Improving Code Team Performance and Survival Outcomes: Implementation of Pediatric Resuscitation Team Training*

Lynda J. Knight, RN, MSN[1]; Julia M. Gabhart, MD[2,3]; Karla S. Earnest, MS, MSN[4]; Kit M. Leong, RHIT, CPHQ[5]; Andrew Anglemyer, PhD[6]; Deborah Franzon, MD[7]

Objective: To determine whether implementation of Composite Resuscitation Team Training is associated with improvement in survival to discharge and code team performance after pediatric in-hospital cardiopulmonary arrest.

Design, Setting, and Subjects: We conducted a prospective observational study with historical controls at a 302-bed, quaternary care, academic children's hospital. Inpatients who experienced cardiopulmonary arrest between January 1, 2006, and December 31, 2009, were included in the control group (123 patients experienced 183 cardiopulmonary arrests) and between July 1, 2010, and June 30, 2011, were included in the intervention group (46 patients experienced 65 cardiopulmonary arrests).

Intervention: Code team members were introduced to Composite Resuscitation Team Training and continued training throughout the intervention period (January 1, 2010–June 30, 2011). Training was integrated via in situ code blue simulations ($n = 16$). Simulations were videotaped and participants were debriefed for education and process improvement. Primary outcome was survival to discharge after cardiopulmonary arrest. Secondary outcome measures were 1) change in neurologic morbidity from admission to discharge, measured by Pediatric Cerebral Performance Category, and 2) code team adherence to resuscitation Standard Operating Performance variables.

Measurements and Main Results: The intervention group was more likely to survive than the control group (60.9% vs 40.3%) (unadjusted odds ratio, 2.3 [95% CI, 1.15–4.60]) and had no significant change in neurologic morbidity (mean change in Pediatric Cerebral Performance Category 0.11 vs 0.27; $p = 0.37$). Code teams exposed to Composite Resuscitation Team Training were more likely than control group to adhere to resuscitation Standard Operating Performance (35.9% vs 20.8%) (unadjusted odds ratio, 2.14 [95% CI, 1.15–3.99]). After adjusting for adherence to Standard Operating Performance, survival remained improved in the intervention period (odds ratio, 2.13 [95% CI, 1.06–4.36]).

Conclusion: With implementation of Composite Resuscitation Team Training, survival to discharge after pediatric cardiopulmonary arrest improved, as did code team performance. Demonstration of improved survival after adjusting for code team adherence to resuscitation standards suggests that this may be a valuable resuscitation training program. Further studies are needed to determine causality and generalizability. (*Crit Care Med* 2014; 42:243–251)

Key Words: interprofessional training; operational performance; patient outcomes; patient safety; pediatric; simulation

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[1]Center for Nursing Excellence, Lucile Packard Children's Hospital, Palo Alto, CA.

[2]Department of Pediatrics, Lucile Packard Children's Hospital, Palo Alto, CA.

[3]Department of Pediatrics, Stanford University, Palo Alto, CA.

[4]Division of Trauma Services, Department of Pediatrics, Lucile Packard Children's Hospital, Palo Alto, CA.

[5]Center for Quality Effectiveness and Process Improvement, Lucile Packard Children's Hospital, Palo Alto, CA.

[6]Division of Global Health Sciences, Department of Epidemiology and Biostatistics, University of California, San Francisco, CA.

[7]Division of Pediatric Critical Care, Department of Pediatrics, Lucile Packard Children's Hospital, Palo Alto, CA.

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Address requests for reprints to: Lynda J. Knight, RN, MSN, 4700 Bohannon Drive #147, Menlo Park, CA 94025. E-mail: lyknight@lpch.org

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Rapid response teams (RRT) that can be deployed to stabilize and prevent patient deterioration have become widely instituted. Through prevention of cardiopulmonary arrest (CPA) events, Rapid Response Team implementation has been associated with decreased mortality rates for children and adults (1–3). Despite these results, for patients who do sustain in-hospital CPA, the chance of survival to discharge remains low. For children, survival rates after in-hospital CPA are only 23–37% (4–6).

