewed studies that included simulated resuscitation scenario assessments.

Simulated Procedural Assessments

Finan et al³² performed a prospective observational pilot study to assess neonatal intubation performance by first-year pediatric residents before and after an educational intervention. Baseline performance was measured by using a validated neonatal intubation checklist and a global rating scale. The 2-hour intervention consisted of a didactic lecture followed by practice of intubation skills utilizing simulation and scripted simulation scenarios; repeat skill measurements were taken after the intervention. Assessments

TABLE 1 Articles Focused On Simulated Procedural Assessments for Pediatric Residents

Study	Design	Educational Intervention/ Assessment	Participants	Measured Outcomes	Results	Implications/Limitations
Finan et al, 2012 ³²	Prospective observational pilot study	Neonatal intubation training session using didactic and simulation components	N = 13 PGY-1 pediatric residents	Simulated preintervention/postintervention intubation assessments using checklists Evaluation of intubation attempts during NICU rotation Comparison with historical control group	Training improved simulated performance No significant improvement in real-life intubation success rate Lower checklist scores in the simulation group with actual intubations Performance scores declined to preintervention levels within 8 wk	Improved simulation performance may not be transferable to clinical setting No baseline data on intubation experience Unblinded postintervention assessments Small sample size
Gaies et al, 2009 ³³	Randomized controlled trial	Control: standard teaching methods (observation) Intervention: simulation procedural modules (eg, BVM, PIV insertion, LP)	N = 38 PGY-1 pediatric residents	Simulated performance evaluation after intervention and 7 mo later Self-reported success in live-patient procedures Knowledge base assessment	Intervention group with: -Improved performance simulated PIV and LP -Improved knowledge examination scores No other differences between groups	Unvalidated modules, checklists, and knowledge examinations Small sample size Clinical performance measured by using self-report
Kessler et al, 2011 ³⁴	Randomized controlled trial	LP simulation training with AV training versus AV training alone	N = 51 PGY-1 to -3 pediatric residents	Self-reported clinical success in first infant LP after training OSCE performance in simulated LP 6 months after training Confidence with LP procedure	Simulation group had more success in obtaining CSF in first LP after training No difference in OSCE performance, knowledge, or confidence between groups initially or 6 mo after training	Initial LP performance reportedly improved, but effect not sustained Clinical performance measured by self-report Unvalidated LP checklist
Nishisaki et al, 2010 ³⁵	Prospective intervention study	Simulation-based just-in-time airway management and orotracheal intubation training	N = 265 (54 pediatric or ER residents) Multidisciplinary team	First-attempt success of orotracheal intubation by residents compared with nonintervention group and historical controls Overall resident success with intubation and adverse events	No change in first-attempt or overall success rate after intervention Simulation training increased resident participation in real-life intubation attempts Despite increased participation, no change in rate of adverse events	Laryngoscopist was selected by attending physician, which led to variable resident participation and underpowered study Not exclusively focused on pediatric residents Resident competence level not defined after simulation training Teams performing intubations were different than during training sessions
Sudikoff et al, 2009 ³⁶	Randomized crossover trial	Simulation based airway management and teamwork training	N = 16 PGY-2 pediatric residents	Performance in simulated airway management (overall performance/harmful actions) Knowledge assessment	Improvement in number of critical actions achieved and harmful actions with simulation training Improvement in knowledge scores	Small sample size No live-patient data collected Unblinded data collection Unvalidated assessment tools

BVM, bag-valve-mask; CSF, cerebrospinal fluid.

