Paediatric out-of-hospital cardiac arrests: epidemiology and outcome

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ABSTRACT

Introduction: Little information is available regarding the outcome of children in our local population who sustained pre-hospital cardiac arrest. This study was performed to determine the survival rate among children after out-of-hospital cardiac arrest, to describe the epidemiology, and to identify predictors of survival.

Methods: The records of 85 children who presented to a paediatric emergency department in cardiac arrest, between 1 June 1997 and 31 September 2001, were reviewed. The characteristics of the patients, cardiac arrest circumstances, and the outcomes of arrest were analysed.

Results: 85 children presented to the emergency department in cardiac arrest during the 52-month study period. 26 out of 85 children (30.6 percent) with cardiac arrest had return of spontaneous circulation (ROSC) after resuscitation efforts at the emergency department. Only four (4.7 percent) survived to be discharged from hospital and three of them survived beyond one year. Two of the cardiac arrest survivors had no change in the neurological status, with the remaining two sustaining severe neurological deficits. Emergency medical service was activated in only 63.7 percent of the patients. 34 percent of the arrests were witnessed, and only 22.9 percent of the children received bystander cardiopulmonary resuscitation (CPR). The positive predictors for survival to hospital discharge in a bivariate analysis were witnessed arrest (p-value is equal to 0.012), presence of bystander CPR (p-value is equal to 0.003), and duration of resuscitation (p-value is equal to 0.028). None who had more than 30 minutes of resuscitation in the emergency department survived. In a multivariate analysis with a logistic regression model, the only two independent predictors of ROSC were witnessed arrest (odds ratio is 3.049; 95% confidence interval [CI] is 1.101-8.444; p-value is equal to 0.032) and duration of resuscitation (odds ratio is 0.353; 95% CI is 0.146 - 0.854; p-value is equal to 0.021).

Conclusion: Out-of-hospital cardiac arrest in children has a poor prognosis and prolonged resuscitation at the emergency department beyond 30 minutes does not improve survival.

Keywords: cardiac arrest, cardiopulmonary resuscitation, emergency medical service, paediatric cardiac arrest

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INTRODUCTION

Several studies have examined the causes and outcome of children who had cardiopulmonary arrest outside hospital settings. The outcome had been poor so far, with very high mortality and neurological morbidity. The published survival rates vary greatly from 3% to 17%[1]. Several studies had reported on the epidemiology, and attempted to identify predictors of survivals in paediatric out-of-hospital cardiac arrest. Hickey et al[2] reported that most successfully-resuscitated paediatric arrest victims are resuscitated in the pre-hospital setting and do not suffer severe neurological injury. Most patients who present to the emergency department (ED) in continued arrest and survive to discharge have severe neurological injury. Another study reported that if resuscitation continued for longer than 20 minutes and required more than two doses of adrenaline, prognosis was poor[3]. However, there is no published data regarding the outcome of these patients in the Singapore population to-date. The objectives of our study were to determine the survival rate among children in our local population who presented to a tertiary care paediatric hospital after an out-of-hospital cardiac arrest, to describe the epidemiology, and to identify predictors of survival.

METHODS

The records of children under the age of 17 years who presented to the ED of a tertiary care paediatric hospital from 1 June 1997 to 30 September 2001 (52-month period) after a cardiac arrest were reviewed. The hospital is an 898-bed tertiary hospital, with integrated women's and paediatric medical services. The ED has an annual attendance of 85,000 to 95,000 patients. The resuscitation team comprises the ED physician, two medical officers from the ED, and if necessary, the "code blue" or the trauma team is activated. The "code blue" team includes the paediatric anaesthetist, intensive care registrar, intensive care nurse, and the paediatric medical registrar. The surgical registrar is also involved when the trauma team is activated. Resuscitation efforts were done according to the guidelines from the American Heart Association for paediatric resuscitation.

The study objects were identified by reviewing the case records of all patients who presented to the ED without spontaneous respiration and palpable pulse. Only patients in whom resuscitation was attempted at the ED were included. Patients who were in rigor mortis were excluded from the study. The characteristics of the patients that were recorded and correlated with outcome were age, sex, race, location of arrest, duration of cardiac arrest to start of cardiopulmonary resuscitation (CPR), duration of cardiac arrest to arrival in hospital, whether arrest was witnessed, presence of bystander CPR, mode of transport to hospital, duration of resuscitation at the ED, and number of doses of adrenaline. Three indices of outcome were analysed: return of spontaneous circulation, survival to discharge from hospital, and survival to one year. The neurological status of the children who survived to one year post-resuscitation was determined by going through the outpatient records of the patients. The neurological status was classified by using the paediatric cerebral (PCPC) and overall performance category scale (POPC)[4]. The terms of resuscitation were according to the definition from the Paediatric Utstein Style[4]. The cause of death was obtained from review of case notes, and coroner's reports.

