Epidemiology and Outcomes From Out-of-Hospital Cardiac Arrest in Children

The Resuscitation Outcomes Consortium Epistry–Cardiac Arrest

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Background—Population-based data for pediatric cardiac arrest are scant and largely from urban areas. The Resuscitation Outcomes Consortium (ROC) Epistry–Cardiac Arrest is a population-based emergency medical services registry of out-of-hospital nontraumatic cardiac arrest (OHCA). This study examined age-stratified incidence and outcomes of pediatric OHCA. We hypothesized that survival to hospital discharge is less frequent from pediatric OHCA than adult OHCA.

Methods and Results—This prospective population-based cohort study in 11 US and Canadian ROC sites included persons <20 years of age who received cardiopulmonary resuscitation or defibrillation by emergency medical service providers and/or received bystander automatic external defibrillator shock or who were pulseless but received no resuscitation by emergency medical services between December 2005 and March 2007. Patients were stratified a priori into 3 age groups: <1 year (infants; n=277), 1 to 11 years (children; n=154), and 12 to 19 years (adolescents; n=193). The incidence of pediatric OHCA was 8.04 per 100 000 person-years (72.71 in infants, 3.73 in children, and 6.37 in adolescents) versus 126.52 per 100 000 person-years for adults. Survival for all pediatric OHCA was 6.4% (3.3% for infants, 9.1% for children, and 8.9% for adolescents) versus 4.5% for adults (P=0.03). Unadjusted odds ratio for pediatric survival to discharge compared with adults was 0.71 (95% confidence interval, 0.37 to 1.39) for infants, 2.11 (95% confidence interval, 1.21 to 3.66) for children, and 2.04 (95% confidence interval, 1.24 to 3.38) for adolescents.

Conclusions—This study demonstrates that the incidence of OHCA in infants approaches that observed in adults but is lower among children and adolescents. Survival to discharge was more common among children and adolescents than infants or adults. **(*Circulation*. 2009;119:1484-1491.)**

Key Words: cardiopulmonary resuscitation ■ death, sudden ■ epidemiology ■ heart arrest ■ pediatrics

Pediatric out-of-hospital cardiac arrest (OHCA) is an uncommon event and is generally described as having exceptionally poor survival with severe neurological sequelae.[1–5] Although pediatric OHCA incidence is thought to be low (≈1 to 20 per 100 000 person-years), the potential years of lost productive life are substantial. Nevertheless, some investigators have questioned whether resuscitation of children with OHCA is warranted because of the reported poor outcomes and associated high financial cost.[1,2]

Clinical Perspective p 1491

Pediatric OHCA has typically been studied within a single emergency medical services (EMS) system or geographic region and over a broad time period.[2,3,6–10] Most studies required a prolonged time interval to accumulate sufficient data, during which time resuscitation guidelines and procedures may have varied widely. Several studies have combined traumatic and medical arrests.[8,10,11] Many publications are summaries of previously published literature[7,8] despite differences in data reporting and research design. Incidence, event characteristics, and outcome data for a large diverse population, derived from prospectively collected case information obtained over a short time interval with a standard data collection system, have not previously been reported.

The Resuscitation Outcomes Consortium (ROC) is a cooperative, North American network of 11 geographic sites

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investigating OHCA. The ROC sites include US and Canadian communities with marked geographic dispersion and diversity, serving an estimated 23.7 million population. ROC sites comprise >260 EMS agencies, including urban and rural, private and municipal, and centralized or decentralized agencies.[12] The ROC investigators developed a prospective population-based database of serially enrolled OHCA victims who were attended by organized EMS response systems.[13]

This report presents the demographics, event characteristics, EMS treatments, and outcomes of the pediatric population from this prospective database. The objectives of this report were to examine age-stratified incidence, descriptive characteristics, and outcomes of pediatric OHCA. Because shockable rhythms of ventricular tachycardia/ventricular fibrillation (VT/VF) are less common among pediatric OHCA, we hypothesized that outcomes of nontraumatic cardiac arrest would be worse among pediatric patients than adults. However, we hypothesized that an initial shockable rhythm would be associated with improved survival compared with a nonshockable rhythm. We also hypothesized that provision of bystander cardiopulmonary resuscitation (CPR) or scene time >10 minutes (implying resuscitation efforts at the scene rather than a "scoop and run" approach) would be associated with improved survival.

