The Temporal Association of the COVID-19 Pandemic and Pediatric Cardiopulmonary Resuscitation Quality and Outcomes*

OBJECTIVES: The COVID-19 pandemic resulted in adaptations to pediatric resuscitation systems of care. The objective of this study was to determine the temporal association between the pandemic and pediatric in-hospital cardiac arrest (IHCA) process of care metrics, cardiopulmonary resuscitation (cardiopulmonary resuscitation) quality, and patient outcomes.

DESIGN: Multicenter retrospective analysis of a dataset comprising observations of IHCA outcomes pre pandemic (March 1, 2019 to February 29, 2020) versus pandemic (March 1, 2020 to February 28, 2021).

SETTING: Data source was the ICU-RESUScitation Project ("ICU-RESUS;" NCT028374497), a prospective, multicenter, cluster randomized interventional trial.

PATIENTS: Children (≤ 18 yr) who received cardiopulmonary resuscitation while admitted to the ICU and were enrolled in ICU-RESUS.

INTERVENTIONS: None.

MEASUREMENTS AND MAIN RESULTS: Among 429 IHCAs meeting inclusion criteria, occurrence during the pandemic period was associated with higher frequency of hypotension as the immediate cause of arrest. Cardiac arrest physiology, cardiopulmonary resuscitation quality metrics, and postarrest physiologic and quality of care metrics were similar between the two periods. Survival with favorable neurologic outcome (Pediatric Cerebral Performance Category score 1–3 or unchanged from baseline) occurred in 102 of 195 subjects (52%) during the pandemic compared with 140 of 234 (60%) pre pandemic ($p = 0.12$). Among survivors, occurrence of IHCA during the pandemic period was associated with a greater increase in Functional Status Scale (FSS) (i.e., worsening) from baseline (1 [0–3] vs 0 [0–2]; $p = 0.01$). After adjustment for confounders, IHCA survival during the pandemic period was associated with a greater increase in FSS from baseline (+1.19 [95% CI, 0.35–2.04] FSS points; $p = 0.006$) and higher odds of a new FSS-defined morbidity (adjusted odds ratio, 1.88 [95% CI, 1.03–3.46]; $p = 0.04$).

CONCLUSIONS: Using the ICU-RESUS dataset, we found that relative to the year prior, pediatric IHCA during the first year of the COVID-19 pandemic was associated with greater worsening of functional status and higher odds of new functional morbidity among survivors.

KEY WORDS: cardiac arrest; cardiopulmonary resuscitation; COVID-19; pediatrics

Ryan W. Morgan, MD, MTR[1]
Heather A. Wolfe, MD, MSHP[1]
Ron W. Reeder, PhD[2]
Jessica S. Alvey, MS[2]
Aisha H. Frazier, MD, MPH[3,4]
Stuart H. Friess, MD[5]
Tensing Maa, MD[6]
Patrick S. McQuillen, MD[7]
Kathleen L. Meert, MD[8]
Vinay M. Nadkarni, MD, MS[1]
Matthew P. Sharron, MD[9]
Ashley Siems, MD, MEd[9]
Andrew R. Yates, MD[6]
Tageldin Ahmed, MD[8]
Michael J. Bell, MD[9]
Robert Bishop, MD[10]
Matthew Bochkoris, MD[11]
Candice Burns, MD[5,12]
Joseph A. Carcillo, MD[11]
Todd C. Carpenter, MD[10]
J. Michael Dean, MD[2]
J. Wesley Diddle, MD[9]
Myke Federman, MD[13]
Richard Fernandez, MD[6]
Ericka L. Fink, MD, MS[11]
Deborah Franzon, MD[7]
Mark Hall, MD[6]
David Hehir, MD MS[1,14]
Christopher M. Horvat, MD[11]
Leanna L. Huard, MD[13]
Arushi Manga, MD[5]
Peter M. Mourani, MD[10]
Maryam Y. Naim, MD, MSCE[1]
Daniel Notterman, MD[15]
Murray M. Pollack, MD[9]
Anil Sapru, MD[13]
Carleen Schneiter, MD[10]
Nerraj Srivastava, MD[13]
Sarah Tabbutt, MD, PhD[7]
Bradley Tilford, MD[8]
Shirley Viteri, MD[14]
David Wessel, MD[9]
Athena F. Zuppa, MD[1]
Robert A. Berg, MD[1]
Robert M. Sutton, MD, MSCE[1]

*See also p. 949.