Data analyses were performed using Statistical Package for Social Sciences (SPSS) for Windows version 11.0 (Chicago, IL, USA). Descriptive statistics for the patients were obtained and reported as median with ranges and frequencies. Association between categorical variables were assessed using chi-square or Fisher's exact tests. Normality assumptions of continuous variables were checked using the Kolmogorov Smirnov 1 sample test. Non-parametric test (Mann-Whitney U) was used to assess the continuous variables, as the normality assumptions were not satisfied. Multivariate analysis was done using logistic regression model. Statistical significance was set at $p<0.05$.

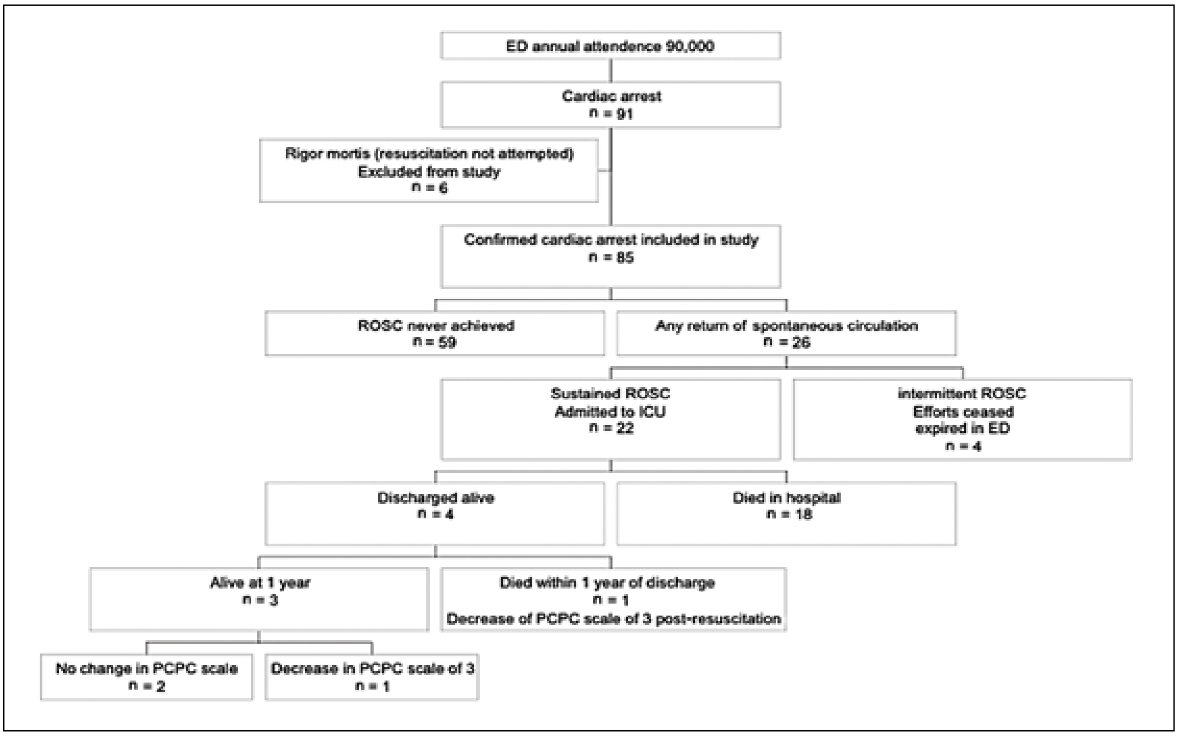
Table I. Characteristics of patients.