Methods

Data for all eligible 9-1-1–initiated calls attended by participating EMS agencies within the 8 US and 3 Canadian ROC sites were electronically submitted to the ROC Epistry–Cardiac Arrest database at the centralized ROC Data Coordinating Center (University of Washington, Seattle). Eligible subjects included those who were evaluated by a participating ROC EMS agency and had attempts at external defibrillation by lay responders or EMS personnel or chest compressions by EMS personnel or were pulseless and did not receive CPR or attempts to defibrillate.[13] Criteria for attempting or terminating resuscitation were determined by local regulations and were not standardized within the ROC. Patients experiencing OHCA as a consequence of blunt, penetrating, or burn trauma were excluded; drowning and mechanical suffocation patients were included. The data set was derived from both the National EMS Information System[14] and the Utstein templates.[15] Final data elements and definitions were selected and modified when necessary by consensus of the ROC investigators.[13]

The ROC Epistry–Cardiac Arrest database was queried for all patients <20 years of age from December 1, 2005, through March 31, 2007. Data elements included subject demographics and event characteristics of cause, bystander CPR, initial recorded cardiac rhythm, scene time, airway management, and drug therapy. EMS treatment was defined as therapy provided by EMS providers beyond assessment of vital signs. Scene time was defined as the interval from first EMS arrival until the transporting vehicle started moving. Initial cardiac rhythm was obtained from the patient care records and was defined as the first rhythm obtained within 5 minutes of pad or electrode placement and before drug administration. Patients were divided a priori into 3 age groups: infants, defined as <1 year of age; children, 1 to 11 years of age; and adolescents, 12 to 19 years of age. The primary outcome measure was survival to hospital discharge.

The ROC database was queried from December 1, 2005, through March 31, 2007, for adult patients ≥20 years for data elements of scene time, percentage EMS treatment, missing initial cardiac rhythm, and survival to hospital discharge.

Statistical Analysis

Descriptive statistics are reported as mean (SD), median (25%, 75%), or number (percent) as indicated. Comparisons of continuous variables between 2 groups were made with *t* tests; ANOVA was used for comparisons across ≥3 groups. Likelihood-ratio χ^2 analyses were used when discrete variables were compared across groups. A univariable logistic regression model was used to calculate the odds ratios of survival across age groups and the effect of initial cardiac rhythm. Multiple logistic regression was used to model the relationship between survival and potential predictors of outcome. Potential predictors derived from the adult literature and a priori expert opinion included age, witnessed arrest, bystander CPR, EMS scene time (<10 versus ≥10 minutes), airway management, and attempts at vascular access.

An analysis of scene time among the pediatric age groups was performed for time <10 minutes. This interval was chosen a priori because we considered an EMS scene time <10 minutes a "scoop and run" approach. Ten minutes was estimated to be the minimum time for EMS providers to arrive at the patient's side, assess the patient, provide initial resuscitation efforts, and transfer the patient to the transporting vehicle. Post hoc analyses of scene time among the combined pediatric age groups versus adult scene time were performed.

The incidence rates were calculated per 100 000 person-years for the 12-month period of March 1, 2006, to February 28, 2007, for both pediatric and adult populations to avoid bias introduced by seasonal variation. Because 1 site had incomplete data, only 10 sites were included in the incidence calculations. For each site, the age category and sex-specific rates were calculated; these rates were standardized by age and sex to the North American population of the US 2000 Census and Canadian 2001 Census (21.4 million persons within the 10 ROC sites). The site rates, weighted by the site population, were then averaged to obtain overall rates. Additionally, to counteract the possibility of incomplete ascertainment at each site, a "hot deck" multiple imputation scheme was used. For a given month, if an agency reported incomplete capture of cases or if the number of submitted cases was substantially fewer than expected on the basis of the average agency rate over March to August 2006 ($P<0.005$), we assumed that ascertainment was not complete for that month at that agency. This was an issue primarily at the startup of reporting for a few agencies. The number of cases for an agency during such a month was then imputed using a Poisson model adjusted for calendar month and agency within each site. Arrest characteristics such as age and sex for the imputed cases were determined by randomly sampling a case from the agency in question. This imputation was repeated 10 times; incidence rates were averaged over repetitions.[12,16,17] Imputation was used for 3.5% of the pediatric cases and 5.1% of the adult cases. These data were collected as part of an observational study that met the requirements for minimal risk research in the United States and Canada and was approved by 74 Institutional Review boards and 34 Research Ethics boards.

