Long-Term Outcomes Following Pediatric Out-of-Hospital Cardiac Arrest*

Erica A. Michiels, MD[1,2,3]; Florence Dumas, MD, PhD[4]; Linda Quan, MD[1,3]; Leah Selby, MD[1]; Michael Copass, MD[1]; Thomas Rea, MD, MPH[1]

Objectives: Pediatric out-of-hospital cardiac arrest is an uncommon event with measurable short-term survival to hospital discharge. For those who survive to hospital discharge, little is known regarding duration of survival. We sought to evaluate the arrest circumstances and long-term survival of pediatric patients who experienced an out-of-hospital cardiac arrest and survived to hospital discharge.

Design: Retrospective cohort study

Setting: King County, WA Emergency Medical Service Catchment and Quaternary Care Children's Hospital

Patients: Persons less than 19 years old who had an out-of-hospital cardiac arrest and were discharged alive from the hospital between 1976 and 2007.

Intervention: None.

Measurements and Main Results: During the study period, 1,683 persons less than 19 years old were treated for pediatric out-of-hospital cardiac arrest in the study community, with 91 patients surviving to hospital discharge. Of these 91 survivors, 20 (22%) subsequently died during 1449 person-years of follow-up. Survival following hospital discharge was 92% at 1 year, 86% at 5 years, and 77% at 20 years. Compared to those who subsequently died, long-term survivors were more likely at the time of discharge to be older (mean age, 8 vs 1 yr), had a witnessed arrest (83% vs 56%), presented with a shockable rhythm (40% vs 10%), and had a favorable Pediatric Cerebral Performance Category of 1 or 2 (67% vs 0%).

Conclusions: In this population-based cohort study evaluating the long-term outcome of pediatric survivors of out-of-hospital cardiac arrest, we observed that long-term survival was generally favorable. Age, arrest characteristics, and functional status at hospital discharge were associated with prognosis. These findings support efforts to improve pediatric resuscitation, stabilization, and convalescent care. (*Pediatr Crit Care Med* 2013; 14:755–760)

Key Words: heart Arrest; outcomes Research; out-of-hospital cardiac arrest; pediatrics; prognosis; survival

Pediatric out-of-hospital cardiac arrest (OHCA) is an uncommon event, and yet thousands of children experience sudden unexpected death each year in North America (1, 2). Substantial resources and efforts are directed to improving resuscitation for pediatric OHCA; however, little is known about the long-term prognosis of pediatric survivors. Information about long-term survival following hospital discharge can help policy makers, clinicians, and families involved in the care of these patients. Poor long-term prognosis among this group would underscore the need to improve care either through strict adherence to best practices or through development of innovative treatments. Conversely, favorable prognosis would lend support to the substantial effort and investment in this condition. Therefore, we sought to describe the long-term survival of pediatric patients who survived to hospital discharge following OHCA. Our secondary goal was to identify predictors of long-term survival.

MATERIALS AND METHODS

Study Design, Setting, and Population

We conducted a retrospective cohort study of all persons less than 19 years old who had an OHCA, were successfully resuscitated, and were discharged alive from a hospital in greater King County, WA, between January 1, 1976, and December 31, 2007.

*See also p. 821.

[1]University of Washington, School of Medicine, Seattle, WA.

[2]Department of Emergency Medicine, Michigan State University College of Human Medicine, Grand Rapids, MI.

[3]Department of Pediatrics, Seattle Children's Hospital, Seattle, WA.

[4]Paris Cardiovascular Research Center, Paris Descartes University, Paris, France.

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Address requests for reprints to: Erica A. Michiels, MD, 4100 Embassy Drive SE, Suite 400, Grand Rapids, MI 49546. E-mail: Erica.michiels@spectrumhealth.org

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King County comprises urban, suburban, and rural areas and is served by two-tiered emergency medical service (EMS) systems that generally followed the American Heart Association Guidelines for resuscitation throughout the years of the study (3). The size of the population increased from 1.1 million in 1970 to 1.9 million in 2010 (4). The study was approved by the Seattle Children's Hospital, Seattle, and King County Public Health and Washington State Institutional Review Boards.