As of March 2022, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus causing COVID-19, has infected nearly 450 million people and caused more than 6 million deaths (1). Although children have lower rates of critical illness and mortality from COVID-19 (2, 3),

RESEARCH IN CONTEXT

- The COVID-19 pandemic led to changes in the delivery of resuscitation care for children with in-hospital cardiac arrest (IHCA).

- The association of the pandemic and these changes with pediatric IHCA outcomes is unknown.

- This study used a dataset from the ICU-RESUS clinical trial to describe the temporal association between the first year of the COVID-19 pandemic and pediatric IHCA characteristics and outcomes.

as many as 30% of children hospitalized with COVID-19 require ICU admission (4). Beyond the provision of care to COVID-19 patients, the pandemic itself widely influenced pediatric institutions and clinicians and pediatric emergency and critical care systems in particular (5–7).

In children with COVID-19, in-hospital cardiac arrest (IHCA) presents both clinical challenges and a public health problem (8–10). Limited pediatric data suggest that children with COVID-19 and IHCA are less likely to achieve return of spontaneous circulation than those without COVID-19 (11). Furthermore, the COVID-19 pandemic has created the impetus for adaptations to resuscitation systems of care. Early in the pandemic, the American Heart Association (AHA) provided interim guidance for the resuscitation of children and infants with confirmed or suspected COVID-19 that aimed to preserve cardiopulmonary resuscitation (CPR) quality while mitigating the risk of SARS-CoV-2 transmission to healthcare providers (10). In an April 2020 survey of 78 U.S. pediatric hospitals, most had implemented substantial changes to their in-hospital resuscitation systems in response to the pandemic with greater focus on protecting providers, which could potentially impair resuscitation performance (7). The association between these widespread resuscitation system changes and pediatric IHCA outcomes and CPR quality during the COVID-19 pandemic is unknown. To address this knowledge gap, we performed a secondary retrospective analysis of data leveraged from a prospective, multicenter,

cluster-randomized interventional trial (The ICU-RESUScitation Project [ICU-RESUS]; NCT02837497) (12, 13). Our objective was to compare pediatric IHCA outcomes and CPR quality metrics in the first year of the COVID-19 pandemic to the year prior to the pandemic. We hypothesized that survival rates would be lower during the pandemic. Additionally, we hypothesized that outcomes would be particularly poor early in the pandemic and therefore conducted an exploratory analysis comparing the prepandemic, early pandemic, and later pandemic periods.

MATERIALS AND METHODS

Setting and Design

The ICU-RESUS study was a multicenter, parallel, hybrid stepped-wedge cluster-randomized trial evaluating a two-part quality improvement bundle of physiology-directed point-of-care training and structured postresuscitation event debriefing compared with usual care (12, 13). It was conducted in 18 pediatric and pediatric cardiac ICUs at 10 clinical sites in the United States. Eight sites (15 ICUs) were member sites of the Collaborative Pediatric Critical Care Research Network, a *Eunice Kennedy Shriver* National Institute of Child Health and Human Development–funded research collaborative; two additional sites (three ICUs) were recruited prior to the study's commencement to meet enrollment goals. The University of Utah Institutional Review Board (IRB) served as the central IRB and approved the ICU-RESUS study protocol with waiver of informed consent (protocol IRB_00093320). An independent data safety and monitoring board appointed by the National Heart, Lung, and Blood Institute (NHLBI) provided regulatory oversight.

