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OUTCOME OF OUT-OF-HOSPITAL CARDIAC OR RESPIRATORY ARREST IN CHILDREN

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ABSTRACT

Background Among adults who have a cardiac arrest outside the hospital, the survival rate is known to be poor. However, less information is available on out-of-hospital cardiac arrest among children. This study was performed to determine the survival rate among children after out-of-hospital cardiac arrest and to identify predictors of survival.

Methods We reviewed the records of 101 children (median age, two years) with apnea or no palpable pulse (or both) who presented to the emergency department at the Hospital for Sick Children in Toronto. The characteristics of the patients and the outcomes of illness were analyzed. We assessed the functional outcome of the survivors using the Pediatric Cerebral and Overall Performance Category scores.

Results Overall, there was a return of vital signs in 64 of the 101 patients; 15 survived to discharge from the hospital, and 13 were alive 12 months after discharge. Factors that predicted survival to hospital discharge included a short interval between the arrest and arrival at the hospital, a palpable pulse on presentation, a short duration of resuscitation in the emergency department, and the administration of fewer doses of epinephrine in the emergency department. No patients who required more than two doses of epinephrine or resuscitation for longer than 20 minutes in the emergency department survived to hospital discharge. The survivors who were neurologically normal after arrest had had a respiratory arrest only and were resuscitated within five minutes after arrival in the emergency department. Of the 80 patients who had had a cardiac arrest, only 6 survived to hospital discharge, and all had neurologic sequelae.

Conclusions These results suggest that out-of-hospital cardiac arrest among children has a very poor prognosis, especially when efforts at resuscitation continue for longer than 20 minutes and require more than two doses of epinephrine. (N Engl J Med 1996;335:1473-9.)

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IN children, the outcome of cardiac arrest outside the hospital has been poor, with very high rates of mortality and neurologic morbidity.[1] Many survivors remain in a persistent vegetative state,[1] recovery from which is unlikely.[2] Recently, much has been written on the prediction of outcome after cardiopulmonary resuscitation (CPR) in adults,[3] and distinct criteria for terminating resuscitation efforts have been developed.[4] In a large study of adults, only 0.4 percent of the patients who failed to respond to advanced cardiac life support before arrival at the hospital survived to discharge from the hospital, and all had moderate-to-severe cerebral disability.[3] Bonnin et al.[4] and Kellermann et al.[3] recommend that resuscitative efforts be terminated at the scene if normothermic adults with cardiac arrest outside the hospital do not regain spontaneous circulation within 25 minutes after the start of standard advanced cardiac life support. Is there a similar time limit for advanced life support in children, beyond which there is no further increase in survival? In a recent survey, there was no clear consensus among clinicians on the optimal duration of resuscitative efforts in pediatric patients.[5]

In our study, we sought to determine the rate of survival among children after an out-of-hospital arrest, to compare current survival rates with survival 10 years ago, to identify predictors of survival in pediatric patients, and to propose guidelines for limiting the duration of CPR in children.

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METHODS

The hospital records of patients who arrived at the Hospital for Sick Children in Toronto after a cardiac or respiratory arrest were reviewed. The hospital is a 350-bed tertiary care pediatric hospital. Its emergency department sees 52,000 patients a year. Cardiopulmonary arrests were managed by a resuscitation team consisting of a senior and a junior pediatric resident, an anesthetic and surgical resident, and an emergency department physician. Efforts at resuscitation and the administration of drugs were based on the guidelines of the American Heart Association for pediatric resuscitation.[6] All patients who presented to the emergency department without spontaneous respiration or a palpable pulse (or with neither) between January 1986 and June 1993 were included in the study. Study subjects were identified by reviewing all deaths that occurred in the emergency department and all patients admitted to the intensive care unit (ICU) after CPR. Only patients in whom resuscitation was attempted were included.

