ORIGINAL RESEARCH

Survival After Out-of-Hospital Cardiac Arrest in Children

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Background—Little is known about survival after out-of-hospital cardiac arrest (OHCA) in children. We examined whether OHCA survival in children differs by age, sex, and race, as well as recent survival trends.

Methods and Results—Within the prospective Cardiac Arrest Registry to Enhance Survival (CARES), we identified children (age <18 years) with an OHCA from October 2005 to December 2013. Survival to hospital discharge by age (categorized as infants [0 to 1 year], younger children [2 to 7 years], older children [8 to 12 years], and teenagers [13 to 17 years]), sex, and race was assessed using modified Poisson regression. Additionally, we assessed whether survival has improved over 3 time periods: 2005–2007, 2008–2010, and 2011–2013. Of 1980 children with an OHCA, 429 (21.7%) were infants, 952 (48.1%) younger children, 276 (13.9%) older children, and 323 (16.3%) teenagers. Fifty-nine percent of the study population was male and 31.8% of black race. Overall, 162 (8.2%) children survived to hospital discharge. After multivariable adjustment, infants (rate ratio: 0.56; 95% CI: 0.35, 0.90) and younger children (rate ratio: 0.42; 95% CI: 0.27, 0.65) were less likely to survive compared with teenagers. In contrast, there were no differences in survival by sex or race. Finally, there were no temporal trends in survival across the study periods (P=0.21).

Conclusions—In a large, national registry, we found no evidence for racial or sex differences in survival among children with OHCA, but survival was lower in younger age groups. Unlike in adults with OHCA, survival rates in children have not improved in recent years. **(*J Am Heart Assoc*. 2015;4:e002122 doi: 10.1161/JAHA.115.002122)**

Key Words: heart arrest • pediatrics • survival

Although many studies exist on outcomes for out-of-hospital cardiac arrest (OHCA) in adults, little is known about survival outcomes in children. To date, the few pediatric reports that exist have reported wide ranges in survival from 2% to 24%.[1–4] These prior studies typically have been limited by small study samples, often including no more than a few centers, thereby limiting their generalizability. Moreover, these studies have been unable to assess whether racial or sex differences in survival exist among children with OHCA. Lastly, with recent advances in resuscitation care, such as an increased emphasis on bystander cardiopulmonary resuscitation (CPR)[5] and improved access to automated external defibrillators (AED),[6] it would be important to understand whether survival for children with OHCA has improved over time.

Until recently, national prospective registries for pediatric OHCA with the capacity to capture data across many sites were unavailable. Beginning in 2005, however, the Cardiac Arrest Registry to Enhance Survival (CARES)[7] was launched to foster a better understanding of the epidemiology of OHCA by systematically collecting data from communities throughout the United States. This registry provides a unique opportunity to address current gaps in knowledge about OHCA in children. Accordingly, we leveraged data from CARES to determine overall survival rates for OHCA in children; examine whether survival differed based upon patient age, sex, race, or first monitored rhythm; and evaluate recent survival trends.

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Received June 8, 2015; accepted September 9, 2015.

Methods

Data Source

A full description of the CARES registry and its development has been previously published.[7] In brief, CARES is a national prospective voluntary registry of pediatric and adult patients with OHCA that was developed by the Centers for Disease Control and Prevention and the Emory University Department of Emergency Medicine. CARES began data collection in October 2005 and has expanded nationally to include 13 state-based registries with community sites in 23 additional states, involving more than 600 emergency medical services (EMS) agencies and over 1000 hospitals representing a catchment area of more than 80 million people or 25% of the US population. All patients with a confirmed OHCA (defined as apnea and unresponsiveness) for whom resuscitation is attempted are identified, including those with termination of resuscitation prior to hospital arrival. Data are collected from 3 sources: 911 dispatch centers, EMS agencies, and receiving hospitals. The accuracy and completeness of data submitted to CARES is confirmed during routine data audits, wherein participating EMS agencies must confirm that the number of cases reported to CARES represents all of the cases in the agency's medical records.