The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

Results

During the 16-month study period, final data were available from 624 patients <20 years of age and 25 405 patients ≥20 years of age. All 11 ROC sites, 148 EMS agencies and 135 hospitals contributed pediatric data. Primary outcome status was unknown for 3 pediatric patients.

Patient Characteristics

Table 1 shows pediatric patient characteristics. Almost half (44%) of the pediatric patients were infants. Males made up 62% of the patients. Nineteen percent of all pediatric patients received no EMS treatment (ie, only vital signs determined), presumably because resuscitation was considered futile (eg, dependent lividity, rigor mortis). The overall population-based incidence of nontraumatic pediatric OHCA was 8.04

Table 1. Patient Characteristics

Characteristic	Infants (n=277)	Children (n=154)	Adolescents (n=193)	All Pediatric (n=624)
Age, mean (SD), y	0.3 (0.2)	4.2 (3.0)	16.4 (2.1)	6.2 (7.3)
Age, median (Q1, Q3), y	0.2 (0.1, 0.4)	3.0 (1.6, 7.0)	17.0 (15.0, 18.0)	1.5 (0.3, 14.5)
Male, n (%)*	160 (59)	92 (60)	134 (69)	386 (62)
Incidence/100 000 person-y (95% CI)	72.71 (62.02–83.39)	3.73 (3.02–4.43)	6.37 (5.30–7.44)	8.04 (7.27–8.81)
EMS treated, n (%)	232 (84)	135 (88)	136 (70)	503 (81)
No EMS treatment, n (%)	45 (16)	19 (12)	57 (30)	121 (19)

*Percentage is of those known.

per 100 000 pediatric person-years (95% confidence interval [CI], 7.27 to 8.81) versus the population-based adult incidence of 126.52 per 100 000 adult patient-years (95% CI, 124.63 to 128.4). The incidence of cardiac arrest was an order of magnitude higher among infants compared with older children or adolescents (Table 1).

Event Characteristics

Table 2 shows event characteristics. Most events occurred in nonpublic locations defined as residence, farm/ranch, residential institution, or healthcare facility. Bystander CPR was provided in approximately one third of the events; bystander automated external defibrillator application was rare. Two thirds of events were recorded as having "no obvious cause." Within the Epistry, an obvious cause of death was determined by prehospital provider documentation from information obtained only at the scene. When no obvious cause was reported, the cause of arrest was presumed to be cardiac.

EMS Treatments

Table 3 shows the EMS interventions provided to the treated patients. Most patients were provided ventilatory support by bag-mask ventilation and/or attempts at advanced airways defined as oral or nasal endotracheal intubation, combitube/laryngeal mask airway, nasal continuous positive airway pressure, or rapid sequence intubation. Intravenous vascular access was attempted in fewer than half of the patients but increased with age. Intraosseous access attempts declined with age. Confirmation of successful vascular access or advanced airway attempts was not reported in the database. Drug therapy was documented in only one third of the patients. Only data on epinephrine (route and dose) are mandatory; reporting of all other drug data is optional. The initial cardiac rhythm was a shockable rhythm of VT/VF in 7% of pediatric arrests when a rhythm was available (Table 3). The frequency of VT/VF as the first rhythm varied from