The characteristics of the patients that were recorded and correlated with outcome were age, diagnosis, the time elapsed and the treatment given between the arrest and arrival at the hospital, pulse, temperature, preexisting illness, cardiac rhythm, the number of doses of resuscitative drugs administered, the duration of attempted resuscitation, arterial-blood gas values, and glucose values. Three indexes of survival were analyzed: the sustained return of a spontaneous circulation and subsequent admission to the ICU, survival to hospital discharge, and survival 12 months after discharge. The time spent in the ICU, the subsequent course and treatment of the disease, and the duration of the hospital stay were noted. A 12-month follow-up was conducted by a review of clinic charts and interviews with care givers by telephone. The eight children who left the hospital with neurologic deficits and survived for at least 12 months had a full neurologic assessment in the outpatient clinic at 12 months. The outcomes of the survivors were classified with the Pediatric Cerebral and Overall Performance Category scores.[7,8] Their status before the arrest, at the time of discharge from the hospital, and one year thereafter was evaluated, and the incremental changes in their scores (delta scores) were calculated. The terms for describing resuscitation were defined according to the Pediatric Utstein Style.[9] Our results were then compared with previously reported outcomes of CPR in children.

Descriptive statistics for the patients were obtained and are reported as means (±SD), medians with ranges, or frequencies, as appropriate. Risk factors influencing survival after an out-of-hospital cardiac or respiratory arrest were identified with chi-square tests, t-tests, and Kruskal–Wallis analysis of variance. Variables found to be significant were then tested in a stepwise multiple logistic-regression analysis, and independent predictors of outcome were identified. Beta coefficients from significant independent predictors were converted to adjusted odds ratios with 95 percent confidence intervals.

RESULTS

During the 7.5-year study period, CPR was initiated in the emergency department in 101 children without vital signs. The median age was 2 years (range, 3 days to 18 years). Other demographic and clinical characteristics of the patients are shown in Table 1. When they arrived in the emergency department, all the patients had no spontaneous respiration, and 80 were pulseless. Attempts at resuscitation were unsuccessful in 37 patients. The remaining 64 patients were transferred to the ICU with a perfusing cardiac rhythm. Fifteen patients (15 percent) survived to

TABLE 1. CHARACTERISTICS OF THE PATIENTS.

CHARACTERISTIC	PATIENTS WITH RESPIRATORY ARREST ONLY (N=21)	PATIENTS WITH CARDIAC ARREST (N=80)	ALL PATIENTS (N=101)	PATIENTS SURVIVING TO HOSPITAL DISCHARGE (N=15)
Age — yr				
Median	6	1	2	2
Range	<1–16	<1–18	<1–18	<1–15
Weight — kg				
Median	20	10	12	10
Range	4–50	2–60	2–60	3–50
Sex — M/F	12/9	40/40	52/49	9/6
Diagnosis or cause of arrest — no. (%)				
SIDS*	0	24	24	0
Trauma	6	15	21	0
Sepsis	2	10	12	4 (33)
Drowning	0	9	9	0
Heart disease or arrhythmia	1	6	7	1 (14)
Seizures	4	3	7	2 (29)
Cancer	1	3	4	1 (25)
Smoke inhalation	0	4	4	1 (25)
Asthma or anaphylaxis	3	0	3	3 (100)
Neuromuscular disease	1	2	3	0
Blocked shunt	1	1	2	1 (50)
Acute hyperkalemia	0	1	1	1 (100)
Drug overdose	1	0	1	1 (100)
Pulmonary embolus	0	1	1	0
Cerebral hemorrhage	1	0	1	0
Progeria	0	1	1	0

*SIDS denotes sudden infant death syndrome.

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hospital discharge, and 13 were alive 12 months after discharge. Of the patients, 21 had a respiratory arrest only (i.e., they had a palpable pulse throughout resuscitation); 9 of these 21 (43 percent) survived to hospital discharge. Of these 9 patients, 5 were neurologically normal after discharge. Of the 80 patients who had a cardiac arrest (those without a palpable central pulse) only 6 patients (8 percent) survived to hospital discharge, and all 6 had moderate-to-severe neurologic sequelae (Fig. 1).

In a bivariate analysis, predictors of successful resuscitation in the emergency department were identified. Patients who survived beyond treatment in the emergency department were more likely to have had a pulse on arrival ($P<0.001$); required significantly fewer doses of epinephrine, bicarbonate, and calcium ($P<0.05$); and had a shorter duration of resuscitation in the emergency department ($P<0.001$). In the initial arterial-blood gas assay, these patients had a significantly higher pH, a lower partial pressure of arterial carbon dioxide, and a higher partial pressure of arterial oxygen ($P<0.01$ for all three variables).