Training resuscitation teams to perform in a way that optimizes patient outcomes is a complex task. The approach to resuscitation training varies among institutions (7–9). Literature is lacking regarding which approach best improves patient outcomes. Regardless of the educational model employed, training resuscitation teams to improve survival to discharge, while minimizing neurologic morbidity, is the ideal. A growing body of literature supports using resuscitation training programs that 1) are multidisciplinary (10); 2) are based on the latest American Heart Association (AHA) resuscitation guidelines (11, 12); 3) use simulation (mock codes) and debriefings (9, 10, 13–15); and 4) are sustained over time (8, 16, 17). In addition, successful programs identify and address system errors, which occur in up to 40% of CPA events (18).

Although each of these components has been associated with improved code team performance or confidence (19, 20), none except adherence to the AHA resuscitation guideline recommendations has substantial evidence supporting improved patient outcomes (21). Resuscitation simulation has not been well studied to support an association with patient-centered outcomes. The report by Andreatta et al (9) in 2011 may have been the first published evidence demonstrating resuscitation simulation may benefit patient outcomes, showing that pediatric survival rates directly correlated with increased numbers of mock codes. The study, however, was unable to speak to causality. More recently, Theilen et al (22) reported that regular integration of in situ resuscitation simulation, with focuses on the deteriorating child, teamwork, and early consultant involvement, was associated with significantly more rapid recognition of deteriorating patients and reduced hospital mortality. The quantity of a provider's previous resuscitation experiences impacts the quality of code team performance and patient outcomes (8, 23). Given this relationship, in the post-Rapid Response Team implementation era of decreased out-of-ICU adult and pediatric CPA events (2, 3), the creation of an ongoing training program that incorporates simulated resuscitation experiences, and allows for self-evaluation and assessment of system errors, is imperative (18).

The purpose of this study was to define how hospital-wide implementation in a pediatric setting of a novel multidisciplinary Composite Resuscitation Team Training program impacted: 1) post-CPA survival to discharge, 2) neurologic morbidity following CPA, and 3) code team performance in actual CPA events.

MATERIALS AND METHODS

To determine whether a Composite Resuscitation Team Training program is associated with improved post-CPA survival to discharge, a prospective observational study using historical controls was conducted at a 302-bed, freestanding, quaternary care, academic children's hospital. The distribution of beds is 117 medical/surgical, 84 critical care (PICU, cardiovascular ICU, and neonatal ICU), 52 obstetric, and 49 nursery beds. This study was reviewed by Stanford University School of Medicine Institutional Review Board and determined a quality improvement project and was exempt; therefore, consent was not required. Included in the analysis were all CPA events, defined as events requiring chest compressions, to which our pediatric code team responded during control (January 1, 2006–December 31, 2009) and intervention (July 1, 2010–June 30, 2011) periods. Our pediatric code team responds to all inpatient and pediatric codes in the institution with the following exceptions: an adult code team and an Obstetrical Emergency Response Immediately team respond to adult visitors and