Data elements collected by the CARES Registry include patient demographics, arrest-specific characteristics (eg, witnessed versus nonwitnessed arrest), resuscitation-specific information (eg, whether CPR is initiated by a bystander, use of an AED), and survival outcomes. The latter is collected by hospital staff trained by CARES. Standardized international Utstein definitions for defining clinical variables and outcomes are used to ensure uniformity in reporting.[8] All records are reviewed by a CARES representative to ensure completeness and accuracy. A full description of the data elements along with a data dictionary is available at https://mycares.net.

Selection of Participants

Between October 2005 and December 2013, a total of 4198 children (those under 18 years of age) with an out-of-hospital arrest were enrolled in CARES. We excluded 167 (4.0%) patients in whom resuscitation was not pursued, as the patient had prior orders of do not attempt resuscitation or obvious signs of death. We excluded 1989 (47.4%) patients with a presumed noncardiac etiology of their arrest in order to ensure that our subgroup comparisons involved similar disease conditions and to avoid confounding the interpretation of the survival outcomes. In addition, we excluded 33 (0.8%) patients who sustained an OHCA in a facility with on-site medical personnel (healthcare facility, physicians' office, hospital, or jail), and 29 (0.7%) patients with missing data regarding emergency room or hospital outcomes. Our final study cohort comprised 1980 children with OHCA (Figure).

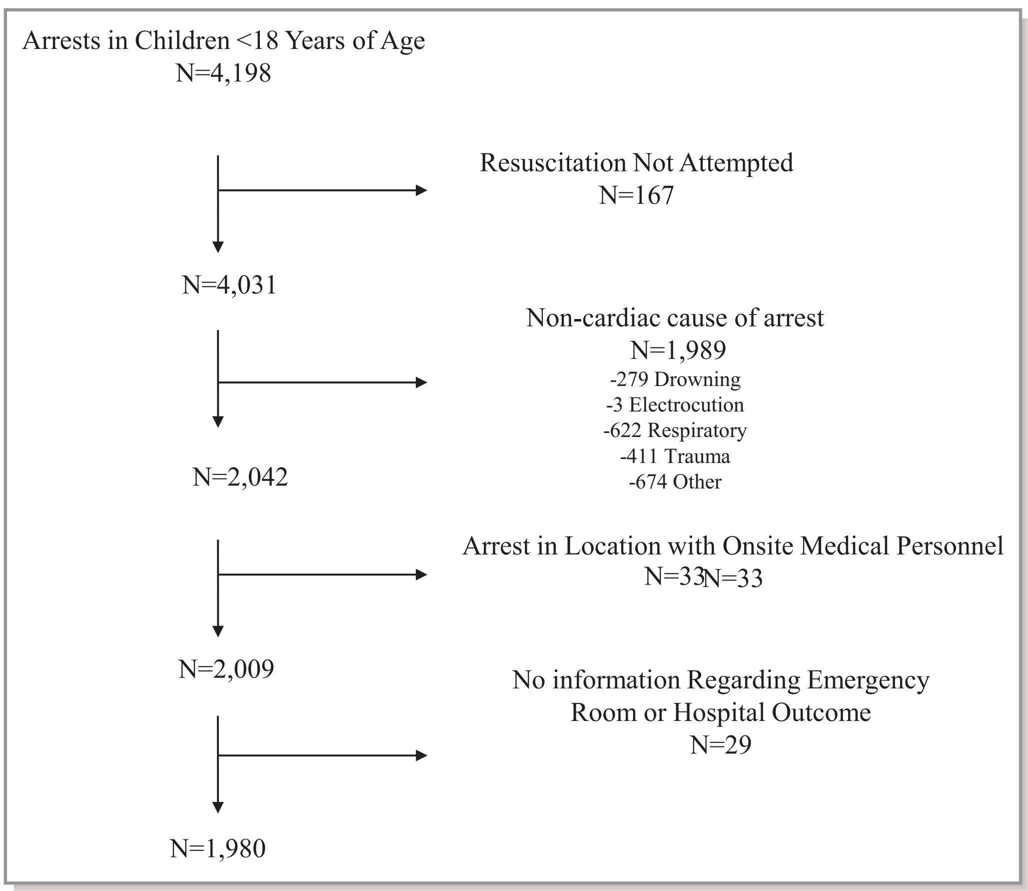

Figure. Study selection process. Flowchart showing selection of patients for inclusion in the final study cohort.