In another bivariate analysis, we identified predictors of survival to hospital discharge (Table 2). Age, weight, sex, and initial arterial-blood gas values were not significant predictors of survival to hospital discharge. Patients who survived to hospital discharge had a significantly shorter interval between the arrest and arrival at the hospital and were more likely to have had a pulse present on arrival. They had a shorter duration of resuscitation in the emergency department and received significantly fewer doses of epinephrine and bicarbonate than did those who died. They were more likely to have a preexisting illness and had a higher initial body temperature. They were less likely to have received advanced CPR (resuscitation administered by emergency medical technicians) before arrival, and they were less likely to have been in asystole in the emergency department.

In our multiple logistic-regression analysis, the independent predictors of survival to hospital discharge were the use of only basic CPR (or no CPR) before arrival at the hospital (adjusted odds ratio, 0.032; 95 percent confidence interval, 0.004 to 0.25; $P<0.001$) and a short duration of resuscitation in the emergency department (adjusted odds

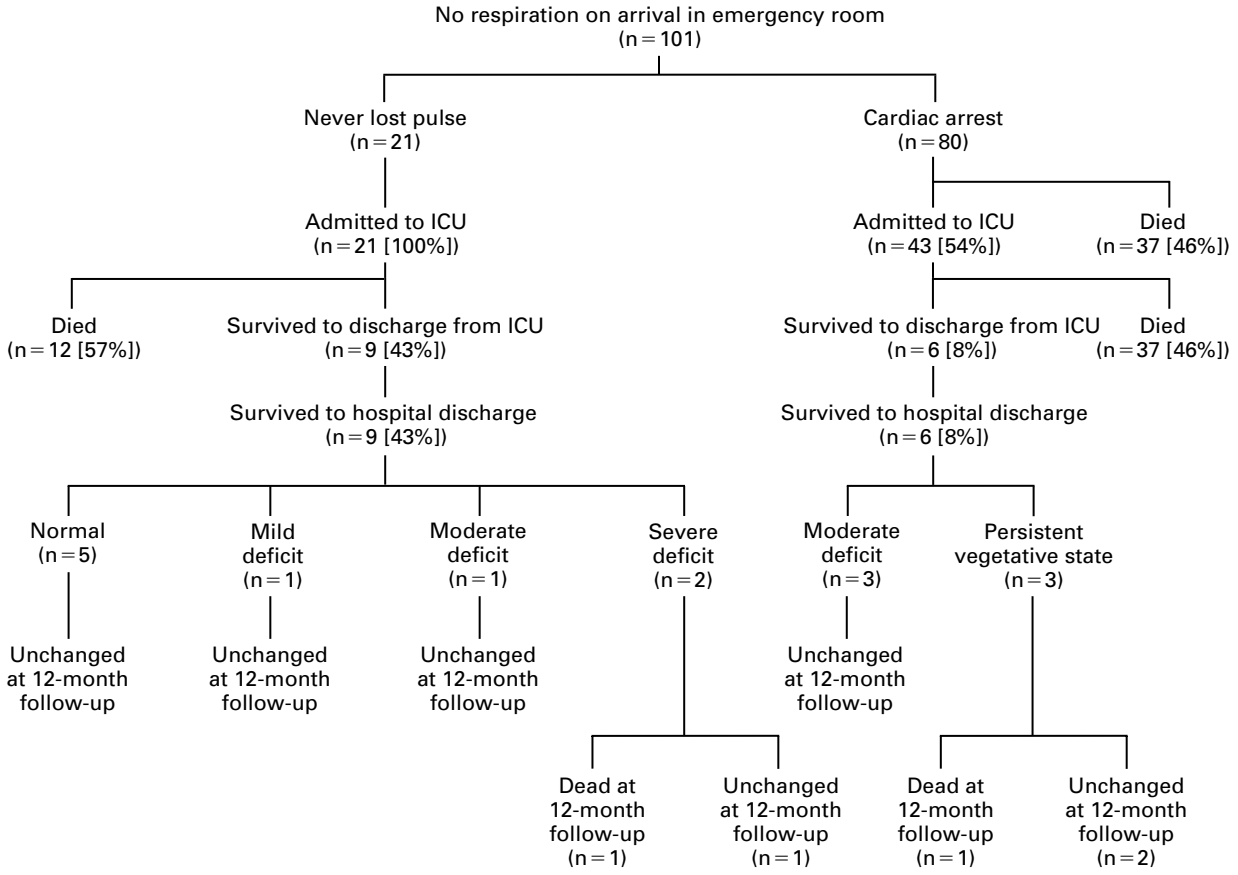

Figure 1. Outcomes of 101 Children Arriving at the Emergency Department without Respiration, with No Palpable Pulse, or Both. ICU denotes intensive care unit.