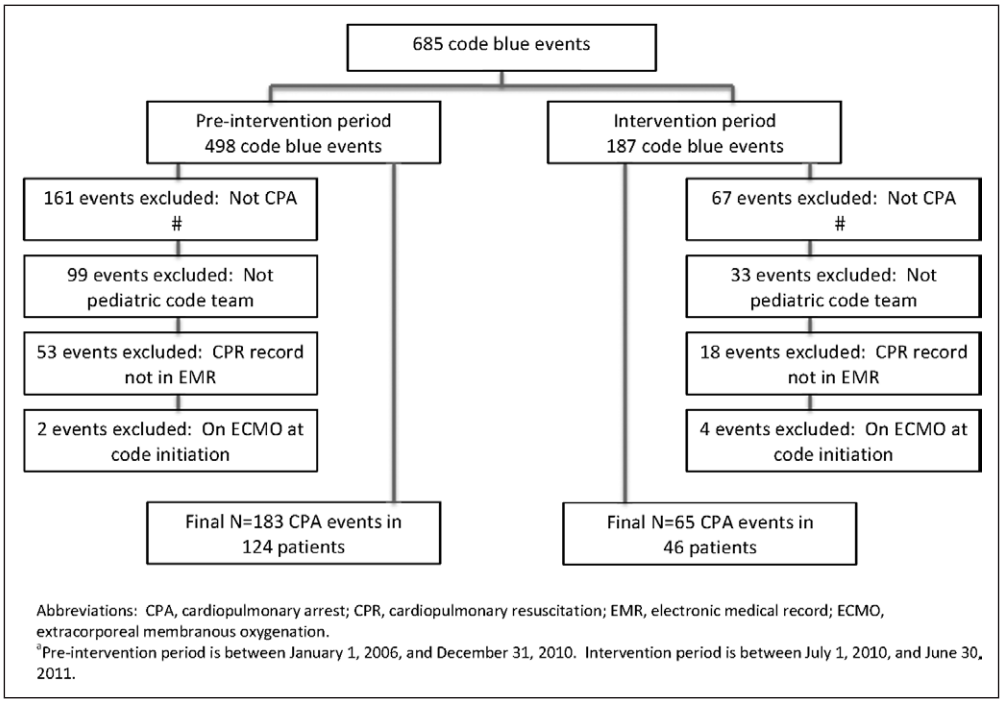

Figure 1. Excluded and included code blue events in the preintervention and intervention periods. Preintervention period is between January 1, 2006, and December 31, 2010. Intervention period is between July 1, 2010, and June 30, 2011. CPA = cardiopulmonary arrest, CPR = cardiopulmonary resuscitation, EMR = electronic medical record, ECMO = extracorporeal membranous oxygenation.

TABLE 1. Multidisciplinary Code Team Members and Components of Composite Resuscitation Training

Multidisciplinary code team members
Physicians: cardiovascular intensive/PICU attendings, critical care fellows, cardiology fellows, general pediatrics hospitalists, pediatrics residents
Staff nurses: ICUs, acute care, transport
Respiratory care providers
Ancillary staff: pharmacists, nursing supervisors, social workers, security officers
Components of composite resuscitation training
American Heart Association Pediatric Advanced Life Support Course Completion[a]
American Heart Association Basic Life Support Course Completion
Familiarization with institution-specific code roles
Familiarization and use of intraosseous drill[b]
Familiarization of location and contents of weight-based pediatric code cart[c]
Practice and education of new cardiopulmonary resuscitation record and debriefing tool[c]
In situ mock code

[a]Not completed by social workers and security officers.
[b]Not completed by respiratory care therapists, social workers, pharmacists, or security officers.
[d]Not completed by social workers, security officers, or pharmacists.

to adult obstetric inpatient codes. A neonatal team responds to codes for neonatal resuscitation in labor and delivery and inpatient neonates and infants in the NICU, well baby nursery, and intermediate care nursery. CPA events were excluded from analysis if the pediatric code team was not the specialty team to respond, if the cardiopulmonary resuscitation (CPR) record was not found in the electronic medical record (EMR), and/or if patient was receiving extracorporeal membranous oxygenation (ECMO) at initiation of the code (**Fig. 1**).

Events were evaluated for code team performance through review of the CPR record using select AHA resuscitation guideline recommendations. We defined a measure of code team adherence, the Standard Operating Performance (SOP) variable, to evaluate whether these guideline recommendations were met, when clinically indicated. Between January and July 2010, pediatric code team responders hospital wide were introduced to the Composite Resuscitation Team Training, which consisted of 1) mandatory viewing of an institution-specific code role video; 2) AHA Pediatric Advanced Life Support (PALS) and Basic Life Support course completion; 3) familiarization with a weight-based pediatric code cart through an online module and hands-on drills; 4) emergency equipment competency for the defibrillator and intraosseaous drill; 5) documentation training on a revised CPR record and a new Quality Management

TABLE 2. Pediatric Code Team Training Before and After Composite Resuscitation Training

Type of Training	Preintervention Period[a]	Intervention Period[b]
American Heart Association Basic Life Support for Healthcare Providers every 2 yr	Nurses and respiratory care therapists	Nurses, respiratory care therapists, pharmacists, security
American Heart Association Pediatric Advanced Life Support certification every 2 yr	Required: ICU and acute care nurses, respiratory care therapists, pediatric interns	Same as preintervention plus pediatrics residents, hospitalists, PICU fellows and attendings, in-house pharmacists
Awareness of institution-specific code roles and responsibilities	None	All members of pediatric code team
Familiarization with and training on emergency equipment (defibrillator, intraosseous insertion, code cart)	None	All members of pediatric code team
Laboratory-based code blue simulation	Pediatrics residents	Acute care and ICU nurses
In situ hifidelity videotaped code blue simulation	None	Every month plus a brief pilot period

[a]Preintervention is between January 1, 2006, and December 31, 2010.
[b]Intervention is between July 1, 2010, and June 30, 2011.

