Simulation-based mock codes significantly correlate with improved pediatric patient cardiopulmonary arrest survival rates*

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Objective: **To evaluate the viability and effectiveness of a simulation-based pediatric mock code program on patient outcomes, as well as residents' confidence in performing resuscitations. A resident's leadership ability is integral to accurate and efficient clinical response in the successful management of cardiopulmonary arrest (CPA). Direct experience is a contributing factor to a resident's code team leadership ability; however, opportunities to gain experience are limited by relative infrequency of pediatric arrests and code occurrences when residents are on service.**

Design: **Longitudinal, mixed-methods research design.**

Setting: **Children's hospital at an tertiary care academic medical center.**

Patients: **Pediatric.**

Interventions: **Clinicians responsible for pediatric resuscitations responded to mock codes randomly called at increasing rates over a 48-month period, just as they would an actual CPA event. Events were recorded and used for immediate debriefing facilitated by clinical faculty to provide residents feedback about their performance.**

Measurements: **Self-assessment data were collected from all team members. Hospital records for pediatric CPA survival rates were examined for the study duration.**

Results: **Survival rates increased to approximately 50% ($p = .000$), correlating with the increased number of mock codes ($r = .87$). These results are significantly above the average national pediatric CPA survival rates and held steady for 3 consecutive years, demonstrating the stability of the program's outcomes.**

Conclusions: **This study suggests that a simulation-based mock code program may significantly benefit pediatric patient CPA outcomes—applied clinical outcomes—not simply learner perceived value, increased confidence, or simulation-based outcomes. The use of mock codes as an integral part of residency programs could provide residents with the resuscitation training they require to become proficient in their practice. Future programs that incorporate transport scenarios, ambulatory care, and other outpatient settings could further benefit pediatric patients in prehospital contexts. (Pediatr Crit Care Med 2011; 12:33–38)**

Key Words: simulation-based pediatric mock codes; pediatric cardiopulmonary arrest; residents' resuscitation training; applied clinical outcomes; improved pediatric patient cardiopulmonary arrest survival rates

The ability to provide rapid resuscitation to a child in cardiopulmonary arrest (CPA) is critical for pediatricians at every level of experience. Most pediatricians receive their training in the management of CPA during residency rotations through neonatology, pediatric critical care, and pediatric emergency medicine (1, 2), where they may perform resuscitations and are required to complete Pediatric Advanced Life Support (PALS) training as part of their formal curriculum. In our teaching hospital setting, resuscitation is provided through the coordinated effort of multiple specialists performing emergency procedures under the direction of a senior resident, the code team leader. The ability of the code team leader is believed to be integral to accurate and efficient clinical response (3–6). Although direct experience is a contributing factor to a resident's leadership ability (3, 7, 8), opportunities for residents and pediatricians to gain this experience is limited by the relative infrequency of pediatric arrests in the clinical environment (9, 10) and whether or not a code occurs at a time when they are available to respond.

The result is predominant reliance on PALS training to acquire and maintain code management competencies. Although effective for providing and sustaining a clinical foundation of conceptual knowledge (3, 11, 12), numerous studies (3, 5, 13–18) have demonstrated that clinical skills decline within several weeks if not applied. These studies suggested that PALS preparation is insufficient to provide residents with the confidence and abilities to perform pediatric resuscitations successfully. Not unexpectedly, physician confidence to respond correctly to CPA is consistently lower than expected for proficient clinicians (6, 9, 14, 19).

Several programs have demonstrated the effectiveness of mock code programs to improve physician confidence in responding to the need for pediatric resuscitation (9, 20–22), and many have called for the inclusion of mock code programs as adjunct support to formal PALS training in pediatric residency programs (3, 9, 13, 14, 19, 20, 23, 24). Hunt et al (3) demonstrated that simulation-based methods in performing mock codes can be utilized to assess proficiencies in the clinical knowledge, skills, and attitudes in the area of pediatric resuscitation, as well as reveal specific aspects of clinical care and management that require remediation and improvement. Although these findings provide important evidence con-

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tributing to the value of mock codes in affecting the clinical care of pediatric patients requiring resuscitation, to date no evidence has demonstrated that the use of simulation-based mock codes significantly benefits patient outcomes for pediatric resuscitations.