Cohort Identification and Data Collection

Subjects were identified from the King County and Seattle EMS cardiac arrest surveillance databases. These databases have prospectively collected information about each OHCA patient treated in Seattle and greater King County since 1976 (5, 6). Patients were determined to have suffered OHCA if an EMS provided cardiopulmonary resuscitation (CPR) and/or the patient was shocked with an automated external defibrillator (AED) (a public-access defibrillator) before arrival in the EMS. Patients less than 19 years old who experienced an OHCA and survived to hospital discharge were eligible for this investigation. A uniform, study-specific data collection form was used to review EMS and hospital records. Information was collected regarding the Utstein characteristics, preexisting comorbidities, and functional status at hospital discharge (7).

We reviewed hospital records to verify survival to hospital discharge, determine preexisting comorbidities, and assess functional status. Functional status at hospital discharge was assessed using the Pediatric Cerebral Performance Category (PCPC) score. The PCPC score is a reliable and validated score created as an efficient way to quantify a child's cognitive function following a critical illness or an injury (8, 9). The score ranges from 1 to 6 where 1 is normal, 2 is mild disability, 3 is moderate disability, 4 is severe disability, 5 is coma or vegetative state, and 6 is brain death (8, 9).

Outcome Measures

To identify subsequent deaths we linked patients to the National Death Index and the Washington State Death Database using identifiers such as name, date of birth, father's name, and/or mother's maiden name. Patients identified in the National Death Index or Washington State Death Database were deemed nonsurvivors. Survival time was calculated from the date of hospital discharge until the date of death or until December 31, 2009 when the database was last searched.

Statistical Analysis

We used descriptive statistics to characterize demographic, clinical, and field care features according to long-term survival status. The Kaplan-Meier product limit method was used to graphically determine long-term survival of the cohort. Because we had limited power to assess the characteristics that predict long-term survival, we could conduct only univariable associations and limited the assessment of prognostic determinants to basic demographic and clinical characteristics that could be readily assessed and that possessed sound clinical rationale. We a priori evaluated the prognostic characteristics of five variables: age, gender, witness status, PCPC score at discharge, and initial arrest rhythm. Age and gender were chosen to evaluate basic demographic differences in our cohort; witness status has been previously shown to be predictive of improved short-term pediatric survival (2); the PCPC score was chosen as a global indicator of functional outcome, and having an initial shockable arrest rhythm has been shown to predict long-term survival in adult populations (10–12). For the purposes of the statistical analysis, PCPC was classified as favorable (PCPC 1 or 2) or unfavorable (PCPC 3–5). We also assessed whether time period of the arrest (1977–1986, 1987–1996, and 1997–2008) was associated with long-term survival.

RESULTS

For the period 1976–2007, there were 1,683 cases of EMS-treated pediatric OHCA in King County. Of those, 91 patients survived to hospital discharge, with an overall survival of 5.4% (**Fig. 1**).

Approximately half of patients were less than or equal to 5 years old (51%) and male (51%). Only 20% of patients had known preexisting comorbidities at the time of arrest, including cardiac (8%), neurologic (8%), and other (4%) comorbidities. Patients' year of arrest was evenly distributed throughout the study period: 1976–1986 (31%), 1987–1997 (39%), and 1998–2007 (30%). The most common cause of arrest was respiratory (27%) followed by a primary cardiac etiology (22%) and drowning (20%). The majority of patients (63%) received bystander CPR and had a witnessed arrest (77%). The presenting rhythm in 33% of patients was shockable. Epinephrine was administered to 59% of patients, with 17% receiving more than three doses. Among those patients where the duration of EMS-provided CPR could be ascertained (n = 71), EMS-provided CPR was less than 10 minutes in 31%, 10–30 minutes in 58%, and more than 30 minutes in 11%. Among the 72 patients for whom PCPC was ascertained, approximately half had a favorable PCPC of 1 or 2 at hospital discharge (**Table 1**).

