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Compression-Only Versus Rescue-Breathing Cardiopulmonary Resuscitation After Pediatric Out-of-Hospital Cardiac Arrest

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ABSTRACT

BACKGROUND There are conflicting data regarding the benefit of compression-only bystander cardiopulmonary resuscitation (CO-CPR) compared with CPR with rescue breathing (RB-CPR) after pediatric out-of-hospital cardiac arrest (OHCA).

OBJECTIVES This study sought to test the hypothesis that RB-CPR is associated with improved neurologically favorable survival compared with CO-CPR following pediatric OHCA, and to characterize age-stratified outcomes with CPR type compared with no bystander CPR (NO-CPR).

METHODS Analysis of the CARES registry (Cardiac Arrest Registry to Enhance Survival) for nontraumatic pediatric OHCAs (patients aged ≤18 years) from 2013-2019 was performed. Age groups included infants (<1 year), children (1 to 11 years), and adolescents (≥12 years). The primary outcome was neurologically favorable survival at hospital discharge.

RESULTS Of 13,060 pediatric OHCAs, 46.5% received bystander CPR. CO-CPR was the most common bystander CPR type. In the overall cohort, neurologically favorable survival was associated with RB-CPR (adjusted OR: 2.16; 95% CI: 1.78-2.62) and CO-CPR (adjusted OR: 1.61; 95% CI: 1.34-1.94) compared with NO-CPR. RB-CPR was associated with a higher odds of neurologically favorable survival compared with CO-CPR (adjusted OR: 1.36; 95% CI: 1.10-1.68). In age-stratified analysis, RB-CPR was associated with better neurologically favorable survival versus NO-CPR in all age groups. CO-CPR was associated with better neurologically favorable survival compared with NO-CPR in children and adolescents, but not in infants.

CONCLUSIONS CO-CPR was the most common type of bystander CPR in pediatric OHCA. RB-CPR was associated with better outcomes compared with CO-CPR. These results support present guidelines for RB-CPR as the preferred CPR modality for pediatric OHCA. (J Am Coll Cardiol 2021;78:1042–1052) © 2021 by the American College of Cardiology Foundation.

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Survival following out-of-hospital cardiac arrest (OHCA) among children remains poor with <10% surviving to hospital discharge in most communities (1). Bystander cardiopulmonary resuscitation (CPR) is associated with better survival in children following OHCA (1). Compression only-cardiopulmonary resuscitation (CO-CPR) appears to be as effective as conventional CPR with rescue breathing (RB-CPR) for adults with OHCA. Therefore, since 2010, the American Heart Association (AHA) and European Resuscitation Council have recommended CO-CPR for untrained lay rescuers and those unwilling to perform rescue breaths for adults with OHCA (2-7). However, CO-CPR may be less effective for children whose OHCAs are most commonly from asphyxia (8,9). Therefore, the AHA and European Resuscitation Council recommend RB-CPR for pediatric OHCA instead of CO-CPR. However, if a bystander is unable to perform rescue breathing, CO-CPR is recommended, which is preferable to no bystander-cardiopulmonary resuscitation (NO-CPR) (10-12).

In the United States, national and statewide efforts have focused on teaching CO-CPR to improve bystander CPR rates, and currently, CO-CPR training is mandated for high school graduates in 39 states and the District of Columbia (2,13). Although these efforts have increased bystander CPR rates and survival in adult OHCA (2), the impact on pediatric OHCA is unknown. The objectives of this study were to test the hypothesis that RB-CPR is associated with improved neurologically favorable survival following pediatric OHCA compared with CO-CPR and to characterize age-stratified outcomes with these 2 types of CPR compared with no bystander CPR.

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METHODS

CARDIAC ARREST REGISTRY TO ENHANCE SURVIVAL. Because of the sensitive nature of the data collected for this study, requests to access the dataset from qualified researchers trained in human subject confidentiality protocols may be sent to CARES (Cardiac Arrest Registry to Enhance Survival). A secondary data analysis of the CARES database was conducted. The CARES registry was established by the Centers for Disease Control and Prevention in collaboration with the Department of Emergency Medicine at the Emory University School of Medicine. The CARES registry includes an overall catchment area of nearly 145 million people in 28 states across the United States. CARES is an emergency medical services (EMS)-based registry for OHCA, composed of a limited standard set of data elements from 3 sources: 911 call centers, EMS providers, and receiving hospitals (14). Responding EMS providers were defined as personnel (emergency medicine technicians and paramedics) who respond to the medical emergency in an official capacity (ie, respond to the 911 call) as part of an organized medical response team and were the designated transporter of the patient to the hospital. Detailed information on the design and development of this registry, as well as the data elements included in the registry, is published elsewhere (15).

CARES analysts confirmed the capture of all cardiac arrests by each community's 911 center during the data review process. Cerebral performance category information was obtained from receiving hospitals. The CARES registry established a point of contact at each participating hospital and trained the contact on CARES hospital element definitions and the data entry process. The local hospital contact abstracted information from the patient's medical record and entered data. All data were entered using a web-based platform, and an Excel file (Microsoft Corporation) was generated with all cardiac arrest events for the specified date range.

