ORIGINAL RESEARCH

Improved Cardiopulmonary Resuscitation Performance With CODE ACES^2: A Resuscitation Quality Bundle

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***Background*—**Over 6000 children have an in-hospital cardiac arrest in the United States annually. Most will not survive to discharge, with significant variability in survival across hospitals suggesting improvement in resuscitation performance can save lives.

***Methods and Results*—**A prospective observational study of quality of chest compressions (CC) during pediatric in-hospital cardiac arrest associated with development and implementation of a resuscitation quality bundle. Objectives were to: 1) implement a debriefing program, 2) identify impediments to delivering high quality CC, 3) develop a resuscitation quality bundle, and 4) measure the impact of the resuscitation quality bundle on compliance with American Heart Association (AHA) Pediatric Advanced Life Support CC guidelines over time. Logistic regression was used to assess the relationship between compliance and year of event, adjusting for age and weight. Over 3 years, 317 consecutive cardiac arrests were debriefed, 38% (119/317) had CC data captured via defibrillator-based accelerometer pads, data capture increasing over time: (2013:13% [12/92] versus 2014:43% [44/102] versus 2015:51% [63/123], $P<0.001$). There were 2135 1-minute cardiopulmonary resuscitation (CPR) epoch data available for analysis, (2013:152 versus 2014:922 versus 2015:1061, $P<0.001$). Performance mitigating themes were identified and evolved into the resuscitation quality bundle entitled CPR Coaching, Objective-Data Evaluation, Action-linked-phrases, Choreography, Ergonomics, Structured debriefing and Simulation (CODE ACES^2). The adjusted marginal probability of a CC epoch meeting the criteria for excellent CPR (compliant for rate, depth, and chest compression fraction) in 2015, after CPR Coaching, Objective-Data Evaluation, Action-linked-phrases, Choreography, Ergonomics, Structured debriefing and Simulation was developed and implemented, was 44.3% (35.3–53.3) versus 19.9%(6.9–32.9) in 2013; (odds ratio 3.2 [95% confidence interval:1.3–8.1], $P=0.01$).

***Conclusions*—**CODE ACES^2 was associated with progressively increased compliance with AHA CPR guidelines during in-hospital cardiac arrest. **(*J Am Heart Assoc.* 2018;7:e009860. DOI: 10.1161/JAHA.118.009860)**

Key Words: cardiopulmonary arrest • cardiopulmonary resuscitation (CPR) • emergency cardiac care • pediatrics • quality and outcomes • quality improvement • sudden cardiac death

More than 6000 pediatric in-hospital cardiac arrests (IHCA) occur in the United States annually.[1] Although published survival to discharge rates following pediatric IHCA have recently increased to 43% to 47% in some centers, most children experiencing IHCA will not survive.[2,3] There is significant variability in survival from pediatric IHCA across

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Accompanying Data S1, Tables S1, S2 and Figure S1 are available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.118.009860

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Clinical Perspective

What Is New?

- On January of 2013, we started a weekly cardiac arrest debriefing program and over the next 36 months we debriefed 317 consecutive events, from which 105 had cardiopulmonary resuscitation (CPR) metrics captured with 2135 60-second epochs of data available for analysis.
- What was unique was that high and low performance examples were rigorously explored to identify mediating themes; lessons learned iteratively evolved into the Resuscitation Quality Bundle entitled CPR Coaching, Objective-Data Evaluation, Action-linked-phrases, Choreography, Ergonomics, Structured debriefing and Simulation (CODE ACES[2]).
- Implementation of the debriefing program and CODE ACES[2] was associated with a 3-fold increase in compliance with the American Heart Association Guidelines for CPR over the 3-year period.

What Are the Clinical Implications?

- The CODE ACES[2] framework can be used to debrief and investigate recurrent patterns that can lead to system change.
- Strategies to optimize resuscitation team performance include assessment of room ergonomics, using action-linked-phrases to minimize delays to time-sensitive actions and developing standard institutional choreography for common events.
- Finally, we introduce the "CPR coach," a team member who coaches compressors to achieve high quality CPR, cognitively unloading the leader so they can focus on advanced life support and reversing the underlying cause of the arrest.

hospitals, suggesting the opportunity to improve survival rates by implementing strategies that decrease errors and optimize resuscitation performance.[4,5]

Promising research suggests post-resuscitation debriefings are associated with subsequent improved resuscitation performance and perhaps even acute survival and neurologic outcomes.[6–10] Dine reported a synergistic effect on chest compression (CC) performance between debriefing and audiovisual cardiopulmonary resuscitation (CPR) feedback devices.[7] We have not identified any reports detailing specific approaches to debriefing targeted at enabling identification of challenges to resuscitation performance and solutions. Important steps for continuous quality improvement in resuscitation include identification of high and low IHCA skill performance, use of debriefings to identify performance mediating factors, and development, testing, and dissemination of identified solutions.

Our objectives were to: (1) implement a weekly cardiac arrest debriefing program; (2) identify recurring impediments to high quality CC in debriefings; (3) develop strategies to address impediments and iteratively create a "Resuscitation Quality Bundle" (RQB); and (4) measure the impact of the RQB on resuscitation performance as measured by compliance to American Heart Association (AHA) Pediatric Advanced Life Support (PALS) Guidelines over the study period.

Methods

Study Design, Population, and Unit of Analysis

This was a prospective observational single-site study of the quality of CC delivered to children during a 3-year period simultaneous with development and implementation of a RQB. The patient study population included any child who received CC at the Johns Hopkins Children's Center, a university-based children's hospital. The units of analysis included 60-second epochs of CC data recorded between January 1, 2013 and December 31, 2015. The study was focused on the quality of CC performance and not on survival. Resuscitation events were eligible if the patient was aged ≤21 years and if a complete defibrillator data file was successfully retrieved after the event. The Johns Hopkins Hospital Institutional Review Board approved use of these data as a Quality Improvement (QI) program. This was not deemed human subjects research, as such there was no requirement for consent to be obtained.

Phases of Resuscitation Quality Bundle Creation and Implementation

Creation and implementation of the RQB occurred in 5 phases: design of surveillance program, data capture, debriefing program, creation of RQB, and program analysis.

Phase 1—Surveillance program

We used an informatics-based, active surveillance program, (ie, the "Resuscitation Event Analysis Clearinghouse (REACH) Surveillance System"), to identify all cardiac arrest events; this system has been described in detail elsewhere.[11] Briefly, this program uses organizational Information Technology (IT) system signals to identify any "potential IHCA," (ie, code button activation, rapid response team pages, electronic medical record, IHCA flow sheets, CPR billing codes) and catalogs based on event details, such as date, time and location, for future analysis.

Phase 2—Data capture

Team members investigate cataloged signals to verify actual IHCA events associated with provision of CC and/or defibrillation. Once an IHCA was identified all available objective

data were collected, including demographic and resuscitation performance data required as part of participation with the AHA Get With The Guidelines-Resuscitation database as well as data from the electronic medical record, the defibrillator record of CC captured with an accelerometer embedded in the defibrillator pads via the Zoll R series (Chelmsford, MA) and bedside monitor vital sign numeric values and waveform data.

Before implementation of this QI program, although the defibrillators could give real-time CC feedback and capture data for post-event review, clinicians placed defibrillator pads on a patient only if the patient had a shockable rhythm. In May of 2013, the Federal Drug Administration approved use of pediatric defibrillator pads to capture and report CC data in children aged <8 years, clearing the way for incorporating the use of the defibrillator in every pediatric IHCA. A key goal of this program was to ensure that the defibrillator be turned on and pads applied within 120 seconds for every pediatric IHCA.

Defibrillator data were reviewed using the manufacturer metrics. Objective CPR performance data were assessed for compliance with the 2010 AHA pediatric Basic Life Support (PBLS) and PALS Guidelines for CC depth and rate and the 2013 AHA consensus recommendation for chest compression fraction (CCF).[12,13] Event data were abstracted and entered into the REACH surveillance database as part of the QI program. CC data were then processed using software developed by the QI team to quantify additional aspects of performance not available in the commercially available manufacturer software. These standardized objective data were transformed into our resuscitation performance debriefing tool and used during debriefings described in Phase 3 (Figure 1).

Clinical volunteers from each discipline used peer-to-peer subjective data collection tools to capture the experience of those who participated in the resuscitation, ie, pharmacist to pharmacist, respiratory therapist to respiratory therapist, nurse to nurse, etc. The forms asked domain specific team elements (ex. Who was the Charge Nurse? Who was the Medication Nurse?), as well as open ended questions related to perceived performance, including anything the rescuer wanted discussed at the debriefing. (Please see Table S1 for example of Pharmacy form.)

Phase 3—Debriefing

We began weekly IHCA debriefings on January 1, 2013. Every Wednesday morning, a 90-minute meeting occurred, locally named "Code Busters." Through trial and error, the catchment period for IHCAs to be discussed at a Wednesday debriefing ended at midnight on the preceding Sunday and included any event in the preceding Sunday to Sunday 7-day period. This provided sufficient time to collect and analyze data as well as to allow attendees to plan to attend the debriefing. The CPR project coordinator sent electronic invitations (including calendar meeting requests) to all clinicians present for IHCA event from all disciplines. For example, if an IHCA occurred in the cardiac catheterization suite and included extracorporeal cardiopulmonary resuscitation (ECPR), the debriefing included representatives from cardiology, cardiac anesthesia, cardiac surgery, catheter laboratory nursing personnel, perfusionists, and any intensive care unit responders. Debriefings started with a statement to create a psychologically safe environment followed by a facilitator exploring the team's memories of their performance and challenges they experienced.[14] At the beginning of our program, little objective data were available, so most debriefings were based on discussion of the subjective experiences of those involved. As our data collection became more robust, review of objective data became the bedrock of the program.

Phase 4—Resuscitation quality bundle

The primary objective of the weekly IHCA debriefings was to help team members identify any errors or deviations from AHA Guidelines that occurred during the resuscitation, explore contributing factors and identify potential preventative solutions. As the program progressed, the secondary objective was to identify recurrent performance-mediating themes. These themes included errors with associated stressors, as well as exemplars of outstanding performance. Strategies were developed and refined to systematically address identified issues. This iterative approach was used to cluster solutions into themes and actionable processes comprising the RQB.

Phase 5—Program analysis

We analyzed and compared CC performance data across years to quantify changes in adherence to AHA PBLS and PALS Guidelines after exposure to the evolving QI Program and RQB.

Data Capture

Before the launch of this QI program, all defibrillators in the Johns Hopkins Children's Center were standardized to 1 model, (ZOLL R Series Plus defibrillator (ZOLL Corp. Chelmsford, MA) with One-step CPR electrodes), and deployed with identical settings configured by our clinical engineering department.

Epochs

Each ZOLL record was partitioned into epochs and analyzed for compliance with AHA PBLS and PALS Guidelines. Epochs were defined as a 60-second period of resuscitation. An event could have ≥1 associated epochs. Time-zero for event

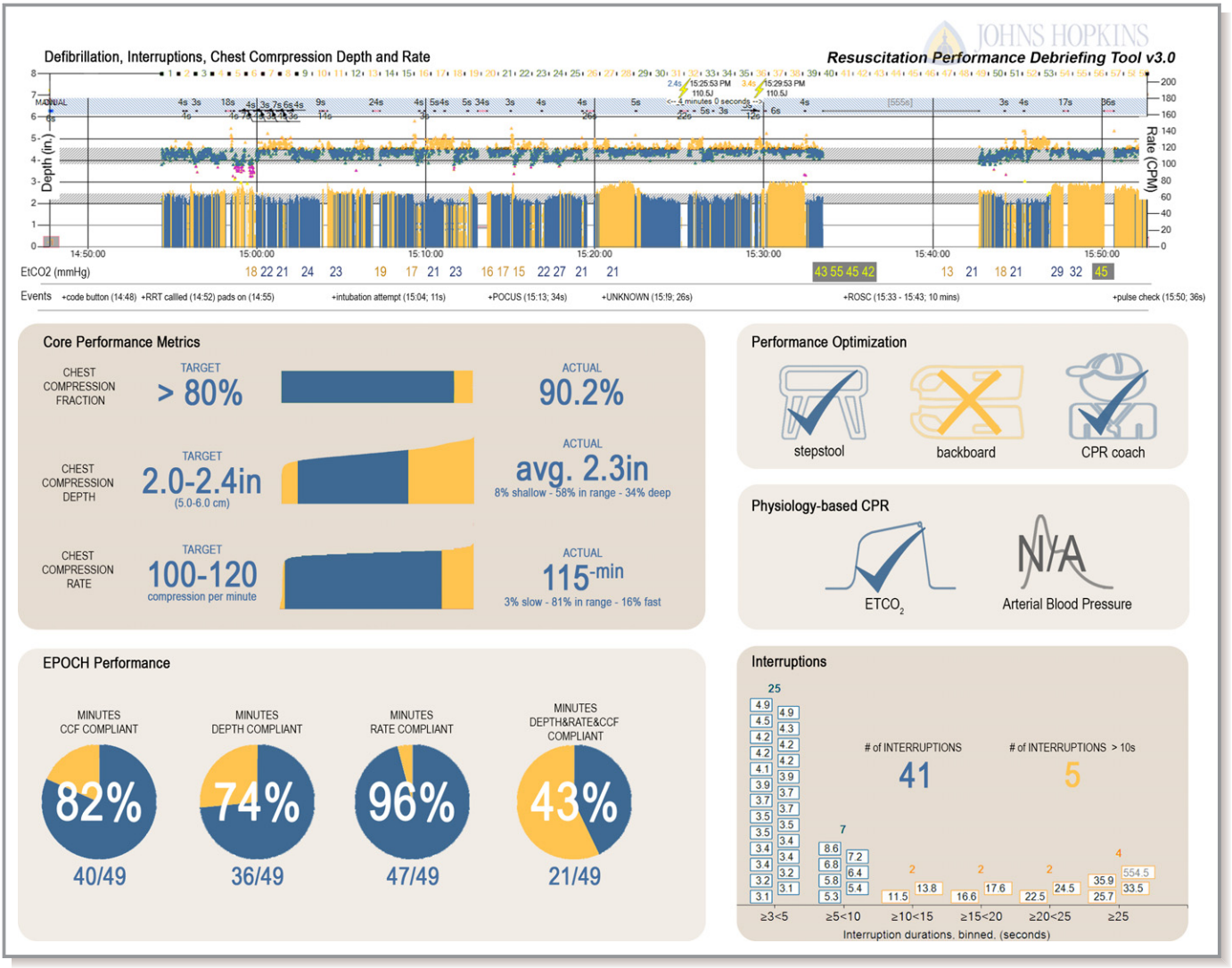

Figure 1. Johns Hopkins Resuscitation Performance Debriefing tool. Using data from the defibrillator, electronic health record, and bedside monitor, the performance debriefing tool is used to comprehensively evaluate performance. A timeline visualizes quality of the resuscitation in terms of: (1) excellent epochs of CPR; (2) depth, rate, and interruptions in chest compressions; (3) defibrillation timing and peri-shock pause durations; (4) defibrillator-based $ETCO_2$ values achieved throughout; and (5) key events (associated with chest compression interruptions). Core performance metrics are presented numerically and graphically with reference targets. Optimization methods and physiology-based CPR techniques are presented including the use of backboard, stepstool, CPR coach, $ETCO_2$ and arterial blood pressure (ie, $ETCO_2$ and/or diastolic blood pressure goals were stated and used to guide chest compression quality). Proportions of minutes compliant for depth, rate, and chest compression fraction are depicted as pie charts; interruptions are presented as a histogram. CPR indicates cardiopulmonary resuscitation; $ETCO_2$, end-tidal carbon dioxide; ROSC, Return of Spontaneous Circulation.

epochs began with the detection of the first CC after the defibrillator was turned on and electrodes were placed on the patient.