Patient Population

In the original ICU-RESUS study, subjects were included if they were less than or equal to 18 years old and greater than or equal to 37 weeks corrected gestational age and received chest compressions of any duration while admitted to one of the 18 participating ICUs. Subjects were excluded if, prior to the arrest, they: 1) were not expected to survive the hospitalization due to a terminal illness (e.g., patients transferred to the ICU for end-of-life care) or had a documented lack of commitment to aggressive ICU therapies; 2)

were brain dead; or 3) had an out-of-hospital cardiac arrest associated with the current hospitalization. The overall ICU-RESUS trial enrolled patients from October 1, 2016, to March 31, 2021 and included only index IHCA events for a given hospitalization. For the purposes of this secondary retrospective study, subjects were included if their cardiac arrest occurred between March 1, 2019, and February 28, 2021.

Data Collection

The ICU-RESUS study used trained research coordinators at each site, who collected standard cardiac arrest and CPR data elements consistent with the Utstein Resuscitation Registry Template for IHCA (14, 15). As a component of the ICU-RESUS study, physiologic waveforms were collected for patients with invasive arterial blood pressure data available. These waveforms were reviewed and analyzed by blinded investigators (R.W.M., R.M.S.) at the Children's Hospital of Philadelphia as previously described (13, 16, 17).

Outcomes and Statistical Analysis

Subjects were categorized according to the date of their CPR event as "pre pandemic" (March 1, 2019—February 29, 2020) or "pandemic" (March 1, 2020 to February 28, 2021). The primary outcome was survival to hospital discharge with favorable neurologic outcome, defined as a Pediatric Cerebral Performance Category (PCPC) score of less than or equal to 3 or no worse than baseline (18–20). Secondary survival outcomes were as follows: 1) immediate CPR event outcome (sustained return of spontaneous circulation greater than or equal to 20 minutes, return of circulation via extracorporeal CPR, or death); 2) survival to hospital discharge; 3) Functional Status Scale (FSS) score at hospital discharge among survivors; 4) new morbidity among survivors, defined as an increase in FSS score by greater than or equal to 3 (21); 5) change in FSS from baseline among survivors; and 6) an alternative definition of survival to discharge with favorable neurologic outcome (PCPC score of ≤ 2 or no worse than baseline) (20). Resuscitation quality and process of care metrics included the following: 1) event-level average diastolic blood pressure (DBP) and systolic blood pressure (SBP) during CPR among subjects with invasive arterial BP data; 2) frequency of average DBP and SBP values meeting predefined

age-based targets (16); 3) end-tidal carbon dioxide ($ETco_2$) values among patients with $ETco_2$ monitoring in place; 4) chest compression rate, depth, and fraction; 5) duration of cardiac arrest prior to commencement of CPR; and 6) metrics of postarrest physiology and quality of care (22, 23) among patients achieving return of circulation.

Categorical variables were summarized as counts and percentages and were compared between the prepandemic and pandemic groups using Fisher exact test. Continuous variables were summarized as medians (Q1–Q3) and compared between groups using the Wilcoxon rank-sum test.

Logistic and linear regression models were designed a priori to control for confounders with established associations with pediatric IHCA outcomes (age category, initial CPR rhythm, timing of CPR [weekday or night/weekend], and illness category), as well as treatment group (ICU-RESUS bundle vs control). Any survival outcomes and CPR physiology and quality outcomes with p values of less than 0.10 on univariate comparison between the prepandemic and pandemic were then evaluated using these multivariable models.

To evaluate the hypothesis that the initial months of the COVID-19 pandemic would be associated with inferior cardiac arrest outcomes, an exploratory analysis compared characteristics and outcomes among three groups: 1) pre pandemic (March 1, 2019 to February 29, 2020); 2) early pandemic (March 1, 2020 to May 31, 2020); and 3) later pandemic (June 1, 2020 to February 28, 2021). Categorical variables were compared with Fisher exact test and continuous variables were compared using the Kruskal-Wallis test. All analyses were performed with SAS Version 9.4 (SAS Institute, Cary, NC), and two-sided p values of less than 0.05 were considered statistically significant. No adjustments were made for multiple comparisons between groups.