Debriefing tool, used to facilitate immediate postevent performance and process improvement; and 6) in situ code blue simulations with a high-fidelity manikin. Multidisciplinary code team members (**Table 1**) were trained according to their specific roles and responsibilities. **Table 2** compares the training code team members received in the preintervention period with the Composite Resuscitation Team Training received in the intervention period. During the intervention period, 90% of core code team members (PICU attendings and fellows, PICU charge nurses, respiratory therapists, pharmacists, and social workers) participated in an in situ simulation.

Training and implementation occurred over a 6-month period (January 1, 2010–June 30, 2010), including monthly videotaped in situ simulations with comprehensive debriefings. Subsequently, Composite Resuscitation Team Training was sustained via ongoing reinforcement of all components and videotaped in situ simulations and debriefings ($n = 10$) throughout the intervention period.

The simulations were announced as a code blue according to standard hospital protocol, without prior notification to the responding pediatric code team that the code blue calls were simulations. First responders and pediatric code team members were instructed to perform according to their roles and responsibilities in an actual CPA event. Code team members in actual code blue events were not videotaped, but data were extracted post events as a quality improvement initiative.

The in situ code blue simulations were conducted between 10 AM and 4 PM on weekdays in areas of the hospital in which the pediatric code team responds, including acute care units, cardiac ICU, PICU, radiology/MRI, and the hospital lobby. Code team composition and specific code roles and responsibilities do not change regardless of the hour or day of the week. The location and focus of the simulations were chosen based on operator and system errors found through review of actual CPA events. Facilitators (L.J.K., J.M.G., D.F.) guided the scenarios, which concentrated on learning objectives involving cognitive, technical, and behavioral skills. Each simulation was videotaped, and the patient's condition improved or deteriorated depending on whether appropriate interventions were performed. A comprehensive debriefing took place after each simulation, focusing on points consistent with mock code learning objectives.

The primary outcome measure was post-CPA survival to discharge. Secondary outcome measures were 1) change in neurologic morbidity from admission to discharge, as assessed by Pediatric Cerebral Performance Category (PCPC), a measure of neurological function for patients less than 18 years (2, 24, 25) and 2) improvement in pediatric code team performance, as assessed by adherence to the SOP in actual CPA events. The SOP variable addressed whether the code team adhered to select 2005 AHA resuscitation guideline recommendations: 1) 2 minutes continuous chest compressions with minimal interruptions, 2) less than 1 minute from heart rate less than 60 to chest compressions, and 3) less than 3 minutes from recognition of ventricular tachycardia/pulseless ventricular fibrillation to shock. As a measure of adherence to institutionally defined code roles, the CPR record and Quality Management Debriefing tool were examined in each CPA event in the intervention period to determine whether a team leader was clearly identified.

The above outcomes for each CPA event were compared between the preintervention and intervention periods. CPR records were reviewed by five authors to determine outcome variable results. Each data point was determined by two authors. If there was a discrepancy between the two reviewers' decisions, a third and fourth author decided upon the final result.

Survival to discharge data were determined by EMR review; 1 was recorded if survival occurred and 2 if the patient died prior to discharge. PCPC data were determined by EMR review for the admission score provided in the chart; discharge PCPC was determined by authors' assessment of neurologic status as per the discharge summary. Patients received no PCPC score if they did not survive to discharge. The change in PCPC score for each patient was determined by the subtraction of the admission score from the discharge score for that patient. Data for code team performance variables were obtained by review of the CPR record in the EMR. Scoring of code team performance variables was performed as follows: the percentage that an intervention was performed when indicated (1–100%) was recorded; a 2 was recorded if an intervention was never performed when indicated or if it was unclear whether the intervention was performed.

The quality of CPR record documentation was compared between the intervention and control groups. Ten CPR records from each group were chosen by computerized randomization. One author (L.J.K.) was blinded to identifying patient information and the year of the event for each CPR record. The author then scored the CPR record with an institution-specific code documentation grading tool, with possible scores of 0–10, with a higher score representing higher quality documentation.

Demographic data, including age and ethnicity, were compared for significant differences in the control and interventions groups. Ethnicity was self-reported by the patient and/or family at admission. To determine if significant differences in illness existed, the control and intervention groups were compared for admission diagnosis category and case-mix index (CMI) score, based on the U.S. Centers for Medicare and Medicaid Services cost weights. Admission PCPC scores were used to assess differences in baseline neurologic morbidity, and these scores were standardly collected per protocol. The two groups were also compared for location of code event (ICU vs out of the ICU) and whether the patient received ECMO immediately following the event.