There were 20 subsequent deaths (22%) in 1,449 person-years of follow-up. Survival following hospital discharge was 92% at 1 year, 86% at 5 years, and 77% at 20 years (**Fig. 2**). Cause-of-death data were available for 18 of 20 subsequent

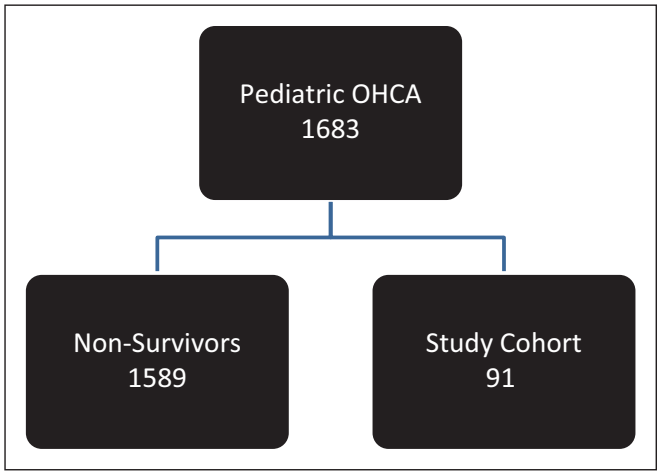
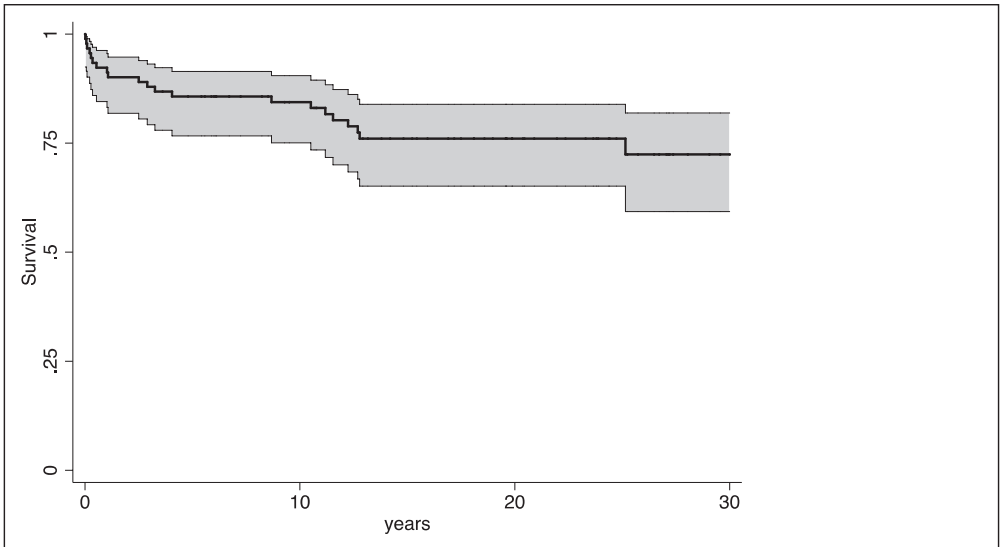


Figure 1. Survival to hospital discharge following cardiac arrest. OHCA = out-of-hospital cardiac arrest.

TABLE 1. Patient Characteristics According to Long-Term Survival Status

Patient Characteristics	Total (91)	Long-Term Survivors (71)	Nonsurvivors (20)
Male sex, *n* (%)	46 (51)	36 (51)	10 (50)
Age > 5 yr old	44 (48)	38 (54)	6 (30)
Pre-existing comorbidities, *n* (%)			
None/unknown	73 (80)	59 (83)	14 (70)
Cardiac	7 (8)	6 (9)	1 (5)
Neurologic	7 (8)	3 (4)	4 (20)
Other	4 (4)	3 (4)	1 (5)
EMS response interval, min (25th to 75th percentile)	5 (4–7)	5 (4–7)	6.5 (4–9)
Bystander CPR, *n/n* (%)	53/84 (63)	38/64 (59)	15/20 (75)
Witnessed, *n/n* (%)	59/77 (77)	49/59 (83)	10/18 (56)
Shockable rhythm, *n/n* (%)	28/85 (33)	26 (40)	2 (10)
Intubated, *n* (%)	69 (82)	53 (82)	16 (84)
Epinephrine doses received, *n* (%)			
0 doses	33 (41)	28 (45)	5 (26)
1–2 doses	34 (42)	25 (40)	9 (47)
>3 doses	14 (17)	9 (15)	5 (26)
Duration of EMS provided CPR, min, *n* (%)			
<10	22 (31)	18 (32)	4 (27)
10–30	41 (58)	34 (61)	7 (47)
>30	8 (11)	4 (7)	4 (27)
Pre-hospital return of spontaneous circulation, *n* (%)	81 (98)	62 (97)	19 (100)
Arrest diagnosis, *n* (%)			
Respiratory	24/90 (27)	16 (23)	8 (38)
Cardiac	20/90 (22)	18 (26)	2 (10)
Drowning	18/90 (20)	13 (19)	5 (24)
Trauma	11/90 (12)	9 (13)	2 (10)
Other	17/90 (19)	13 (19)	4 (19)
Year of arrest, *n* (%)			
1977–1986	28 (31)	21 (30)	7 (35)
1987–1996	36 (39)	28 (39)	8 (40)
1997–2008	27 (30)	22 (31)	5 (25)
Initial Pediatric Cerebral Performance Category score at hospital discharge, *n* (%)			
1	21 (29)	21 (40)	0 (0)
2	14 (19)	14 (27)	0 (0)
3	4 (6)	2 (4)	2 (10)
4	20 (28)	13 (25)	7 (35)
5	13 (18)	2 (4)	11 (55)