RESULTS:

A total of 429 children with IHCAs (234 in the prepandemic period and 195 in the pandemic period) met study criteria and were included in the final cohort. Patient demographics and prearrest characteristics are compared between groups in **Supplemental Table 1** (http://links.lww.com/PCC/C194) and **Table 1**, respectively. In this population, IHCAs in the pandemic period cohort were associated with greater frequency of

hypotension as a preexisting condition prior to IHCA (65.6% vs 51.3%; difference: 14.3% [95% CI, 5.1–23.6]; $p = 0.003$). We did not identify other significant associations in demographic or patient characteristics between the groups. Cardiac arrest event characteristics are detailed in **Table 2**. The pandemic period was associated with IHCAs occurring less frequently on weeknights and more frequently on weekends. Also, there was an association between hypotension as the

immediate cause of arrest (pandemic vs pre pandemic: 55.9% vs 45.3%; difference: 10.6% [95% CI, 1.2–20.1]; $p = 0.03$). Cardiac arrest physiology, chest compression mechanics, and CPR quality metrics are detailed in **Table 3**, and postarrest physiologic and quality of care metrics are detailed in **Supplemental Table 2** (http:// links.lww.com/PCC/C195). Of note, resuscitation during the pandemic period was associated with higher values of the lowest recorded postarrest arterial Pco_2

TABLE 1.
Prearrest Patient Characteristics

Patient Characteristics	Pre Pandemic (N = 234)	Pandemic (N = 195)	p
Preexisting medical conditions, n (%)			
Respiratory insufficiency	199 (85.0)	162 (83.1)	0.60
Hypotension	120 (51.3)	128 (65.6)	0.003
Congestive heart failure	28 (12.0)	28 (14.4)	0.48
Pneumonia	31 (13.2)	19 (9.7)	0.29
Sepsis	38 (16.2)	20 (10.3)	0.09
Trauma	4 (1.7)	10 (5.1)	0.06
Renal insufficiency	28 (12.0)	31 (15.9)	0.26
Malignancy	14 (6.0)	6 (3.1)	0.17
Pulmonary hypertension	28 (12.0)	32 (16.4)	0.21
Congenital heart disease	125 (53.4)	117 (60.0)	0.20
Preevent characteristics			
Illness category, n (%)			0.09
Medical cardiac	64 (27.4)	53 (27.2)	
Medical noncardiac	94 (40.2)	58 (29.7)	
Surgical cardiac	62 (26.5)	64 (32.8)	
Surgical noncardiac	10 (4.3)	11 (5.6)	
Trauma	4 (1.7)	9 (4.6)	
Interventions in place prior to event, n (%)			
Central venous catheter	146 (62.4)	137 (70.3)	0.10
Vasoactive infusion	105 (44.9)	102 (52.3)	0.15
Invasive mechanical ventilation	158 (67.5)	134 (68.7)	0.84
Non-invasive ventilation	46 (19.7)	35 (17.9)	0.71
End-tidal CO_2 monitoring, n (%)	148 (63.2)	121 (62.1)	0.84
Pediatric Risk of Mortality[a], median (interquartile range)	3.0 (0.0–9.0)	4.0 (0.0–10.0)	0.25
Vasoactive Inotropic Score[b], median (interquartile range)	0.0 (0.0–5.5)	0.0 (0.0–7.5)	0.14
Cardiac arrest location, n (%)			0.50
PICU	119 (50.9)	92 (47.2)	
Pediatric cardiac ICU	115 (49.1)	103 (52.8)	

[a]Pediatric Risk of Mortality evaluated 2–6 hr prior to cardiac arrest.
[b]Vasoactive Inotropic Score evaluated 2 hr prior to cardiac arrest.