Table 2. Event Characteristics

Characteristic	Infants (n=277), n (%)	Children (n=154), n (%)	Adolescents (n=193), n (%)	All Pediatric (n=624), n (%)
Nonpublic location	266 (96)	133 (86)	152 (78)	551 (88)
Bystander witnessed	39 (14)	42 (27)	40 (21)	121 (19)
EMS witnessed	8 (3)	7 (5)	8 (4)	23 (4)
Bystander CPR	102 (37)	61 (40)	54 (28)	217 (35)
Bystander AED	0 (0)	2 (1)	1 (1)	3 (0)
No obvious cause of arrest/missing*	205 (74)	101 (66)	114 (59)	420 (67)
Obvious cause of arrest*	72 (26)	53 (34)	79 (41)	204 (33)
Chemical poisoning	0 (0)	0 (0)	1 (1)	1 (0)
Drowning	2 (1)	20 (13)	7 (4)	29 (5)
Drug poisoning	0 (0)	0 (0)	17 (9)	17 (3)
Electrocution	0 (0)	1 (1)	2 (1)	3 (0)
Foreign body obstruction	1 (0)	3 (2)	0 (0)	4 (1)
Hanging	1 (0)	2 (1)	27 (14)	30 (5)
Mechanical suffocation	9 (3)	5 (3)	3 (2)	17 (3)
Nontraumatic exsanguination	1 (0)	0 (0)	0 (0)	1 (0)
Respiratory	3 (1)	1 (1)	3 (2)	7 (1)
SIDS	37 (13)	1 (1)	0 (0)	38 (6)
Smoke inhalation	0 (0)	1 (1)	0 (0)	1 (0)
Strangulation	0 (0)	1 (1)	3 (2)	4 (1)
Terminal illness	1 (0)	0 (0)	1 (1)	2 (0)
Other obvious cause	17 (6)	18 (12)	15 (8)	50 (8)

AED indicates automated external defibrillator; SIDS, sudden infant death syndrome.
*Cause is defined as clinical impression of EMS providers and not confirmed from hospital record.

Table 3. EMS Treatment Characteristics

	Infants	Children	Adolescents	All Pediatric
Intervention, n (%)	232	135	136	503
Airway, bag/mask	214 (92)	121 (90)	122 (90)	457 (91)
Airway, advanced	150 (65)	103 (76)	112 (82)	365 (73)
Resuscitation drug therapy	46 (20)	47 (35)	59 (43)	152 (30)
IV line attempted	34 (15)	64 (47)	112 (82)	210 (42)
IO line attempted	130 (56)	54 (40)	6 (4)	190 (38)
Initial cardiac rhythm available, n (%)	205	130	134	469
VF/VT	8 (4)	7 (5)	20 (15)	35 (7)
Asystole/PEA	172 (84)	108 (83)	103 (77)	383 (82)
Cannot determine	25 (12)	15 (12)	11 (8)	51 (11)
Initial cardiac rhythm missing,* n (%)	27 (12)	5 (4)	2 (1)	34 (7)
Subjects with evaluable times, n	171	100	104	375
Time EMS on scene,† mean (SD),‡ min	17.3 (12.2)	19.1 (11.0)	25.7 (11.3)	20.1 (12.1)
Time EMS on scene† <5 min, n (%)	18 (11)	7 (7)	1 (1)	26 (7)
Time EMS on scene† <10 min,§ n (%)	54 (32)	24 (24)	4 (4)	82 (22)
Time EMS on scene† <15 min, n (%)	82 (48)	38 (38)	13 (13)	133 (35)

IV indicates intravenous; IO, intraosseous; and PEA, pulseless electric activity.

*P=0.0007 for a test for differences in the rates of missing first rhythm between treated pediatric and adult arrests (n=14 675, 4% with unknown rhythm).

†Percent is of those subjects with evaluable times.

‡P<0.001 for a test for differences in mean scene time for pediatric versus adult arrests (n=8505; mean=26.4 minutes, SD=12.1 minutes).

§P<0.0001 for a test of the difference in the rates of scene time <10 minutes across all pediatric age groups.

4% to 5% of infants and children to 15% of adolescents with a recorded initial rhythm. The rhythm was undetermined in 11% of patients. In addition, the rhythm was missing for 7% of pediatric arrests compared with 3% of adult arrests during the same time period (P<0.001).