Imbalances in variables between the preintervention and intervention groups were evaluated using Fisher exact test for categorical variables and unpaired *t* tests for continuous variables. To identify covariates potentially confounding the association between the intervention and selected outcomes, we selected clinically relevant variables including age at admission, sex, ethnicity, location of code event, admission diagnosis category, admission PCPC, and the use of ECMO. All variables that had a *p* value cutoff point of 0.25 using the Wald test from logistic regression were eligible for the multivariable analyses

(26, 27). Using stepwise model building techniques, we built a final multivariable model estimating the effect of the intervention on the mortality and SOP adherence. Where applicable, we present both unadjusted crude odds ratios (cOR) and adjusted odds ratios (OR). For variables extracted from CPR records, the reviewer interrater reliability was calculated via Cohen's κ statistic. All analyses were performed in R Project for Statistical Computing (R Development Core Team, Vienna, Austria) (28).

RESULTS

Included in the analysis were 183 CPA events in 124 patients from the 4-year control period and 64 CPA events in 46 patients in the 1-year intervention period. Excluded events are described in (**Fig. 1**). In the intervention period, 51% of codes occurred during 10 AM–4 PM and 78% of events occurred on weekdays. There were no significant differences between the preintervention and intervention groups based on age, ethnicity, sex, or location of code event (**Table 3**). Statistically significant differences were notable for the intervention group having more neurologic morbidity at admission compared with the preintervention group (mean PCPC of 2.9 vs 2.1, $p < 0.0001$), more admissions for a cardiac diagnosis (67% vs 48%, $p = 0.017$), and more use of ECMO immediately following a CPA event (20% vs 6%, $p = 0.0025$). There was a nonstatistically significant increase in severity of illness, represented by mean CMI score (9.9 vs 7.7, $p = 0.085$), in the intervention group compared with the preintervention group. A total of 60.9% of patients ($n = 28$) in the intervention group survived to discharge following a CPA event, whereas 40.3% of patients ($n = 50$) in the preintervention group survived until discharge (cOR, 2.3 [95% CI, 1.15–4.60]) (**Table 4**). This calculation was based on the first CPA event for each patient.

TABLE 3. Demographic Characteristics of Preintervention and Intervention Groups[a]

Characteristic	Preintervention Group ($n = 124$ Patients; 183 Cardiopulmonary Arrest Events)	Intervention Group ($n = 46$ Patients; 65 Cardiopulmonary Arrest Events)	*p*
Age (yr), ± SD			
Median (interquartile range)[b]	0.67 (0.12–4.00)	0.96 (0.25–3.75)	0.46
Ethnicity (%)[c]			
Hispanic	38 (31)	20 (43)	0.15
Non-Hispanic	86 (69)	26 (57)	
Gender (%)			
Male	68 (55)	25 (54)	1.00
Location of code event (%)[c]			
ICU	167 (91.3)	60 (92.3)	0.57
Out of ICU	16 (8.7)	5 (7.7)	
Admission diagnosis category (%)[c]			
Respiratory	23 (18)	8 (17)	1.00
Cardiac	61 (47.5)	32 (67)	0.017
Infectious	6 (4.5)	1 (2)	0.676
Gastrointestinal	15 (12)	2 (4)	0.246
Oncologic	2 (1.5)	1 (2)	1.00
Neurologic	3 (2.5)	1 (2)	1.00
Other	18 (14)	3 (6)	0.198
Mean admission Pediatric Cerebral Performance Category[b]	2.1	2.9	< 0.0001
Mean admission case-mix index score[b]	7.7	9.9	0.0854
Extracorporeal membranous oxygenation following cardiopulmonary arrest event (%)[c]	11 (6.0)	13 (20)	0.0025

[a]Preintervention is between January 1, 2006, and December 31, 2010. Intervention is between July 1, 2010, and June 30, 2011.
[b]Unpaired *t* tests were used for age, admission Pediatric Cerebral Performance Category score, and case-mix index score.
[c]Fisher exact test was used for ethnicity, admission diagnosis category, location of code event, and extracorporeal membranous oxygenation.