TABLE 2.
Cardiac Arrest Characteristics

Cardiac Arrest Characteristic	Pre Pandemic (*N* = 234)	Pandemic (*N* = 195)	*p*
Immediate cause(s) of event, *n* (%)			
Arrhythmia	40 (17.1)	25 (12.8)	0.23
Cyanosis without respiratory decompensation	9 (3.8)	10 (5.1)	0.64
Hypotension as immediate cause of event	106 (45.3)	109 (55.9)	0.03
Respiratory decompensation	129 (55.1)	97 (49.7)	0.29
Duration of CPR (min), median (interquartile range)	5.0 (2.0–27.0)	5.0 (2.0–23.0)	0.89
Duration of CPR (min), *n* (%)			0.89
< 6	118 (50.4)	100 (51.3)	
6–15	42 (17.9)	34 (17.4)	
16–35	29 (12.4)	28 (14.4)	
> 35	45 (19.2)	33 (16.9)	
CPR timing, *n* (%)[a]			0.005
Weekday	130 (55.6)	103 (52.8)	
Weeknight	53 (22.6)	26 (13.3)	
Weekend	51 (21.8)	66 (33.8)	
Pharmacologic interventions during event			
Epinephrine, *n* (%)	174 (74.4)	154 (79.0%)	0.30
Minutes to first dose[b], median (interquartile range)	1.0 (0.0–2.0)	1.0 (0.0–2.5)	0.76
Number of doses[b], median (interquartile range)	2.5 (1.0–7.0)	2.0 (1.0–5.0)	0.11
Average interval between doses[c], median (interquartile range)	4.1 (3.1–6.0)	4.5 (3.3–7.0)	0.19
Atropine, *n* (%)	23 (9.8)	12 (6.2)	0.22
Calcium, *n* (%)	93 (39.7)	76 (39.0)	0.92
Sodium bicarbonate, *n* (%)	103 (44.0)	86 (44.1)	> 0.99
Vasopressin, *n* (%)	4 (1.7)	2 (1.0)	0.69
Amiodarone, *n* (%)	8 (3.4)	5 (2.6)	0.78
Lidocaine, *n* (%)	9 (3.8)	8 (4.1)	> 0.99
Fluid bolus, *n* (%)	52 (22.2)	42 (21.5)	0.91
First documented rhythm, *n* (%)			0.13
Pulseless electrical activity/ asystole	99 (42.3)	95 (48.7)	
Ventricular fibrillation/ tachycardia	15 (6.4)	18 (9.2)	
Bradycardia with poor perfusion	120 (51.3)	82 (42.1)	

CPR = cardiopulmonary resuscitation.

[a]Weekday is between 7 AM and 11 PM Monday to Friday; weeknight is after 11 PM Monday to Thursday; weekend is from 11 PM on Friday through 7 AM on the following Monday.

[b]Only calculated among subjects with at least one dose of epinephrine.

[c]Only calculated among subjects with at least two doses of epinephrine.

TABLE 3.
Intraarrest Physiologic and Quality-of-Care Metrics

Measurement	Pre Pandemic (N = 234)	Pandemic (N = 195)	p
Timing of CPR interventions			
Pre-CPR arrest duration (s)[a], median (interquartile range)	27.1 (0.3–81.1)	27.0 (0.9–67.3)	0.94
Pre-CPR arrest duration < 30 s, n (%)[a]	42 (17.9)	36 (18.5)	0.87
Time from pulselessness to delivery of defibrillation (min)[b], median (interquartile range)	0.0 (0.0–2.0)	1.0 (0.0–4.0)	0.06
CPR physiology			
Average DBP (mm Hg), median (interquartile range)	38 (31–54)	43 (31–53)	0.64
Adequate DBP, n (%)[c]	72/80 (90.0)	64/72 (88.9)	> 0.99
Average SBP (mm Hg), median (interquartile range)	83 (62–115)	82 (62–106)	0.37
Adequate SBP, n (%)[d]	62/79 (78.5)	50/70 (71.4)	0.35
Average $ETco_2$ (mm Hg), median (interquartile range)	20 (14–29)	24 (15–34)	0.18
Average $ETco_2$ ≥ 20 mm Hg, n (%)	37/70 (52.9)	42/71 (59.2)	0.50
CPR mechanics			
Chest compression rate (per min), median (interquartile range)	116 (107–125)	118 (110–125)	0.58
Target chest compression rate, n (%)[e]	52/105 (49.5)	55/97 (56.7)	0.33
Chest compression fraction, median (interquartile range)	0.97 (0.91–1.00)	0.95 (0.87–1.00)	0.27
Adequate chest compression fraction, n (%)[f]	81/105 (77.1)	62/96 (64.6)	0.06
Average chest compressiondepth (mm), median (interquartile range)	37.3 (27.2–51.0)	41.8 (28.3–64.9)	0.57
Ventilation rate during CPR (breaths/min), median (interquartile range)	30 (23–35)	26.2 (22–37)	0.33