For treated and transported patients with evaluable times (n=375 pediatric patients, n=8505 adult patients), mean scene time for EMS providers was significantly shorter for pediatric arrests (20.1±12.1 minutes) than adult arrests (26.4±12.1 minutes). Furthermore, EMS scene time varied substantially across pediatric age groups (Table 3). The only EMS scene time at which groups were compared was EMS scene time <10 minutes, occurring for 32% of infants versus 24% of children versus 4% of adolescents (P<0.0001).

Survival Outcomes

Table 4 shows survival outcomes. Survival to hospital discharge for all nontraumatic pediatric OHCA was 6.4% compared with 4.5% survival for adult patients (P=0.03). When stratified by age, survival rates for children and adolescents were significantly higher than for infants or adults. Drowning and mechanical suffocation are included in the ROC Epistry–Cardiac Arrest database as cardiac arrests rather than traumatic arrests for both adults and children. Because drowning and mechanical suffocation are excluded in other analyses of pediatric cardiac arrest, we calculated the overall survival for the 3 age groups, excluding known drowning or mechanical suffocation. This analysis revealed a mean overall survival for infants of 3.4% (95% CI, 1.2 to 5.6), for children of 8.5% (95% CI, 3.7 and 13.4), and for adolescents of 8.2 (95% CI, 4.3 to 12.2) and 6.1% (95% CI, 4.1 to 8.0) overall. Because survival was not significantly different from the initial group and because all other ROC Epistry–Cardiac Arrest studies include these subgroups, the remainder of the analyses includes these patient subgroups.

Unadjusted odds ratios for survival after OHCA in all children and adolescents compared with adults were 2.11 (95% CI, 1.21 to 3.66) and 2.04 (95% CI, 1.24, 3.38), respectively, whereas infants had an odds ratio of 0.71 (95% CI, 0.37 to 1.39). Overall survival rate among pediatric patients who received EMS treatment was 7.8%, with 3.5% for infants, 10.4% for children, and 12.6% for adolescents. Unadjusted odds ratios for survival in EMS-treated infants and adolescents were significantly different from those in adults. Among those receiving EMS treatment, the number needed to treat (NNT) to save a life (ie, survival to hospital discharge) was 13 for pediatric OHCA versus 13 for adult OHCA and 29 for infants, 10 for children, and 8 for adolescents.

Pediatric patients with VT/VF had a higher survival to discharge rate compared with pediatric patients with an initial rhythm of asystole/pulseless electric activity. When adjusted for age group, witnessed arrest, obvious cause of arrest, sex, and site, only age group <1 year (odds ratio, 0.28; 95% CI, 0.10 to 0.76) and witnessed arrest (6.81; 95% CI, 3.09 to 15.03) were statistically associated with survival. No other factor, including bystander CPR, airway management, vascular access, or scene time >10 minutes, was statistically associated with outcome. However, because the number of survivors was low, this study is underpowered to detect these relationships.

Table 4. Survival Outcomes Among Pediatric Subjects With Known Outcomes

	Infants	Children	Adolescents	All Pediatric
All subjects, n	275	154	192	621
Survival to hospital discharge*				
n (%)	9 (3.3)	14 (9.1)	17 (8.9)	40 (6.4)
95% CI for rate	1.2–5.4	4.6–13.6	4.8–12.9	4.5–8.4
Odds ratio for survival (reference adult)	0.71	2.11	2.04	...
95% CI	0.37–1.39	1.21–3.66	1.24–3.38	...
EMS-treated subjects, n	230	135	135	500
Survival to hospital discharge				
n (%)	8 (3.5)	14 (10.4)	17 (12.6)	39 (7.8)
95% CI for rate	1.1–5.9	5.2–15.5	7.0–18.2	5.5–10.2
Odds ratio for survival (reference adult)	0.43	1.38	1.72	...
95% CI	0.21–0.87	0.79–2.41	1.03–2.87	...
Initial rhythm VT/VF,† n	8	7	20	35
Survival to hospital discharge				
n (%)	0 (0)	1 (14)	6 (30.0)	7 (20)
95% CI for rate	0.0–37.5	0.0–40.2	9.9–50.1	6.8–33.3
Initial rhythm asystole/PEA†	172	108	102	382
Survival to Hospital Discharge				
n (%)	4 (2.3)	7 (6.5)	8 (8)	19 (5)
95% CI for rate	0.1–4.6	1.8–11.1	2.6–13.1	2.8–7.2
ROSC in the field,‡ n	14	17	34	65
Survival to hospital discharge				
n (%)	4 (28.6)	8 (47.1)	12 (35.3)	24 (37)
95% CI for rate	4.9–52.2	23.3–70.8	19.2–51.4	5.2–48.7
Transported, n	179	106	107	392
Survival to hospital discharge				
n (%)	8 (4.5)	14 (13.2)	17 (15.9)	39 (10.0)
95% CI for rate	1.4–7.5	6.8–19.7	9.0–22.8	7.0–12.9