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ratio, 0.058; 95 percent confidence interval, 0.010 to 0.33; P = 0.001). The observation that the use of advanced CPR before arrival at the hospital is a predictor of death can be explained by the association of advanced CPR with a longer interval between the arrest and arrival at the hospital. The median time from the arrest to arrival at the emergency department for those who received advanced CPR was 20 minutes (range, 5 to 60; n = 69), as compared with 5 minutes (range, 1 to 15) for those who received basic CPR or no CPR before arrival (P<0.001). Patients in the latter group had their arrests very close to the hospital and were brought to the emergency department by private transport. The logistic-regression model successfully predicted survival to hospital discharge for 90 percent of the patients with a sensitivity of 98 percent and specificity of 47 percent.

The relation of survival to hospital discharge to the duration of resuscitation in the emergency department is shown in Figure 2. No patients who required more than two doses of epinephrine or resuscitation in the emergency department for longer than 20 minutes survived to hospital discharge. The only statistically significant predictors of survival to hospital dis-

TABLE 2. PREDICTORS OF SURVIVAL TO HOSPITAL DISCHARGE AFTER A CARDIAC OR RESPIRATORY ARREST.*

VARIABLE	SURVIVAL TO HOSPITAL DISCHARGE (N = 15)	DEATH (N = 86)	P VALUE
Interval between arrest and hospital arrival — min†			
Median	10	20	0.02
Range	2–30	1–60	
Preexisting illness — no.	8	21	0.02
Prehospital treatment — no. (%)			0.01
Basic or no CPR	8 (38)	13 (62)	
Advanced CPR	7 (9)	73 (91)	
Palpable pulse on arrival in emergency department — no.	9	12	<0.001
Body temperature in emergency department — °C‡	36.8±2.0	34.4±3.2	0.03
Electrocardiographic rhythm in emergency department — no. (%)			0.006
Asystole	3 (5)	52 (95)	
Sinus	10 (29)	25 (71)	
Other	1 (12)	7 (88)	
Unknown	1 (33)	2 (67)	
Initial blood gas values in emergency department§			
pH	7.05±0.26	6.94±0.31	0.28
$PaCO_2$ — mm Hg	64±51	69±49	0.76
PaO_2 — mm Hg			
Median	186	103	0.16
Range	61–314	10–510	
Base deficit — mmol/liter	−15±6	−18±9	0.33
Median no. of doses in emergency department (range)			
Epinephrine	0 (0–2)	2 (0–9)	<0.001
Bicarbonate	0 (0–2)	2 (0–7)	0.002
Calcium	0 (0–1)	0 (0–3)	0.12
Atropine	0 (0–0)	0 (0–3)	0.17
No. of defibrillations			
Median	0	0	0.94
Range	0–1	0–5	
Duration of resuscitation in emergency department — min			
Median	6	16.5	<0.001
Range	2–18	3–115	

*For patients with preexisting illness and palpable pulse, percentages are the proportions of all patients with each outcome who had the characteristic. For other characteristics, percentages are the proportions of all patients with the characteristic who had each outcome. Plus–minus values are means ±SD.

†Data were available for 13 patients who survived to discharge and 70 who died.

‡Data were available for 10 patients who survived to discharge and 42 who died.

§Data were available for 10 patients who survived to discharge and 64 who died. $PaCO_2$ denotes the partial pressure of arterial carbon dioxide, and PaO_2 the partial pressure of arterial oxygen.

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charge after a cardiac arrest were a relatively shorter duration of resuscitation in the emergency department and fewer doses of epinephrine (Table 3).