CPR = cardiopulmonary resuscitation, DBP = diastolic blood pressure, $ETco_2$ = end-tidal carbon dioxide, SBP = systolic blood pressure.
[a]Time from pulselessness to onset of CPR among subjects with evaluable physiologic waveforms.
[b]Only calculated among subjects who received at least one defibrillation attempt.
[c]Average DBP ≥ 25 mm Hg for age < 1 yr or ≥ 30 mm Hg for age ≥ 1 yr.
[d]Average SBP ≥ 60 mm Hg for age < 1 yr or ≥ 80 mm Hg for age ≥ 1 yr.
[e]Average chest compression rate 100–120 compressions per minute.
[f]Average chest compression fraction > 0.90.
All CPR physiology, mechanics, and ventilation rate values represent event-level averages for each patient, generated by averaging data from 30-s data epochs throughout CPR.

value. We did not identify other differences in these measurements between the prepandemic and pandemic periods.

Univariable outcome analyses are summarized in **Table 4**. Survival to hospital discharge with favorable neurologic outcome occurred in 102 of 195 subjects (52.3%) during the pandemic as compared with 140 of 234 subjects (59.8%) pre pandemic (difference: −7.5% [95% CI, −16.9 to 1.9]; p = 0.12). We did not identify any differences in immediate event outcomes, rates of survival to hospital discharge, total FSS score at discharge, or PCPC at discharge. Among survivors, IHCA in the pandemic period was associated with a greater increase (i.e., worsening) in FSS score from baseline (pandemic vs pre pandemic: 1 [0–3] vs 0 [0–2]; p = 0.01). After adjustment for confounders, survival in the pandemic period remained associated with a greater increase in FSS score from baseline (+1.19 [95% CI, 0.35–2.04] FSS points; p = 0.006) and was associated with greater odds of new morbidity (adjusted odds ratio, 1.88 [95% CI, 1.03–3.46]; p = 0.04).

TABLE 4.
Patient Outcomes

Outcomes	Pre Pandemic (*N* = 234)	Pandemic (*N* = 195)	*p*
Immediate outcome of cardiopulmonary resuscitation event, *n* (%)			0.60
Return of spontaneous circulation ≥ 20 min	169 (72.2)	132 (67.7)	
Transitioned to extracorporeal membrane oxygenation	44 (18.8)	43 (22.1)	
Died	21 (9.0)	20 (10.3)	
Survival to hospital discharge, *n* (%)	146 (62.4)	113 (57.9)	0.37
Survival to hospital discharge with favorable neurologic outcome, *n* (%)[a]	140 (59.8)	102 (52.3)	0.12
Survival to hospital discharge with favorable neurologic outcome (alternate definition), *n* (%)[b]	132 (56.4)	94 (48.2)	0.10
Total FSS score at hospital discharge, median (interquartile range)	9 (6–13)	9 (8–14)	0.09
Pediatric Cerebral Performance Category score at hospital discharge, *n* (%)			0.36
1–Normal	63 (26.9)	49 (25.1)	
2–Mild disability	40 (17.1)	28 (14.4)	
3–Moderate disability	19 (8.1)	15 (7.7)	
4–Severe disability	22 (9.4)	20 (10.3)	
5–Coma/vegetative state	2 (0.9)	1 (0.5)	
6–Death	88 (37.6)	82 (42.1)	
Change in FSS score from baseline to hospital discharge (survivors only), median (interquartile range)	0 (0–2)	1 (0–3)	0.01
New morbidity[c] (survivors only), *n* (%)	28 (19.2)	34 (30.1)	0.06

FSS = Functional Status Scale.

[a]Survival to hospital discharge with Pediatric Cerebral Performance Category (PCPC) score 1–3 or unchanged from baseline.

[b]Survival to hospital discharge with PCPC score 1–2 or unchanged from baseline.

[c]Increase (worsening) from baseline FSS by 3 points or more.

The exploratory analysis comparing prepandemic, early pandemic, and later pandemic periods is shown in **Supplemental Table 3** (http://links.lww.com/PCC/C196).