*Test of difference between pediatric and adult survival, $P=0.0340$.

†Odds ratio of survival between VT/VF and asystole/pulseless electric activity (PEA) group, 4.78; 95% CI, 1.85 to 12.33; $P=0.0012$.

‡Cases for which return of spontaneous circulation (ROSC) was noted; some sites were known to underreport ROSC.

Discussion

In this North American multisite database, the overall population-based incidence of nontraumatic pediatric OHCA was 8 per 100 000 person-years and was an order of magnitude higher among infants (73 per 100 000) compared with either children (4 per 100 000) or adolescents (6 per 100 000). The incidence of OHCA in infants approached the incidence observed in adults. In addition, pediatric patients were more likely to survive to discharge than adults (6.4% versus 4.5%; $P=0.03$). Specifically, children and adolescents were twice as likely to survive to hospital discharge as infants and adults. Pediatric patients who had VT/VF as the initial rhythm were much more likely to survive to discharge than those with asystole/pulseless electric activity (20% versus 5%; $P=0.004$).

In contrast to previous studies of adult arrests, the incidence of pediatric OHCA in several studies has included traumatic arrests and ranged from 9.1 to 19.7 per 100 000 person-years.[2,6,10] This study reports an overall incidence of nontraumatic pediatric OHCA of 8.1 per 100 000 person-years and excludes respiratory arrests with a pulse and cardiac arrests associated with blunt, penetrating, or burn trauma. This study thus provides a more accurate estimate of the incidence of medical cardiopulmonary arrest in children and demonstrates that the incidence of OHCA in infants is 10-fold greater than that of children and adolescents. This is the first report to provide incidence figures for age subgroups. We also provide an incidence of pediatric cardiac arrest that can be directly compared with the adult ROC incidence of 126.52 per 100 000 person-years during the same time period.

Differences in published pediatric incidence figures are multifactorial and can be explained in part by the inclusion of traumatic cardiac arrests, which account for ≈30% of all pediatric arrests. Other potential explanations include different age populations, race, and urban versus rural locations. In a smaller study from Helsinki, the incidence of OHCA in patients <16 years of age was 7.5 per 100 000 peron-years.[6] Sirbaugh et al[2] reported an incidence of 11.2 per 100 000 of patients <18 years excluding traumatic arrest. In the Sirbaugh et al study, the frequency of OHCA within the black population was disproportionately high. These studies reporting incidence figures are primarily from urban sites.[2,6,10] The ROC is composed of diverse locations throughout the United

States and Canada, with representation from urban, suburban, and rural sites. Our data represent a broader spectrum of OHCA than do the studies of a single site.

Outcomes from pediatric OHCA are generally described as dismal, and some investigators suggest that aggressive therapy is futile.[1,2] We report an overall survival rate to hospital discharge among all pediatric patients who received EMS treatment of 7.8% (3.5% for infants, 10.4% for children, and 12.6% for adolescents). Although the survival rate is similar to that in previous reports,[3] it is substantially better than others.[2,10] Importantly, this study demonstrates that commonly reported overall survival figures are heavily influenced by very poor infant survival, whereas children and adolescents have substantially greater survival compared with adults. These survival figures are the highest survival figures reported for pediatric OHCA. The NNT of 13 to save a pediatric life compares favorably with the NNT for other aggressive interventions considered quite effective such as implantation of an implantable cardioverter-defibrillator in patients with ventricular arrhythmias (NNT of 8) and immediate revascularization in patients with cardiogenic shock (NNT of 13).[18] Furthermore, the potential years of life gained for pediatric survivors are much greater than for adult survivors.