TABLE 4. Outcomes in Preintervention and Intervention Periods

Outcome	Preintervention	Intervention	OR (CI)
Survival to discharge following cardiopulmonary arrest event[a]	50/124 (40.3%)	28/46 (60.9%)	cOR = 2.30 (95% CI, 1.15–4.60)
Mean increase in Pediatric Cerebral Performance Category score (from admission to discharge)	0.27	0.11	$p = 0.37$
Adherence to resuscitation Standard Operating Performance[b]	38/183 (20.8%)	23/64 (35.9%)	cOR = 2.14 (95% CI, 1.15–3.99)
Performance of chest compressions < 60 s from heart rate < 60	124/145 (85.5%)	48/61 (78.7%)	cOR = 0.63 (95% CI, 0.29–1.35)
Performance of 2 min continuous chest compressions between rhythm checks	34/166 (20.5%)	23/63 (36.5%)	cOR = 2.23 (95% CI, 1.18–4.22)
Performance of shock < 3 min from recognized ventricular fibrillation/pulseless ventricular tachycardia	13/27 (48.1%)	7/12 (58.3%)	cOR = 1.51 (95% CI, 0.38–5.96)

OR = odds ratio, cOR = crude odds ratios.

Preintervention is between January 1, 2006, and December 31, 2009. Intervention is between July 1, 2010, and June 30, 2011.

[a]Included in analysis was the first cardiopulmonary arrest (CPA) event only for each patient.

[b]Included in analysis was each CPA event for each patient. Adherence was present if all interventions (chest compressions within 1 min of heart rate < 60, defibrillation within 3 min of initial ventricular fibrillation/pulseless ventricular tachycardia, and 2 min continuous chest compressions) were performed when clinically indicated.

In the multivariable analyses estimating the effect of the intervention on survival after adjusting for SOP adherence, the odds of survival in the intervention group remained significantly increased compared with the preintervention group (OR, 2.13 [95% CI, 1.06–4.36]). After adjusting for cardiac diagnosis, the odds of survival in the intervention group remained significantly increased compared with the preintervention group (OR, 2.06 [95% CI, 1.02–4.25]). The Bonferroni *p* value for Studentized residuals in the multivariable analysis exceeded 1.

Because of the potential for effect modification, we stratified by SOP adherence. The odds of survival between the two groups was improved when the team adhered to SOP (cOR, 5.50 [95% CI, 1.00–30.29]), compared with when not adherent to the SOP (cOR, 1.66 [95% CI, 0.74–3.69]). The pediatric code team was more likely in the intervention ($n = 23$; 35.9%) period than preintervention ($n = 38$; 20.8%) to adhere to the SOP (cOR, 2.14 [95% CI, 1.15–3.99]) (Table 4). We also stratified by cardiac diagnosis for similar effect modification comparing the preintervention group with the intervention group. Survival was higher when the admitting diagnosis was not cardiac related (uOR, 4.90 [95% CI, 1.53–15.62]) than when the admitting diagnosis was cardiac related (uOR, 1.19 [95% CI, 0.49–2.90]).

Within the intervention group, the odds of survival were not statistically different between ICU and non-ICU events (cOR, 0.30 [95% CI, 0.02–3.53]). The intervention group had less, but not to a significant degree, accrual of neurologic morbidity (mean change, 0.11 vs 0.27; $p = 0.37$). When team performance variables were examined individually, performance of 2 minutes continuous chest compressions showed improvement (Table 4).

In the multivariable analyses estimating the effect of the intervention on adherence to SOP after adjusting for baseline differences in admission PCPC, the odds of SOP adherence in the intervention group remained significantly increased compared with the preintervention group (OR, 2.23 [95% CI, 1.08–4.67]). All other covariates, including ECMO use, considered in multivariable analyses were not included in the final model due to a loss of statistical significance. In the intervention group, seven of 13 patients (53.8%) receiving ECMO after a CPA event survived to discharge, whereas this was the case for only three of 11 patients (27.3%) in the control group. The difference between the two groups in survival to discharge among ECMO patients is not significant ($p = 0.237$).

In subgroup analysis of only CPA events in which there was adherence to the SOP, survival improved in the intervention compared with the preintervention group (cOR, 5.50 [95% CI, 1.00–30.29]). Within the intervention group alone, survival was significantly higher when the team adhered to the SOP (cOR, 6.00 [95% CI, 1.15–31.23]) compared with when the team did not adhere. Analysis comparing when a team leader was clearly identified versus not, in the intervention period, showed the odds of SOP adherence was higher (cOR, 6.81 [95% CI, 0.78–59.09]) but not significant. Data were not available for the preintervention period detailing during which CPA events a team leader was clearly identified.