A total of 235 bed-days in the ICU (median, 2; maximum, 92) were attributable to the 49 patients who were transferred there with a perfusing cardiac rhythm but did not survive to hospital discharge. In comparison, 144 ICU bed-days (median, 5; maximum, 55) were used by the 15 patients who survived to hospital discharge. The cause of death in the majority of the patients (38 of 49) who were transferred to the ICU but did not survive to hospital discharge was withdrawal of treatment due to severe hypoxic–ischemic encephalopathy; 16 of these had reached brain-stem death when treatment was withdrawn. Of these patients, 11 (69 percent) had undergone efforts at resuscitation for 20 minutes or less in the emergency department.

The outcomes of the patients who survived to hospital discharge are shown in Figure 1. The Pediatric Cerebral Performance Category and the Pediatric Overall Performance Category scores were calculated. Since these two scores were identical in our patients, only the Pediatric Overall Performance Category scores will be described. Of the nine patients who survived to hospital discharge after a respiratory arrest, only seven had no change in the score from before the arrest until hospital discharge, and two (22 percent) had a one- or two-category deterioration in function. All five of the neurologically normal patients who survived to hospital discharge had a palpable pulse on presentation (respiratory arrest only), and they were resuscitated within five minutes in the emergency department. Only one of the five received epinephrine, which was given to manage severe bronchoconstriction. All six of the patients who survived to hospital discharge after a cardiac arrest, however, had a substantial deterioration (median, 2 categories; range 1 to 4) in their Pediatric Overall Performance Category scores and required one or two doses of epinephrine and 6 to 18 minutes of resuscitation in the emergency department. Three of these six patients (50 percent) were discharged from the hospital in a persistent vegetative state. Two were still in a persistent vegetative state 12 months after the arrest, and one died 6 months after discharge. No improvements in the Pediatric Overall Performance Category scores of the six patients who survived cardiac arrest were noted between hospital discharge and 12 months after discharge.

There was no significant difference in outcome between patients who arrived at the hospital from January 1986 to December 1986 and patients who arrived from July 1992 to June 1993. In 1986, 10 of 16 patients with arrests survived to be transferred to the ICU, and 3 of the 16 (19 percent) survived to hospital discharge. In 1993, 22 patients arrived at the emergency department, 17 of whom were admitted to the ICU and 22 percent of whom survived to hospital discharge. Slightly larger doses of epinephrine were used in 1993 (0.04 ± 0.03 mg per kilogram of body weight) than in 1986 (0.03 ± 0.02 mg per kilogram), and fewer patients received calcium in 1993 than in 1986 (18 percent vs. 50 percent). However, neither of these differences was statistically significant.

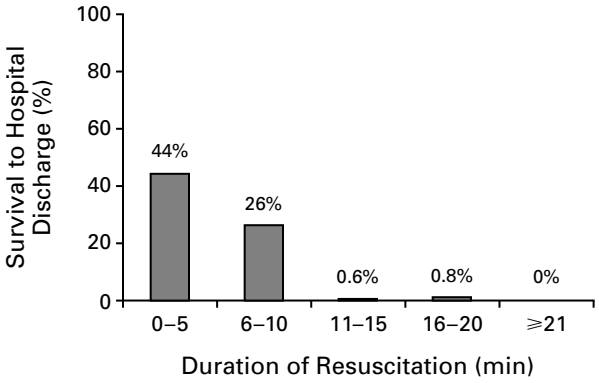

Figure 2. Probability of Survival to Hospital Discharge According to the Duration of Resuscitation in the Emergency Department. Ninety-three percent of the 15 survivors were resuscitated within 11 minutes.

DISCUSSION

In this study, the rate of survival to hospital discharge in children requiring CPR in the emergency department was 15 percent. This disappointingly low survival rate is similar to the rates in previous studies of cardiopulmonary resuscitation in children, which range from 0 to 23 percent.[1,10,11] This rate is also similar to those associated with out-of-hospital arrests in adults in whom asystole or electromechanical dissociation was initially recorded by medical personnel. In adults, survival rates of 5 to 10 percent are seen.[12] In our study no change in survival occurred between 1986 and 1993. The use of larger doses of epinephrine, which have been associated with an increase in the rate of return of spontaneous circulation,[13] does not appear to have had an influence on survival to hospital discharge. This echoes the results of other studies.[6,14] In our patients, the most common causes of arrest were the sudden infant death syndrome, trauma, and near-drowning. This is similar to the pattern found in previous pediatric studies and has not changed over the past 10 years.[1]