Compliance With CPR Performance Goals

Thresholds were selected defining CC rate, depth and interruption duration compliance based on AHA 2010 guidelines for pediatric patients.[12] CC rate was compliant if between 100 and 120 CC/min.[12] For patients aged <1 year CC depth was considered compliant if >3.8 cm, and >5 cm for those aged >1 year.[12] Interruptions >10 seconds were non-compliant/excessively long.[12] CCF ≥80% was compliant.[13]

Epoch-Level Variables

Performance variables recorded for each epoch included: CC rate, depth, interruptions and chest compression fraction (CCF), and a composite variable we refer to as "excellent CPR," ie, compliance with all 3 measures (rate+depth+CCF). Average CC rate and depth for the epoch determined compliance for those variables. CCF was defined as the

proportion of time CC were performed during a resuscitation (and for each epoch) relative to total time that CC were indicated (ie, because of loss of pulse or Heart Rate <60 and indicators of poor perfusion). Ongoing CC were CC without interruption. Interruptions were defined as any pause in CCs >3 seconds; these contributed to non-compression time for use in calculation of the CCF and for analysis of interruptions. The frequency of interruptions longer than 3 seconds and those longer than 10 seconds were determined.[15,16] We compared the proportion of epochs compliant with the AHA 2010 PBLS and PALS Guidelines for all CC quality metrics across the study period.[12] Our primary outcome measure was the proportion of CC epochs per year that met the criteria for "excellent CPR."

Statistical Analysis

Demographics were reported at the patient-event level. Performance data were reported at the epoch level. Both were reported in aggregate as well as stratified by year. Median values and interquartile ranges were reported for continuous variables with comparisons made using the Kruskal-Wallis non-parametric test. For categorical variables, frequencies and proportions were reported, and differences were analyzed using Fisher exact test or Chi-square statistic. To assess the percentage of epochs by year that achieved compliance by rate, depth, CCF, as well as excellent CPR, we used logistic regression adjusting for patient age and weight. Models included robust cluster variance estimators to adjust for the potential correlation of epochs within events. We report odds ratios and marginal probabilities with 95% confidence intervals. *P* values ≤0.05 were considered significant. Statistics were performed with Stata/SE 15.1 for Windows (64-bit x86-64), (StataCorp LLC, College Station, TX). To protect confidential patient information, the data, analytic methods, and study materials will not be readily available for purposes of reproducing the results or replicating the procedure. However, it may be possible to make the deidentified data set available for review with appropriate institutional review board and institutional approval.

Results

Events

Over the 3-year study period, 241 children had 317 cardiac arrest events that were debriefed. Defibrillator records that contained CPR quality data were captured in 38% (119/317) of events with an increasing proportion over time (2013:13% [12/92] versus 2014:43% [44/102] versus 2015:51% [63/123], *P*<0.001). Fourteen records contained <1 minute of quality data and were not included in the analysis. Thus, there were 93 children who had 105 events that contributed CPR quality records with ≥1 complete epochs of data. There were 2135 60-second epochs of quality data captured by the defibrillator.

Fifty-eight percent of patients were male and the weights and ages of the children with IHCA data captured varied significantly across the 3 years of the study (see Table 1); children in 2013 were older and heavier. This may be explained by the fact that the Federal Drug Administration had not approved the use of the defibrillator pads with embedded accelerometer for children aged <8 years until May 2013. The median (interquartile range) event duration was 15 (5.0, 29.0) minutes with no significant changes by year. More events took place during the 7 am to 11 pm time period (DAY:76% versus NIGHT:24%) although given the distribution of hours (7 am–11 pm: 66%; 11 pm–7 am 33%) the difference is not statistically significant (*P*=0.145). Similarly, more events occurred during the week than on the weekend (WEEK:78% versus WEEKEND: 22%; *P*=0.256). Most events (72%) occurred entirely within the hospital rather than beginning with OHCA with resuscitation continued in the hospital (28%), with no significant changes in distribution across years. More than 95% of events occurred in a "critical care area," ie, Pediatric Intensive Care Unit 54% (57/105) or Pediatric Emergency Department 39% (41/105), with 2% (2/105) of events occurring while under the supervision of an anesthesiologist (ie, Operating Room, Magnetic Resonance Imaging suite). There were 3 IHCA events that occurred on the general wards over the 3-year period, representing only 3% of events. The most frequent first documented rhythm was pulseless electrical activity 58% (61/105) followed by bradycardia with poor perfusion 20% (21/105), asystole 12% (13/105), pulseless ventricular tachycardia, or ventricular fibrillation 8% (8/105) (and one unknown), with no significant changes in the distribution over the 3-year study period.

Chest Compression and Interruption Quality

Over the 3-year study period, there was a marked increase in the proportion of epochs that were compliant with the AHA PBLS and PALS Guideline (see Table 2).[12] Our primary outcome measure is the proportion of epochs compliant with all 3 chest compression quality measures (rate+depth+CCF), ie, "excellent CPR" epochs. Adjusting for age category and weight, there was a 3.2 increase in the odds that CC epochs would meet the criteria for excellent CPR in 2015, after CPR Coaching, Objective-Data Evaluation, Action-linked-phrases, Choreography, Ergonomics, Structured debriefing and Simulation (CODE ACES^2) was developed and implemented, than in 2013: (odds ratio 3.2 [95% confidence interval (CI): 1.3–8.1], *P*=0.01). The adjusted marginal probability of excellent CPR in 2013 was 19.9% (95% CI: 6.9, 32.9) versus 41.8% (30.5, 53.0) in 2014 and 44.3% (35.2, 53.3) in 2015.

Table 1. Demographic Characteristics of Patients With Chest Compression Quality Data Captured During In-Hospital Cardiac Arrests Between 2013 and 2015

	2013	2014	2015	Total	
No. of patients	11	34	48	93	
No. of cardiac arrest events	11	40	54	105	
Age, y					
Median, IQR	8.3 (3.7–15.2)	1.4 (0.4–7.3)	1.5 (0.5–7.0)	1.8 (0.44–8.9)	*P*=0.03
Min-max	0.07 to 20.05	0.01 to 17.5	0.04 to 17.6	0.01 to 20.05	
<1 y, n (%)	1 (9%)	14 (41%)	20 (42%)	35 (38%)	*P*=0.1
≥1 y, n (%)	10 (91%)	20 (59%)	28 (58%)	58 (62%)	
Weight, kg					
Median, IQR	30.0 (13.2–40.0)	9.8 (6.4–23.6)	9.3 (6.0–18.1)	10.0 (6.3–28.0)	*P*=0.03
Min-max	3.0 to 70.0	2.9 to 93.1	3.2 to 106.0	2.9 to 106.0	
Sex					
Female n (%)	5 (45%)	17 (50%)	22 (46%)	44 (42%)	*P*=0.93
Male n (%)	6 (55%)	17 (50%)	26 (54%)	49 (58%)	
Arrest duration, min					
Median, IQR	13.0 (3.0–22.0)	19.0 (4.5–35.0)	14.5 (5.0–26.0)	15.0 (5.0–29.0)	*P*=0.47

IQR indicates interquartile range.

When evaluating individual metrics, the most substantial gains were made in compliance with the CC rate metric (100–120/min) (adjusted marginal probabilities in 2013:30.2% [95% CI: 10.8, 49.7] versus 2014:63.4% [52.8, 74.1] versus 2015:78.8% [72.4, 85.2], $P<0.001$). Compliance with CCF >80% increased, though not significantly: 2013:66.2% (95% CI: 50.8, 81.6) versus 2014:83.0 (75.2, 90.9) versus 2015:79.8 (75.4, 84.2), $P=0.13$. Depth compliance increased then declined, but these were also not significant: 2013:55.2% (95% CI: 23.7, 86.7) versus 2014:67.1% (55.6, 78.7) versus 2015:60.9% (50.3, 71.5), $P=0.65$.

When stratified by age, CCF increased significantly for children aged <1 year over the 3 years (up to 73.5%; $P<0.001$), but was never as high as that of children aged >1 year, which was high at the start (82.3%) with no significant change throughout (85.5%).[13] Notably, when stratified by age, compliance with AHA PBLS Guidelines for chest compression depth improved for children aged <1 year but for children aged >1 year showed a small decline (though not significant).[12] The debriefings identified factors contributing to this decline in compliance with CC depth (see Discussion).

Resuscitation Quality Bundle Elements

In addition to reviewing whether the CC were compliant with the AHA Guidelines, providers also identified and reviewed instances of errors or breaches in best practices per expert consensus or institutional goals[12,13] (See Table 3). Performance mediating strategies were developed based on behaviors observed to enhance high performance or to mitigate low performance. These strategies were categorized into elements of a multifactorial RQB. The 7 elements identified were: 1) CPR coach, 2) objective date evaluation, 3) action-linked phrases, 4) choreography, 5) ergonomics 6) structured debriefing, and 7) simulation. Our program is now referred to as "CODE ACES[2]."[17]

Discussion

This study describes the development of a RQB now called CODE ACES[2], associated with improved compliance with the AHA PBLS and PALS Guidelines during IHCA. The magnitude of improvement measured is notable when put in the context of resuscitation performance reported in the literature. Niles et al recently reported pediatric IHCA metrics captured by pediRES-Q, an International Resuscitation Collaborative, with data from 12 hospitals across North America and Europe (including Johns Hopkins).[18] That multicenter data set is remarkably similar in size to ours, ie, 112 events (versus our 105 events) and 2046 60-second epochs (versus our 2135 epochs). Of their data set, 384 (19%) were considered "excellent epochs," ie, meeting guidelines for CC rate, depth, and CCF, which is similar to our baseline in 2013 of 22%. This highlights the important progress we made in our single-site cohort, ie, the proportion of "excellent epochs" of CPR

Table 2. Year-to-Year Chest CC of all AHA Quality Metrics

	Total	2013	2014	2015	*P* Value
CC quality measures					
CC events (n)	105	11	40	54	
All CC epochs (n)	2135	152	922	1061	
Event average CC metrics—median, IQR					
CC Rate (per min)	114 (108–120)	114 (106–125)	116 (113–128)	110 (107–115)	<0.001*
CC depth (cm): aged ≤1 y	4.2 (3.3–4.7)	2.2 (2.2–2.2)	4.4 (2.8–4.8)	4.0 (3.6–4.7)	0.35
CC depth (cm): aged >1 y	5.4 (4.4–6.0)	5.9 (4.2–6.6)	5.4 (4.6–6.0)	5.3 (4.2–5.8)	0.43
CCF	0.93 (0.85–0.96)	0.91 (0.76–0.97)	0.94 (0.88–0.98)	0.93 (0.84–0.95)	0.19
Cumulative epoch cc metrics[†]					
Rate compliant: n (%)	1130 (69%)	30.2 (10.8, 49.7)	63.4 (52.8, 74.1)	78.8 (72.4, 85.2)	<0.001*
Depth compliant: n (%)	1349 (63%)	55.2 (23.7, 86.7)	67.1 (55.6, 78.7)	60.9 (50.3, 71.5)	0.65
CCF compliant: n (%)	1718 (81%)	66.2 (50.8, 81.6)	83.0 (75.2, 90.9)	79.8 (75.4, 84.2)	0.13
Rate+depth+CCF compliant: n (%)	884 (41%)	19.9 (6.9, 32.9)	41.8 (30.5, 53.0)	44.3 (35.3, 53.3)	0.04*

AHA indicates American Heart Association; CC, chest compression; CCF, chest compression fraction; IQR, interquartile range.
*Indicates statistical significance at $P<0.05$.
[†]Marginal probabilities with 95% confidence interval from logistic regression models adjusting for age and weight.

increased from 22% to 45% over the 3-year study period. The pediRES-Q network noted particularly low compliance with guidelines for the younger children.[18] Infants aged <1 year received "excellent epochs" of CPR only 5% of the time, compared with 46% at Johns Hopkins in 2015 after implementation of our CODE ACES[2] program.

There are 3 key findings to highlight. The first is that our data reinforce previous published reports that a post-event debriefing program, in combination with real-time defibrillator-based CC feedback during IHCA events, is associated with measurable improvements in actual resuscitation performance.[6–10] The second is that our Resuscitation Quality Improvement Program has created novel approaches to capture, analyze and visually depict IHCA CC to more fully characterize CC performance during resuscitation. The third finding is that by systematically focusing resuscitation debriefings on variables associated with high and low performance and identifying recurring themes we have developed standardized solutions to impediments and structured these solutions into a data driven resuscitation quality bundle.

CODE-ACES[2] is now an ongoing performance improvement program that focuses on techniques and strategies to improve resuscitation compliance with AHA PBLS and PALS Guidelines. Benchmarking of metrics over time and creation of an institutional shared mental model of key components of a RQB have been integral to this process. Although each of the CODE-ACES[2] elements can stand-alone, they are all synergistic and require reinforcement through training, education, and debriefing.