STUDY SAMPLE. All pediatric cases ≤18 years of age with nontraumatic OHCA submitted to the registry during the study period were eligible for inclusion. From January 1, 2013, through December 31, 2019, CARES captured all 911-activated nontraumatic cardiac arrest events, defined as apnea and unresponsiveness in which resuscitation with either CPR or defibrillation was attempted. Children with obvious signs of death (eg, rigor mortis or dependent lividity) or for whom a "do not resuscitate" order was respected were not included. Standardized international Utstein definitions for defining clinical variables and outcomes were used to ensure uniformity in reporting (16). Because the etiology of cardiac arrest in children is difficult to determine, especially in cases that result in death, all nontraumatic cases were included regardless of presumed etiology, including respiratory, cardiac, drowning, electrocution, or other. Arrests that occurred in medical facilities or nursing homes, traumatic arrests, arrests with rescue-breathing only, and 911 responder-witnessed arrests were excluded from the analysis. This study was approved by the Institutional Review Boards at both Emory University and The Children's Hospital of Los Angeles. Given the use of deidentified data, the

ABBREVIATIONS AND ACRONYMS

AED = automated external defibrillator

AHA = American Heart Association

CO-CPR = compression only-cardiopulmonary resuscitation

CPR = cardiopulmonary resuscitation

EMS = emergency medical services

NO-CPR = no bystander-cardiopulmonary resuscitation

OHCA = out-of-hospital cardiac arrest

RB-CPR = cardiopulmonary resuscitation with rescue breathing study was determined to be exempt from Institutional Review Board review by the Children's Hospital of Philadelphia.

VARIABLES OF INTEREST AND STUDY OUTCOME. Patient characteristics obtained from the database included age, sex, race/ethnicity, bystander witness status, arrest location, initial rhythm, automated external defibrillator (AED) use, and region of arrest. Race/ethnicity were evaluated to identify whether CPR provision was influenced by race. Race was assigned as considered by the child, family, or 911 emergency responder. The race category included White, Black, Hispanic/Latino, other (American-Indian/Alaska, Asian, and Native-Hawaiian/Pacific), and unknown. Age groups included infants (<1 year), children (1 to 11 years), and adolescents (≥12 years). Bystander CPR was defined as CPR administered by a layperson defined as lay family member, layperson, or layperson with medical training (ie, physicians, nurses, or paramedics that were not part of the organized emergency medical response). RB-CPR was defined as CPR with chest compressions and rescue breaths. CO-CPR was defined as CPR with chest compressions only.

The primary outcome of interest was neurologically favorable survival, defined as a cerebral performance category score of 1 (no neurologic disability) or 2 (moderate disability) at the time of discharge (17). Neurologically unfavorable survival was defined as a cerebral performance category score of 3 (severe disability), or 4 (coma or vegetative state) or death.

STATISTICAL ANALYSIS. Descriptive analyses report overall child and arrest characteristics, characteristics for arrests that had bystander and NO-CPR, and characteristics for arrests that had RB-CPR and CO-CPR. Pearson's chi-square testing was used to compare baseline characteristics between CPR groups and to describe the percentage of arrests with neurologically favorable survival. Temporal trends across years were analyzed using the nonparametric test for trend (nptrend in STATA software). Logistic regression models with robust standard errors were used to examine the associations of the predictors with the probability of neurologically favorable survival. The analysis was adjusted for potential confounders including year of arrest, age, sex, race/ethnicity, bystander witness status, arrest location, rhythm, AED use before EMS arrival, and region. Further analyses examined whether neurologically favorable survival differed across bystander CPR type within each age group. Stratified logistic regressions are presented for each age group, with neurologically favorable survival as the outcome, adjusting for covariates as described in the preceding text.