In the analysis of agreement between reviewers' data extraction from the CPR record for each of the three variables of interest for SOP adherence, there was 90.6% agreement (κ 0.90 [95% CI, 0.88–0.92]) among all data points. The quality of CPR record documentation, as determined by the difference in means, was not significantly different between the groups (mean difference = –1.3 [95% CI, –2.77 to 0.17]). The mean score for the quality of the preintervention code records was 4.4 (SD = 1.96), while the postintervention mean was 5.7 (SD = 1.34).

DISCUSSION

This study demonstrated that the Composite Resuscitation Team Training may be associated with increased survival to discharge, as well as improved pediatric code team performance. Although in situ simulation was only one part of the composite training, this to our knowledge, it is only the third published study to show a positive association between resuscitation simulation and improved patient outcomes (9, 22). This study's findings that code team adherence to AHA recommendation guidelines improved, and that survival remained improved after adjustment for adherence to the SOP, suggest that the intervention's association with improved survival may be contributory rather than temporal alone. The analyses for effect modification of SOP adherence on survival show improved survival when adherent to AHA standards compared with when not adherent, however not significantly so. This leads us to suggest that it is composite training in total, not individual elements of training that affect team performance and survival. These data support the findings by Andreatta et al (9) and Theilen et al (22) that code blue simulation can be associated with increased pediatric survival. These results also support a growing body of literature showing simulation team training associated with improved code team performance (10, 13, 15, 19, 20).

Improvement in survival to discharge cannot be explained by differing characteristics between the two study groups. The most notable differences between the two groups were worse neurologic morbidity at admission, more admissions for a cardiac diagnosis, and more patients receiving ECMO following a CPA event (Table 3) in the intervention group. There was also a trend in the intervention group toward higher acuity by CMI score. Although rapid deployment of ECMO has been shown to increase survival to discharge in cases of ongoing refractory CPR (29), we are uncertain if the increased number of ECMO cases in the intervention period indicates more use of rapid deployment or whether it reflects the institution's expansion of the cardiovascular ICU and heart failure program during the same period. Importantly, ECMO use was considered in multivariable analyses and was ultimately not included in the final analysis model due to a loss of statistical significance. Given that survival outcomes for cardiac arrest (out of hospital) due to a cardiac cause are worse than survival outcomes due to a noncardiac cause (30), the increased survival in the intervention period despite a higher percentage of patients admitted for a primary cardiac diagnosis is noteworthy. Analyses in our study population support this as well. Stratifying for cardiac diagnosis in the multivariable analysis showed a lower likelihood of survival in cardiac patients. The intervention group's improved survival despite a borderline increase in CMI, and potentially less physiologic reserve to sustain a CPA event, further supports other factors impacting survival.

A limitation of the multivariable analysis model may be that all events in all patients were included in the model, and since some patients had repeated events, this could be a confounder. It might be argued that if a single code team resuscitated the same patient more than once, performance could be incrementally improved. However, a residual analysis for repeated events indicated no unusually large residuals, suggesting that this approach to analyzing repeated events was valid.

The discrepancy in group size between the intervention and control groups may be a limitation to the study. This was a resource- and time-limited intervention. However, when looking at yearly averages, the mean number of CPA events per year in the 4-year control period is approximately 46. There are 64 CPA events in the intervention group. The increased number of CPA events in the intervention group may be attributable to the statistically significant increase in patients admitted for a cardiac diagnosis, ICU expansion, and the trend toward overall greater morbidity (by CMI), as evidenced in Table 3. RRT utilization was well-established in the preintervention and intervention periods and not felt to contribute significantly to the outcomes of this study.

Furthermore, the success of our RRTs and the subsequent low prevalence of our out-of-ICU code events may limit the generalizability of our results. For this reason, a multiinstitutional study to assess the implementation of the Composite Resuscitation Team Training among similar pediatric institutions to assess survival outcomes among a larger population would be essential. The favorable 1-year results of the intervention open the door for future articles addressing the sustainability of improved outcomes and team performance.