TABLE 2 Articles Focused on Simulated Resuscitation Scenario Assessments for Pediatric Residents

Study	Design	Educational Intervention / Assessment	Participants	Measured Outcomes	Results	Implications/Limitations
Andreatta et al, 2011 ³⁷	Longitudinal, mixed-methods design	Recorded mock code scenarios were reviewed	N = 228 Multidisciplinary team (PGY-2 and 3 pediatric residents)	Simulated mock codes conducted Confidence to lead codes Actual patient survival rates	Improvement in pediatric resuscitation survival rates, positive correlation with increased number of mock codes Confidence in leading codes improved	The first study to document correlation between a mock code program and clinical outcomes Did not include assessment/documentation of individual residents' competence
Barry et al, 2012 ³⁸	Prospective cohort study with preintervention and postintervention design	Delivery room-based educational sessions on resuscitation equipment and neonatal resuscitation scenarios	N = 51 PGY-1 pediatric residents as intervention group	Checklists assessing equipment assembly and resuscitation performance	Improvement in equipment checklist scores postintervention with retained knowledge 1 to 2 y later Equipment score higher in intervention group as senior residents compared with controls No difference in resuscitation scores between intervention and control senior residents	No live-patient data collected No randomization to groups or blinding Unblinded evaluators
Tofil et al, 2011 ³⁹	Prospective observational cohort study	Weekly videotaped simulation-based resuscitation scenarios Monthly practice of IO needle placement	N = 34 PGY-2 pediatric residents as intervention group PGY-3 pediatric residents as control group for survey	Checklists assessing performance on video review Presurvey/postsurvey assessing confidence	Simulation-based resuscitation performance did not improve Simulation course improved PGY-2 residents' confidence with various resuscitation skills	Increased confidence did not translate to improved performance No live-patient data collected Scenarios used differed over course of study Checklists lacked content validity

IO, intraosseous.

of performance of actual intubations (using the same checklist and global rating scale) during the intervention group's NICU rotations were taken and compared with historical controls of first-year pediatric residents from the previous year. Significant improvement in simulated procedure performance was documented after the intervention ($P < .01$) compared with baseline. When comparing actual intubation success rates, the intervention group's mean success rate of 67.5% was slightly but not significantly improved from the historical cohort success rate of 63.15% ($P = .06$). However, when assessing the intervention group's performance of actual intubations, there were no differences between the pre-intervention and real-life checklist scores (ie, they performed less well in the clinical setting than in the simulation environment), and the intervention group actually obtained lower checklist scores during their NICU rotation compared with the historical cohort group. Performance scores declined to preintervention levels within 8 weeks when measured in a clinical setting.

Gaies et al³³ used a randomized controlled trial comparing a control group of pediatric interns learning to perform procedures via standard teaching methods (observation of more experienced clinicians) and an intervention group of pediatric interns learning via simulation-based modules focused on bag-mask ventilation, venipuncture, peripheral intravenous (PIV) catheter insertion, and lumbar puncture (LP) skills. Evaluations by using structured checklists, observation of simulated skills, and knowledge examination scores were performed after the initial intervention and 7 months later. Residents' self-reported procedural success in live-patient procedures was

also measured. Participants in the intervention group performed PIV placement more successfully than controls (78% vs 35%; $P = .01$) and scored significantly higher on the knowledge examinations for several procedures, as well as on the checklists for PIV placement (81% vs 61%; $P = .003$) and LP (77% vs 68%; $P = .04$) at the initial assessment. No differences were found between groups 7 months after the intervention, and both groups demonstrated declining skills. No significant differences were found in success with live-patient procedures.

Kessler et al³⁴ performed a randomized controlled trial comparing LP simulation training combined with audiovisual (AV) training versus AV training alone to assess pediatric residents' LP skills. Before training, questionnaires were used to assess previous experience/training, a short quiz was given to assess knowledge base, and a 4-point Likert scale was used to assess confidence with LPs in both groups. An infant LP checklist was used to assess LP skills, as well as observed structured clinical examinations (OSCE), by using the simulator at baseline and 6 to 8 months later. Residents in the intervention group received simulation training and AV training while the control group received AV training alone. The intervention group had greater self-reported success on their first real-life LP after receiving training (94% success in simulation plus AV training group, median encounter 56 days after training vs 47% in AV training alone group, median 52 days after training; $P = .005$). However, no difference was found between groups in their comfort, knowledge base, or OSCE performance (initially or 6–8 months later).