CPR coach

When the 2005 AHA Adult BLS and PBLS Guidelines emphasized the importance of high-quality CPR, we found that such emphasis, while warranted, can produce unintended consequences.[19] In 2007, we noted frequent delays in defibrillation and intubation as well as failure to identify and treat reversible causes. Through debriefings and observations of simulated cardiac arrests, the resuscitation leadership recognized that the code team leader cannot simultaneously focus on high quality CPR, early defibrillation, ALS algorithms *and* identification of reversible causes of arrest—≥1 of these foci is inevitably compromised. To maximize resource effectiveness through division of labor we introduced a role that was initially called the quality CPR (QCPR) leader. This person was instructed to focus on directing high quality CPR while the code team leader focused on the higher level problem-solving of managing the patient according to the appropriate PALS algorithm and diagnosing reversible causes. Ultimately, we recognized the CPR coach can cognitively unload the code team leader so that instead of spending mental energy on monitoring quality of CC, they can run through H's and T's earlier in the resuscitation. While this QCPR leader role was easily accepted and incorporated into our Pediatric Intensive Care Unit culture, it caused confusion when used during resuscitations performed outside of the Intensive Care Unit, particularly when the QCPR leader stood at the foot of the bed, in a position near the code team leader. To prevent such confusion, we needed to more clearly differentiate the QCPR and team leader roles and clarify the chain of command. We

Table 3. Types of Errors Discussed During Weekly In-Hospital Cardiac Arrest Debriefings

Type of Error	Examples
Delays in care	Delay in defibrillation (goal of ≤180 s) Delay in delivery of first dose of epinephrine for non-shockable rhythm (goal of <5 min) Delay in starting chest compressions (breeched institutional goal of starting chest compressions in ≤10 s of loss of pulse or heart rate <60 with poor perfusion)
Pauses	Prolonged pause in chest compressions for the use of point-of-care ultrasound Prolonged pause during procedures (rhythm check, defibrillation, intubation, chest tube, surgical dissection for placement of ECMO catheters, etc.) Inadequate pause when unable to move chest with BMV and unable to intubate without pausing Inadequate pause to assess initial rhythm and determine if defibrillation is indicated
Other	Defibrillating a non-shockable rhythm Use of sodium bicarbonate or calcium with no clear indication Neglect to use backboard Neglect to use stepstool Neglect to place defibrillator pads to enable real-time feedback Epinephrine given <every 3 min Epinephrine given >every 5 min
Institutionally defined error, based on new standards	No Quality CPR coach assigned Defibrillator not placed directly across from the compressor Defibrillator not placed on the same side as the patient monitor Turning patient >1 time (ie, do not coordinate placement of backboard and placement of back pad) Delay in use of end-tidal carbon dioxide (within 30 s of turning on defibrillator that has $ETCO_2$) Delay in activation of ECMO (goal of 5 min after chest compressions started, if ROSC not yet achieved) Prolonged pause in chest compression when moving patient from Emergency Medical Services gurney to Emergency Department bed

BMV indicates bag-mask ventilation; ECMO, extracorporeal membrane oxygenation; ROSC, return of spontaneous circulation.

changed the title of this role from the QCPR leader to the QCPR coach and, ultimately, to CPR coach. We made it clear that the CPR coach's function is independent from that of the code team leader and can reduce the responsibilities of the code team leader. However, the CPR coach ultimately reports to the code team leader and tries to achieve the goals delineated by the code team leader (see additional discussion below). We then attempted to identify the ideal physical position of the CPR coach, ultimately placed directly across from the chest compressor. This allowed the compressor and the CPR coach to make eye contact and ensured that the compressor and airway manager could clearly hear the CPR coach with no need for loud voices. In this position, the CPR coach can point to the CC data on the defibrillator screen, to assist in the coaching. The CPR coach focuses on coaching those resuscitation team members who are performing CC and bag-mask-ventilation to ensure they perform excellent chest compressions, appropriate (and not excessive) ventilation, and rapid defibrillation with minimal peri-shock pause. We have now incorporated this CPR coach role into our formal institutional resuscitation curricula for training pediatric residents,[20] introducing first-year medical students to in-hospital BLS[21] and for nursing annual competencies.

The CPR coach initially performed subjective assessments of chest compression quality, while providing encouragement, and switching out compressors as needed. Now, the CPR coach focuses on objective data to coach compressors, using several methods to drive performance including verbal guidance and modeling best practices as they orient rescuers to and direct optimization of displayed CC performance data. Examples of CC performance data include "external metrics," ie, CC metrics displayed by the defibrillator (CC depth and rate), and "internal metrics," ie, arterial or venous pressure measurements displayed by the bedside monitor, hand-held end-tidal carbon dioxide ($ETCO_2$) device, etc. . .). If an arterial catheter is present, the arterial diastolic pressure can assist in evaluation of effectiveness of chest compression depth. The relaxation pressure can serve as a surrogate for aortic end-diastolic pressure that helps determine coronary perfusion pressure. If a central venous or right atrial catheter is in place, the arterial relaxation pressure minus the central venous pressure provides an estimate of coronary perfusion pressure, with a goal of >20 mm Hg.[13] The end-tidal carbon dioxide ($ETCO_2$) will trend with pulmonary blood flow $ETCO_2$ as a surrogate for cardiac output and quality of chest compressions. If the $ETCO_2$ is low, the CPR coach will encourage the compressor to improve CC quality, such as depth and rate, providing data and goals to the compressor. Chest compressions are considered optimized if: 1) the teams is achieving age-appropriate diastolic blood pressure (>30 mm Hg for children, >25 for infants)[3], 2) $ETCO_2$

>20 and as close to 25 as possible,[13,] and simultaneously 3) rescuers attempt to comply with "external" parameters guidelines, ie, age appropriate CC depth and rate with no leaning—yet monitor actual rate and depth needed to achieve the internal physiologic goals.

In general, CPR coaches will attempt to guide rescuers to optimize all mechanics of resuscitation simultaneously. However, the experienced CPR coach, in conjunction with the code team leader, can select the most important monitoring variables to emphasize, tailored to the patient's age and factors such as presence of heart defects or open chest. At this point we have not incorporated elements such as cerebral near-infared spectroscopy goals into the CPR coach goals but will watch for data to support doing so at some point. We created cognitive aids listing the parameters noted above (eg, pocket cards and information placed on each defibrillator cart (Figure S1). We also created curricula training the code team leaders and the CPR coaches on these parameters, the hierarchy of these parameters and how to communicate these goals, (ie, how the team leader states the goals to the CPR coach and the CPR coach guides the compressors to achieve those goals).

From the science of teams perspective, the CPR coach performs 2 functions that may go unfulfilled when under time pressure and high stakes outcomes.[22,23] First, the role is dedicated to performance monitoring and backup or supporting behavior (ie, detecting and correcting performance issues in fellow team members).[24] Second, the role maximizes use of available resources, a key team leadership function,[25,26] in real time to support adherence to guidelines. Codifying these functions into the CPR coach role improves role clarity during a code and helps balance workload across the team by offloading responsibility from the primary team leader. Leary et al previously reported about code leader offloading, using explicitly defined "physician/nurse code leadership dyads," with physician leaders focused on medical aspects of IHCAs and nurses focused on organization of the room, reporting success in decreasing overcrowding associated with IHCA arrests.[27] Infinger et al described the role of CPR performance coaching for out-of-hospital cardiac arrests with improvement in CC depth and shortening time to defibrillation.[28] Pilot data at our institution on the CPR coach role have been encouraging and was used in designing a recently published multicenter, randomized, controlled trial of simulated cardiac arrests to analyze the impact of the CPR coach on compliance with BLS Guidelines.[29] Cheng et al demonstrated a significant improvement in compliance with excellent CPR, chest compression depth, and fraction as well as a significant decrease in pre-shock pause, post-shock pause, and peri-shock pause in simulated cardiac arrests for those with a CPR coach versus without one.[29] Next steps are to study the impact of the CPR coach on survival and optimize how the code team leader leverages the cognitive unloading provided by the CPR coach.

Objective data evaluation

Following every cardiac arrest, our CODE ACES[2] team gathers all available data from the bedside monitor, defibrillator, electronic health record, and emergency alerting systems. These data are rigorously analyzed to characterize and benchmark CPR technical performance and select the metrics to be evaluated (see Table 4 for a list of common metrics given monitor and/or defibrillator data availability). Each event is assessed for age-based compliance with AHA CC targets, process of care exceptions, defibrillation timing and appropriateness, physiologic markers of cardiac output/perfusion such as diastolic blood pressure and $ETCO_2$, and pre-arrest vital signs. All data are visually displayed and presented in a standardized format during weekly post-event debriefings. Areas of high and low guidelines compliance are discussed during the debriefing to identify event factors that hinder or enhance performance. Raw CC data from the defibrillator are transformed into the Johns Hopkins Resuscitation Performance Debriefing Tool for each event (See Figure 1), including a breakdown of compliance with AHA guidelines at the minute epoch level.

Table 4. Metrics Used to Facilitate Objective Data Evaluation

Resuscitation performance metrics
Time from pulselessness to initiation of compressions
(For ventricular fibrillation/pulseless ventricular tachycardia - Time from shockable rhythm to defibrillation/was <180 s
Frequency, duration and timing of interruptions (binned by <5, 5 to 9.9, 10 to 14.9, 15 to 19.9, ≥20 s
Overall chest compression fraction/was CCF >90%
Average CC depth/was CC depth guideline compliant for age appropriate guideline
Average CC rate/was CC rate guideline compliant
Percent compressions compliant for depth
Depth, rate, CCF, # of interruptions >10 s per each 1 min of CPR (ie, values for 60s epochs)
Number and patterns of epoch compliance for resuscitation
Ex. Percent of "excellent epochs," 60 s epochs compliant for depth, rate and CCF
$ETCO_2$ achieved throughout resuscitation, timing, and duration >20 mm Hg
Diastolic blood pressure achieved throughout resuscitation, timing, and duration
>30 mm Hg (children)
>25 mm Hg (infants)

CC indicates chest compression; CCF, chest compression fraction; $ETCO_2$, end-tidal carbon dioxide.

When our resuscitation quality program began, we used reports available from the defibrillator manufacturer after each cardiac arrest to objectively ground our weekly debriefings. While these reports were found to be an excellent starting point for the debriefing, we soon realized averaging of metrics such as CC depth, CC rate, and total CCF did not provide sufficient information about the resuscitation quality. In fact, it can result in a false sense of security. For example, if half of the CC were delivered at 80/minute and the remaining half were delivered at 140/minute, the average CC rate would fall within the 100 to 120/minute rate considered to be compliant, even though none of the CC were actually compliant for rate. To emphasize a goal of delivering CC precisely compliant with the AHA Guidelines, we needed a new approach, with a more refined method of data presentation and analysis. Histograms were developed, visually highlighting what proportion of individual CCs were compliant with AHA Guidelines for CC rate and depth, making it efficient for the facilitator to immediately highlight performance gaps. We ultimately found if we divided every resuscitation into 60-second epochs and analyzed and depicted CC quality metrics for each epoch we could more rapidly identify compliance/non-compliance patterns. It also helped us identify specific resuscitation events, such as the arrival of the CPR coach or switch compressors that influenced CC performance. This visual comparison of minute-to-minute performance during the arrest facilitated the debriefing discussion and also increased our statistical power when analyzing our institutional performance over time. This performance evaluation approach is now used during all post-resuscitation debriefings including those that take place after in-situ or our "Sim Hospital" based mock codes.

Action-linked phrases

We have previously reported the performance advantages that result when rescuers speak observations aloud, and link them directly with a resuscitation action.[17] Several key examples include: 1) "There's no pulse, I'm starting compressions"—will decrease time to starting compressions, 2) "That's ventricular fibrillation, start compressions and get a defibrillator"—will decrease time to shock, and 3) "Shock delivered, resume CPR"—will reduce duration of post-shock pause in CC.

During the weekly debriefings, the facilitator listens closely to the initial interventions as they are reported by the rescuer who discovered that the patient was pulseless. The facilitator solicits overlapping details from as many team members as possible to develop a complete and accurate report of these crucial preliminary events. For example, if a nurse says "I was suctioning and noticed his heart rate suddenly dropped from 90 to 50, so I pressed the Code Button and went to get the step stool and epinephrine," we will highlight how in the hospital many of us have paradoxically forgotten our "first responder instincts."[30] In a previous study, we observed first responders in the hospital setting had essentially lost instincts to open the airway or initiate chest compressions, but rather reported feeling a responsibility to "prepare the room" for the Code Team. In debriefings, we point out if we pulled a limp and blue child from a pool, we would never run away from that child but would immediately start chest compressions, which usually creates an "aha moment" for those being debriefed, helping them to simplify their priorities in the future.

In all of our simulation trainings and weekly IHCA debriefings, if someone notices the patient has lost a pulse or the heart rate has dropped <60, we reinforce the next action must be to start CC (unless the patient has a "Do not resuscitate" order). We review the data captured on the bedside monitor (either from electrocardiogram, pulse oximetry waveform, or central/arterial line pulsations) to determine the time elapsed between loss of pulse (or Heart Rate <60/min) and initiation of CC. We reinforce that our institutional standard that providers should begin CC within 10 seconds of pulseless arrest (or Heart Rate <60/min with signs of poor perfusion) and then discuss strategies to increase likelihood of success the next time. Training in the use of action-linked phrases is now incorporated into monthly simulation-based training for rapid response teams, and annual "First Few Minutes" training for ward nurses.

Action-linked phrases combine 2 critical behaviors of high-performance teams,[31] ie, 1) situational awareness update or "call out" with 2) task delegation. Situational awareness is defined in 3 levels: possessing timely and accurate information, correct interpretation of the information, and projecting of the current state into likely future states.[32] By linking those call outs to specific actions, the interpretation or meaning of that information is made explicit and is a red flag to speak up if a team member has a different mental model.