Study Outcome

The outcome of interest was survival to hospital discharge. We examined whether survival differed by the following prespecified patient subgroups of interest: age group (categorized as infants [0 to 1 year], young children [2 to 7 years], older children [8 to 12 years], and teenagers [13 to 17 years]), sex, race (white, black, Hispanic, other, or unknown), and first monitored rhythm (ventricular tachycardia [VT] and ventricular fibrillation [VF] versus asystole and pulseless electrical activity). Additionally, we evaluated temporal trends in survival by comparing survival rates for 3 time periods: 2005–2007, 2008–2010, and 2011–2013.

As a secondary outcome, we examined survival to discharge with favorable neurologic outcome across the same prespecified subgroups. Within CARES, neurological outcomes are assessed using Pediatric Cerebral Performance Category scores, wherein a Pediatric Cerebral Performance Category score of 1 indicates no neurological disability, 2 for moderate disability, 3 for severe disability, and 4 for coma/vegetative state. In this study, we defined a favorable neurological outcome as survival with a Pediatric Cerebral Performance Category score of $\leq$2.[9]

Statistical Analysis

Characteristics of those patients surviving to hospital discharge were compared to those not surviving to discharge using Student *t* test for continuous variables and χ^2 or Fisher's exact test for categorical variables. Survival in the entire study cohort was described using simple proportions. For the purposes of describing trends in survival, we compared survival rates over 3 time periods: (2005–2007, 2008–2010, and 2011–2013) using the Mantel–Haenszel test for trend.

To evaluate whether rates of survival to discharge differed by our prespecified subgroups, we constructed modified Poisson logistic regression models to assess predictors of survival. These models were adjusted for patients' age, sex, race, first monitored rhythm, and calendar year of cardiac arrest. We used Zou's methodology to directly estimate rate ratios in these models by specifying a Poisson distribution and including a robust variance estimate.[10] If differences in OHCA survival were observed for a given subgroup, we examined rates of bystander CPR (ie, not delivered by EMS or first responder [fire, police] personnel) or AED use in each strata and evaluated whether these processes mediated survival differences in that subgroup. This was accomplished by additionally adjusting for these variables in the modified Poisson models and assessing whether the estimates of effect were attenuated. We defined AED use as any AED use prior to hospital arrival, regardless of who initiated use of the AED (eg, bystander, first responder, or responding EMS personnel). Additionally, we repeated the above analyses for our secondary outcome of survival to discharge with favorable neurological status.

All study analyses were performed with SAS 9.3 (SAS Institute, Cary, NC) and R version 2.15.0 (R development core team, Vienna, Austria).[11] All analyses were evaluated using a 2-sided significance level of 0.05. There were 15 (9.3%) patients in whom Pediatric Cerebral Performance Category data were not available. These data were considered to be missing at random and handled using a single imputation approach using IVEware software (University of Michigan, Ann Arbor, MI).[12] All authors have read and agree to the manuscript as written. None of the sponsoring organizations of CARES had any role in the study design, analyses and their interpretation, or writing of the manuscript. The study was conducted on de-identified quality improvement registry data and did not meet criteria for requirement of informed consent. The final manuscript draft was approved by the CARES National Data Sharing Committee.