Nishisaki et al³⁵ performed a prospective intervention study by using simulation-based airway management in a PICU at a tertiary children's hospital over a 14-month period. A multidisciplinary group including pediatric residents, emergency medicine residents, PICU nurses, and respiratory therapists received just-in-time simulation training (individual bag-valve-mask and intubation training followed by multidisciplinary team training) at the beginning of the residents' 24-hour on-duty period. The primary outcome measure was the first-attempt success rate when pediatric residents performed orotracheal intubation on actual pediatric patients, whereas the secondary measures were overall success rates and the incidence of tracheal intubation-associated events. Primary and secondary outcomes were compared with those of a nonintervention group of residents (who did not receive refresher simulation training over the same time period) as well as with historical controls from a 2.5-year period before the intervention occurred. PICU intubation outcome data were captured and reviewed within the National Emergency Airway Registry for Kids. Independent, trained observers rated actual intubations in the PICU by using an assessment tool for team technical and behavioral skills. First-attempt and overall intubation success rates did not change when comparing the intervention group with the nonintervention group and with historical controls, but the actual laryngoscopist performing the intubation varied and was not always a pediatric resident. However, participation in intubation attempts by intervention group residents increased (35.4% vs 20.9%; $P = .002$) without an associated increase in adverse events (19.9% vs 22.0%; $P = .62$).

Sudikoff et al³⁶ performed a randomized crossover trial assessing the effectiveness of a simulation-enhanced session on pediatric airway management and teamwork. PGY-2 pediatric residents were divided into 2 groups, with both participating in 2 initial simulated scenarios during which baseline airway and teamwork skills were assessed. The intervention group returned for a simulation-enhanced session on pediatric airway management and teamwork, whereas the control group received no supplemental education. The groups then returned 2 months later for reassessment. Checklists were used to assess critical actions completed in airway management, harmful actions performed, and overall performance. The intervention group had higher mean global competency scores ($P < .05$), more critical actions achieved (although not statistically significant), and fewer harmful actions performed (no statistical analysis conducted). Teamwork was found to improve for both groups, independent of the educational intervention. No live-patient data were collected for this study.

Simulated Resuscitation Scenario Assessments

Andreatta et al³⁷ used a longitudinal, mixed-methods design to assess multidisciplinary teams (pediatric residents, medical students, nursing, and pharmacy staff) at a children's hospital in a tertiary care academic medical center over a 4-year period with recorded and reviewed simulation-based mock code scenarios. The primary goal of the program was to provide senior residents with the opportunity to perform as team leader during the mock codes, which were called randomly during the week at least monthly. Each senior resident

participated in at least 1 mock code, and they received debriefings on their videotaped performance after the session. Outcomes included the self-perception of ability to lead a code, and hospital records for real pediatric cardiopulmonary arrest survival rates were documented for 48 months after the mock code curriculum was started. This study was the first to document a significant correlation between a mock code program and clinical outcomes. Survival rates increased from a baseline of 33% to ~50% ($P < .005$) for 3 consecutive years, correlating with the increased number of mock codes performed ($r = 0.87$). The survival rates for pulseless rhythms were well above the national average as well (45%–56% depending on year reported vs national average of 27%). In addition, residents rated themselves as being above average in their abilities to lead an actual code after the mock code event (but not statistically significant compared with baseline). Because the mock code program did not include a summative assessment of each resident's resuscitation knowledge and skills after completing the program, competence for each individual resident could not be documented.