Choreography

This element includes intentional structured plans promoting a shared mental model on the way in which a team physically interacts with the room, the equipment, the patient and one another to reduce error and time to task completion. We observed prolonged delays in CC and even dislodgement of vascular catheters and endotracheal tubes associated with activities such as placement of defibrillator pads, switching compressors, placing a backboard and moving a patient. In addition, we also observed that team members often stopped the tasks they were performing when a teammate attempted to organize the team. We used simulation, in the laboratory and in situ, to identify the ideal choreography and CPR priorities for any given maneuver.[33] We now refer to this as a variant of our previously described teaching style "rapid cycle deliberate practice;"[20] now described as "rapid cycle

deliberate prototyping." We now train leaders to specifically direct team members to continue their current tasks while next steps are discussed or directed. For more complex actions, this can take the form of the code team leader or the CPR coach making a statement that alerts the entire team that something is about to happen. The CPR coach will state to the compressor "Continue CPR while I organize the team," followed by the detailed instruction of the upcoming action.

We created a video of our institution's "gold standard" approach and choreography of the first 3 minutes of a cardiac arrest and use it during training sessions. There are different videos for staff depending on staff roles and locations in the hospital, ie, ward nurses and security.[34] We implemented an institutional standard choreography for common and recurrent actions such as switching of compressors, (See Figure 2) and for defibrillation to minimize pre-shock pause and maximize coronary perfusion pressure.[34] Either predetermined (passive) or just-in-time (active) choreography reinforces shared mental models that allow for dynamic and random teams to work together more effectively and is emphasized heavily during institutional training sessions and in weekly cardiac arrest debriefings.

Ergonomics

While coaching targets psychomotor performance improvement (ie, better CC resulting in optimal perfusion) and choreography targets task execution through shared mental models and coordinated action, ergonomics focuses on optimizing the interaction of environment with these and other human factors driven behavior. During this intervention, we used 2 techniques to understand environmental factors that inhibit performance. We used a method we call "Room Diagramming." Room diagramming took place either pre-or post-event. Pre-event room diagrams mapped how the patient bed would be oriented for ECPR cannulations, and where surgeons, Operating Room nurses, compressors, defibrillator, etc. . . would be and how this would vary depending on femoral versus neck cannulation, room size, configuration, etc. . . to optimize ergonomics. These plans were practiced during monthly ECPR simulations. Post-event room diagrams were used during our weekly debriefings. When sub-par performance (eg, a long interruption as measured by the defibrillator or bedside monitor) was identified, participants would draw a diagram of the resuscitation. These included the location of the patient (with his/her orientation in the environment), individuals including their role in the resuscitation (active/passive/observer), and equipment. These diagrams facilitated discussion and identification of potential causes for the poor performance. Then using table-top simulation methods,[35] solutions for that particular problem were explored by modifying the diagram, creating configuration permutations, and determining the likely impact on the problem; we call this method a room diagram enhanced table top exercise (rdTTX) and use the Johns Hopkins Resuscitation Room Diagram Tool (Figure 3). Through the use of this technique we evolved the concept of Quality of CPR Sightlines, (see Figure 2). This ergonomic approach ensures the code team leader, the CPR coach, the Airway/head of bed provider, and active chest compressor all have visual access to crucial internal and external quality feedback, patient physiologic data, and one another; all elements when inaccessible had been identified during our debriefings as contributing factors to poor performance in multiple resuscitations.

During our study of each patient room, we assessed sight lines and evaluated what we now refer to as "sound channels." This helped us understand why someone could not see the real-time feedback on the defibrillator screen and could not hear medication orders. We recognized that at nearly every event resuscitation team members consistently worked around large pieces of equipment or furniture in the room, many of which were not necessary to the resuscitation. While a ventilator might need to stay in the room, a commode or reclining chair did not. In addition, the team often left the defibrillator wherever it was delivered into the room even if it faced away from the compressor and other team members. To optimize the ability of a compressor to use the information from the defibrillator to inform their quality of CC, our institutional standard has become for the defibrillator to be at the bedside directly across from the compressor. To increase the likelihood this will occur, we determined the need for modification of the defibrillator cart. We chose one with a slim profile, that does not get in the way of team members and is tall such that the screen is elevated above the patient and can easily be seen from across the bed. The cart has multiple drawers labeled to hold adult pads, pediatric pads, gel, $ETCO_2$ cuvettes (plastic adapters connecting bag to mask or endotracheal tube), and sterile gowns for compressors when we activate ECPR. Finally, this cart holds a backboard on it so that when an emergency alert is triggered the person who grabs it is able to simultaneously bring in the backboard, defibrillator pads/paddles, and $ETCO_2$ supplies—all key elements to initiate and optimize high-quality BLS.

Structured debriefing

During this project, we determined that a comprehensive debriefing of a cardiac arrest event requires 45 minutes, in addition to the time necessary to collect, analyze, and prepare CPR performance and patient physiology data for review before the meeting. As described above, in addition to the patient data, the CODE-ACES[2] team solicits role-based data and information to be included during debriefing through a set of survey instruments we call peer-to-peer debriefing forms, ie role-relevant (physician/fellow, pharmacy, nursing, and respiratory therapy), questions related to non-technical skills[36] and quality of CPR concerns to inform the discussion.

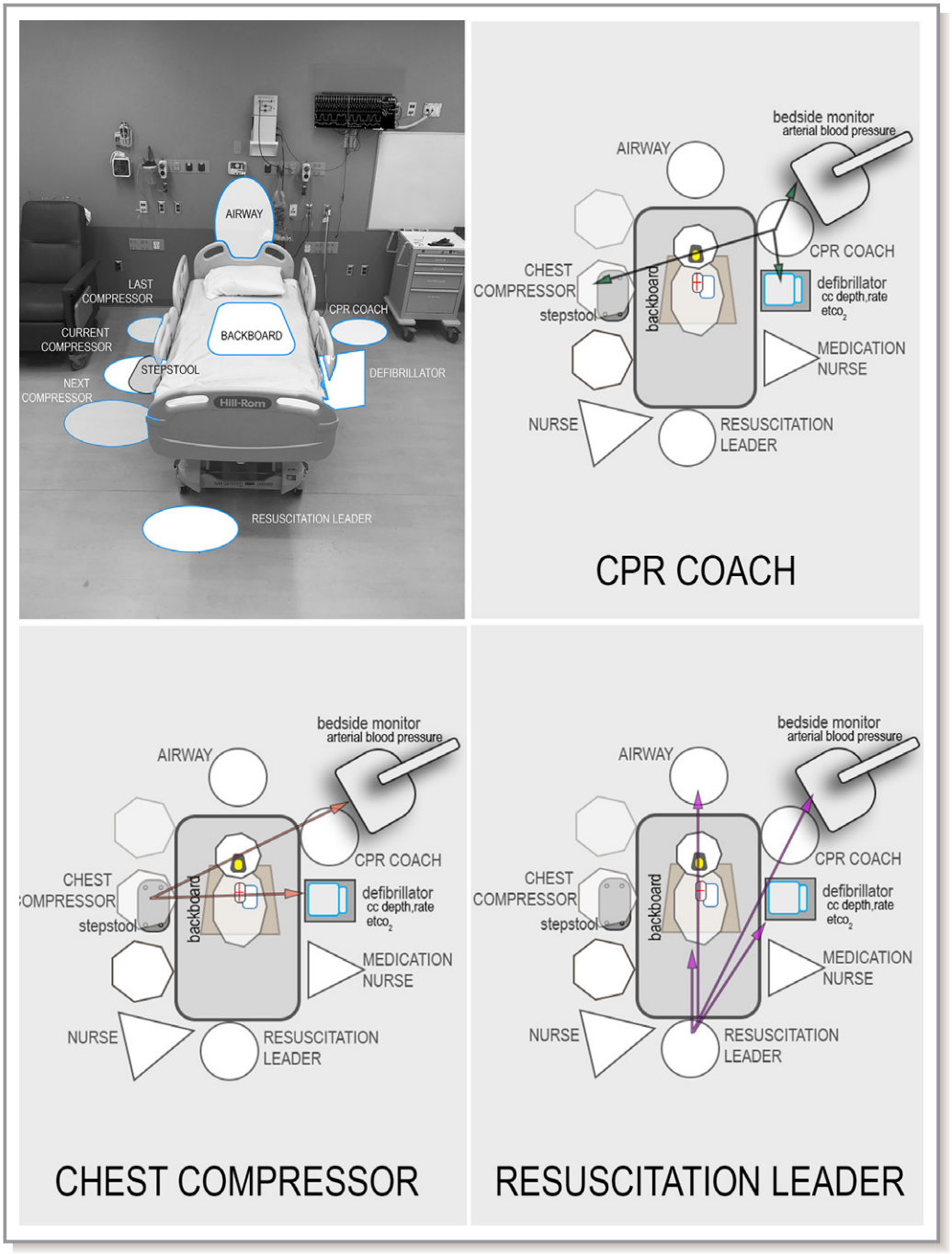

Figure 2. Introduction of CPR coach, choreography and ergonomics to optimize resuscitation performance. Introduction of CPR coach role to optimize compliance with AHA guidelines and cognitively unload the resuscitation leader; choreography of key roles during an in-hospital cardiac arrest to enhance communication and ergonomics, with important "sight lines" from perspective of the compressor, the CPR coach and the leader are highlighted. CC indicates chest compression; CPR, cardiopulmonary resuscitation; $ETCO_2$, end-tidal carbon dioxide.

The debriefing begins with a psychological safety, privacy, and confidentiality acknowledgement[14,37,38] (Data S1) and introduction of participants by name and role. After completing those elements targeted at creating a safe environment, we move into a case-specific discussion.

The event debriefing begins when the physician or nurse who was caring for the patient before the cardiac arrest gives an overview of the patient's history. Next, the rescuer who initiated CC describes events immediately preceding the need for compressions and their perception of the indication for CC. We

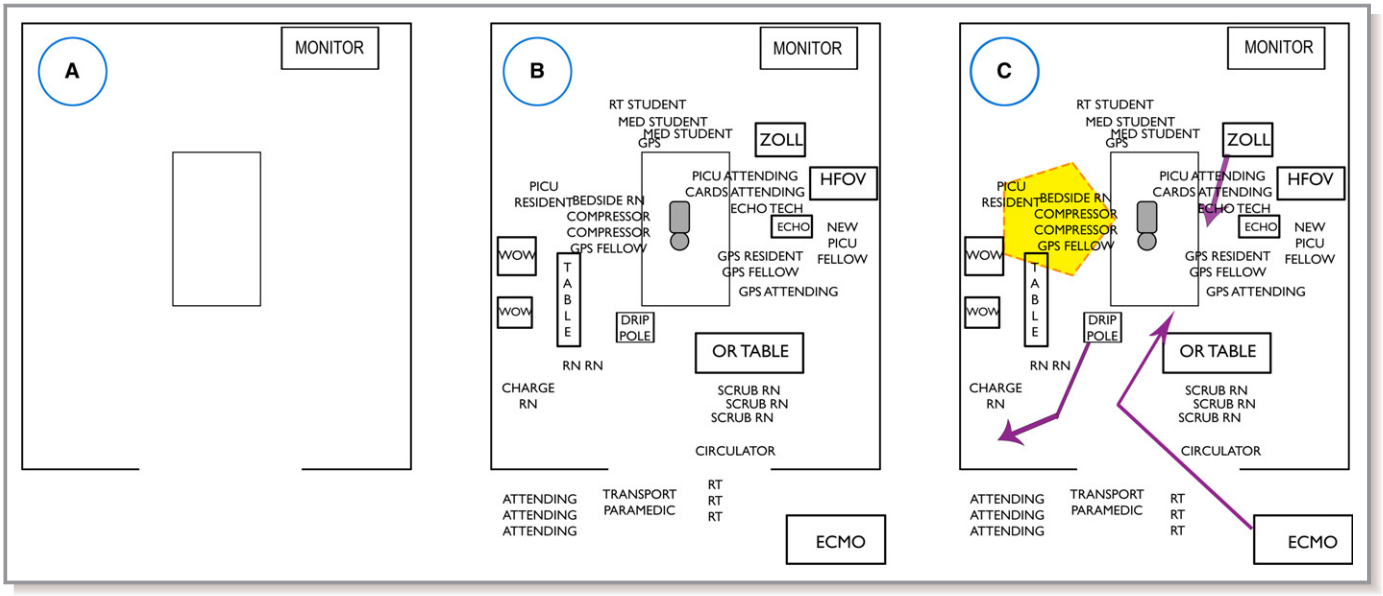

Figure 3. Johns Hopkins Resuscitation Room Diagram Tool. Facilitates understanding of the spatial issues of a cardiac arrest event, should also capture the dynamic nature of every resuscitation. Use of the Room Diagram Tool emphasizes: the number of people in the room, sight lines, ergonomics, and communication. **A**, A blank tool, (**B**) initial phase of a resuscitation with patient, team and equipment drawn in, and (**C**) tool after areas of concern were discussed (eg, orange circle indicating source of noise) as well as how equipment was moved based on priority (eg, red arrow indicating ECMO equipment moving from hallway to bedside). Can be used for an event that happened to debrief retrospectively or can be used to design an the "ideal event" prospectively. CARDS indicates cardiology; DRIP, IV pole with multiple medication pump; ECHO, Echocardiogram machine; ECMO, extracorporeal membrane oxygenation; GPS, General Pediatric Surgery; HFOV, High Frequency Oscillatory Ventilator; MED, medical; PICU, Pediatric Intensive Care Unit; RN, Registered Nurse.

identify other key roles, usually who was acting as the code team leader, CPR coach, compressors, airway manager, medication nurse, documenter, pharmacist, and potentially other roles. We then review patient monitor data beginning with the few minutes preceding the cardiac arrest and through the first few minutes of the resuscitation—we may review additional data, based on the questions that arise during the debriefing. We review the cardiac rhythm at the time of the cardiac arrest and documentation in the electronic medical record. During this review and debriefing process, clarification questions are asked. The core team members leading the debriefing sessions primarily use the debriefing with good judgement methodology.[39,40] This method allows a debriefer to safely and directly identify a performance gap and then fill that gap based on the participants mental model/frame and experiences.

We review the Johns Hopkins Resuscitation Performance Debriefing Tool (v3.0 Johns Hopkins University, Baltimore MD) (Figure 1). We focus much of the discussion on the age appropriate AHA PBLS metrics and PALS Guidelines and assess compliance and focusing the discussion on any impediments to compliance, and what can be done to remove those impediments. We review any electronic medical record data about timing of defibrillation, epinephrine and/or other medications, intubation, and ECPR documentation. At that time, we verify the data that will be entered into the Get With The Guidelines—Resuscitation database and determine if the team has committed any of what Get With The Guidelines—Resuscitation identifies as Process of Care Exceptions, or breaches of evidence based best practices. At the end of the discussion, we synthesize lessons learned and action items which then trigger institutional QI mechanisms (eg, reporting to the pediatric CPR committee, providing case-based data for ECPR simulation, etc.).