EMS = emergency medical service, CPR = cardiopulmonary resuscitation.



	Cohort	Deaths	person -years	Survival (95%CI)
1 year	91	7	86	92.3 (84.5-96.3)
5 years	78	13	405	85.7 (76.6-91.4)
10 years	65	13	748	85.7 (76.6-91.4)
20 years	39	19	1240	77.1 (66.3-84.9)

Figure 2. Long-term survival following hospital discharge.

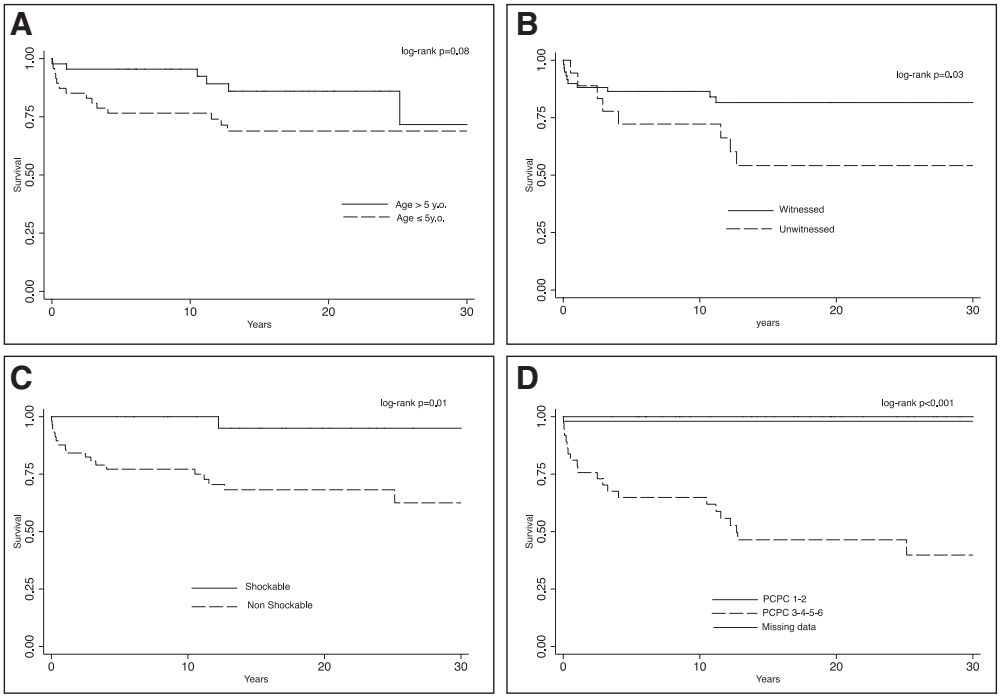


Figure 3. Long-term survival according to age (**A**); witness status (**B**); initial arrest rhythm (**C**); and Pediatric Cerebral Performance Category (PCPC) at hospital discharge (**D**).

deaths, and deaths were primarily due to anoxic brain damage (33%) and sequelae of accident (33%). Compared to those who subsequently died, long-term survivors were more likely at the time of hospital discharge to be older (age > 5 years; $p = 0.08$) (**Fig. 3*A***), have experienced a witnessed arrest (83% vs 56%; $p = 0.03$) (**Fig. 3*B***), have presented with a shockable initial rhythm (40% vs 10%; $p = 0.01$) (**Fig. 3*C***), and have a favorable PCPC of 1 or 2 (67% vs 0%; $p < 0.001$) (**Fig. 3*D***). Those with a PCPC of 1 or 2 at hospital discharge had a five-fold lower risk of subsequent death compared with those with a PCPC of 3–5. Gender and time period were not associated with long-term survival.