Results

Of the 1980 pediatric OHCAs, 1170 (59.0%) occurred in males. The majority of children with OHCA were young, with 429 (21.7%) occurring in infants, 952 (48.1%) in young children, 276 (13.9%) in older children, and 323 (16.3%) in teenagers. Patients of black race (629 [31.8%]) comprised the largest racial group, while 526 (26.6%) were of white race, 264 (13.3%) of Hispanic ethnicity, 39 (2.0%) of other races, and 522 (26.4%) of unknown race. The vast majority of patients (1778 [90.0%]) involved nonshockable cardiac arrest rhythms of asystole or pulseless electrical activity. Teenage patients were much more likely to have a first monitored-rhythm of VT or VF (105/323 [32.5%]) as compared with only a rate of 7.0% (30/428) in infants and 4.3% (41/950) in younger children. Most (1750 [88.4%]) patients had their cardiac arrest in a private residence, with teenage patients much less likely to sustain an OHCA in a private residence (222/323 [68.7%]) as compared with 91.6% (393/429) of infants and 93.2% (887/952) of younger children.

Predictors of Survival

Overall, 162 (8.2%) patients survived to hospital discharge. Table 1 compares the baseline characteristics of those patients surviving and not surviving to hospital discharge. Older children were more likely to survive an OHCA compared to patients of younger ages. Patients with a witnessed arrest and a first-monitored shockable rhythm of VT or VF had higher unadjusted rates of survival to hospital discharge.

After multivariable adjustment, only patient age and cardiac arrest rhythm were significantly associated with

Table 1. Baseline Characteristics of Patients Surviving and Not Surviving to Hospital Discharge

	Survivors, N (%) (n=162)	Nonsurvivors, N (%) (n=1818)	*P* Value
Demographics			
Age groups			<0.001
0 to 1 year	27 (16.7)	402 (22.1)	
2 to 7 years	41 (25.3)	911 (50.1)	
8 to 12 years	26 (16.0)	250 (13.8)	
13 to 17 years	68 (42.0)	255 (14.0)	
Female sex*	55 (34.0)	754 (41.5)	0.06
Race			0.87
White	43 (26.5)	483 (26.6)	
Black	51 (31.5)	578 (31.8)	
Hispanic	25 (15.4)	239 (13.1)	
Other	1 (0.6)	38 (2.1)	
Unknown	42 (25.9)	480 (26.4)	
Event characteristics			
Arrest location			<0.001
Private residence	95 (58.6)	1655 (91.0)	
Public area with likely AED	16 (9.9)	27 (1.5)	
Other public area	45 (27.8)	121 (6.7)	
Other	6 (3.7)	15 (0.8)	
Witnessed arrest	115 (71.0)	442 (24.3)	<0.001
First monitored rhythm†			<0.001
Asystole	28 (17.3)	1339 (73.8)	
Idioventricular/PEA	29 (17.9)	218 (12.0)	
Unknown nonshockable rhythm	32 (19.8)	132 (7.3)	
Ventricular fibrillation	48 (29.6)	92 (5.1)	
Ventricular tachycardia	25 (15.4)	33 (1.8)	
First rhythm VT/VF†	73 (45.1)	125 (6.9)	<0.001
Who initiated CPR‡			0.57
First responder	43 (26.5)	571 (31.4)	
Layperson	76 (46.9)	739 (40.7)	
Responding EMS personnel	43 (26.5)	506 (27.9)	
AED used	45 (27.8)	259 (14.2)	<0.001
AED user			<0.001
AED by bystander	13 (8.0)	14 (0.8)	
AED by first responder	27 (16.7)	207 (11.4)	
AED by EMS	5 (3.1)	38 (2.1)	
No AED used	117 (72.2)	1559 (85.8)	

AED indicates automated external defibrillator; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; PEA, pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.
*One patient with missing information on sex (nonsurvivor).
†Four patients with missing information on first documented rhythm and first rhythm VT/VF (all nonsurvivors).
‡Two patients with missing information on who initiated CPR (both nonsurvivors).

survival (Table 2). While there were no differences in survival between teenagers and older children, infants (adjusted rate ratio [RR]: 0.56; 95% CI: 0.35, 0.90) and young children (adjusted RR: 0.42; 95% CI: 0.27, 0.65) were less likely to survive to hospital discharge compared with teenagers. In contrast, there were no significant differences in survival by patient sex or race. Patients with a first-monitored rhythm of VT or VF were 5 times more likely to survive than patients with an initial cardiac arrest rhythm of pulseless electrical activity or asystole (adjusted RR 5.51; 95% CI 3.86, 7.87). Finally, there were no unadjusted temporal trends in survival across the 3 time periods, with overall survival rates to discharge of 4.3% (4 survivors/93 overall) between 2005 and 2007, 7.9% (42/531) between 2008 and 2010, and 8.6% (116/1356) between 2011 and 2013 (P=0.21).