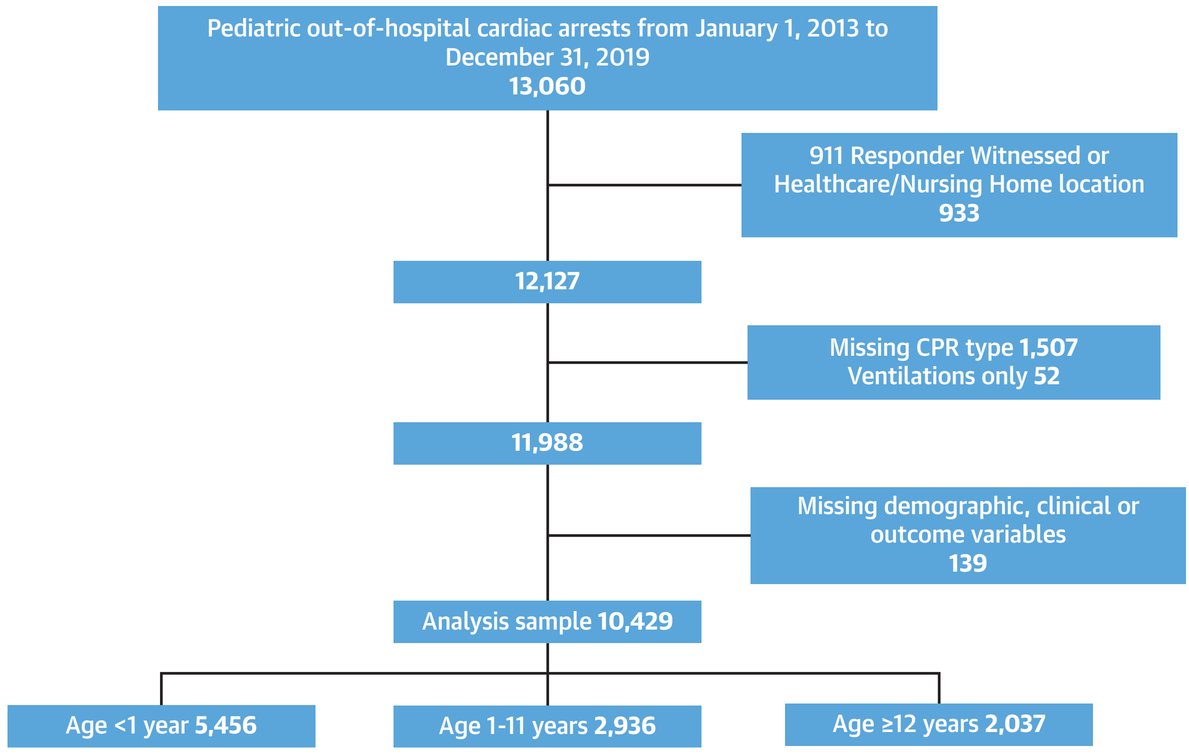
Results are expressed as ORs and marginal probabilities (adjusted neurologically favorable survival) with 95% CIs. Marginal probabilities are calculated as the mean value of the neurologically favorable survival based on predicted values for each observation if all observations had that value from each logistic regression model. Associations were deemed significant at $P < 0.05$ on 2-sided testing. To correct for multiple comparisons, the Bonferroni correction was utilized at a total alpha of 0.05 with $P < 0.017$ (0.05 divided by 3), for the comparison of NO-CPR, CO-CPR, and RB-CPR. Additionally, P values and 95% CIs presented in this report have not been adjusted for multiplicity, and therefore, inferences drawn from these statistics may not be reproducible. Analyses were performed using STATA software version 14.2.

RESULTS

PATIENT CHARACTERISTICS. A total of 13,060 pediatric cardiac arrests were captured in the CARES database (Figure 1), 46.5% (6,074 of 13,060) received bystander CPR. Following exclusions, 10,429 arrests were evaluated, 55.6% (2,318 of 4,241) received CO-CPR and 45.3% (1,923 of 4,241) received RB-CPR. The presumed etiology of arrest was cardiac in 44.4% (4,634 of 10,429), respiratory in 32.8% (3,424 of 10,429), drowning in 8.8% (913 of 10,439), drug overdose in 1.8% (182 of 10,429), electrocution in 0.2% (17 of 10,429), exsanguination in 0.2% (19 of 10,429) and other in 11.9% (1,240 of 10,429). Arrests were more common in infants, males, and White and Black children. The majority of arrests were unwitnessed, located in a home/residence, with a nonshockable rhythm, and with no AED use before EMS arrival (Table 1). Bystander CPR characteristics are described in Table 1. Over the 6-year period of the study, the rates of bystander CPR did not change, but there was a significant increase in the proportion of pediatric OHCAs receiving CO-CPR (Supplemental Table 1). Bystander CPR was most commonly provided by a lay family member (71.7%, 3,040 of 4,241) followed by lay person (21.9%, 928 of 4,241) and lay person with medical training (6.4%, 273 of 4,241). Lay person family members (CO-CPR 54.8%, 1,666 of 3,040) and lay persons (CO-CPR 58.9%, 547 of 928) were more likely to perform CO-CPR, whereas lay persons with medical training were more likely to perform RB-CPR (61.5%, 168 of 273); $P < 0.001$.

ASSOCIATION OF NEUROLOGICALLY FAVORABLE SURVIVAL WITH CO-CPR VS RB-CPR. Neurologically

FIGURE 1 Flow Diagram With Inclusion and Exclusion Criteria



Total number of pediatric cardiac arrests that were captured in the CARES database and those that were excluded with reasons for exclusion that included arrest that were 911 responder-witnessed or health care/nursing home location, missing CPR type, ventilation only, and missing demographic, clinical or outcome variables. The numbers of arrests in each group are shown at the bottom of the figure. CPR = cardiopulmonary resuscitation.

favorable survival was observed in 8.6% (897 of 10,429) cardiac arrests. Over the 6-year period of the study, there was no change in neurologically favorable survival (**Table 2**). Unadjusted for demographic and clinical characteristics, OHCAs with RB-CPR and CO-CPR had better outcomes compared with NO-CPR (RB-CPR 13.4%, CO-CPR 12.2%, NO-CPR 5.8%; $P <$ 0.001). On multivariable analysis, RB-CPR (adjusted proportion 12.0%; 95% CI: 10.7-13.2, adjusted OR: 2.16; 95% CI: 1.78-2.62) and CO-CPR (adjusted proportion 9.7%; 95% CI: 8.7-10.7; adjusted OR: 1.61; 95% CI: 1.34-1.94) were both independently associated with neurologically favorable survival compared with NO-CPR (adjusted proportion 6.8%; 95% CI: 6.2-7.4) (**Table 2**). In a separate model comparing RB-CPR and CO-CPR excluding those who had NO-CPR, RB-CPR was associated with a higher odds of neurologically favorable survival compared with CO-CPR (adjusted OR: 1.36; 95% CI: 1.10-1.68) (**Table 3**). Additional sensitivity analyses were conducted excluding bystander CPR provided by lay medical providers without a change in overall results (Supplemental Tables 2 and 3).