Attendance at the weekly structured debriefings varies. There is a core group that attends every week to ensure that QI work will continue regardless of staff attendance. For debriefing of some arrests, all clinical staff that attended the resuscitation may be present but on occasion, there may be only 1 or 2 clinical staff members present as the result of vacations or having other clinical conflicts. Typically, the "system" still benefits because of the work done in gathering the peer-to-peer debriefing forms and review of the objective data from the defibrillator, etc. . . We use a combination of the Epic Code Narrator attendee list (in combination with our REACH This was previously defined email list where people write a list of who they remember to be in attendance) with the Outlook email invitation list. In addition, we have a designated clinical champion for each area, so that if no one is able to be present for an arrest in that area, at least the clinical champion in that area will come and bring the details

they have ascertained and take back lessons learned from the discussion, ie, (Radiology, PACU, etc. . .).

These structured debriefings have the added benefit of functioning as a source of accurate and timely data for organizational systems integration and regulatory reporting processes. For example, as participants of the AHA's Get With The Guidelines—Resuscitation national registry, we use the weekly debriefings to discuss and finalize any incomplete data elements from the resuscitation and rapidly identify any core measures (eg, time to shock, time to first epinephrine, Endotracheal Tube confirmation) that lie outside recommended parameters. These data are then presented at the monthly CPR Advisory Committee meeting. The detailed discussion of the factors contributing to any performance gaps enables identification of recommendations needed to improve processes or modify policies. Recommendations for equipment updates are presented to the Capital Budget Committee for funding. This ensures we are in full compliance with all regulatory requirements regarding data capture and review for emergency events and have all necessary equipment for best practices. An 11-item debriefing and discussion guide that describes this process is located in Table S2.

Simulation

We use simulation to support our resuscitation quality improvement program beyond the traditional BLS and PALS courses, frequently through the Rapid Cycle Deliberate Prototyping approach. As mentioned above, we conducted a series of simulations to determine the optimal location for the CPR coach to stand relative to the compressor, the defibrillator/CPR feedback device and the Code team leader. We also have simulated whether they can and should be responsible for related tasks including operating the defibrillator, monitoring ventilation quality, or administering medication. Ultimately, in our institution we decided that having them operate the defibrillator made sense as they were handling the device with CPR feedback, but giving medications introduced too much cognitive load. We have used simulation to determine the ideal choreography to place the backboard and the defibrillator pads at the same time to minimize interruptions, now reliably being able to do both simultaneously in <3 seconds.[33,34] In summary, we use simulation to understand the problem, to find an ideal solution and then to train our team until they have a shared mental model of the solution.

In summary, we have developed a Resuscitation Quality Bundle associated with improved compliance with AHA PBLS and PALS Guidelines that can serve as a template for other hospitals. This program has several key components. The first involved development and implementation of an active surveillance program that successfully increased capture of cardiac arrest events. The second was implementation of a weekly, structured cardiac arrest debriefing program associated with a progressive increase in capture of defibrillator accelerometer-based data, enabling objective data evaluation. The third was to systematically capture lessons learned from the debriefing exercises, as well as tools developed to facilitate the debriefings. These elements were tied together into a resuscitation quality bundle we now call CODE ACES^2. The development of this program has enabled our institution to have a shared mental model of the choreography and scripting of key elements of pediatric resuscitation, as well as factors that mediate performance. Ultimately, we will be measuring the impact on long-term clinical outcomes.

Limitations

First, in this manuscript, we share our institution's approach to the complex problem of IHCA. The solutions we present may not be generalizable to all programs, nor have we studied each one in a controlled fashion. However, we are hopeful that describing the CODE ACES^2 elements supplemented by our tools, aids, examples, and previous work will be useful to those starting a debriefing program and those attempting to improve compliance with AHA guidelines in their institution. Second, the proportion of cardiac arrest event data that were collected via the defibrillator during 2013 was only a small fraction of that captured in 2015. It is possible that there was selection bias and that the compressions we did not capture differed in quality from those that were captured, and that we are over-representing the improvement in compliance. Third, we have not reported survival data in this study. To measure improvement compliance with guidelines across our Children's Center and have the power to detect a difference, we included all cardiac arrest events where chest compressions were performed within the walls of the hospital, including events starting outside the walls of the hospital; we also included repeat events. This means we are not able to explore the impact of the CODE ACES^2 program on survival to discharge.

Finally, we observed a biphasic response in compliance with CC depth guidelines. We believe this is multifactorial in nature. The use of arterial catheters allows a code team leader to monitor, prioritize and target the diastolic blood pressure over CC depth, and this would not be reflected in the defibrillator record. Also, there is growing concern at our institution that the AHA recommended CC depth is not appropriate for some children (ie, for example that 3.8 cm may be too deep for a 4 kg 2-month-old), thus the code team leader would define a depth goal different than the AHA goal based on patient-specific physiology. These are important issues to consider as institutions develop quality programs.

Conclusions

Over a 3-year period, we debriefed >300 IHCAs, created a culture of capturing and using CC quality data to refine resuscitation performance and identified recurring debriefing themes that were transformed into a resuscitation quality bundle. CODE-ACES^2 focuses on strategies that mediate performance, ultimately driving improved compliance with PBLS and PALS Guidelines. Benchmarking of metrics over time and creation of an institutional shared mental model regarding key components of a resuscitation have been integral to improved resuscitation performance.

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References

1. Knudson JD, Neish SR, Cabrera AG, Lowry AW, Shamszad P, Morales DL, Graves DE, Williams EA, Rossano JW. Prevalence and outcomes of pediatric in-hospital cardiopulmonary resuscitation in the United States: an analysis of the Kids' Inpatient Database. *Crit Care Med*. 2012;40:2940–2944.
2. Girotra S, Spertus JA, Li Y, Berg RA, Nadkarni VM, Chan PS; American Heart Association Get With the Guidelines–Resuscitation Investigators. Survival trends in pediatric in-hospital cardiac arrests: an analysis from Get With the Guidelines-Resuscitation. *Circ Cardiovasc Qual Outcomes*. 2013;6:42–49.
3. Berg RA, Sutton RM, Reeder RW, Berger JT, Newth CJ, Carcillo JA, McQuillen PS, Meert KL, Yates AR, Harrison RE, Moler FW, Pollack MM, Carpenter TC, Wessel DL, Jenkins TL, Notterman DA, Holubkov R, Tamburro RF, Dean JM, Nadkarni VM; Eunice Kennedy Shriver National Institute of Child Health and Human Development Collaborative Pediatric Critical Care Research Network (CPCCRN) Pediatric Intensive Care Quality of Cardio-Pulmonary Resuscitation (PICqCPR) investigators. Association between diastolic blood pressure during pediatric in-hospital cardiopulmonary resuscitation and survival. *Circulation*. 2018;137:1784–1795.
4. Jayaram N, Spertus JA, Nadkarni V, Berg RA, Tang F, Raymond T, Guerguerian AM, Chan PS; American Heart Association's Get with the Guidelines-Resuscitation Investigators. Hospital variation in survival after pediatric in-hospital cardiac arrest. *Circ Cardiovasc Qual Outcomes*. 2014;7:517–523.
5. Ornato JP, Peberdy MA, Reid RD, Feeser VR, Dhindsa HS; NRCPR Investigators. Impact of resuscitation system errors on survival from in-hospital cardiac arrest. *Resuscitation*. 2012;83:63–69.
6. Edelson DP, Litzinger B, Arora V, Walsh D, Kim S, Lauderdale DS, Vanden Hoek TL, Becker L, Abella BS. Improving in-hospital cardiac arrest process and outcomes with performance debriefing. *Arch Intern Med*. 2008;168:1063–1069.
7. Dine CJ, Gersh RE, Leary M, Riegel BJ, Bellini LM, Abella BS. Improving cardiopulmonary resuscitation quality and resuscitation training by combining audiovisual feedback and debriefing. *Crit Care Med*. 2008;36:2817–2822.
8. Jiang C, Zhao Y, Chen Z, Chen S, Yang X. Improving cardiopulmonary resuscitation in the emergency department by real-time video recording and regular feedback learning. *Resuscitation*. 2010;81:1664–1669.
9. Zebuhr C, Sutton RM, Morrison W, Niles D, Boyle L, Nishisaki A, Meaney P, Leffelman J, Berg RA, Nadkarni VM. Evaluation of quantitative debriefing after pediatric cardiac arrest. *Resuscitation*. 2012;83:1124–1128.
10. Wolfe H, Zebuhr C, Topjian AA, Nishisaki A, Niles DE, Meaney PA, Boyle L, Giordano RT, Davis D, Priestley M, Apkon M, Berg RA, Nadkarni VM, Sutton RM. Interdisciplinary ICU cardiac arrest debriefing improves survival outcomes. *Crit Care Med*. 2014;42:1688–1695.
11. Duval-Arnould JM, Newton HM, McNamara L, Engorn BM, Jones K, Bernier M, Dodge P, Salamone C, Bhalala U, Jeffers JM, Engineer L, Diener-West M, Hunt EA. Design and deployment of a pediatric cardiac arrest surveillance system. *Crit Care Res Pract*. 2018;2018:9187962.
12. Berg MD, Schexnayder SM, Chameides L, Terry M, Donoghue A, Hickey RW, Berg RA, Sutton RM, Hazinski MF. Part 13: pediatric basic life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2010;122:S862–S875.
13. Meaney PA, Bobrow BJ, Mancini ME, Christenson J, de Caen AR, Bhanji F, Abella BS, Kleinman ME, Edelson DP, Berg RA, Aufderheide TP, Menon V, Leary M; CPR Quality Summit Investigators, the American Heart Association Emergency Cardiovascular Care Committee, and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Cardiopulmonary resuscitation quality: [corrected] improving cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association. *Circulation*. 2013;128:417–435.
14. Edmondson A. Psychological safety and learning behavior in work teams. *Adm Sci Q*. 1999;44:350–383.
15. Abella BS, Alvarado JP, Myklebust H, Edelson DP, Barry A, O'Hearn N, Vanden Hoek TL, Becker LB. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. *J Am Med Assoc*. 2005;293:305–310.
16. Kleinman ME, Brennan EE, Goldberger ZD, Swor RA, Terry M, Bobrow BJ, Gazmuri RJ, Travers AH, Rea T. Part 5: Adult Basic Life Support and Cardiopulmonary Resuscitation Quality: 2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2015;132:S414–S435.
17. Hunt EA, Cruz-Eng H, Bradshaw JH, Hodge M, Bortner T, Mulvey CL, McMillan KN, Galvan H, Duval-Arnould JM, Jones K, Shilkofski NA, Rodgers DL, Sinz EH. A novel approach to life support training using "action-linked phrases". *Resuscitation*. 2015;86:1–5.
18. Niles DE, Duval-Arnould J, Skellett S, Knight L, Su F, Raymond TT, Sweberg T, Sen AI, Atkins DL, Friess SH, de Caen AR, Kurosawa H, Sutton RM, Wolfe H, Berg RA, Silver A, Hunt EA, Nadkarni VM; pediatric Resuscitation Quality (pediRES-Q) Collaborative Investigators. Characterization of pediatric in-hospital cardiopulmonary resuscitation quality metrics across an international resuscitation collaborative. *Pediatr Crit Care Med*. 2018;19:421–432.
19. Hazinski MF, Nadkarni VM, Hickey RW, O'Connor R, Becker LB, Zaritsky A. Major changes in the 2005 AHA Guidelines for CPR and ECC: reaching the tipping point for change. *Circulation*. 2005;112:IV206–IV211.
20. Hunt EA, Duval-Arnould JM, Nelson-McMillan KL, Bradshaw JH, Diener-West M, Perretta JS, Shilkofski NA. Pediatric resident resuscitation skills improve after "rapid cycle deliberate practice" training. *Resuscitation*. 2014;85:945–951.
21. Hunt EA, Duval-Arnould JM, Chime NO, Jones K, Rosen M, Hollingsworth M, Aksamit D, Twilley M, Camacho C, Nogee DP, Jung J, Nelson-McMillan K, Shilkofski N, Perretta JS. Integration of in-hospital cardiac arrest contextual

curriculum into a basic life support course: a randomized, controlled simulation study. *Resuscitation*. 2017;114:127–132.