DISCUSSION

During the first year of the COVID-19 pandemic, we failed to identify a statistically significant difference in pediatric IHCA event outcomes and hospital survival rates compared with the year prior in patients enrolled in the ICU-RESUS clinical trial. Similarly, metrics of CPR quality and postarrest care were not demonstrably different. However, there was an association with worse functional status at hospital discharge, relative to baseline, among cardiac arrest survivors during the pandemic compared with those who survived to discharge during the year prior. These data provide

insights into pediatric IHCA outcomes during the COVID-19 pandemic.

Regarding the primary outcome of this study—survival to hospital discharge with favorable neurologic outcome—we failed to identify a difference between the prepandemic and pandemic periods. Similarly, we did not observe statistically significant differences in the secondary survival outcomes of immediate event outcome and survival to hospital discharge. Importantly, this study lacked the statistical power to detect this potentially clinically meaningful difference between groups, as it used a convenience sample from a prospective trial. Survival with favorable neurologic outcome was observed in 60% of patients pre pandemic versus 52% post pandemic with a 95% CI for the absolute difference between periods ranging from −16.9% to +1.9%. Thus, we cannot exclude the possibility of a clinically meaningful reduction in rates of

AT THE BEDSIDE

- This study identified an association between the first year of the COVID-19 pandemic with worse functional status among survivors at hospital discharge compared with the year prior.

- We did not find statistically significant temporal differences in survival rates, although this may have been limited by statistical power.

- These findings provide insights into pediatric IHCA outcomes during the COVID-19 pandemic.

neurologically intact survival in the pandemic cohort compared with the prepandemic cohort. Alternatively, our findings may suggest that initial adaptations and strategies, which were largely aimed at securing provider safety, did not affect outcomes to a great extent. It is possible that ICU teams were able to generally preserve the prepandemic quality of care delivered to cardiac arrest patients during the pandemic. This may have been particularly feasible at the large, academic, and generally well-resourced ICUs included in the parent trial. Importantly, although the PCPC score employed to define the primary outcome is a standard for cardiac arrest research (20), it represents a subjective assessment of brain function and lacks granularity in detecting neurofunctional morbidity (18, 20).

When the FSS score, a measure of functional status at hospital discharge (21, 24), was used to detect morbidity among survivors, we observed that IHCA during the pandemic was associated with more substantial worsening in overall functional status from baseline and a higher odds of a new functional morbidity. We initially hypothesized that outcome differences would be more pronounced in the early pandemic period, during the height of pandemic-related strain and rapid system changes. In contrast, the observed differences in functional outcomes were actually more evident in the later pandemic period. This may implicate the resuscitation system changes that were not yet implemented in the earliest stages of the pandemic. It also raises the possibility that ICU providers and teams were able to navigate the pressures of the early pandemic but that clinician burnout or fatigue, changes in

workforce composition, or a host of other cumulative pandemic effects then exerted negative consequences (5, 25–29), although this is purely speculative in the absence of specific data. Although there were minimal differences in the documented patient characteristics between periods, prearrest hypotension was more common during the pandemic, which may reflect later rescue of deteriorating patients in the setting of altered care environments. Although additional differences in patient characteristics were not identified in this study, previous studies have reported substantial changes in PICU admission rates and differences inpatient diagnoses (e.g., decreased viral respiratory illnesses resulting in PICU admission) during this same period of the pandemic (30, 31). It is therefore possible that there were additional unmeasured pandemic-related differences in the types of patients that required CPR during this time, which could have played a role in the findings of differential functional status outcomes.