	No. (%) n=85
Age (in years)	
Median	1.5
Range	0 - 17
Sex	
Male	42 (49.4)
Female	43 (50.6)
Race	
Chinese	53 (62.4)
Malay	21 (24.7)
Indian	10 (11.8)
Others	1 (1.2)
Location	
Home	67 (78.8)
Public area	9 (10.7)
Clinic	3 (3.5)
Ambulance	6 (7)
EMS activation	
Ambulance	54 (63.5)
Private transport	31 (36.5)
Arrest witnessed	
Bystander – layperson	20 (23.5)
Medical professional	3 (3.5)
Ambulance personnel	6 (7)
None	56 (66)
Bystander CPR	
Layperson	9 (10.6)
Medical professional	11 (12.9)
Cardiac rhythm	
Asystole	82 (96.5)
VT/VF	2 (2.4)
Pulseless electrical activity (PEA)	1 (1.1)

RESULTS

During the 52-month study period, a total of 91 children presented to the ED in cardiopulmonary arrest. Six of them were in rigor mortis, and no resuscitation was attempted. 85 patients whereby resuscitations were attempted were included in the study. The median age is 1.5 years (mean 4.3 years; range day 12 neonate to 17 years). Table I describes the demographical and clinical characteristics of the patients. The most frequent cause of out-of-hospital cardiopulmonary arrest was secondary to respiratory disorders. There were 10 cases of cardiac arrest due to injuries, and six of them were home accidents. Causes of traumatic cardiac arrest were fatal falls (2), suffocation (2),

Fig. 1 Utstein template for children with cardiac arrest at the emergency department.



road traffic accidents (2), strangulation (1), drowning (1), severe head trauma (1) and electrocution (1) (Table II).

Twenty-six (30.6%) of the patients had return of spontaneous circulation (ROSC) after resuscitation at the ED, of which four of them had intermittent ROSC and expired in the ED. 22 (25.8%) survived to admission to the intensive care unit (ICU) for subsequent management. 18 eventually died in the ICU and only four (4.7%) survived to discharge from hospital. One of the four survivors sustained a second cardiac arrest three months post-discharge from hospital and died. Only three of them were still alive after one year, and one of them had significant neurological deficit (spastic quadriplegia) with deterioration in the PCPC and POPC of three scales. The remaining two survivors had no change in their PCPC and POPC scales on discharge and at one year (Fig. 1). The characteristics of the survivors are shown in Table III.

The emergency medical service (EMS) ambulances were activated in 63.5% (54 of 85) of the patients, and the remaining 36.5% of the patients were brought in to the ED by private transport. 78.8% (67 of 85) of the collapses occurred at home, while the remaining 21.2% occurred at public places, clinics or en-route to hospital. 34% (29 of 85) of the cardiac arrests were witnessed, of which 7% (6 of 85) witnessed by EMS personnel, 23.5% (20 of 85) by bystanders, and 3.5% (3 of 85) by medical professionals.

Table II: Aetiology of paediatric cardiac arrest.

	No. (%) n=85
Respiratory	
Infections	22
Asthma	4
Chylothorax	1
Others	1
Total	28 (32.9)
Cardiac	
Congenital heart disease	14
Myocarditis	3
Others	2
Total	19 (22.5)
Trauma	10 (11.8)
Neurological	
Central hypoventilation	1
Neuromuscular disease	4
Hypoxic ischaemic encephalopathy	3
Cerebral haemorrhage	2
Total	10 (11.8)
Gastrointestinal	
Intestinal obstruction	3
Biliary atresia	1
Severe dehydration-gastroenteritis	2
Total	6 (7)
Septic shock	2 (2.3)
Anaphylactic shock	1 (1.2)
Chromosomal anomalies	4 (4.7)
Cancer	2 (2.3)
Enterovirus 71	1 (1.2)
Sudden infant death syndrome	1 (1.2)
Acute salicylate poisoning	1 (1.2)

Table III. Profile of the survivors.

	Age (in years)	Sex	Pre-existing illness	Cause of cardiac arrest	Bystander CPR	Arrest witnessed by	Duration of resuscitation in ED (in min)	No. of adrenaline doses	Survival to 1 year	Neurological status at 1 year
1	0.1	Male	Down's syndrome	Down's syndrome with massive chylothorax	Yes	Mother	30	9	Yes	No change
2	11	Male	Asthma	Status asthmaticus	No	Paramedics	6	3	Yes	PCPC and POPC
3	0.3	Male	Multiple food allergies	Anaphylactic shock	Yes	Dad	20	6	Yes	Decrease of PCPC and POPC by 3 scales
4	0.6	Male	Central hypoventilation syndrome	Central hypoventilation syndrome	Yes	Mother	5	2	No	NA