22. Driskell JE, Salas E, Johnston J. Does stress lead to a loss of team perspective? *Group Dyn Theory Res Pract*. 1999;3:291.
23. Ellis AP. System breakdown: the role of mental models and transactive memory in the relationship between acute stress and team performance. *Acad Manag J*. 2006;49:576–589.
24. Porter CO, Hollenbeck JR, Ilgen DR, Ellis AP, West BJ, Moon H. Backing up behaviors in teams: the role of personality and legitimacy of need. *J Appl Psychol*. 2003;88:391.
25. Morgeson FP, DeRue DS, Karam EP. Leadership in teams: a functional approach to understanding leadership structures and processes. *J Manage*. 2010;36:5–39.
26. Burke CS, Stagl KC, Klein C, Goodwin GF, Salas E, Halpin SM. What type of leadership behaviors are functional in teams? A meta-analysis *Leadersh Q*. 2006;17:288–307.
27. Leary M, Schweickert W, Neefe S, Tsypenyuk B, Falk SA, Holena DN. Improving providers' role definitions to decrease overcrowding and improve in-hospital cardiac arrest response. *Am J Crit Care*. 2016;25:335–339.
28. Infinger AE, Vandeventer S, Studnek JR. Introduction of performance coaching during cardiopulmonary resuscitation improves compression depth and time to defibrillation in out-of-hospital cardiac arrest. *Resuscitation*. 2014;85:1752–1758.
29. Cheng A, Duff JP, Kessler D, Tofil NM, Davidson J, Lin Y, Chatfield J, Brown LL, Hunt EA; International Network for Simulation-based Pediatric Innovation Research and Education (INSPIRE) CPR. Optimizing CPR performance with CPR coaching for pediatric cardiac arrest: A randomized simulation-based clinical trial. *Resuscitation*. 2018;132:33–40.
30. Hunt EA, Walker AR, Shaffner DH, Miller MR, Pronovost PJ. Simulation of in-hospital pediatric medical emergencies and cardiopulmonary arrests: highlighting the importance of the first 5 minutes. *Pediatrics*. 2008;121:e34–e43.
31. Salas E, Rosen MA, Burke CS, Goodwin GF. The wisdom of collectives in organizations: an update of the teamwork competencies. In: *Team Effectiveness in Complex Organizations: Cross-Disciplinary Perspectives and Approaches*. New York, NY: Routledge; 2009:39–79.
32. Endsley MR. Toward a theory of situation awareness in dynamic systems. *Hum Factors*. 1995;37:32–64.
33. Sullivan N, Duval-Arnould JM, Perretta JS, Rosen M, Hunt EA. Using simulation to design choreography for the first few minutes of a cardiac arrest. *Clin Simul Nurs*. 2015;11:489–493.
34. Johns Hopkins Medicine Simulation Center, Resuscitation Website, Resuscitation Tools: Johns Hopkins Hospital institutional standardized choreography for clinical responders for the First Few Minutes of an adult cardiac arrest. Available at: https://www.hopkinsmedicine.org/simulation_center/resuscitation/ffm_training.html. Accessed October 26, 2018.
35. Dausey DJ, Buehler JW, Lurie N. Designing and conducting tabletop exercises to assess public health preparedness for manmade and naturally occurring biological threats. *BMC Public Health*. 2007;29:92.
36. Jones KR, Rosen M, Duval-Arnould J, Hunt EA. Development of a cardiopulmonary resuscitation non-technical skills scoring tool (CPR-NTS). *Crit Care Med*. 2014;42:A1427.
37. Rudolph JW, Raemer DB, Simon R. Establishing a safe container for learning in simulation. *Simul Healthc*. 2014;9:339–349.
38. Fanning RM, Gaba DM. The role of debriefing in simulation-based learning. *Simul Healthc*. 2007;2:115–125.
39. Rudolph JW, Simon R, Raemer DB, Eppich WJ. Debriefing as formative assessment: closing performance gaps in medical education. *Acad Emerg Med*. 2008;15:1010–1016.
40. Rudolph JW, Simon R, Rivard P, Dufresne RL, Raemer DB. Debriefing with good judgment: combining rigorous feedback with genuine inquiry. *Anesthesiol Clin*. 2007;25:361–376.

SUPPLEMENTAL MATERIAL

Data S1. Johns Hopkins Resuscitation Debriefing Privacy and Confidentiality.

Johns Hopkins Resuscitation Debriefing Privacy and Confidentiality

Thank you for coming today to discuss and learn from last week's pediatric cardiac arrest events. The purpose of this QI initiative is to identify every pediatric cardiac arrest event in the hospital, discuss what went well and what didn't in order to develop strategies to improve performance in the future. In order to inform each case's discussion we will review as much objective data as possible in order to identify instances of high and low performance and to gain insight as to what have mediated them such as communication, leadership, shared mental models, equipment and room ergonomics. There is increasing literature which suggests that debriefing real events with data from those events leads to subsequent future performance benefits and we are operating in part using this concepts and methods from this evidence. Although objective data is our gold standard we also recognize the complexity of these events and the importance of your observations and actions. Understanding what decisions were made during these events provide tremendous valuable insight as to why things happened the way they did and what we might learn from them to take with us into the future. To that end we ask questions from a place of genuine curiosity with an aim to learn and never to interrogate or to make anyone feel bad; we will try our hardest to ask questions respectfully and always with a productive purpose in mind. We know that everyone here is intelligent, has worked and trained hard, and wants to provide the best care possible to children in the hospital every day. We ask that everyone honors that commitment and one another by sharing the lessons learned from this discussion while maintaining the privacy and confidentiality of each other.

Table S1. Johns Hopkins Pharmacy Acute Event Peer-to-Peer Debriefing Form.

Pediatric RRT/ PICU Code Blue/Alpha Trauma/DART Response Debriefing for Pharmacy
Privileged and Confidential/Peer Review Protected

******Please use blue or black pen******

Event Date: _____ Event Time: _____ AM/PM Location: _____ MRN: _____

Patient Name: _____ Patient Weight: _____ kg Patient in Isolation: Yes No

Pharmacist Completing Form: _____ Other Responding Pharmacist(s): _____

1. Indication for the Pediatric RRT/PICU Code Blue/DART:
   ☐ Respiratory Distress ☐ Cardiac Arrest ☐ Anaphylaxis ☐ Altered Mental Status
   ☐ Hypotension ☐ Seizure ☐ DART ☐ Other: _____

2. Which of the 5 questions of the Pharmacist's script were asked?

Who is the team leader?	☐ Yes	☐ No
Who is the medication RN	☐ Yes	☐ No
What is the patient's weight?	☐ Yes	☐ No
Does the patient have a working IV?	☐ Yes	☐ No
What algorithm is being followed?	☐ Yes	☐ No

   If no, which questions were not asked and why? _____

3. Medications administered (please list):

   _____

4. Timing of first epinephrine dose after initiation of chest compressions: _____

5. Was ECMO discussed/activated after the first dose of epinephrine? ☐ Yes ☐ No

6. Number of doses of epinephrine administered: _____

7. Were all doses of epinephrine given within the recommended 3 - 5 minute interval? ☐ Yes ☐ No

8. Was sodium bicarbonate administered? ☐ Yes ☐ No

   If yes, what was the indication: ☐ Acidosis ☐ Hyperkalemia ☐ Unknown

9. Was calcium chloride/gluconate administered? ☐ Yes ☐ No

   If yes, what was the indication: ☐ Hypocalcemia ☐ Hyperkalemia ☐ Unknown

10. Were there any missing medication(s) or supplies? ☐ Yes ☐ No

    If yes, please list: _____

11. Any concerns about teamwork/communication? ☐ Yes ☐ No

    If yes, please describe: _____

12. Any positive feedback about teamwork/communication? ☐ Yes ☐ No

    If yes, please describe: _____

13. List any interventions you made that you would like to share?

    _____

Please email or return the completed form to LeAnn's or Lisa's mailbox Last Updated 5/17
Additional forms can be found on the I-drive under Pediatric Pharmacy/Emergency Drug Bags/Debriefing

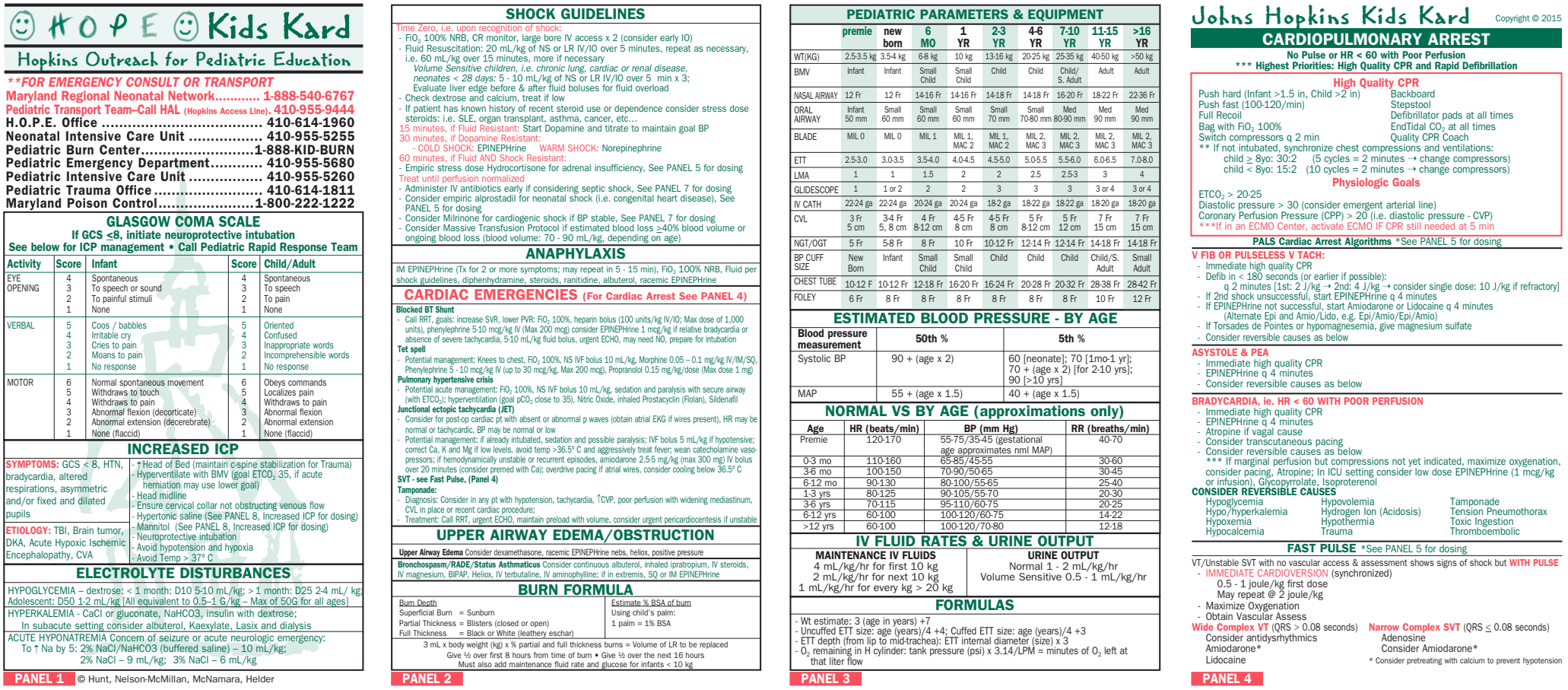
Table S2. Johns Hopkins Resuscitation Debriefing and Discussion Guide.

Johns Hopkins Resuscitation Debriefing and Discussion Guide

1. Review **patient history**: 2-3 Sentences with relevant medical history, present illness, any prior cardiac arrest this admission/ever.
2. Describe **preceding events**: conditions, exposures, and perceived stability leading up to the event. Discuss likelihood and nature of arrest onset, gradual vs. precipitous, expected vs. sudden, potential causal interventions. Given pre-arrest timing and duration Inquire what was done (if anything) to prepare.
3. Discuss physiology-basis or team-decision making that prompted **the initiation of CPR**.
4. Describe the **first few minutes** of the resuscitation including: initiation of CC, quality of CPR, role assignments, kinetics, sound, CRM/TeamSTEPPS challenges/wins.
5. Review **objective data** including bedside monitor second to second data and JH CPR Performance Report Card (if available). For OR/Cath/MRI review Anesthesia record.
6. Discuss **coaching** feedback direction style used and methods employed: was it quantitative “make your rate 100 / try to get co2 >20”, qualitative “good depth”, relative “deeper/ slower”, reinforcing “good job, just like that”. Which were effective and why?
7. **Pharmacy**: medication administration, access, dosing, communication, algorithm adherence, 5 questions asked?
8. **Redo / Repeat:** if you could go back and change something what would be? If we should repeat something for similar patients / situations, what should it be?
9. Event impact **on non-event related patient care**. Open discussion as we evolve discussion points: think how were resources allocated safely / unsafely/ unintended consequences due to response, etc.
10. General **ECPR** topics to include: candidacy discussion/confusion. If activated within in appropriate timing. Were ECPR benchmarks met?
11. Time permitting: **precision/personalized CPR** approach for this patient. Was discussed prior to arrest? Was adhered to?

Figure S1. Johns Hopkins Kids Kard Pediatric Acute Emergencies Cognitive Aid*

*Cognitive Aid for pediatric emergencies with area designed to support cardiac arrest management, includes AHA CPR depth and rate targets, and expert consensus-based targets



☺ H O P E ☺ Kids Kard

Hopkins Outreach for Pediatric Education

****FOR EMERGENCY CONSULT OR TRANSPORT**

Maryland Regional Neonatal Network..... 1-888-540-6767
Pediatric Transport Team–Call HAL (Hopkins Access Line). 410-955-9444
H.O.P.E. Office 410-614-1960
Neonatal Intensive Care Unit 410-955-5255
Pediatric Burn Center.....1-888-KID-BURN
Pediatric Emergency Department..... 410-955-5680
Pediatric Intensive Care Unit 410-955-5260
Pediatric Trauma Office 410-614-1811
Maryland Poison Control.....1-800-222-1222

GLASGOW COMA SCALE

If GCS ≤8, initiate neuroprotective intubation
See below for ICP management • Call Pediatric Rapid Response Team

Activity	Score	Infant	Score	Child/Adult
EYE OPENING	4	Spontaneous	4	Spontaneous
	3	To speech or sound	3	To speech
	2	To painful stimuli	2	To pain
	1	None	1	None
VERBAL	5	Coos / babbles	5	Oriented
	4	Irritable cry	4	Confused
	3	Cries to pain	3	Inappropriate words
	2	Moans to pain	2	Incomprehensible words
	1	No response	1	No response
MOTOR	6	Normal spontaneous movement	6	Obeys commands
	5	Withdraws to touch	5	Localizes pain
	4	Withdraws to pain	4	Withdraws to pain
	3	Abnormal flexion (decorticate)	3	Abnormal flexion
	2	Abnormal extension (decerebrate)	2	Abnormal extension
	1	None (flaccid)	1	None (flaccid)

INCREASED ICP

SYMPTOMS: GCS < 8, HTN, bradycardia, altered respirations, asymmetric and/or fixed and dilated pupils

ETIOLOGY: TBI, Brain tumor, DKA, Acute Hypoxic Ischemic Encephalopathy, CVA

- ↑Head of Bed (maintain c-spine stabilization for Trauma)
- Hyperventilate with BMV (goal $ETCO_2$ 35, if acute herniation may use lower goal)
- Head midline
- Ensure cervical collar not obstructing venous flow
- Hypertonic saline (See PANEL 8, Increased ICP for dosing)
- Mannitol (See PANEL 8, Increased ICP for dosing)
- Neuroprotective intubation
- Avoid hypotension and hypoxia
- Avoid Temp > 37° C

ELECTROLYTE DISTURBANCES

HYPOGLYCEMIA – dextrose: < 1 month: D10 5-10 mL/kg; > 1 month: D25 2-4 mL/ kg; Adolescent: D50 1-2 mL/kg [All equivalent to 0.5–1 G/kg – Max of 50G for all ages]