The purpose of this study was to evaluate the feasibility and effectiveness of a pediatric mock code program on patient outcomes, as well as residents' confidence in performing resuscitations. We addressed three research questions: 1) What do residents report learning as a result of their participation in the mock code program? 2) To what extent do mock codes impact residents' perceptions of their ability to direct a code? 3) To what extent does a mock code program influence clinical outcomes (survival rates) for pediatric patients with CPA?

METHODS

The prospective institutional review board approved study was completed between calendar years 2005 and 2009 at the University of Michigan tertiary care academic medical center. There are 85 pediatric medicine residents per year in various pediatric specialty programs, all of whom are required to complete American Heart Association PALS certification at the beginning of their residency and recertification every 2 yrs thereafter. The American Heart Association updated guidelines released in 2005 were implemented for both PALS training and as part of this program. Before the commencement of this study, mock codes were used periodically as part of residency training (25); however, a consistent and formal program that included assessment components was not implemented until 2005 after our institution invested in a simulation center to facilitate routine, ongoing code training.

The primary goal of the mock code program was to provide the opportunity for senior residents to perform as a team leader, who is able to assign and supervise tasks and, if necessary, performs them when others cannot. Senior residents were provided formative feedback about their performance leading the team and directing the completion of specific tasks associated with basic resuscitation, airway support, circulation, and arrhythmia. Each senior resident participated in at least one mock code, but more often they participated in two or more mock codes. If more than one senior resident responded to a mock code, they took turns leading the scenarios. Junior residents participated by performing clinical tasks during the mock codes throughout the 4-yr program, so by the end of this study, junior residents from the previous years had performed clinical tasks in multiple mock codes before advancing to the team leadership role as senior resident. The total number of junior and senior residents who participated over the 4-yr period was 228.

Mock codes were called randomly at least monthly, Monday through Friday during the day shift. All code team members responded to the mock event as they would an actual code event. Participants included senior pediatric residents, pediatric residents on the code team at the time the code was called, pediatric intensive care unit nurses, medical students on the pediatric ward team, pediatric hospitalists, chief pediatric residents, and pediatric pharmacists. Pediatric ward nurses participated several times per year. Mock codes were facilitated, using either a METI Pediatric HPS (Sarasota, FL) or Laerdal SimBaby (Stavanger, Norway) patient mannequin in the pediatric clinical bay of our Clinical Simulation Center or an actual pediatric patient room. The simulated pediatric bay is outfitted with furnishings, equipment, instruments, and supplies typically found in pediatric patient care rooms.

Previous studies documented deficits in the performance of resuscitation skills during mock code events that included the failure to: 1) follow life support protocols (PALS algorithm, assess/reassess); 2) secure airway (bag valve mask, endotracheal intubation, different endotracheal tube sizes); 3) manage breathing (administration of oxygen, ventilation, chest tube placement, thoracentesis); 4) manage circulation (dysrhythmia recognition, rhythm identification, initiation of chest compressions, defibrillation at correct energy level and time interval); 5) determine initial neurologic status; 6) estimate the patient's weight; 7) rapidly establish vascular access (intravenous, intraosseous, central catheter); 8) make use of intravenous fluid boluses; 9) order the appropriate dose and concentration of medications and fluids; 10) correctly manage the time intervals for therapies (chest compressions, defibrillation, administration of medications and fluid); 11) identify a team leader; and 12) use closed-loop confirmatory communication within the code team to promote efficient and effective decision making and implementation (3, 13, 26). Our curriculum incorporated these elements identified in the literature, as well as code scenarios that incorporated pathophysiological conditions common to our pediatric population: sepsis (immunosuppressed patients and normal); respiratory distress (bronchiolitis, pneumonia); increased intracranial pressure/herniation (intracranial mass, intracranial trauma, meningitis, seizures); and anaphylactic shock, cardiogenic shock (congestive heart failure, congenital heart disease, myocarditis). Each mock code included one or more scenarios with these elements embedded in the cases, with emphasis on pulseless rhythms in 2005, followed by more focus on rhythms with a pulse in 2006, and a balance between the two in 2007.