For our secondary end point, we found that 125 (77.2%) survivors had survival with favorable neurological status. As with the primary analysis, this outcome also differed by patients' age (Table 3). Infants (adjusted RR: 0.46; 95% CI: 0.27, 0.81) and young children (adjusted RR: 0.37; 95% CI: 0.23, 0.61) were less likely to survive with favorable neurologic status compared with teens. Additionally, patients with a first-documented rhythm of VT or VF were significantly more likely to survive with favorable neurologic outcome compared to those with a first-documented rhythm of asystole or pulseless electrical activity (adjusted RR 6.82; 95% CI 4.55, 10.22). There were no differences in survival with favorable neurologic outcome based upon race or sex.

To determine potential mediators of survival differences by age group and cardiac arrest rhythm, we examined for differences in rates of bystander CPR and AED use among the strata in these 2 groups (Table 4). Rates for both were higher in teenagers and those with first-monitored rhythm of VT or VF. After further adjustment of bystander CPR and AED use in the multivariable models, the estimates of effect for the age and cardiac arrest rhythm subgroups were minimally affected (Table 5).

Table 2. Model of Select Predictors for Survival to Discharge

Predictor	Unadjusted Survival Rates	Adjusted Rate Ratio (95% CI)	*P* Value
Age			<0.001
0 to 1 year	27/429 (6.3)	0.56 (0.35, 0.90)	
2 to 7 years	41/952 (4.3)	0.42 (0.27, 0.65)	
8 to 12 years	26/276 (9.4)	0.80 (0.49, 1.28)	
13 to 17 years	68/323 (21.1)	Reference	
Sex			0.25
Male	107/1170 (9.2)	Reference	
Female	55/809 (6.8)	0.82 (0.59, 1.14)	
Race			0.38
White	43/526 (8.2)	Reference	
Black	51/629 (8.1)	1.01 (0.67, 1.53)	
Hispanic	25/264 (9.5)	1.51 (0.91, 2.50)	
Other	1/39 (2.6)	0.39 (0.05, 2.86)	
Unknown	42/522 (8.0)	1.03 (0.67, 1.58)	
First monitored rhythm			<0.001
Asystole/PEA	89/1778 (5.0)	Reference	
VT/VF	73/198 (36.9)	5.51 (3.86, 7.87)	
Year			0.32
2005–2007	4/93 (4.3)	Reference	
2008–2010	42/531 (7.9)	1.85 (0.66, 5.18)	
2011–2013	116/1356 (8.6)	2.07 (0.76, 5.64)	

PEA indicates pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.

Discussion

Within a large, national registry, we evaluated survival outcomes for pediatric patients sustaining an OHCA. Only 1 in 12 children with an OHCA survived to hospital discharge,

Table 3. Model of Select Predictors for Survival to Discharge With Favorable Neurologic Outcome

Predictor	Adjusted Rate Ratio (95% CI)	*P* Value
Age		<0.001
0 to 1 year	0.46 (0.27, 0.81)	
2 to 7 years	0.37 (0.23, 0.61)	
8 to 12 years	0.64 (0.37, 1.11)	
13 to 17 years	Reference	
Female sex	0.87 (0.60, 1.27)	0.48
Race		0.94
White	Reference	
Black	0.95 (0.60, 1.50)	
Hispanic	1.11 (0.60, 2.06)	
Other	0.50 (0.07, 3.71)	
Unknown	0.93 (0.58, 1.51)	
First monitored rhythm		<0.001
Asystole/PEA	Reference	
VT/VF	6.82 (4.55, 10.22)	
Year		0.23
2005–2007	Reference	
2008–2010	2.93 (0.70, 12.30)	
2011–2013	3.27 (0.80, 13.37)	

PEA indicates pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.