HYPERKALEMIA - CaCl or gluconate, NaHCO3, insulin with dextrose; In subacute setting consider albuterol, Kaexylate, Lasix and dialysis

ACUTE HYPONATREMIA Concern of seizure or acute neurologic emergency:
To ↑ Na by 5: 2% NaCl/NaHCO3 (buffered saline) – 10 mL/kg;
2% NaCl – 9 mL/kg; 3% NaCl – 6 mL/kg

PANEL 1 © Hunt, Nelson-McMillan, McNamara, Helder

SHOCK GUIDELINES

Time Zero, i.e. upon recognition of shock:
- FiO_2 100% NRB, CR monitor, large bore IV access x 2 (consider early IO)
- Fluid Resuscitation: 20 mL/kg of NS or LR IV/IO over 5 minutes, repeat as necessary, i.e. 60 mL/kg over 15 minutes, more if necessary
  Volume Sensitive children, i.e. chronic lung, cardiac or renal disease, neonates < 28 days: 5 - 10 mL/kg of NS or LR IV/IO over 5 min x 3; Evaluate liver edge before & after fluid boluses for fluid overload
- Check dextrose and calcium, treat if low
- If patient has known history of recent steroid use or dependence consider stress dose steroids: i.e. SLE, organ transplant, asthma, cancer, etc…

15 minutes, if Fluid Resistant: Start Dopamine and titrate to maintain goal BP

30 minutes, if Dopamine Resistant:
- COLD SHOCK: EPINEPHrine WARM SHOCK: Norepinephrine

60 minutes, if Fluid AND Shock Resistant:
- Empiric stress dose Hydrocortisone for adrenal insufficiency, See PANEL 5 for dosing

Treat until perfusion normalized
- Administer IV antibiotics early if considering septic shock, See PANEL 7 for dosing
- Consider empiric alprostadil for neonatal shock (i.e. congenital heart disease), See PANEL 5 for dosing
- Consider Milrinone for cardiogenic shock if BP stable, See PANEL 7 for dosing
- Consider Massive Transfusion Protocol if estimated blood loss ≥40% blood volume or ongoing blood loss (blood volume: 70 - 90 mL/kg, depending on age)

ANAPHYLAXIS

IM EPINEPHrine (Tx for 2 or more symptoms; may repeat in 5 - 15 min), FiO_2 100% NRB, Fluid per shock guidelines, diphenhydramine, steroids, ranitidine, albuterol, racemic EPINEPHrine

CARDIAC EMERGENCIES (For Cardiac Arrest See PANEL 4)

Blocked BT Shunt
- Call RRT, goals: increase SVR, lower PVR: FiO_2 100%, heparin bolus (100 units/kg IV/IO; Max dose of 1,000 units), phenylephrine 5-10 mcg/kg IV (Max 200 mcg) consider EPINEPHrine 1 mcg/kg if relative bradycardia or absence of severe tachycardia, 5-10 mL/kg fluid bolus, urgent ECHO, may need NO, prepare for intubation

Tet spell
- Potential management: Knees to chest, FiO_2 100%, NS IVF bolus 10 mL/kg, Morphine 0.05 – 0.1 mg/kg IV/IM/SQ, Phenylephrine 5 - 10 mcg/kg IV (up to 30 mcg/kg, Max 200 mcg), Propranolol 0.15 mg/kg/dose (Max dose 1 mg)

Pulmonary hypertensive crisis
- Potential acute management: FiO_2 100%, NS IVF bolus 10 mL/kg, sedation and paralysis with secure airway (with $ETCO_2$); hyperventilation (goal pCO_2 close to 35), Nitric Oxide, inhaled Prostacyclin (Flolan), Sildenafil

Junctional ectopic tachycardia (JET)
- Consider for post-op cardiac pt with absent or abnormal p waves (obtain atrial EKG if wires present), HR may be normal or tachycardic, BP may be normal or low
- Potential management: if already intubated, sedation and possible paralysis; IVF bolus 5 mL/kg if hypotensive; correct Ca, K and Mg if low levels, avoid temp >36.5° C and aggressively treat fever; wean catecholamine vasopressors; if hemodynamically unstable or recurrent episodes, amiodarone 2.5-5 mg/kg (max 300 mg) IV bolus over 20 minutes (consider premed with Ca); overdrive pacing if atrial wires, consider cooling below 36.5° C

SVT - see Fast Pulse, (Panel 4)

Tamponade:
- Diagnosis: Consider in any pt with hypotension, tachycardia, ↑CVP, poor perfusion with widening mediastinum, CVL in place or recent cardiac procedure;
- Treatment: Call RRT, urgent ECHO, maintain preload with volume, consider urgent pericardiocentesis if unstable

UPPER AIRWAY EDEMA/OBSTRUCTION

Upper Airway Edema Consider dexamethasone, racemic EPINEPHrine nebs, heliox, positive pressure

Bronchospasm/RADE/Status Asthmaticus Consider continuous albuterol, inhaled ipratropium, IV steroids, IV magnesium, BIPAP, Heliox, IV terbutaline, IV aminophylline; if in extremis, SQ or IM EPINEPHrine

BURN FORMULA

Burn Depth	Estimate % BSA of burn
Superficial Burn = Sunburn	Using child's palm:
Partial Thickness = Blisters (closed or open)	1 palm = 1% BSA
Full Thickness = Black or White (leathery eschar)	

3 mL x body weight (kg) x % partial and full thickness burns = Volume of LR to be replaced
Give ½ over first 8 hours from time of burn • Give ½ over the next 16 hours
Must also add maintenance fluid rate and glucose for infants < 10 kg

PANEL 2

PEDIATRIC PARAMETERS & EQUIPMENT

	premie	new born	6 MO	1 YR	2-3 YR	4-6 YR	7-10 YR	11-15 YR	>16 YR
WT(KG)	2.5-3.5 kg	3.5-4 kg	6-8 kg	10 kg	13-16 kg	20-25 kg	25-35 kg	40-50 kg	>50 kg
BMV	Infant	Infant	Small Child	Small Child	Child	Child	Child/ S. Adult	Adult	Adult
NASAL AIRWAY	12 Fr	12 Fr	14-16 Fr	14-16 Fr	14-18 Fr	14-18 Fr	16-20 Fr	18-22 Fr	22-36 Fr
ORAL AIRWAY	Infant 50 mm	Small 60 mm	Small 60 mm	Small 60 mm	Small 70 mm	Small 70-80 mm	Med 80-90 mm	Med 90 mm	Med 90 mm
BLADE	MIL 0	MIL 0	MIL 1	MIL 1, MAC 2	MIL 1, MAC 2	MIL 2, MAC 3	MIL 2, MAC 3	MIL 2, MAC 3	MIL 2, MAC 3
ETT	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-5.5	5.5-6.0	6.0-6.5	7.0-8.0
LMA	1	1	1.5	2	2	2.5	2.5-3	3	4
GLIDESCOPE	1	1 or 2	2	2	3	3	3	3 or 4	3 or 4
IV CATH	22-24 ga	22-24 ga	20-24 ga	20-24 ga	18-2 ga	18-22 ga	18-22 ga	18-20 ga	18-20 ga
CVL	3 Fr 5 cm	3-4 Fr 5, 8 cm	4 Fr 8-12 cm	4-5 Fr 8 cm	4-5 Fr 8 cm	5 Fr 8-12 cm	5 Fr 12 cm	7 Fr 15 cm	7 Fr 15 cm
NGT/OGT	5 Fr	5-8 Fr	8 Fr	10 Fr	10-12 Fr	12-14 Fr	12-14 Fr	14-18 Fr	14-18 Fr
BP CUFF SIZE	New Born	Infant	Small Child	Small Child	Child	Child	Child	Child/S. Adult	Small Adult
CHEST TUBE	10-12 F	10-12 Fr	12-18 Fr	16-20 Fr	16-24 Fr	20-28 Fr	20-32 Fr	28-38 Fr	28-42 Fr
FOLEY	6 Fr	8 Fr	8 Fr	8 Fr	8 Fr	8 Fr	8 Fr	10 Fr	12 Fr

ESTIMATED BLOOD PRESSURE - BY AGE

Blood pressure measurement	50th %	5th %
Systolic BP	90 + (age x 2)	60 [neonate]; 70 [1mo-1 yr]; 70 + (age x 2) [for 2-10 yrs]; 90 [>10 yrs]
MAP	55 + (age x 1.5)	40 + (age x 1.5)

NORMAL VS BY AGE (approximations only)

Age	HR (beats/min)	BP (mm Hg)	RR (breaths/min)
Premie	120-170	55-75/35-45 (gestational age approximates nml MAP)	40-70
0-3 mo	110-160	65-85/45-55	30-60
3-6 mo	100-150	70-90/50-65	30-45
6-12 mo	90-130	80-100/55-65	25-40
1-3 yrs	80-125	90-105/55-70	20-30
3-6 yrs	70-115	95-110/60-75	20-25
6-12 yrs	60-100	100-120/60-75	14-22
>12 yrs	60-100	100-120/70-80	12-18

IV FLUID RATES & URINE OUTPUT

MAINTENANCE IV FLUIDS
4 mL/kg/hr for first 10 kg
2 mL/kg/hr for next 10 kg
1 mL/kg/hr for every kg > 20 kg

URINE OUTPUT
Normal 1 - 2 mL/kg/hr
Volume Sensitive 0.5 - 1 mL/kg/hr

FORMULAS

- Wt estimate: 3 (age in years) +7
- Uncuffed ETT size: age (years)/4 +4; Cuffed ETT size: age (years)/4 +3
- ETT depth (from lip to mid-trachea): ETT internal diameter (size) x 3
- O_2 remaining in H cylinder: tank pressure (psi) x 3.14/LPM = minutes of O_2 left at that liter flow

PANEL 3

Johns Hopkins Kids Kard

CARDIOPULMONARY ARREST

No Pulse or HR < 60 with Poor Perfusion
***** Highest Priorities: High Quality CPR and Rapid Defibrillation**

High Quality CPR

Push hard (Infant >1.5 in, Child >2 in)
Push fast (100-120/min)
Full Recoil
Bag with FiO_2 100%
Switch compressors q 2 min
Backboard
Stepstool
Defibrillator pads at all times
EndTidal CO_2 at all times
Quality CPR Coach

** If not intubated, synchronize chest compressions and ventilations:
child ≥ 8yo: 30:2 (5 cycles = 2 minutes → change compressors)
child < 8yo: 15:2 (10 cycles = 2 minutes → change compressors)

Physiologic Goals

$ETCO_2$ > 20-25
Diastolic pressure > 30 (consider emergent arterial line)
Coronary Perfusion Pressure (CPP) > 20 (i.e. diastolic pressure - CPV)
***If in an ECMO Center, activate ECMO IF CPR still needed at 5 min

PALS Cardiac Arrest Algorithms *See PANEL 5 for dosing

V FIB OR PULSELESS V TACH:
- Immediate high quality CPR
- Defib in < 180 seconds (or earlier if possible):
  q 2 minutes [1st: 2 J/kg → 2nd: 4 J/kg → consider single dose: 10 J/kg if refractory]
- If 2nd shock unsuccessful, start EPINEPHrine q 4 minutes
- If EPINEPHrine not successful, start Amiodarone or Lidocaine q 4 minutes (Alternate Epi and Amio/Lido, e.g. Epi/Amio/Epi/Amio)
- If Torsades de Pointes or hypomagnesemia, give magnesium sulfate
- Consider reversible causes as below

ASYSTOLE & PEA
- Immediate high quality CPR
- EPINEPHrine q 4 minutes
- Consider reversible causes as below

BRADYCARDIA, ie. HR < 60 WITH POOR PERFUSION
- Immediate high quality CPR
- EPINEPHrine q 4 minutes
- Atropine if vagal cause
- Consider transcutaneous pacing
- Consider reversible causes as below

*** If marginal perfusion but compressions not yet indicated, maximize oxygenation, consider pacing, Atropine; In ICU setting consider low dose EPINEPHrine (1 mcg/kg or infusion), Glycopyrrolate, Isoproterenol

CONSIDER REVERSIBLE CAUSES

Hypoglycemia
Hypo/hyperkalemia
Hypoxemia
Hypocalcemia
Hypovolemia
Hydrogen Ion (Acidosis)
Hypothermia
Trauma
Tamponade
Tension Pneumothorax
Toxic Ingestion
Thromboembolic

FAST PULSE *See PANEL 5 for dosing

VT/Unstable SVT with no vascular access & assessment shows signs of shock but **WITH PULSE**
- IMMEDIATE CARDIOVERSION (synchronized)
  0.5 - 1 joule/kg first dose
  May repeat @ 2 joule/kg
- Maximize Oxygenation
- Obtain Vascular Assess

Wide Complex VT (QRS > 0.08 seconds)
Consider antidysrhythmics
Amiodarone*
Lidocaine

Narrow Complex SVT (QRS ≤ 0.08 seconds)
Adenosine
Consider Amiodarone*

* Consider pretreating with calcium to prevent hypotension

PANEL 4

MEDICATIONS

CARDIAC ARREST AND SHOCK

ADENOSINE — **0.1 mg/kg IV/IO Rapid Bolus**
May repeat at 0.2 mg/kg, then 0.3 mg/kg IV/IO after 2 minutes
Max first dose 6 mg, Max subsequent dose 12 mg
administer using a stopcock attached to a 10 mL NS flush

ALPROSTADIL — FOR DUCTAL DEPENDENT LESIONS: 0.05 – 0.1 MCG/KG/MIN

AMIODARONE — **5 mg/kg IV/IO; Max single first dose: 300 mg; Max subsequent dose: 150 mg**
Max total dose: 15 mg/kg/24 hours OR 2.2 G daily
Consider pretreatment with calcium to prevent hypotension
If no pulse, push undiluted
If pulse, dilute and give over 20-60 minutes
Monitor for hypotension
Post Resuscitation Infusion: 5 - 10 mcg/kg/min

ATROPINE — **0.02 mg/kg IV/IO, 0.04 - 0.06 mg/kg ETT**
Min single dose 0.1 mg, Max single dose 0.5 mg Repeat q 5 minutes,
to Max total dose 1 mg

CALCIUM CHLORIDE — **(10%) - 20 mg/kg IV/IO (0.2 mL/kg) over 5 minutes, Max dose of 1 G**