Video recordings of the mock codes were used for immediate debriefing that was facilitated by a process-trained designated clinical faculty and included all other team members to the extent possible. Debriefing encompassed approximately 30% of the training event. All debriefings were considered as formative assessments to provide the residents with information about their performance strengths and weaknesses to identify areas where they should focus their future learning. Before debriefing, faculty reiterated that the intent of the mock code was to provide a learning experience and that performance assessment and discussion should be constructive and specific, without personal condemnation or intimidation. The senior resident provided self-assessment, whereas the faculty and other team members provided pertinent feedback about what went well and what could be improved. Discussion ensued to review specific case details, including diagnosis, treatments, and medication choices, as well as aspects of leadership and team dynamics.

Data collection included the number of mock codes conducted, reported learning outcomes from the mock code events, residents' self-perception ratings, and real CPA survival rates for pediatric patients. We asked residents to "Please list what you learned during today's mock code" to assess their perceived learning outcomes and used a 6-point rating scale (1 = very poor; 6 = outstanding) to capture residents' self-perceptions of their ability to lead an actual code. The University of Michigan Hospitals and Health Centers Office of Clinical Affairs provided hospital records for pediatric resuscitation survival rates for 48 months after its start (2005–2008). The University of Michigan Hospitals and Health Centers uses the American Heart Association National Registry of Cardiopulmonary Resuscitation database for data definitions and entry (27). Survival rates were defined as the percentage of patients who survived CPA and were subsequently discharged from the hospital. Other contextual factors potentially confound the analyses of patient survivability data; therefore, other training interventions, inconsistent patient characteristics, and changes in personnel, scheduling, instruments, equipment, furnishings, and facilities were monitored throughout the program. We used the All Patient Refined Diagnosis-Related Group patient classification scheme to track the type of patient we treated throughout the course of the study. The All Patient Refined Diagnosis-Related Group includes the severity of patient illness and provides a means of identifying the potentially confounding case acuity variable (length of stay, cost per case, readmission

Table 1. Key learning outcomes from mock code (252 responses)

Clinical Techniques		Management	
Intubation/airway	182	Code response algorithm	128
Medication selection	76	Manage specific situation	105
BVM	75	Assess/reassess/double-check	63
IV access	75	Planning/prioritizing	39
IO access	42	Stress management	27
Medication dosing	34	Time	14
Defibrillation	32	Task assignment/completion	12
Compressions	18	Importance of crowd control	5
Fluids	13		
Team Factors		Diagnostic Factors	
Member roles	76	Cardiac rhythms	58
Ask for help	38	ICP	38
Leadership	37	Vital signs	9
Patient interaction	30	Shock	9
Communication	18	Pneumothorax	5
Supplies/Resources		Safety Techniques	
Cart contents/function	15	Brozelow-Luten tape	6
Equipment size/settings	13	Chart	4
Monitor placement/function	11	Labeling syringes	2
Location of equipment/supplies	9		

BVM, bag valve mask; IV, intravenous; IO, intraosseous; ICP, intracranial pressure.

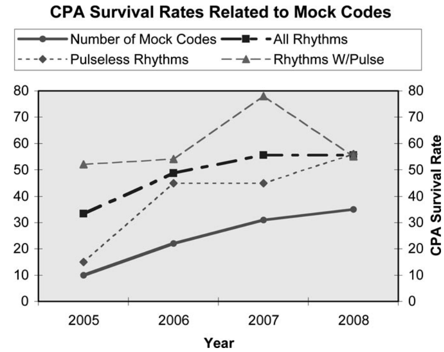

Figure 1. Real pediatric survival rates (*right scale*) related to the number of mock codes (*left scale*). Actual survival rates for pulseless rhythms, rhythms with a pulse, and all rhythms are presented. *CPA*, cardiopulmonary arrest.

Table 2. Mock code program effect sizes on actual cardiopulmonary arrest survival rates

Change Between Years	CPA Survival Rate	Effect Size (Cohen's *d*)[a]
2005–2006	Pulseless	30
	W/pulse	2
	All rhythms	15
2006–2007	Pulseless	0
	W/pulse	24
	All rhythms	3
2007–2008	Pulseless	22
	W/pulse	44[b]
	All rhythms	0

CPA, cardiopulmonary arrest.
[a]Cohen's *d* standard values are 0.2 (small), 0.5 (medium), and 0.8 (large); [b]reduced effect.

rate) from the National Association of Children's Hospitals and Related Institutions database (28).