Comparison with adult survival outcomes is complicated by differing frequencies with which resuscitation is undertaken. In this ROC data set, only 19% of pediatric patients had no resuscitative efforts provided, whereas 40% of adults had no resuscitation. Perhaps more pediatric patients receive CPR in the field even though it is obvious that death has occurred. If so, this will underestimate the survival figures for EMS-treated pediatric OHCA and/or overestimate the EMS-treated survival rate among adult OHCAs compared with pediatric OHCAs. Despite that, the rate of survival to hospital discharge was higher among patients <20 years compared with those ≥20 years of age. Recently, 2 studies have reported better outcomes among children after cardiac arrest compared with adults.[5,19] First, a study from the National Registry of Cardiopulmonary Resuscitation showed that the survival to hospital discharge after pulseless in-hospital cardiac arrest was higher among children (0 to 18 years) than adults (27% versus 18%), primarily because of better outcomes with a first documented rhythm of asystole/pulseless electric activity. Within the last year, the large Swedish Cardiac Arrest Registry study of >40 000 OHCAs from 1990 to 2005 demonstrated that children and young adults (<35 years of age) have higher survival rates than infants or older adults. These age-stratified trends are similar to our ROC data. In contrast to previous views that treatment of pediatric OHCA is futile,[2,20] these survival to hospital discharge data indicate that resuscitative efforts for pediatric OHCA can be effective despite the high frequency of patients with an initially nonshockable rhythm.

The frequency of VT/VF during pediatric OHCA has been a topic of great interest over the last decade. In the ROC Epistry–Cardiac Arrest, VF/VT was observed in all age groups, and the frequency increased with age. The overall frequency of pediatric VT/VF among those with a documented first cardiac rhythm within 5 minutes of pad or electrode placement was 7%, with 4% to 5% in infants and children and 15% in adolescents. Previous studies have reported VT/VF occurring in as high as 19%[4] or as low as 2% to 4%.[2,3] True frequency of pediatric VT/VF during OHCA has been elusive because cardiac rhythms are often not documented and patients with sudden infant death syndrome are often included in the analysis.[2,4] Data for initial cardiac arrest rhythm were missing in 7% of the patients in this study and not interpretable in 11%. The frequency of missing data is statistically significantly higher than among adults in this database. Consistent with other reports, unadjusted survival was significantly greater in patients with VT/VF compared with patients with asystole/pulseless electric activity.[4,5,7,21]

The vast majority of pediatric cardiac arrests occurred in nonpublic locations, primarily residences. This was true across all age groups, although the frequency declined with increasing age. This has important implications for community preparedness for pediatric arrest. Parents and family members are typically the first to encounter a child and have the first opportunity to perform CPR. However, bystander CPR was reported for only one third of the events. This rate is higher than that reported in Houston[2] but similar to other reports.[3,10] Animal data,[22] adult OHCA data,[23,24] and pediatric studies[8] have shown that bystander CPR is associated with better outcomes, even though our study could not confirm that association. These findings emphasize the need for new approaches to improve bystander CPR rates for children with OHCA.

The resuscitation approach provided for children may be different from that provided for adults. The EMS mean scene time was significantly shorter for pediatric patients than for adults (20.1±12.1 versus 26.4±12.14 minutes; $P<0.0001$). We believe that EMS scene time <10 minutes is a marker of a "scoop and run" approach. Impressively, 32% of infants had EMS scene times <10 minutes compared with 4% of adolescents. Moreover, the frequency of advanced treatments also declined with decreasing age. In contrast, the percentage of patients with no EMS treatment was lower for pediatric OHCA compared with adult OHCA.[25] The implications of these apparently dissimilar EMS resuscitation approaches for children are not clear and deserve further study.