CALCIUM GLUCONATE — **60 mg/kg (Max 3 G)**

DEXTROSE — **0.5 – 1 G/kg (Max 50 G)**
< 1 month: 5-10 mL/kg of 10% Dextrose
> 1 month: 2-4 mL/kg of 25% Dextrose
Adolescent: 1-2 mL/kg of 50% Dextrose

EPINEPHrine — **0.01 mg/kg of 1:10,000 IV/IO** (0.1 mL/kg); Max single dose of 1 mg
0.1 mg/kg of 1:1000 ETT for >28 days (0.1 mL/kg); Max single dose of 2.5 mg
Administer q 4 min in cardiac arrest

GLUCAGON — **< 20 kg: 0.5 mg and patients ≥ 20 kg: 1 mg · IV/IM/SubQ, Max single dose 1 mg**

HYDROCORTISONE — **Shock - 2 mg/kg IV/IO/IM; Max single dose 100 mg**

INSULIN — **0.1 units/kg IV/IO with 0.5 G/kg of dextrose for hyperkalemia**
Max dose of Insulin 10 units; aspart or regular

LIDOCAINE — **1 mg/kg IV/IO, 2 - 3 mg/kg ETT Max dose of 100 mg**
May repeat q 5 minutes to Max total dose 3 mg/kg
Post Resuscitation Infusion: 20 - 50 mcg/kg/min

MAGNESIUM SULFATE — **50 mg/kg, Max dose of 2 G**
If no pulse, push undiluted
If pulse, dilute and give over 20 - 60 minutes, Monitor for hypotension and bradycardia

SODIUM BICARBONATE — (8.4%) - 1 mEq/kg IV/IO
For infants < 10 kg, dilute with equal volume of sterile water
administer only with clear indication

VASOPRESSIN — **0.4 units/kg dose IV/IO; Max dose of 40 units**

ADDITIONAL DRUGS

ALBUMIN — **5% albumin - 0.5 - 1 G/kg (10 - 20 mL/kg);**
25% albumin - 0.5 - 1 G/kg (2 - 4 mL/kg);

CHARCOAL, ACTIVATED — **Initial dose: 1 G/kg PO or gastric tube**
Max dose of 100 G. Contact Poison Control @ 1-800-222-1222

DiphenhydrAMINE — **1 mg/kg IV/IM/PO q 4 hours**
Max total dose 50 mg (contains propylene glycol)

FUROSEMIDE — **1 mg/kg IV/IM q6 - 8 hours; 2 mg/kg PO q6 - 8 hours.**
Max 200 mg IV/day, 600 mg PO/day.

NALOXONE — **Respiratory depression: 0.001-0.005 mg/kg IV/IM/IO/SUBQ,**
May redose, Max dose: 0.1 mg
Full Reversal: 0.1 mg/kg IV/IO/IM/SUBQ; Max dose 2 mg

RANITIDINE — **0.5 - 1 mg/kg IV/IM q 6 - 8 hours, Max dose of 50 mg**

PANEL 5

MEDICATIONS

RESPIRATORY

INHALED BRONCHODILATORS

ALBUTEROL — **<20 kg: 2.5 mg; ≥20 kg: 5 mg, in 3 mL NS nebulized**
May be repeated q 20 mins x 3 or continuous

EPINEPHrine — **Racemic: 0.25 - 0.5 mL of 2.25% solution in 2 mL NS nebulized**
1:1000: 2.5 - 5 mL in 3 mL NS nebulized

IPRATROPIUM — **0.25 - 0.5 mg/dose in 3 mL NS q20min x 3 acute use, then q4-8 hours;**
May be given with albuterol

IM/SubQ AND IV BRONCHODILATORS

IM/SubQ EPINEPHrine — **0.01 mg/kg of 1:1000 (0.01 mL/kg) q 20 minutes x 3**
Max single dose 0.5 mg

IM EPINEPHrine AUTOINJECTOR — **10 - 29 kg: EpiPen Jr. 0.15 mg IM**
≥ 30 kg: EpiPen 0.3 mg IM;
Used for pts with allergic reaction involving ≥ 2 systems
May redose q 5 - 15 min

MAGNESIUM SULFATE — **75 mg/kg IV/IO (Max dose 2 G)**
Give over 20 - 60 minutes. Monitor for hypotension/bradycardia

TERBUTALINE — **Loading dose: 2 - 10 mcg/kg IV over 30 minutes, Max dose of 1 mg**
Initial infusion rate: 0.1 - 0.2 mcg/kg/minute, titrate up in increments of
0.1 - 0.2 mcg/kg/minute every 30 minutes
Max infusion rate: 4 mcg/kg/minute (note doses as high as 10 mcg/kg/min have been used) monitor cardiac enzymes

STEROIDS

DEXAMETHASONE — **0.25 - 0.5 mg/kg/dose IV/IO q6 hours for airway edema (Max dose 10 mg)**
0.6 mg/kg/dose IM/PO for croup (Max dose 16 mg)

MethylPREDNISolone — **Loading dose: 2 mg/kg/dose IV/IM for status asthmaticus**
Max loading dose of 60 mg.
Maintenance: 0.5mg/kg/dose IV/IM q 6 hours up to 5 days
Max maintenance dose 80 mg/day

PrednisoLONE/ PrediniSONE — **2 mg/kg/day PO daily for acute asthma**
Max total dose 80 mg/day

SEDATION AND PAIN MANAGEMENT (Unintubated Patient)**

**Apply O_2, Monitor with $ETCO_2$, Prepare equipment for airway rescue

ACETAMINOPHEN — **10 - 15 mg/kg/dose q 4 - 6 hours PO/PR (Max single dose 650 mg); IV dose**
12.5 mg/kg/dose IV (see reference for further dosing as interval dependent on age)
Contraindicated in patients with known hepatic disease

BARBITUATE — **listed under neuro/seizure and increased ICP sections**

BENZODIAZEPINES — **listed under induction and neuro/seizure sections**

FentaNYL — **0.5 - 1 mcg/kg IV/IO q 30-60 minutes, Max dose 50 mcg.**
Intranasal dosing: 1 - 2 mcg/kg using an atomizer (Max dose 100 mcg);
risk of rigid chest
Give no faster than 1 mcg/kg/minute

HYDROmorphone — **0.015 mg/kg IV q 4 - 6 hrs PRN,** (Max dose 1 mg for opiate naïve patients for IV dosing.) 0.03 - 0.08 mg/kg PO q4 - 6 hrs PRN, (Max dose of 4 mg for opiate naïve patients.)

IBUPROFEN — **10 mg/kg/dose PO q 6 - 8 hrs (Max single dose 800 mg)**
Max dose 40 mg/kg/day
Contraindicated in patients with trauma or bleeding disorder.

KETAMINE — **0.5 - 1 mg/kg IV, Max dose of 150 mg**

KETOROLAC — **0.5 - 1 mg/kg IV/IM q 6-8 hours**
Max single dose 30 mg. Caution with renal insufficiency.
Contraindicated in patients with trauma or bleeding disorder

MORPHINE — **0.05 - 0.1 mg/kg IV/IM/IO/SubQ** Max adult dose 5 mg.

PANEL 6

MEDICATIONS

VASOACTIVE INFUSIONS

DOPamine — **5 - 20 mcg/kg/min**

DOBUTamine — **2 - 20 mcg/kg/min**

EPINEPHrine — **0.01 - 0.2 mcg/kg/min, up to 1 in severe circumstances**

ESMOLOL — **50 - 300 mcg/kg/min**

ISOPROTERENOL — **0.05 - 2 mcg/kg/min**

MILRINONE — **Loading dose: 50 mcg/kg IV over 10-60 minutes**
Infusion: 0.25 - 1 mcg/kg/min
consider dose adjustment with renal dysfunction

NICARDIPINE — **0.5 - 5 mcg/kg/min**

NITROGLYCERIN — **0.5 - 20 mcg/kg/min**

NITROPRUSSIDE — **0.5 - 10 mcg/kg/min; caution cyanide toxicity**

NOREPINEPHRINE — **0.01 - 0.2 mcg/kg/min, up to 1 in severe circumstances**

PHENYLEPHRINE — **Bolus: Usual starting bolus dose 1 mcg/kg and range per effect 1 - 10 mcg/kg; consider up to 30 mcg/kg for Blocked BT shunt or Tet spell); Max single dose of 200 mcg**
Infusion: 0.5 - 5 mcg/kg/minute

VASOPRESSIN — **0.5 - 2 MILLIUnits/kg/min for hypotension;**
0.5 - 10 MILLIUnits/kg/hr for DI

ANTIBIOTICS - FIRST DOSE FREQUENCY DETERMINED BY AGE, INDICATION AND RENAL FUNCTION

ACYCLOVIR — **Dose using IBW; ≤ 12 yrs: 20 mg/kg/dose IV;**
> 12 yrs: 10 mg/kg/dose IV

AMPICILLIN — **25 - 50 mg/kg/dose IV/IM**
50 - 100 mg/kg/dose IV/IM for severe infections.
(Max dose 2 G)

CEFAZOLIN — **25 mg/kg/dose IV (Max dose 2 G)**

CEFEPIME — **50 mg/kg/dose IV (Max dose 2 G)**

CEFOTAXIME — **50 mg/kg/dose (Max dose 2 G)**

CefTRIAXone — **50 - 75 mg/kg/dose IV**
50 mg/kg/dose q12 hours IV/IM for meningitis.
Use with caution in patients with penicillin allergy
Contraindicated in infants < 1 month of age. Do not administer with calcium-containing solutions or products. (Max dose 2 G)

GENTAMICIN — **2.5 mg/kg/dose IV/IM** Infuse over 30 minutes. Obtain peak and trough levels with third dose.
Dose based on Ideal Body Weight (IBW) unless the patient is a neonate or underweight

MEROPENEM — **33 mg/kg/dose IV (Max dose 2 G)**

PIPERACILLIN/ TAZOBACTAM — **Dosing based on piperacillin content. 100 mg/kg/dose IV (Max dose 4 G)**

VANCOMYCIN EMPIRIC DOSING — 15 mg/kg/dose IV/IO
20 mg/kg/dose IV/IO for meningitis, pneumonia, osteomyelitis, and MRSA bacteremia
(Max dose 2 G) Infuse over 60 minutes
Evaluate trough levels in patients with varying renal function

NOTE: Every effort has been made to ensure these drug dosages and procedures are in accordance with accepted standards at time of publication. The user is urged to check the product information sheet included in each medication package, which includes recommended doses, warnings and contraindications. JANUARY 2015

PANEL 7

MEDICATIONS

NEURO/SEIZURES**

**Apply O_2, Monitor with $ETCO_2$, Prepare equipment for airway rescue

DIAZEPAM — **0.05 - 0.1 mg/kg IV/IO q 15 - 30 minutes, 0.2 mg/kg PR**
Max total dose 10 mg

LORazepam — **0.05 - 0.1 mg/kg IV/IO/IM**
Max total dose 4 mg (contains propylene glycol).

MIDAZOLAM — **0.1 mg/kg IV/IO/IM** Max total sedative dose 4 mg.
Intranasal: 0.2 - 0.3 mg/kg/dose Max 10 mg using an atomizer

FOSPHENYTOIN — **Loading dose: 15 - 20 mg phenytoin equivalent (PE)/kg IV/IO/IM**
Max dose of 2 G. Must be diluted for IV/IO administration
Max infusion rate: 3 mg PE/kg/min or 150 mg/min

PHENobarbital — **Loading dose: 15 - 20 mg/kg IV/IO SLOWLY, then 5 mg/kg/dose q 20 minutes until seizures controlled. Max dose 1 G**
Max total dose 30 mg/kg

levETIRAcetam — **Loading dose: 20 mg/kg IV/IO over 15 minutes (Max 1.5 G)**

INCREASED ICP (See PANEL 1 for ICP Management)

HYPERTONIC SALINE — **To↑Na by 5: 2% NaCl/NaHCO3 (buffered saline) – 10 mL/kg;**
2% NaCl – 9 mL/kg; 3% NaCl – 6 mL/kg

MANNITOL — **Initial dose: 0.25 - 1 G/kg IV over 2 minutes, may repeat once**
Must use in-line filter. Larger doses may require a fluid bolus to avoid hypotension

PENTobarbital — **1 - 3 mg/kg IV,** 2 - 6 MG/KG PO/IM/PR
Max dose 100 mg ***total or single dose***

INTUBATION MEDICATIONS

PREMEDICATIONS

ATROPINE — **0.02 mg/kg IV/IO/IM.**
Min dose 0.1 mg Max dose 0.5 mg

GLYCOPYRROLATE — **0.004 mg/kg IV/IM; Max dose 0.1 mg**

LIDOCAINE — **1 mg/kg IV/IO for patient's at risk for increased ICP or bronchospasm**
Max dose 100 mg

INDUCTION AGENTS

ETOMIDATE — **0.3 mg/kg IV/IO for normotensive patient**
0.15 mg/kg IV/IO for hypotensive patient
Max dose 20 mg

FentaNYL — **1 - 2 mcg/kg IV/IO q 30 - 60 minutes Max single dose of 100 mcg**
Give no faster than 1 mcg/kg/min (risk of rigid chest) if occurs, consider naloxone or paralytic with BMV.

KETAMINE — **1 - 2 mg/kg IV/IO; 2 - 5 mg/kg IM.** Max single dose of 150 mg
consider for bronchodilation properties

MIDAZOLAM — **0.05 - 0.1 mg/kg IV/IO** Max single dose of 4 mg

PROPOFOL (Induction Only) — **2 mg/kg IV/IO**

PARALYTICS administration with a sedative is recommended

PANCURONIUM — **0.1 mg/kg dose IV/IO q 30 - 60 minutes, paralyzing dose**
0.01 mg/kg, defasciculating dose

ROCURONIUM — **1.2 mg/kg IV/IO (Max dose 100 mg)**

SUCCINYLCHOLINE — **1 - 2 mg/kg IV/IO (Max 200 mg IV),**
2 - 4 mg/kg IM (Max 150 mg IM - due to limited volume for IM meds)
Can use 4 mg/kg IM to break laryngospasm
Contraindicated in patients with neuromuscular disease and renal failure

VECURONIUM — **0.1 - 0.2 mg/kg IV/IO q 30 - 60 minutes (Max dose 10 mg)**

PANEL 8