Additional factors associated with neurologically favorable survival following multivariable adjustment included age >1 year, witnessed arrests, and shockable rhythm. Arrests in Black children, at a home/residence, and arrests associated with AED use before EMS arrival had decreased neurologically favorable survival (**Tables 2 and 3**).

NEUROLOGICALLY FAVORABLE SURVIVAL AND THE TYPE OF BYSTANDER CPR ACROSS AGE GROUPS. Neurologically favorable survival was observed in 4.6% (250 of 5,456) of infants, 10.6% (312 of 2,936) of children, and 16.5% (335 of 2,037) of adolescents. In infants, neurologically favorable survival was observed in 5.2% (58 of 1,109) of arrests with CO-CPR, 6.9% (67 of 973) with RB-CPR, and 3.7% (125 of 3,374) with NO-CPR; $P <$ 0.001 (**Table 4**). In multivariable analysis, RB-CPR was associated with neurologically favorable survival compared with NO-CPR (adjusted

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TABLE 1 Characteristics of NO-CPR, CO-CPR, and RB-CPR

	NO-CPR (n = 6188)	CO-CPR (n = 2318)	RB-CPR (n = 1923)	*P* Value
Year of arrest				
2013	515 (8.3)	189 (8.2)	204 (10.6)	0.001
2014	566 (9.1)	226 (9.8)	215 (11.2)	
2015	782 (12.6)	281 (12.1)	242 (12.6)	
2016	833 (13.5)	328 (14.2)	262 (13.6)	
2017	1,051 (17.0)	359 (15.5)	252 (13.1)	
2018	1,162 (18.8)	437 (18.9)	339 (17.6)	
2019	1,279 (20.7)	498 (21.5)	409 (21.3)	
Age, y				
<1	3,374 (54.5)	1,109 (47.8)	973 (50.6)	<0.001
1-11	1,661 (26.8)	640 (27.6)	635 (33.0)	
≥12	1,153 (18.6)	569 (24.6)	315 (16.4)	
Sex				
Female	2,561 (41.4)	888 (38.3)	808 (42.0)	0.018
Male	3,627 (58.6)	1,430 (61.7)	1,115 (58.0)	
Race/ethnicity				
White	1,708 (27.6)	899 (38.8)	844 (43.9)	<0.001
Black	2,253 (36.4)	595 (25.7)	413 (21.5)	
Hispanic	731 (11.8)	237 (10.2)	133 (6.9)	
Other	194 (3.1)	58 (2.5)	36 (1.9)	
Unknown	1,302 (21.0)	529 (22.8)	497 (25.8)	
Bystander-witnessed arrest				
Unwitnessed	4,873 (78.7)	1,591 (68.6)	1,343 (69.8)	<0.001
Witnessed	1,315 (21.3)	727 (31.4)	580 (30.2)	
Arrest location				
Nonhome/public	791 (12.8)	333 (14.4)	251 (13.1)	0.155
Home/residence	5,397 (87.2)	1,985 (85.6)	1,672 (86.9)	
Shockable rhythm				
Nonshockable	5,815 (94.0)	2,075 (89.5)	1,777 (92.4)	<0.001
Shockable	373 (6.0)	243 (10.5)	146 (7.6)	
AED used before EMS				
No	4,977 (80.4)	1,842 (79.5)	1,558 (81.0)	0.424
Yes	1,211 (19.6)	476 (20.5)	365 (19.0)	
Region				
Midwest	1,676 (27.1)	556 (24.0)	482 (25.1)	<0.001
Northeast	687 (11.1)	224 (9.7)	234 (12.2)	
South	2,318 (37.5)	791 (34.1)	568 (29.5)	
West	1,507 (24.4)	747 (32.2)	639 (33.2)	

Values are n (%). Demographic and clinical characteristics are shown by CPR group: NO-CPR, CO-CPR, and RB-CPR. *P* values reported via chi-square tests.
AED = automated external defibrillation; CO-CPR = compression only-cardiopulmonary resuscitation; CPR = cardiopulmonary resuscitation; EMS = emergency medical services; NO-CPR = no bystander-cardiopulmonary resuscitation; RB-CPR = cardiopulmonary resuscitation with rescue breathing.