Chest compression rate and depth, intraarrest hemodynamics, time from pulselessness to CPR, chest compression fraction (the proportion of the cardiac arrest during which chest compressions were being provided), and other CPR quality metrics were similar between the prepandemic and pandemic periods. These findings of preserved CPR quality are striking because of the widespread resuscitation practice adaptations enacted by American children's hospitals early in the pandemic. Of 78 institutions surveyed in April 2020, 71 (91%) had changed their inpatient emergency response systems because of the pandemic. Most did so specifically for confirmed or suspected COVID-19 patients, but 27 (38%) made changes to existing protocols for all patients (7). As these alterations principally focused on protecting providers, we hypothesized that they might adversely influence the quality of resuscitation care provided at the bedside, but we did not observe such decrements in CPR quality. A particularly notable observation is that the donning of personal protective equipment and alterations to the complement of providers at the bedside did not perceivably delay the initiation of CPR during the pandemic. This may reflect the establishment of systems within these ICUs to ensure that care delivery was maintained despite the prioritization of healthcare worker safety. For example, the ICUs may have used tools reported to be implemented in other studies, including simulation, preemptive role assignment, and use of ancillary

technologies (7). Our data additional suggest that clinicians did not demonstrate hesitancy in initiating high-quality CPR for children when it was indicated.

The setting for this study should be considered in interpreting our findings. The ICU-RESUS trial was conducted in ICUs at large academic children's hospitals. The resources and experience of these centers may have blunted the potential adverse effects of the pandemic on the care of critically ill children. Alternatively, as busy referral centers, these institutions may have been more predisposed to the systematic stresses of the pandemic. The ICU-RESUS trial itself may have also influenced the relationship between the pandemic and CPR quality and outcomes. During the study period, most centers were enrolled in the trial's resuscitation quality improvement bundle, which may have facilitated high-quality resuscitation care despite systems challenges. Notably, most sites rapidly transitioned the cardiac arrest debriefing portion of the ICU-RESUS bundle to virtual settings in response to the pandemic, such that some of the potential positive influence of the intervention remained. The 60% survival to discharge rate observed during this 2-year period is higher than that previously reported in studies of CPR in ICU patients (16, 32) and suggests that these ICUs are high performing in this clinical area. Further observational studies should address the impact of the COVID-19 pandemic on PICU care across broader, more diverse settings.

This study has limitations. First, the observational nature of this study allows us to identify associations, but we cannot attribute causality of our findings to the pandemic. Second, this is a secondary study of a larger clinical trial. Data collection was limited to that designed for the primary trial, and COVID-specific data were not collected. However, the prospective nature of patient identification and data collection provides significant advantages over typical observational resuscitation registry studies. Third, the aforementioned nature of the study centers may limit the extrapolation of these findings to other types of hospitals.

CONCLUSIONS

In this retrospective observational study, pediatric IHCA survival rates were not demonstrably different in the first year of the COVID-19 pandemic compared with the year prior. However, children surviving to hospital discharge experienced greater worsening in functional outcome from baseline.

1   Department of Anesthesiology and Critical Care Medicine, Children's Hospital of Philadelphia, University of Pennsylvania School of Medicine, Philadelphia, PA.

2   Department of Pediatrics, University of Utah, Salt Lake City, UT.

3   Cardiac Center, Nemours/Alfred I. duPont Hospital for Children, Wilmington, DE.

4   Department of Pediatrics, Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, PA.

5   Department of Pediatrics, Washington University School of Medicine, St. Louis, MO.

6   Department of Pediatrics, Nationwide Children's Hospital, The Ohio State University, Columbus, OH.

7   Department of Pediatrics, Benioff Children's Hospital, University of California San Francisco, San Francisco, CA.

8   Department of Pediatrics, Children's Hospital of Michigan, Central Michigan University, Detroit, MI.

9   Department of Pediatrics, Children's National Hospital, George Washington University School of Medicine, Washington, DC.

10 Department of Pediatrics, University of Colorado School of Medicine and Children's Hospital Colorado, Aurora, CO.

11 Department of Critical Care Medicine, UPMC Children's Hospital of Pittsburgh, University of Pittsburgh, Pittsburgh, PA.

12 Department of Pediatrics and Human Development, Michigan State University College of Human Medicine, Grand Rapids, MI.

13 Department of Pediatrics, Mattel Children's Hospital, University of California Los Angeles, Los Angeles, CA.

14 Department of Pediatrics, Nemours/Alfred I. duPont Hospital for Children and Thomas Jefferson University, Wilmington, DE.

15 Department of Molecular Biology, Princeton University, Princeton, NJ.

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