Quantitative and qualitative methods were used to analyze the resulting data. We calculated effects sizes (Cohen's *d*), and used SPSS 16.0 to calculate descriptive and inferential statistics with statistical significance set at $p < .05$ and SPSS Text Analysis for Surveys 3.0 for qualitative analyses of reported learning outcomes (SPSS Inc., Chicago, IL). One researcher (P.A.) and a research assistant used the constant comparative method of theme generation to code all qualitative data until saturation and agreement were reached between the researchers on thematic categorization. We calculated the mean and SD values for residents' perceptions of their ability to lead an actual code.

RESULTS

Qualitative analysis of the responses to the query, "Please list what you learned during today's mock code," yielded six main categories specific to various attributes of the content that are presented in Table 1. This thematic framework enabled us to identify explicitly noted key factors and the frequencies with which they were mentioned (Table 1). Because residents participated multiple times throughout the 3 yrs of their residency program, a total of 252 responses were collected over the 4-yr study. These data confirmed that the mock codes provided the context to practice those areas of resuscitation that prior studies have identified as important but were weakly performed by pediatric residents.

Overall, residents rated themselves as being above average in their abilities to lead an actual code following the mock code event (4.20 ± 0.91). This rating slightly increased for residents who completed multiple mock codes (4.33 ± 0.97). The impact of multiple mock codes did not have an effect on residents' perceptions of their abilities to manage an actual code per Cohen's *d* convention ($d < 0.2$).

The mock code program seemed to significantly contribute to improved actual CPA clinical outcomes for pediatric patients. The CPA survival rates for pediatric patients for each year of the study are presented in Figure 1. In 2005, our pediatric CPA survival rate was 33% after the introduction of ten informal mock codes. After the routine integration of the formal mock code program into our residency curriculum, we were able to significantly increase CPA survival rates to approximately 50% within 1 yr, in increments that correlated with the increasing number of mock code events ($r = .87$). Effect sizes (Cohen's *d*) for CPA survival rates were calculated for both pulse-present and pulseless rhythms and are presented in Table 2. None of the potential confounding factors varied over the period of study (Table 3).

DISCUSSION

An expanding body of literature suggests that simulation can be successfully used as a platform for robust medical education and comprehensive assessment of clinical knowledge and skills in simulated pediatric CPA contexts (3, 5, 13, 21, 29–32). Although limited evidence supports the assertion that competencies gained through simulation-based training transfer to the applied clinical context (33–35), the degree to which simulation-based training and assessment reflects actual clinical performance has remained questionable because of the challenges associated with tracking clinical performance data. Cappelle and Paul (9) asserted that mock codes are worthwhile to improve confidence and decrease anxiety, without evidence that they significantly reduce the morbidity or mortality of patients with cardiac and/or respiratory arrest. Although confidence is an important factor in clinical care, ultimately it is clinical performance that is the required outcome from any training exercise. Several previous studies (9, 20–22) have documented that mock codes increase the confidence of residents in their abilities to lead and supervise a code; however,

Table 3. Variance in potential confounding variables

Variable	2005	2006	2007	2008
Extraneous code Training Interventions	PALS	PALS	PALS	PALS
Beds	198	198	198	198
Patient days	55,023	57,124	58,085	54,527
Census, %	85	87	88	81
APR-DRG Total Pediatric Inpatient Case Mix Indices	1.44	1.55	1.54	1.65
Discharge avg LOS	5.73	6.41	6.41	6.75
NACHRI Patient Acuity Index	N/A[2]	2.27	2.17	2.42
CPA events	49	42	54	45
CPA survival rate, %	33	48	56	56
Pulseless survival rate,[3] %	15	45	45	56
Pulse-present survival rate,[a] %	52	54	78	55
Mock codes	10	22	31	35
Sr. residents Trained (Year/Total Program)	20	29/49	29/78	29/107
Jr. residents Trained (Year/Total Program)	40	56/96	56/152	56/208
Physician staff[b]	18	18	18	18
Nursing staff	149	150	153	151
Facilities and equipment[5]	N/C	N/C	N/C	N/C

PALS, Pediatric Advanced Life Support; APR-DRG, All Patient Refined Diagnosis-Related Groups; LOS, length of stay; NACHRI, National Association of Children's Hospitals and Related Institutions developed in 2006; CPA, cardiopulmonary arrest; Sr., senior; Jr., junior; N/C, no changes.