OR: 1.65; 95% CI: 1.19-2.30); however, CO-CPR was not associated with outcome (Table 4, Central Illustration). In children, neurologically favorable survival was observed in 13.9% (89 of 640) of arrests with CO-CPR, 17.3% (110 of 635) with RB-CPR, and 6.8% (113 of 1,661) with NO-CPR; $P < 0.001$. In multivariable analysis, both RB-CPR and CO-CPR were associated with neurologically favorable survival compared with NO-CPR. In adolescents, neurologically favorable survival was observed in 23.7% (135 of 569) of arrests with CO-CPR, 25.7% (81 of 315) with RB-CPR, and 10.3% (119 of 1153) with NO-CPR; $P < 0.001$. In multivariable analysis, both RB-CPR and CO-CPR were associated with neurologically favorable survival compared with NO-CPR.

DISCUSSION

This investigation has several important findings. CO-CPR is the most common type of CPR for pediatric OHCA in the United States. In the overall pediatric cohort aged 0 to 18 years, both RB-CPR and CO-CPR were associated with neurologically

TABLE 2 Logistic Regression of the Association of Type of Bystander CPR With Favorable Survival

	Unadjusted Neurologically Favorable Survival		Adjusted Neurologically Favorable Survival		Adjusted OR		
	%	*P* Value	%	95% CI	OR	95% CI	*P* Value
CPR type							
NO-CPR	5.8	<0.001	6.8	6.2-7.4			
CO-CPR	12.2		9.7	8.7-10.7	1.61	1.34-1.94	<0.001
RB-CPR	13.4		12.0	10.7-13.2	2.16	1.78-2.62	<0.001
Year of arrest							
2013	8.2	0.487	7.7	6.2-9.2			
2014	10.1		9.9	8.1-11.6	1.41	0.98-2.03	0.067
2015	8.3		8.1	6.8-9.5	1.07	0.76-1.52	0.694
2016	7.7		7.7	6.5-9.0	1.01	0.71-1.43	0.977
2017	8.4		8.6	7.4-9.8	1.16	0.84-1.62	0.369
2018	9.1		9.4	8.2-10.5	1.30	0.95-1.80	0.103
2019	8.7		8.6	7.5-9.6	1.15	0.84-1.58	0.382
Age, y							
<1	4.6	<0.001	6.6	5.9-7.3			
1-11	10.6		10.2	9.3-11.2	1.79	1.48-2.17	<0.001
≥12	16.5		9.8	8.8-10.9	1.70	1.38-2.09	<0.001
Sex							
Female	7.8	0.013	8.4	7.6-9.1			
Male	9.1		8.8	8.1-9.4	1.07	0.91-1.25	0.416
Race/ethnicity							
White	10.1	<0.001	9.5	8.6-10.4			
Black	6.6		7.5	6.6-8.5	0.73	0.59-0.90	0.003
Hispanic	7.6		7.8	6.3-9.3	0.76	0.57-1.01	0.062
Other	9.7		8.9	6.1-11.8	0.91	0.58-1.45	0.703
Unknown	9.6		8.9	7.8-9.9	0.91	0.74-1.12	0.361
Bystander-witnessed arrest							
Unwitnessed	3.7	<0.001	4.7	4.2-5.3			
Witnessed	23.2		16.2	14.9-17.6	4.51	3.81-5.34	<0.001
Arrest location							
Nonhome/public	24.5	<0.001	13.5	12.0-15.0			
Home/residence	6.2		7.3	6.8-7.9	0.44	0.37-0.53	<0.001
Shockable rhythm							
Nonshockable	6.1	<0.001	6.8	6.3-7.3			
Shockable	40.9		21.7	19.1-24.3	4.71	3.84-5.77	<0.001
AED used before EMS							
No	8.0	<0.001	9.0	8.4-9.5			
Yes	11.2		7.5	6.6-8.4	0.78	0.64-0.94	0.010
Region							
Midwest	7.6	<0.001	8.2	7.2-9.2			
Northeast	8.5		8.1	6.7-9.5	0.98	0.75-1.30	0.914
South	7.9		8.6	7.7-9.5	1.07	0.87-1.33	0.513
West	10.5		9.1	8.1-10.0	1.15	0.92-1.44	0.213

Adjusted neurologically favorable survival, ORs, 95% CIs, and *P* values are from a logistic regression model with neurologically favorable survival as the outcome variable and covariates age group, year of arrest, sex, race/ethnicity, bystander-witnessed arrest, arrest location, shockable rhythm, AED used before EMS, and region of arrest. No adjustments for multiple testing were applied.

Abbreviations as in Table 1.

favorable survival compared with NO-CPR in pediatric OHCA. RB-CPR was associated with a higher odds of neurologically favorable outcome compared with CO-CPR (adjusted OR: 1.36; 95% CI: 1.10-1.68). In age-stratified analysis, RB-CPR was associated with neurologically favorable survival compared with NO-CPR in all age groups. CO-CPR was associated with neurologically favorable survival compared with NO-CPR in children and adolescents, but not in infants.