Table 4. Bystander CPR and AED Use by Age and Arrest Rhythm

	Bystander CPR	AED Use
Age		
0 to 1 year	177/427 (41.5%)	45/427 (10.5%)
2 to 7 years	384/952 (40.3%)	113/952 (11.9%)
8 to 12 years	110/276 (39.9%)	49/276 (17.8%)
13 to 17 years	144/323 (44.6%)	97/323 (30.0%)
First monitored rhythm		
Nonshockable		
Asystole/PEA	717/1776 (40.4%)	233/1778 (13.1%)
Shockable		
VT/VF	97/198 (49.0%)	71/198 (35.9%)

AED indicates automated external defibrillator; CPR, cardiopulmonary resuscitation; PEA, pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.

and survival did not improve over the 9-year study period. Survival differed by age group (with lower survival among younger children below 8 years of age) and first monitored rhythm and these differences in survival were not explained by differential rates of bystander CPR or AED use. In contrast, there were no differences in survival by sex or race. Collectively, our study provides new insights into survival outcomes among children with OHCA.

Table 5. Model of Select Predictors for Survival to Discharge After Further Adjustment for AED Use and Bystander CPR

Predictor	Adjusted Rate Ratio (95% CI)	*P* Value
Age		0.002
0 to 1 year	0.58 (0.36, 0.93)	
2 to 7 years	0.43 (0.28, 0.67)	
8 to 12 years	0.81 (0.50, 1.31)	
13 to 17 years	Reference	
Female sex	0.83 (0.59, 1.15)	0.25
Race		0.37
White	Reference	
Black	1.01 (0.67, 1.53)	
Hispanic	1.51 (0.91, 2.50)	
Other	0.38 (0.05, 2.82)	
Unknown	1.02 (0.66, 1.57)	
Cardiac arrest rhythm		<0.001
Asystole/PEA	Reference	
VT/VF	5.38 (3.74, 7.75)	
Period of arrest		0.34
2005–2007	Reference	
2008–2010	1.82 (0.65, 5.12)	
2011–2013	2.04 (0.75, 5.56)	
Bystander CPR	1.11 (0.77, 1.60)	0.75
AED used	1.05 (0.77, 1.44)	0.58

AED indicates automated external defibrillator; CPR, cardiopulmonary resuscitation; PEA, pulseless electrical activity; VF, ventricular fibrillation; VT, ventricular tachycardia.

Several prior studies have reported survival outcomes for pediatric patients with OHCA. However, wide variation in overall survival has been reported in these studies. In one of the largest studies of OHCA containing 624 pediatric patients, the authors reported similar survival rates (7.8%) compared with those of our study cohort.[3] Similarly, a study of 459 pediatric patients from Denmark reported an overall survival rate of 8.1%, with survival lowest among patients less than 1 year of age.[13] In another study of nearly 600 pediatric patients under 12 years of age, the survival rate was 8.6%, but this rate differed from the overall survival rate of 5.7% of those under 13 years of age in our cohort.[2] Other studies have reported markedly different survival rates than those seen in our study cohort. In a population-based study of 233 pediatric patients with OHCA in the Netherlands, 24% of patients in whom resuscitation was attempted survived to hospital discharge.[1] In contrast, a study in Ontario, Canada found that 503 children with OHCA had a survival rate of only 2.0%.[4]

The variability in survival reported in prior studies can be at least partially explained by differences in the characteristics of the study population. For example, some prior studies have included patients drawn from a single geographic region.[1,2] By using a large, national, contemporary registry, we were able to report on the survival outcomes of nearly 2000 children from a range of geographic settings within the United States and provide a more precise estimate on OHCA survival in this population. Another reason for the large variability in reported OHCA survival in children may be because most prior studies have included a heterogeneous group of patients with different etiologies for OHCA (cardiac, respiratory, trauma, submersions, poisonings), and survival is known to vary by etiology of OHCA.[14] In this study, we focused our analyses on only OHCA due to a presumed cardiac etiology.