[a]Real patient data; [b]pediatric intensive care unit/pediatric cardiothoracic intensive care unit staff physicians.

many of these same studies (21, 22) contended that, although residents were confident in their overall abilities after a mock code, actual performance of resuscitation revealed significant deficits. Numerous studies (3, 5, 13–18) have documented that retention of knowledge and skills associated with pediatric resuscitation degrade within several weeks of training if they are not maintained and applied, leading Durojaiye and O'Meara (12) to propose that the retention of learned resuscitation skills could be improved by intensive and accurate training techniques repeated every 3–6 months.

Our mock code curriculum was based on the prior literature that identified specific deficits in resuscitation skills (3, 13, 26), and the results of our qualitative analysis yielded categories and key factors reflective of this curriculum content. These results included team and leadership behaviors, diagnostic reasoning, clinical skills, and discriminating aspects unique to pediatric resuscitation, such as intraosseous access as a noncollapsible venous structure and the accurate estimation of the pediatric patient's weight for selecting the appropriate equipment sizes, defibrillation energy, and doses of medications and fluids. These data substantiate that both broad and detailed knowledge, skills, and attitudes were reinforced through participation in the mock codes.

Although the impact of multiple mock codes did not have a statistically significant effect on residents' perceptions of their abilities to manage an actual code, we did see a progression in the complexity of self-reported learning outcomes as residents completed more codes over time. For example, one resident who completed five mock codes over 2 yrs first reported learning outcomes associated with completing a full-body assessment routinely, securing the airway, maintaining liberal use of fluids, and noted that patient deterioration could be fast. After three mock codes, the resident reported more specific learning outcomes that included handling medication doses and variability of vocal cord location, expanding differential diagnoses, limiting respiratory rate, and sticking to an assigned function on the team. When the resident had progressed to a leadership position, the reported learning outcomes included identifying himself/herself as leader, speaking forcefully and clearly, knowing the algorithms, and knowing the configuration of the room and how it was equipped. Another example is from a resident who participated in seven mock codes over 2 yrs but had not yet advanced to a leadership position. Self-reported learning outcomes for the first mock code included the order of completing the patient evaluation and working as a team member. After completing four mock codes, the resident reported more clinically specific learning outcomes, including premedications for intubation, evaluation of pulseless arrest, evaluation of respiratory distress, and antibiotic choices for specific illnesses. These trends in the qualitative data provide some evidence of improved knowledge resulting from the mock codes.

Our results are the first to document a significant correlation to improved clinical outcomes as a result of a routine and frequent mock code program for pediatric residents. Although our patient population includes many of the most critically ill or injured children, the resulting patient outcomes were well above the national 27% survival rate for pulseless rhythms (36), demonstrating a substantial, sustained impact of the mock code program on CPA survival rates for both pulseless rhythms and those with a pulse. The influence of the curriculum on the survival rates is particularly of note for the time periods 2005–2006 where the focus was principally on pulseless rhythms, compared with 2006–2007 where the focus was on pulse-present rhythms. The effects of a balanced curriculum incorporating both types of rhythms are apparent in the 2007–2008 results. This represents a significant contribution to the literature because it provides the missing link to key limiting factors associated with simulation-based instruction; specifically, the implications of providing training outside the applied clinical context with merely the expectation that simulation-based outcomes will transfer to clinical outcomes. Our results—combined with those of others demonstrating the effectiveness of simulation-based mock codes for teaching, practice, assessment, and confidence building—contribute strong evidence for their routine use in resident education (3, 5, 13, 20, 21, 30–32, 35). Interestingly, our senior residents reported only moderate levels of confidence in their abilities to lead an actual code, despite favorable clinical performance and comments reflecting increased levels of clinical knowledge and team responsibility. We hypothesize that the extraneous stressors—associated with time sensitive, complex clinical judgment, directing multiple tasks, and managing team dynamics within a challenging environment—factor into physicians' level of confidence when estimating their abilities. As a result, competent physicians, who understand the limiting factors of pediatric CPA resuscitation, may report lower confidence levels specifically because of their competence.