A cause of arrest was not readily ascertained by the EMS providers or by review of the prehospital patient care record in many of the cases. By the design of the database, the cause is from the perspective of the EMS provider rather than determined after hospital admission. Ong and colleagues[11,26] have shown that the ultimate diagnosis as determined by coroner's diagnosis and autopsy has a poor correlation with the prehospital impression. This is the first description of cause solely from the EMS provider perspective and suggests that determining the cause in the field is challenging and of limited value.

Study Limitations

The ROC Epistry–Cardiac Arrest is a large, diverse observational study conducted over a short time period. However, a large database with significant heterogeneity of event identification and potential variability in data abstraction may limit validity.[13] Of note, the ROC Epistry–Cardiac Arrest database

does not capture outcomes beyond hospital discharge, including neurological outcome. The ROC Epistry–Cardiac Arrest, primarily a prehospital database, draws its data primarily from existing data, thereby meeting the requirements of minimal risk research in the United States and Canada. Thus, all information was collected without patient consent. Determining neurological outcome was beyond the scope of the ROC Epistry–Cardiac Arrest; individual consent would have been required to obtain this information. Additionally, data entry was not complete for many of the variables, and incompleteness may differ between the pediatric and adult data. Because the absolute number of survivors to hospital discharge was low, the statistical power to detect potentially important predictors was limited. Although inclusion of sudden infant death syndrome cases and patients with rigor mortis is appropriate and exclusion of these cases can bias the samples, these patients were obviously dead, and their inclusion will underestimate the effect of resuscitative efforts for patients with a chance to survive. The ROC Epistry–Cardiac Arrest was designed primarily as an adult database, and many definitions such as cause may not be appropriate for pediatrics as for other databases. Despite these deficiencies, the ROC data set can evaluate important issues such as processes and outcomes for children, variability within EMS systems, assessment of new resuscitation practices implemented over multiple populations, and hypothesis-generating data for potential pediatric cardiac arrest interventional trials.

Conclusions

This epidemiological observational study collected with the same data definitions, EMS systems, and time period as adult data allows valid direct comparison with adult data. We demonstrate that the incidence of OHCAs in infants approaches that observed in adults. Remarkably, pediatric patients were more likely to survive to discharge than adults, and children and adolescents were twice as likely to survive compared with infants or adults. Patients with an initial rhythm of VT/VF have better survival than those with asystole/pulseless electric activity.

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Disclosures

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CLINICAL PERSPECTIVE

Pediatric out-of-hospital cardiac arrest (OHCA) is an uncommon event and is generally described as having exceptionally poor survival with severe neurological sequelae. Population-based data for pediatric cardiac arrest are scant and largely from urban areas. Some investigators have questioned whether resuscitation of children with OHCA is warranted because of the reported poor outcomes and associated high financial cost. The Resuscitation Outcomes Consortium (ROC) Epistry–Cardiac Arrest is a population-based emergency medical services registry of OHCA. This study examined age-stratified incidence and outcomes of OHCA for 621 persons <20 years of age. The incidence of pediatric OHCA was 8.04 per 100 000 person-years but 10-fold greater for infants <1 year (72.71 per 100 000 person-years), approaching the incidence of OHCA in adults. Survival for all pediatric OHCA was 6.4% versus 4.5% for adults. Pediatric patients were more likely to survive to discharge than adults (6.4% versus 4.5%; $P=0.03$). Unadjusted odds ratio for pediatric survival to discharge compared with adults was 0.71 (95% confidence interval, 0.37 to 1.39) for infants, 2.11 (95% confidence interval, 1.21 to 3.66) for children, and 2.04 (95% confidence interval, 1.24 to 3.38) for adolescents. When adjusted for age group, witnessed arrest, obvious cause of arrest, sex, and site, only age group and witnessed arrest were statistically associated with survival. This study demonstrates that commonly reported overall survival figures are heavily influenced by very poor infant survival, whereas children and adolescents have substantially greater survival compared with adults.

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Epidemiology and Outcomes From Out-of-Hospital Cardiac Arrest in Children: The Resuscitation Outcomes Consortium Epistry–Cardiac Arrest

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