DISCUSSION

In this cohort of pediatric OHCA victims who were successfully resuscitated and discharged alive from the hospital, approximately 80% survived at least 10 years following hospital discharge. Commonly available clinical information from the OHCA event and the patient's functional status at hospital discharge provided useful long-term prognostic information.

Thousands of children suffer OHCA each year in North America. In a measureable fraction, resuscitation can be achieved so that the child survives short-term and is discharged alive from the hospital (1, 2, 13, 14). However, little is known about long-term outcomes following discharge. Among adults who suffer OHCA and are resuscitated to survive to hospital discharge, long-term survival approaches that of the age-matched counterparts who do not suffer arrest (10). Additionally, long-term prognosis in adult OHCA survivors appears to be improving over time in part due to hospital-based care and changes in prehospital interventions (11, 12). This improved survival has not been demonstrated in the pediatric population (1, 2, 13, 15–18). In this pediatric cohort, we observed that nearly 80% of those who survived to hospital discharge from their OHCA were still alive 10 years later. Although the 10-year

survival in this pediatric cohort was better than that in the geographically matched adult population, survival in this pediatric cohort is far worse than the survival in age-matched children (12). A similar outcome was observed in long-term follow-up of children who survived sepsis, underscoring the need for a long-term view of the sick and injured child (19). Nonetheless, the overall long-term survival of this pediatric OHCA cohort is substantial and emphasizes the importance of efforts to improve pediatric resuscitation and functional outcome.

From the a priori predictor variables, we observed that witness status ($p = 0.03$), initial shockable rhythm ($p = 0.01$), and a favorable PCPC score at hospital discharge ($p < 0.001$) were predictive of long-term survival. Previous pediatric resuscitation studies have identified that witness status and a shockable presenting rhythm are associated with survival to hospital discharge (1, 2, 18). We observed that these characteristics are also predictive of long-term survival. A favorable functional status at hospital discharge was also associated with long-term survival. Thus efforts to improve long-term prognosis may aim to improve neurologic recovery following OHCA. Such efforts might include prehospital care that could influence brain recovery such as CPR or hospital-based interventions that include extracorporeal CPR and medically-induced hypothermia (14, 20–22). Ongoing clinical study will help identify optimal therapies aimed at improving prognosis (14, 22, 23). Based on the findings of this study, functional status at discharge provides a meaningful prediction of long-term survival.

There were several limitations to this study. Although this is the first study to evaluate pediatric long-term prognosis, the number of survivors is modest, so there was limited ability to evaluate the range of characteristics that might independently influence survival. The cohort was from one county where the large majority of hospital-based care of children is centered at a single hospital. Additionally, the EMS systems of the study community are mature and achieve a high overall OHCA survival, though the pediatric survival (5.4%) in this cohort was in keeping with reported national averages (1, 2). We do not know if or how these characteristics would influence the long-term prognosis observed in this investigation, but they could affect generalizability.

This study required linking data systems that can introduce the chance of error. Additionally, survivors may have changed their names—especially if they were female—so there was possibly a bias to underestimate long-term deaths. As children rarely have recorded social security numbers, we were unable to use this as a search method. To address this limitation, we used alternate search strategies that relied on date of birth and parents' name. Additionally, we did not see a difference in long-term outcome between males and females, suggesting that name change did not produce bias in follow-up.

The PCPC score provides a validated, rapid assessment of functional status, which is useful but not comprehensive (8). We did not formally evaluate the interreviewer reliability of the PCPC score, although a prior study of pediatric intensive care patients established the PCPC score as reliable and valid with excellent interreviewer reliability (8). This study assessed survival but did not assess quality of life over time during long-term survival. Future studies should attempt to characterize quality of life and functional status during follow-up (13, 14, 24).

In this population-based cohort study evaluating the long-term outcome of pediatric survivors of OHCA, we observed that long-term survival was generally favorable, with nearly 80% alive 10 years following discharge. Witness status, initial shockable rhythm, and functional status at hospital discharge were associated with prognosis. This finding supports efforts to improve pediatric resuscitation, stabilization, and convalescent care. Future research should work to characterize the long-term quality of life and functional status of survivors and better define the predictors of long-term prognosis in an effort to improve survival and functional outcome.

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