Barry et al³⁸ performed a prospective cohort study with a preintervention and postintervention design to assess the effect of delivery room-based educational sessions on pediatric residents' ability to assemble resuscitation equipment and their performance in leading a neonatal resuscitation. PGY-1 residents received the educational intervention before and after their NICU rotations in their intern year and were reevaluated again as senior residents. The intervention group's performance was compared with a control group of senior pediatric residents who had

previously completed their NICU rotation but did not receive the educational intervention. Checklists were used to assess resident performance in equipment assembly and simulated resuscitation leadership skills. The intervention group's equipment assembly score increased significantly (from 53% to 83%; $P < .0001$) after the intervention and did not decline when they returned 1 to 2 years later as senior residents (87%). Their equipment score as senior residents was significantly higher than that of the control group of senior residents (87% vs 65%; $P = .0001$). The intervention group's ability to lead a simulated resuscitation improved significantly after the initial educational intervention (from 76% to 85%; $P = .001$) and was maintained as senior residents (85%) but was not superior to that of the control group of senior residents (81%). The study did not include live-patient data.

Tofil et al³⁹ performed a prospective observational cohort study to assess resident comfort and performance with simulated resuscitation scenarios and procedural skills, particularly intraosseous needle insertion and intubation. The study used a monthly PICU simulation course for PGY-2 residents that consisted of weekly 1-hour sessions utilizing simulation-based resuscitation scenarios and procedural skills with immediate videotape-assisted debriefing sessions. Checklists were used to score resident performance during the videotape reviews. Surveys assessing comfort were completed preintervention and postintervention, and responses were compared with those of PGY-3 residents who had not participated in the simulation sessions. The intervention increased overall resident confidence in managing various pediatric resuscitation events and in their

perceived procedural ability, but the checklists of the video-based reviews failed to show improvement in performance. The study did not include live-patient data.

DISCUSSION

As an educational tool for pediatric residents, simulation remains in its infancy. Given the current lack of a standardized means for curriculum or assessment design using simulation, the studies described in this article are vastly different in terms of their structure and measured outcomes. The articles in this review reveal that results are mixed when assessing the impact of simulation on pediatric resident procedural proficiency and resuscitation performance compared with traditional training methods. Some studies indicate that simulation may be a viable training mechanism for teaching procedural and resuscitation skills to pediatric residents,^{33,36–38} whereas others reveal minimal or no effect on resident performance.^{32,34,35,39} Simulation can help to identify deficiencies in residents' resuscitation knowledge or performance, as recent studies have revealed deficiencies in residents' airway management skills, time to initiation of critical resuscitation maneuvers, and recognition and treatment of unstable cardiac dysrhythmias.^{40–43} In identifying deficient areas of knowledge/procedural proficiency, simulation may help guide residency curricula to train pediatric residents based on educational need.

Applying an educational modality to patient care is challenging but should remain the ultimate goal of future simulation training research in pediatrics. Several studies have documented that mock codes increase resident confidence in their abilities to lead and

supervise a code but that increased confidence does not always translate into improved actual performance during a real-life resuscitation.^{39,44–47} In addition, resident proficiency during simulation training is not necessarily indicative of improved performance during actual patient care settings,^{32,33,35} and a drawback of several of the studies in this review is that they did not assess the impact of training on live patients.^{36,38,39,43} The landmark study by Andreatta et al³⁷ was the first to document improvements in patient care outcomes as the result of a rigorous simulation pediatric mock code curriculum because it showed improvement in hospital-wide pediatric cardiopulmonary arrest survival rates. Documenting improvements in patient outcomes or real-life procedural success should remain a focus of future simulation research.