In our analysis, we were particularly interested in identifying patient characteristics that were associated with a greater or lesser chance of survival. Race and sex are known predictors of survival in the adult population,[15,16] but we did not find similar patterns of racial or sex differences in OHCA survival among children. Our findings may differ from prior adult studies examining racial differences, given that our analysis was conducted using a more contemporary patient population as compared with many of the adult studies. Additionally, several prior studies have drawn patients from a single city or area of the country, whereas our study drew patients from a wide range of geographic locations and thus may be less susceptible to regional treatment bias.[15,17,18] Lastly, unlike in adults where lower rates of bystander CPR among some racial groups have been implicated as a cause for worse outcomes, rates of bystander CPR in our study did not differ according to race. We did, however, find that infants and younger children had a lower likelihood of survival when compared to teenage patients, but this difference was not mediated by differential rates of bystander CPR or AED use. This difference in OHCA survival by age group in children deserves further study to determine whether there are physiologic differences in how older and younger children recover from cardiac arrest. One additional important finding in our study was the lack of improvement in survival over the course of the 9-year study period. Given updated guidelines regarding a renewed focus on delivery of high-quality and bystander CPR, advances in hospital care of patients sustaining an OHCA, and improved access to AEDs, this lack of survival improvement is somewhat surprising, especially since OHCA survival has been shown to improve among adults during the same time period and even within the CARES registry.[19–22]

One additional important finding in our study was the differential rates of bystander CPR and use of an AED based upon first-monitored rhythm, especially in teenagers. We found that teenage patients more commonly had a first-monitored rhythm of VT or VF, more often had an OHCA outside the home, and thus may have been more likely to receive CPR or treatment with an AED when compared with younger patients. The difference in treatment of OHCA based upon age may represent a critical opportunity to better educate caregivers of infants and young children on the importance of CPR training should their child arrest in the home, given the epidemiology of OHCA we observed based on a child's age.

Our study should be interpreted in the context of the following limitations. The CARES registry is an observational registry and is subject to the same limitations as all observational data, including the possibility of unmeasured confounding. Second, although we had information on rates of bystander CPR and AED use, CARES does not collect information on every aspect of resuscitation care, including the quality of CPR. Moreover, information on therapeutic hypothermia was not systematically collected in CARES before 2009. Consequently, we were unable to assess CPR quality or hypothermia use in our analyses. Third, CARES does not collect information on certain medical comorbidities such as structural heart disease or congenital dysrhythmias. These factors could have, in part, accounted for some of the differences in survival across age groups. Fourth, given the relative infrequency of pediatric OHCA and our study sample size within each time period, we cannot exclude the possibility of real survival trends that we were not able to detect. Finally, although CARES now collects data from many sites throughout the United States, our findings may not be generalizable to non-CARES communities in the United States or outside the United States.

Conclusions

In a large, national registry of pediatric OHCA, we found that only 1 in 12 children survived to hospital discharge. Infants and young children had lower survival rates than older children, and these survival differences were not mediated by differential rates of bystander CPR or AED use. Unlike in adults, there was no evidence for racial or sex disparities in survival or improved survival trends among children with OHCA.

Sources of Funding

Dr Jayaram was supported by a T32 training grant (HL110837) from the National Heart, Lung, and Blood Institute. Dr Chan is supported by a R01 Award (1R01HL123980) from the National Heart Lung and Blood Institute. Grant funding partners of CARES include the American Red Cross, American Heart Association, Medtronic Foundation, and Zoll Corporation.

Disclosures

Dr Chan has worked as a consultant with the American Heart Association. Dr McNally is supported by grant funding from CARES and serves as Executive Director of the program. Grant funding partners of CARES include the American Red Cross, American Heart Association, Medtronic Foundation, and Zoll Corporation.

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Journal of the American Heart Association
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J Am Heart Assoc. 2015;4:e002122; originally published October 8, 2015;
doi: 10.1161/JAHA.115.002122
The *Journal of the American Heart Association* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Online ISSN: 2047-9980