In 2008, in order to increase bystander CPR rates in adults with OHCA, the American Heart

TABLE 3 Logistic Regression Comparing the Association of CO-CPR and RB-CPR With Neurologically Favorable Survival

	Adjusted Neurologically Favorable Survival		Adjusted OR		
	%	95% CI	OR	95% CI	*P* Value
CPR type					
CO-CPR	11.6	10.4-12.7			
RB-CPR	14.2	12.8-15.6	1.36	1.10-1.68	0.005
Year of arrest					
2013	10.4	7.7-13.1			
2014	12.8	9.9-15.7	1.36	0.82-2.25	0.233
2015	12.0	9.6-14.4	1.23	0.76-1.98	0.403
2016	11.6	9.3-13.9	1.16	0.72-1.88	0.536
2017	14.2	11.9-16.5	1.59	1.01-2.51	0.046
2018	14.6	12.4-16.8	1.66	1.06-2.59	0.026
2019	12.4	10.5-14.2	1.29	0.83-2.00	0.265
Age, y					
<1	9.0	7.7-10.4			
1-11	15.6	13.9-17.3	2.17	1.68-2.82	<0.001
≥12	14.7	12.7-16.7	1.98	1.48-2.66	<0.001
Sex					
Female	12.0	10.7-13.4			
Male	13.2	12.0-14.4	1.15	0.93-1.42	0.207
Race/ethnicity					
White	14.0	12.6-15.5			
Black	10.7	8.9-12.6	0.67	0.50-0.90	0.008
Hispanic	11.1	8.3-14.0	0.71	0.47-1.07	0.097
Other	12.4	6.5-18.3	0.83	0.40-1.74	0.622
Unknown	13.2	11.3-15.2	0.92	0.70-1.21	0.541
Bystander-witnessed arrest					
Unwitnessed	7.5	6.4-8.6			
Witnessed	20.8	18.7-22.9	3.87	3.08-4.85	<0.001
Arrest location					
Nonhome/public	21.1	18.2-24.1			
Home/residence	10.6	9.6-11.6	0.37	0.29-0.48	<0.001
Shockable rhythm					
Nonshockable	9.9	8.9-10.9			
Shockable	30.3	25.8-34.9	5.04	3.79-6.70	<0.001
AED used before EMS					
No	13.5	12.5-14.6			
Yes	10.5	8.9-12.1	0.69	0.52-0.90	0.006
Region					
Midwest	11.9	10.2-13.6			
Northeast	13.7	11.0-16.3	1.23	0.86-1.77	0.261
South	13.4	11.7-15.1	1.19	0.89-1.60	0.240
West	12.4	10.7-14.0	1.06	0.78-1.44	0.698

Adjusted neurologically favorable survival, ORs, 95% CIs, and *P* values are from a logistic regression model with neurologically favorable survival as the outcome variable and covariates age group, year of arrest, sex, race/ethnicity, bystander-witnessed arrest, arrest location, shockable rhythm, AED used before EMS and region of arrest. Arrests with no bystander CPR are omitted from this model. No adjustments for multiple testing were applied.

Abbreviations as in Table 1.

Association changed its guidelines to recommend CO-CPR as an acceptable alternative to RB-CPR (18). The subsequent stronger recommendations in 2010, 2015, and 2017 for CO-CPR in adult OHCA followed the multiple randomized trials comparing dispatcher-assisted CPR by CO-CPR and RB-CPR, which showed superior outcomes with CO-CPR, and meta-analyses that concluded dispatcher instructions to bystanders should focus on CO-CPR (3-6,19-21).

This is the first report to demonstrate an increase in the rate of CO-CPR in pediatric OHCA in the United States. Over the 5 years of this study, the rates of bystander CPR did not change, but the proportion of CO-CPR increased with no change in neurologically favorable survival (Supplemental

TABLE 4 Association of Bystander CPR Type With Neurologically Favorable Survival, Stratified by Age Group

	Unadjusted Neurologically Favorable Survival			Adjusted Neurologically Favorable Survival		Adjusted OR			
	N	%	*P* Value	%	95% CI	OR	95% CI	*P* Value	*P* Value[a]
Infants									
NO-CPR	125 of 3,374	3.7	<0.001	4.0	3.4-4.7				
CO-CPR	58 of 1,109	5.2		4.6	3.5-5.6	1.16	0.83-1.62	0.394	
RB-CPR	67 of 973	6.9		6.1	4.8-7.5	1.65	1.19-2.3	0.003	0.072
Children									
NO-CPR	113 of 1,661	6.8	<0.001	7.4	6.2-8.7				
CO-CPR	89 of 640	13.9		12.5	10.2-14.8	1.94	1.41-2.68	<0.001	
RB-CPR	110 of 635	17.3		16	13.4-18.6	2.73	2.00-3.72	<0.001	0.046
Adolescents									
NO-CPR	119 of 1,153	10.3	<0.001	13.5	11.6-15.4				
CO-CPR	135 of 569	23.7		18.6	16-21.2	1.71	1.23-2.37	0.001	
RB-CPR	81 of 315	25.7		21.0	17.3-24.6	2.12	1.44-3.11	<0.001	0.290

This table presents the unadjusted percent of out-of-hospital cardiac arrests with favorable outcome by age group, with *P* values from chi-square tests. Adjusted neurologically favorable survival, ORs, 95% CIs, and *P* values are from stratified logistic regression models (by age group) with neurologically favorable survival as the outcome variable and covariates year of arrest, sex, race/ethnicity, bystander-witnessed arrest, arrest location, shockable rhythm, AED used before EMS, and region of arrest. No adjustments for multiple testing were applied. [a]This *P* value shows the difference between adjusted neurologically favorable survival between CO-CPR and RB-CPR.