22.9% (20 of 85) of the patients received bystander CPR prior to arrival of EMS personnel, of which 10.6% (9 of 85) of the patients received bystander CPR from laypersons, and another 12.9% (11 of 85) from medical professionals. The ambulance personnel provided mainly basic cardiac life support consisting of cardiac compressions, bag-mask ventilation, and defibrillation with automated external defibrillators (AEDs). 31.8% (27 of 85) of the patients received no CPR prior to arrival in the ED, and these patients were brought in by private transport. None of these patients who received no prior CPR survived to hospital discharge. Only four of the 31 patients who arrived in private transport received bystander CPR from laypersons. Of the four survivors, three of them received bystander CPR and one received CPR from an ambulance paramedic who witnessed the cardiac arrest en-route to hospital.

The most common initial cardiac rhythm for patients with cardiac arrest was asystole (96.5%; 82 of 85). There was only one patient with pulseless electrical activity on arrival to the ED, and he survived. The cause of cardiac arrest was due to hypoxia resulting from status asthmaticus. There were only two (2.4%) patients with ventricular fibrillation/pulseless ventricular tachycardia, of which one had pulseless ventricular tachycardia on arrival, which was converted to sinus rhythm in the ED, but subsequently died in the ICU. This patient was found to have myocarditis on post-mortem. Another patient with ventricular fibrillation received defibrillation by ambulance personnel, but was in asystole on arrival to ED. He had initial ROSC after resuscitation but subsequently died in ICU.

The predictors of survival to hospital discharge for patients who sustained out-of-hospital cardiac

Table IV. Predictive factors of survival for paediatric cardiac arrest.

Variable	Survival to hospital discharge n=4	Death n=81	p-value
Age (in years)			
Median	0.45	2.50	0.415
Range	0-11	0-17	
Interval between arrest and hospital arrival (in minutes)			
Median	27.5	35	0.185
Range	10-30	1-90	
Interval between arrest and CPR (in minutes)			
Median	5	15	0.104
Range	0-15	0-90	
Pre-existing illness	4	49	0.145
EMS activation			
Ambulance	3	51	0.536
Private transport	1	30	
Witness status			
Yes	4	25	0.012
No	0	56	
Location of arrest			
Home	3	64	0.621
Elsewhere	1	17	
Bystander CPR			
Yes	3	17	0.039
No	1	64	
Median no. of doses in ED (range)			
Adrenaline	4.5 (2-9)	6 (1-30)	0.501
Duration of resuscitation in ED (in minutes)			
Median	13	30	0.028
Range	5-30	5-80	

Table V. Predictive factors of return of spontaneous circulation (ROSC).

Variable	ROSC n=26	No ROSC n=59	p-value
Age (in years)			
Median	2.5	1.2	0.658
Range	0-16	0-17	
Interval between arrest and hospital arrival (in minutes)			
Median	30	35	0.042
Range	1-60	10-90	
Interval between arrest and CPR (in minutes)			
Median	10	15	0.086
Range	0-60	0-90	
Pre-existing illness	20	33	0.053
Bystander CPR			
No	19	46	0.642
Yes	7	13	
EMS activation			
Yes	15	39	0.422
No	11	20	
Witness status			
Yes	14	15	0.024
No	12	44	
Location			
Home	16	51	0.009
Elsewhere	10	8	
Median no. of doses in ED (range)			
Epinephrine	5 (1-10)	6 (1-30)	0.003
Duration of resuscitation in ED			
Median	25	30	0.012
Range	5-60	10-80	

ROSC: return of spontaneous circulation.

arrest were next analysed (Table IV). Factors that correlated positively to survival in a bivariate analysis were witnessed arrest as compared with unwitnessed arrest (p=0.012), presence of bystander CPR (p=0.039), and duration of resuscitation in the ED (p=0.028). The median duration of resuscitation is 13 minutes for those who survived, as compared to 30 minutes for those who died. None of those who survived were resuscitated beyond 30 minutes, though there was initial return of spontaneous circulation in one of the patient who was resuscitated for 60 minutes but eventually died in the ICU. There was a male predominance in the patients who survived to discharge (all four survivals were male). However, that did not achieve statistical significance (p=0.055).