The predictors we identified for short-term survival (i.e., for admission to the ICU) were similar to the predictors of survival to hospital discharge except for the arterial-blood gas indicators. Fiser and Wrape[15] noted that an initial pH of less than 7.0 was a predictor of poor outcome, but other researchers found that metabolic and acid–base variables during resuscitation did not significantly affect long-term outcome.[16,17] Similarly, in our study, initial blood gas

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TABLE 3. PREDICTORS OF SURVIVAL TO HOSPITAL DISCHARGE AFTER A CARDIAC ARREST.*

VARIABLE	SURVIVAL TO HOSPITAL DISCHARGE (N=6)	DEATH (N=74)	P VALUE
Interval between arrest and hospital arrival — min†			
Median	5	20	0.08
Range	2–30	2–60	
Preexisting illness — no.	2	18	0.5
Prehospital treatment — no. (%)			0.06
Basic or no CPR	4 (25)	12 (75)	
Advanced CPR	2 (3)	62 (97)	
Body temperature in emergency department — °C‡	36.1±2.1	34.4±3.4	0.18
Electrocardiographic rhythm in emergency department — no. (%)			0.1
Asystole	3 (5)	52 (95)	
Sinus	2 (12)	15 (88)	
Other	1 (12)	7 (88)	
Initial blood gas values in emergency department§			
pH	6.9±0.17	6.87±0.29	0.37
$PaCO_2$ — mm Hg	62±44	74±52	0.45
PaO_2 — mm Hg			
Median	111	86	0.38
Range	76–207	10–500	
Base deficit — mmol/liter	−20±2.6	−19.5±7.7	0.49
Median no. of doses in emergency department			
Epinephrine	1 (1–2)	2 (1–9)	0.05
Bicarbonate	1 (0–2)	2 (0–7)	0.07
Calcium	0 (0–1)	0 (0–3)	0.3
Atropine	0 (0–0)	0 (0–3)	0.2
No. of defibrillations			
Median	0	0	0.4
Range	0–1	0–5	
Duration of resuscitation in emergency department — min			
Median	9	20	0.03
Range	6–18	6–115	

*For patients with preexisting illness and palpable pulse, percentages are the proportions of all patients with each outcome who had the characteristic. For other characteristics, percentages are the proportions of all patients with the characteristic who had each outcome. Plus–minus values are means ±SD.

†Data were available for 5 patients who survived to discharge and 59 who died.

‡Data were available for 4 patients who survived to discharge and 34 who died.

§Data were available for 5 patients who survived to discharge and 53 who died. $PaCO_2$ denotes the partial pressure of arterial carbon dioxide, and PaO_2 the partial pressure of arterial oxygen.

values did not significantly affect survival to hospital discharge, and a child's long-term survival, especially as a neurologically intact person, should be the goal of pediatric resuscitation efforts.

The predictors of survival to hospital discharge we identified included a short interval between the arrest and arrival at the hospital, a palpable pulse on presentation, comparatively fewer doses of epinephrine, and a relatively short duration of resuscitation in the emergency department. Other factors operating before arrival at the hospital, such as a short time from the arrest to the beginning of effective CPR, have been shown to improve the outcome of pediatric resuscitation efforts.[18] In our study, as in previous pediatric studies,[10,19,20] the application of advanced CPR before arrival did not improve long-term survival. However, in 72 of the 80 patients in our study who received advanced CPR before arrival, the treatment consisted only of bag–valve–mask ventilation and chest compressions. For many of these patients there were long intervals between the arrest and arrival at the hospital. There are, however, inherent inaccuracies involved in measuring that interval and in assessing the quality of prehospital resuscitation; where possible, we relied on the emergency medical service's records of treatment and the timing of events.