This study differs from other studies examining resuscitation training programs in its interprofessional design of the training. Since the pivotal publication of the Institute of Medicine's "To Err is Human: Building a safer healthcare system" report, hospitals have made strides to incorporate team training in emergency drills, using in situ or simulated environments (31). Most published studies regarding code blue preparedness training have included primarily residents and nurses (10, 13–15). However, the literature is sparse regarding ongoing code blue preparedness education that includes all code team members, from hospital security officers to team leader. This interprofessional Composite Resuscitation Team Training was created with the recognition that all code blue participants have significant roles and responsibilities that contribute to team dynamics and patient outcomes and provides the opportunity to examine the code blue experience from all perspectives within the pediatric code team. The all-inclusive approach also allowed for identification of educational gaps and provided the opportunity to improve communication, as well as the technical and cognitive skills, critical for optimal code team performance, and patient outcomes.

The simulation component, specifically the in situ approach, may have contributed to the association with improved survival. We observed what several studies in various medical disciplines have shown: in situ drills can help identify and correct potential safety concerns (latent errors) without exposing patients to the risks associated with these concerns (32–34).

While neither potential safety issues identified through the in situ simulations nor how these concerns were addressed were principal outcome measures of this study, **Table 5** shows a sample of the latent errors that were identified through this

TABLE 5. Latent Errors Discovered Through In Situ Code Blue Simulations

Staff uncertain of function of postanesthesia care unit code blue alarm
Operator uncertain of which algorithm to follow when code blue called
Security, admissions staff uncertain of first-responder tasks and appropriate team to call
Multiple medical teams respond, leaving uncertainty of who is team leader
Staff emergency access denied to secure areas
Staff uncertain of how to conduct postevent debriefings
Pharmacy without space to draw up medications
Staff with misperceptions regarding when to employ code blue vs Rapid Response Team
Staff unable to locate resuscitation equipment in code cart

study's in situ simulations. These latent errors may not have been exposed in a simulation laboratory.

Although not all CPA events occurred during the same time of day as in situ simulation drills, core code team members (ICU physicians and nurses) who participated in simulation training during the intervention period typically work both days and nights. Not all acute care nurses participated due to temporal constraints, but all first responders underwent the other components of training (Table 1). In addition, previous evidence suggests that the frequency of the 16 in situ simulations, approximately one every 3 weeks, would have been sufficient to contribute to the improved resuscitation performance seen in our study (35, 36).

Additional study limitations are similar to those of other prospective observational studies with historical controls and of studies attempting to evaluate code team performance based on review of the CPR record. It is possible other interventions implemented within the hospital at the same time as this study might have increased survival to discharge following CPA events. We are not aware of any such interventions. Also limiting the study's generalizability is the complexity of the Composite Resuscitation Team Training, in that it is not a single intervention but multiple simultaneous changes to an institution's approach to resuscitation training. The composite model may make it difficult to implement with limited resources and leaves in question whether the intervention is effective only when implemented as a whole or whether only certain components are necessary to achieve significant results. A single component of the intervention, such as a larger percentage of the code team undergoing PALS training, may have contributed more significantly than other components, to improved performance and survival. For example, one might argue that the interventions group's increase in PALS training alone produced the improved outcomes. However, given that much of the country's pediatric code team training consists of PALS training primarily, but the national survival rate for in-hospital pediatric CPA is 22–37% which is less than our result of 60.9%, (Table 3), we do not think increased PALS training alone likely produced our improved results (4–6, 21, 37–40).

Finally, our data showing significant improvement in pediatric code team performance are dependent on the accuracy of the CPR record. Nationally, quality of documentation during CPA events has been recognized as suboptimal (41, 42). Although the accuracy of this type of chart review has its limitations, it remains a standard method to code team performance evaluation. Importantly, we found no difference between the two study groups in the quality of CPR record documentation.

CONCLUSION

Implementation of Composite Resuscitation Team Training, which includes in situ code blue simulation, in our freestanding, quaternary care academic children's hospital, was associated with statistically significant improvement in survival to discharge. The increased survival to discharge does not appear to be explained by differences in patient characteristics or severity of illness in the preintervention and intervention populations. Furthermore, this increased survival to discharge was associated with no increased accrual of neurologic morbidity, occurred despite a general trend toward higher acuity, and was significant even after adjustment for SOP adherence. Code team adherence to AHA resuscitation guideline recommendations also improved. The result of improved patient survival associated with the use of Composite Resuscitation Team Training suggests for the model to be considered when creating a resuscitation training program. Future research should focus on replicating these findings in adult and pediatric inpatient settings, conducting a randomized control trial to determine causality, evaluating the cost-effectiveness of the intervention, and developing efficient methods of sustaining in situ code blue simulation.

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