Abbreviations as in Table 1.

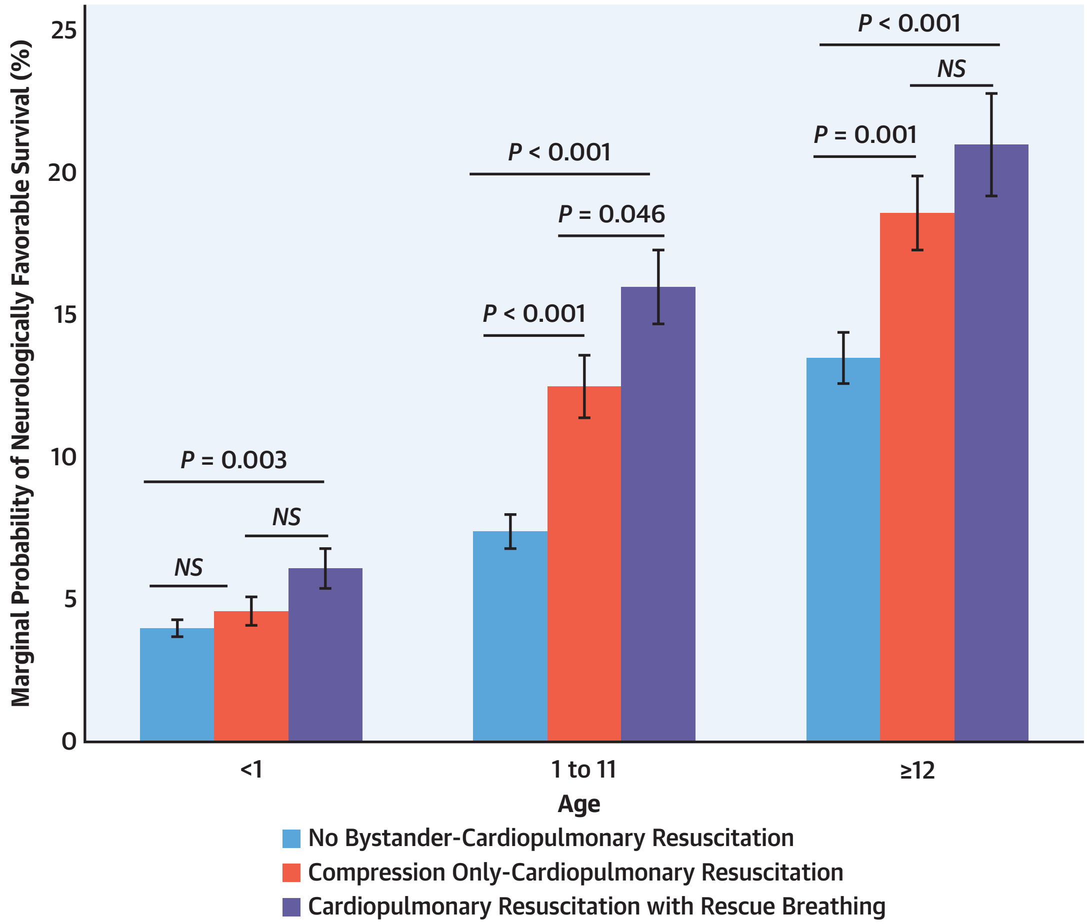
Table 1). This increase in CO-CPR in pediatric OHCA was also reported from 2007 to 2014 in Japan where there was an increased rate of bystander CPR and an increased proportion of CO-CPR without a change in neurologically favorable survival (22). The lack of change in neurologically favorable survival over time may be explained by the observation in the present study of the higher odds of neurologically favorable survival associated with RB-CPR compared with CO-CPR.

The current report found that both RB-CPR and CO-CPR were associated with neurologically favorable survival in the overall pediatric cohort, in children aged 1 to 11 years and in adolescents. These results are similar to 2 recent reports from Japan. In the first, Fukada et al (23) examined pediatric OHCA from 2011 to 2012 in children and adolescents aged 1 to 17 years, and found that both RB-CPR and CO-CPR were associated with neurologically favorable outcome at 1 month following cardiac arrest compared with NO-CPR. Goto et al (22) examined 6810 pediatric OHCAs in children aged <18 years from 2007 to 2014 and found RB-CPR was associated with better outcomes compared with CO-CPR in children aged 1 to 17 years; however, there was no difference between RB-CPR and CO-CPR in children with cardiac etiology, initial shockable rhythm, or age >8 years. For infants, there was no difference in outcomes with RB-CPR versus CO-CPR when there was a cardiac etiology or a witnessed arrest (22). By contrast, in the present study, neurologically favorable survival in infants was only observed with RB-CPR, and RB-CPR was also associated with greater neurologically favorable survival compared with CO-CPR in children aged 1 to 11 years. In the current analysis, in the overall cohort, RB-CPR was associated with higher neurologically favorable survival compared with CO-CPR. These differences were not seen in age subgroup analysis; however, CO-CPR was associated with neurologically favorable survival compared with NO-CPR in children and adolescents, but not in infants.