In earlier studies, children with a respiratory arrest who still had a palpable pulse had a better outcome than those with a cardiac arrest,[17,20-22] and patients who needed comparatively fewer doses of resuscitative drugs also had improved survival.[11,16,17] None of our patients who were given more than two doses of epinephrine survived to hospital discharge, a relation identical to that found in previous studies.[11,16,17,22]

A short duration of resuscitation in the emergency department was a strong predictor of survival in our study; no patients who required such resuscitation for more than 20 minutes survived to hospital discharge. A review of the literature identified five previous studies in which the duration of resuscitation after a pediatric cardiopulmonary arrest had been assessed. Zaritsky et al.[17] noted that all survivors of cardiopulmonary arrest, inside or outside the hospital, underwent CPR for less than 10 minutes. Gillis et al.[22] found no survivors if CPR after an in-hospital cardiac arrest lasted more than 15 minutes. Barzilay et al.[16] found significantly improved survival after both in-hospital and out-of-hospital arrests if the duration of CPR was less than 5 minutes; and in the study by Nichols et al.,[11] the threshold was 15 minutes. Innes et al.[20] found that no patients survived if CPR after an in-hospital or out-of-hospital cardiopulmonary arrest lasted more than 30 minutes.

Variations in the patient populations may account for some of the differences in outcome seen in these studies. Only a small proportion (range, 0 to 27 percent) of patients had out-of-hospital arrests, which have a poorer outcome than do in-hospital arrests.[11,16,20] In addition, there were different proportions of patients who had respiratory arrest only (range, 0 to 50 percent), as opposed to cardiac arrest. In a recent study of 60 children who had an out-of-hospital cardiac arrest with a median resuscitation time of 30 minutes after arrival in the emergency department, there was no evidence of effective

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restoration of cerebral function, even in patients who survived.[19]

In a study of children who drowned, or nearly drowned, in Seattle, Quan et al.[23] suggested that efforts at resuscitation lasting more than 25 minutes are not warranted. Bonnin et al.[4] and Kellermann et al.[3] recommended that resuscitative efforts be terminated when normothermic adults with out-of-hospital cardiac arrests do not regain spontaneous circulation after 25 minutes of standard advanced cardiac life support (or 20 minutes if there has been no palpable pulse whatsoever during the attempted resuscitation). The current data suggest that after out-of-hospital cardiac arrests in normothermic children, attempts at effective cardiopulmonary resuscitation in the emergency department for longer than 20 minutes are futile.

In contrast to adult patients, in whom a cardiac dysrhythmia is often the precipitating event in an arrest,[24] children usually have an arrest secondary to hypoxia.[1] If the hypoxic insult has been of sufficient duration and severity to stop the heart, the severe anoxia undergone by the central nervous system often precludes a neurologic recovery except in the setting of hypothermia. In earlier studies of the neurologic outcome of out-of-hospital cardiac arrests in children, all survivors of arrest had serious neurologic disabilities,[1,19,21] as was the case in our study. Some patients who survived required extremely expensive care,[19] and many remained in a vegetative state.[1] In one study, children discharged from the hospital in a persistent vegetative state either died or, at best, showed only minimal awareness after an average of 4.5 years.[2] The costs of care for these patients were greater than $90,000 per year per patient.[2]

Gray et al.[25] have shown that prolonged efforts at resuscitation after out-of-hospital arrests in adults are futile in all but exceptional cases, such as those involving recurrent but not persistent arrest, or in cases of hypothermia. In our study, there were nine children who had nearly drowned; they had a mean temperature of 32°C (range, 25 to 37) on arrival in the emergency department, and none survived. Submersion victims warmer than 30 to 32°C do not have the benefit of hypothermic protection, and cool water thus does not offer the protection provided by icy water.[26,27] In Seattle, where icy water temperatures are uncommon, Quan et al.[23] found no protective effect provided by moderate hypothermia. Thus, except for cases of profound hypothermia (temperature, less than 30°C) and of recurrent but not persistent arrest, prolonged efforts at resuscitation are not indicated in pediatric patients after an out-of-hospital cardiopulmonary arrest.

Treating a child with a cardiopulmonary arrest takes place in an emotionally charged situation, and the decision to stop efforts at resuscitation is difficult. However, the results of our study and previous studies suggest that except when treating children with severe hypothermia (temperature, less than 30°C) or with recurrent but not persistent arrest, resuscitative efforts in the emergency department after an out-of-hospital cardiac arrest should be limited to 20 minutes and two doses of epinephrine.

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