The success of our mock code program is likely a direct result of two factors: a) the rapid expansion of the program to reach all of our pediatric residents; and b) the development of a comprehensive curriculum that addressed performance deficits identified in the literature (3, 8, 12, 13, 22, 32, 37, 38). We were able to expand the mock code program significantly from ten mock codes in 2005 to an average of three mock codes per month by 2008. The program has become a routine part of the residency curriculum and is included as part of the normal clinical practice of the pediatric code team. The incremental annual increases in mock code events significantly correlate with the increase in patient survival rates, suggesting the benefits of consistent, routine, and frequent mock codes. As noted in the results section, no other changes were made in the pediatric units during the period of the study that would account for these outcomes (additional training, staffing, equipment, protocols, etc.).

Our mock code program provided senior residents with the opportunity to lead and direct the code team during resuscitation, as distinct from performing skills associated with clinical tasks. Cooper and Wakelam (38) reported that codes in which the team leader participated in hands-on clinical tasks—rather than focusing on leadership—had a higher likelihood of errors, delays, and poor team functions that were likely to affect outcomes. To improve code leadership, Hunt et al (3) proposed that successful code team leaders should identify themselves as such, assign tasks, confirm the quality of procedures (e.g., airway support, compressions, medications), communicate effectively, and double-check orders to ensure that all therapies are administered as requested. The results from our study support these previous findings and lend confirmatory support for the assertion that code team leaders should focus on leading the code team and not on performing task-specific measures while doing so.

In summary, we have shown that a simulation-based mock code program significantly correlates to improved patient outcomes; our pediatric patient CPA survival rates were almost twice the national average for lethal rhythms. Future programs that include standardized simulation actors in the role of parents who are present during their pediatric patient's resuscitation, incorporating transport scenarios, and conducting mock codes in ambulatory care and other outpatient settings could further benefit pediatric patients in prehospital contexts.

A limitation of this study is that, because we were interested in evaluating the overall system-level programmatic impact on clinical outcomes, rather than individual performances of the senior residents, we did not perform summative assessment of each resident's resuscitation knowledge and skills after completing the program. Although this is consistent with system-level program evaluation methodology, the result is that we are not able to assert definitively individual competence for each resident. That said, there are several exceptional studies that have demonstrated mock codes as an excellent platform for competency-based assessment (3, 5, 13, 14) and simulation as an optimal modality through which to measure performance (3, 13, 21, 22, 30, 32, 35). These studies, in conjunction with our own findings demonstrating that mock codes directly correlate with improved applied clinical outcomes, provide convincing evidence of the value of routine and comprehensive mock codes in all pediatric clinical care environments. Another limitation of the study is that we did not track details associated with the occurrence of CPA events themselves, such as the day and time, whether it was witnessed, and the elapsed time to compressions and shock. Again, this is consistent when conducting program evaluation where these types of system-level factors are embedded into the aggregate analyses. Although these details may contribute to resuscitative efforts, rhythm recognition and response times were embedded within the curriculum that was tracked programmatically. The training occurred during the weekday shifts; however, the residents who participated were consistently distributed across all shifts and, therefore, we believe that the day and time of the event were not confounding to the overall analyses.

CONCLUSIONS

This study provides evidence that a simulation-based mock code program may significantly improve pediatric patient CPA survival rates, demonstrating a training impact on applied clinical outcomes—not simply learner-reported perceived value, increased confidence, or simulation-based outcomes. These findings are the first of their kind in demonstrating that simulation-based mock codes can provide a sustainable and transferable learning context for advanced clinical training and assessment that ultimately improve patient care. The use of mock codes as an integral part of residency programs could provide all residents with the quantity and quality of resuscitation training they require to become proficient in their practice.

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