Although assessment tools have been evaluated in several studies that ascertained which valid and reliable measures of performance and resident competency could be obtained by using simulation, the clinical significance of measured performance in a simulated setting is uncertain.^{48–52} The lack of validated, reproducible, and reliable measurement tools is a significant limitation of simulation training, and the need to develop validated instruments is of paramount importance to develop consistency across institutions.^{53,54} 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 more standardized approach to simulation training.^{55,56}

In July 2013, the ACGME procedural requirements for pediatrics will change

compared with those in 2007.^{2,57} Residents will be required to demonstrate procedural competence in bag-mask ventilation, bladder catheterization, giving immunizations, incision and drainage of abscesses, LP, reduction of a simple dislocation, simple laceration repair, simple removal of a foreign body, temporary splinting of a fracture, umbilical venous catheter placement, and venipuncture. The ACGME will continue to accept simulation training as a mechanism to document competence for placement of an intraosseous line, and will also require the simulated placement of an umbilical catheter. When important for a resident's post-residency training, simulation will be an acceptable means of teaching arterial line placement, arterial puncture, chest tube placement, circumcision, endotracheal intubation, PIV catheter placement, thoracentesis, and umbilical artery catheter placement.² With further restrictions in resident work hours and direct procedural experience, it is likely that validated simulation training in other ACGME-required procedural competencies will need to be formally implemented into residency training curriculum in the future.

Implementation of simulation training into a pediatric residency curriculum may be a vital component of resident education in the future, but there is currently minimal evidence-based research on how best to do so. As highlighted in this review, there is great variation in the approach to the utilization of simulation and curricular design across institutions. Although the majority of pediatric studies have used simulation centers or in situ simulation programs for assessment of resident performance and procedural proficiency,^{23,27,28,33,36,43,48,49,57,58} alternative techniques such as the creation of a

formal mock code curriculum^{24,37,41,59} and just-in-time procedural training as part of the PICU rotation^{20,35} have also been performed. Although some of these curriculum designs have achieved meaningful results, there is a lack of consensus for the ideal approach to simulation implementation into a pediatric residency program. In addition, some studies have used a multidisciplinary team to create a more realistic resuscitation environment,^{20,35,37,57} but future research that assesses individual resident performance during these scenarios may help to document resident competency.

Another potential hurdle to implementation is the uncertainty over the recommended frequency of simulation courses during residency. Although simulation can be beneficial in improving resident proficiency in the short-term, skill decay is common. Studies have shown that retention of pediatric resuscitation knowledge and skills declines within weeks of training if they are not maintained and applied,^{6,13–17,41,60} and the optimal time for retraining is currently undefined. Few studies have addressed long-term retention after a simulation course, and those that did have shown variable results.^{33,34,36–38,57} More research is needed to delineate the most favorable time for “refresher” courses to occur. Finally, there are potential programmatic obstacles to the implementation of simulation training into residency curriculum, including faculty time constraints, lack of faculty training/comfort with simulation technology, and cost of equipment.⁶¹

This review has several important limitations. First, despite using multiple research strategies and the expertise of a reference librarian, querying articles relevant specifically to pediatric

simulation research was challenging. A small number of important articles were not identified until a thorough review of references was performed. This difficulty is likely secondary to the heterogeneity in study design, intervention strategies, and assessed outcomes related to pediatric simulation research. In addition, several of the articles in this review did not have MeSH terms linked to them, which made them difficult to identify by using our search strategy. To keep this review focused, we limited our search to the use of simulation for pediatric resident education and training. In doing so, meaningful data on simulation in the adult-focused training programs may have been omitted. Finally, the creation of validated assessment tools could potentially generate a body of research that may lend itself better to a systematic review in the future.

CONCLUSIONS

As pediatric residency programs adjust to duty hour restrictions for their trainees, the development of effective adjunctive educational strategies is critical. As cited in this review, simulation may be an effective modality for procedural and resuscitation training, but current research is mixed in terms of its actual educational utility. Goals of future research should include focusing on the creation of validated assessment tools to help standardize training across institutions, determining the frequency of simulation training to maximize retention, and applying skills learned in simulation training to actual patient care performance/outcomes. As simulation becomes more readily available and accepted in training centers, its educational role will be better defined as research progresses and collaboration occurs. If used properly,

simulation training may prove to be a useful tool for pediatric residency programs as they educate and certify their resident trainees to meet the requirements of graduate education.

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