Additional factors associated with decreased neurological favorable survival included Black race and AED use before EMS arrival. In previous analyses from the CARES registry, Black children have been shown to have decreased bystander CPR provision related to neighborhood social determinants of health (24). Although shockable rhythms were associated with neurologically favorable survival AED use before EMS arrival was associated with decreased neurological favorable survival. This observation has been noted in arrests related to drowning, and although the exact reasons for this finding are unknown, it is possible that the quality of bystander CPR was affected during AED application and use, or that AED use is a surrogate for other factors that influence outcomes, including prolonged times until EMS arrival (25).

Overall, the results of this study support current guidelines that recommend RB-CPR for pediatric OHCA. These results also support the use of RB-CPR and CO-CPR in children and adolescents with pediatric OHCA. However, CO-CPR was not associated with neurologically favorable survival in infants;

CENTRAL ILLUSTRATION Neurologically Favorable Survival and Cardiopulmonary Resuscitation Type in Infant, Children, and Adolescents



Naim, M.Y. et al. J Am Coll Cardiol. 2021;78(10):1042–1052.

Adjusted neurologically favorable survival and *P* values are from stratified logistic regression models (by age group) with neurologically favorable survival as the outcome variable and covariates year of arrest, sex, race/ethnicity, bystander-witnessed arrest, arrest location, shockable rhythm, AED used before EMS, and region of arrest. No adjustments for multiple testing were applied. **Blue bars** indicate NO-CPR; **red bars**, CO-CPR; and **purple bars**, RB-CPR. **Error bars** indicate 95% confidence intervals. CO-CPR = compression only-cardiopulmonary resuscitation; CPR = cardiopulmonary resuscitation; NO-CPR = no bystander-cardiopulmonary resuscitation; RB-CPR = cardiopulmonary resuscitation with rescue breathing.

therefore, RB-CPR should continue to be the recommended modality. CO-CPR is associated with increased bystander CPR rates and survival in adults who experience OHCA (2), and CO-CPR has been the focus of public health campaigns including statewide educational efforts (2), high school education (26,27), and dispatcher assisted CPR (3-5,28). Although these efforts have improved overall outcomes after OHCA in adults, it is possible that they have disadvantaged children, especially infants and young children. The results of this study have important implications on bystander CPR education and training, which should continue to emphasize RB-CPR for infants in cardiac arrest and teach lay rescuers how to perform RB-CPR.

STUDY LIMITATIONS. These data are observational and therefore may be challenged by unmeasured confounding. Determining the etiology of a cardiac arrest in the field is problematic, so all nontraumatic etiologies were considered regardless of the presumed initial etiology that was chosen in the field. Type of bystander CPR is a supplemental element in the CARES registry and therefore was not available for all arrests because only a subset of agencies chose to enter this data element. A pediatric OHCA may have received more than 1 type of bystander CPR from 2 different bystanders (eg, CO-CPR from one bystander and RB-CPR from another bystander). The study did not include data on dispatcher instruction, the quality of CPR, and training of the lay rescuer although lay persons with medical training were more likely to perform RB-CPR compared with lay family members and lay persons. It is possible that the group of lay persons with medical training provided superior chest compressions, thus improving outcomes in the RB-CPR group independent of the potential benefits of rescue breaths. A sensitivity analysis was performed excluding arrests with CPR provided by lay medical rescuers that continued to support the superiority of RB-CPR compared with CO-CPR in pediatric OHCA. Duration of CPR was not available and time to CPR was not analyzed due to the number of unwitnessed arrests. There are other post-cardiac arrest in-hospital confounders, for example, targeted temperature management that may have affected outcome. In addition, there is no long-term follow-up of survivors. The trend analysis of bystander CPR rates has a potential for information bias in the form of recruitment bias as each year new agencies are added to the CARES registry. Although in the overall cohort RB-CPR was associated with improved outcome compared with CO-CPR in the age subgroup analysis, these differences were not observed likely secondary to inadequate power to detect differences within the smaller groups. These findings need to be validated in larger studies. Performing a randomized control trial to compare these 2 types of CPR in pediatric OHCA is likely not feasible.

CONCLUSIONS

In the overall pediatric cohort aged 0 to 18 years, RB-CPR was associated with a greater odds of neurologically favorable survival compared with CO-CPR. CO-CPR was associated with neurologically favorable survival compared with NO-CPR in children and adolescents, but not in infants. These results support the present AHA guidelines with RB-CPR as the preferred modality for pediatric OHCA.

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PERSPECTIVES

COMPETENCY IN PATIENT CARE AND PROCEDURAL SKILLS: Although CO-CPR is associated with higher rates of bystander participation and patient survival in adults suffering OHCA, in pediatric cases outcomes are better with RB-CPR than CO-CPR.

TRANSLATIONAL OUTLOOK: Larger studies are needed to confirm the advantage of RB-CPR over CO-CPR for infants in cardiac arrest.

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KEY WORDS bystander CPR, cardiac arrest, child, compression-only CPR, out-of-hospital cardiac arrest, pediatric

APPENDIX For supplemental tables, please see the online version of this paper.