Age, race, location of arrest, mode of transport (ambulance versus private transport), doses of resuscitation drugs such as adrenaline, atropine, bicarbonate, inotropic agents, pre-existing illness, duration of cardiac arrest to start of CPR, and duration of cardiac arrest to arrival in the ED did not reveal any significant differences. No multivariate analysis was done because of the limited numbers of survival to discharge. Similarly, in another bivariate analysis, patients with a witnessed arrest (14 of 29) were more likely to achieve ROSC than those who were not witnessed (12 of 56) (p=0.024) (Table V).

Patients who had their cardiac arrest at home were less likely to have response to resuscitation (16 of 67) than those who collapsed elsewhere outside of home (10 of 18; p=0.009). This was because patients who had cardiac arrest at home were less likely to be witnessed (13 of 67; 19.4%) as compared to those who collapsed elsewhere (16 of 18; 88.9%) (p<0.001). Those who have ROSC were also more likely to have a shorter duration of resuscitation in the ED (median time 25 min) than those who died (30 min) (p=0.012). The dose of adrenaline correlated positively to ROSC (median 5 doses) as compared with those who died (median 6 doses) (p=0.003). The median time interval between arrest and hospital arrival is also likely to be shorter in those who achieved ROSC (30 min) than those with no response (35 min) (p=0.042). A multivariate analysis using a logistic regression model showed that the only 2 independent predictors of ROSC were witnessed arrest (odds ratio = 3.049; 95% CI = 1.101- 8.444; p=0.032) and duration of resuscitation (odds ratio = 0.353; 95% CI = 0.146 - 0.854; p=0.021)

DISCUSSION

Limited information is available about the effects of CPR in children who sustained out-of-hospital cardiopulmonary arrest, although it is known that the outcome is poor. In our study, the rate of survival to hospital discharge for out-of-hospital paediatric cardiac arrest was 4.5%. This is similar to figures reported in previous pre-hospital studies done in other urban centres, such as Houston, Texas (2%)[5], San Francisco (3%)[6], and Toronto (7.5%)[3]. A collective review of 44 articles published from 1970 to 1997 on paediatric cardiac arrest was reported, and the authors found that overall survival after out-of-hospital cardiac arrest was poor at 8.4%, as compared to in-patient arrest survivals (24%)[7]. It is known that large cities tend to have lower survival rates, which is related to slower response time by the ambulance service as a result of high-rise buildings and traffic congestions[8].

The racial composition of our study population (62.4% Chinese, 24.7% Malay, 12.9% Indian/Others) was significantly different from the general Singapore population of 76.2% Chinese, 13.8% Malay, 10% Indian/Others (p=0.006). However, when the study population was compared with the racial distribution of all patients attending the ED (67.7% Chinese, 17.1% Malay, 15.2% Indian/Others) during the same period, from June 1997 to September 2001, there was no difference statistically (p=0.172). Thus, the difference seen could be explained by the higher percentage of non-Chinese patients attending the ED during that period.

The most common aetiologies of cardiac arrest in our patients were respiratory disorders (32.9%), cardiac diseases (23.3%) and trauma (12.5%). The aetiologies seen in this study differ from previous studies done, which were based on American and European populations, where the most common causes were sudden infant death syndrome (SIDS) and trauma[3,5,7,9,10]. In our series, there was only one patient diagnosed to have SIDS on post-mortem, though 50% of our patients were 18 months old or less. A previous study done in Singapore on sudden infant death reported the incidence of SIDS to be 0.08-0.2 per 1000 life births[11]. This may be attributed to the cultural differences in the sleeping practices for babies between the Asians and Caucasians, with Asian babies more likely to be put to sleep in the supine position, and share the same bedrooms as their parents. All the 10 patients who sustained cardiac arrest from traumatic causes in our study did not survive. Previous studies done to evaluate the effects of CPR on paediatric trauma patients in cardiac arrest have shown similar dismal results, with survival rates of 1-4%[5,7,12].

The critical links in the paediatric chain of survival are prevention, early CPR, early EMS activation, and early advanced life support (ALS)[13]. Several studies done had shown that early effective bystander CPR and witnessed arrest are crucial to increasing the chances of survival[7,14]. Though the results from our study also revealed both witnessed arrest and bystander CPR as positive predictors of survival in the bivariate analyses, the limitation in our study was the small number of survivals. Nevertheless, we were able to identify witnessed arrest as an independent predictor of ROSC in our multivariate analysis. In our study, 34% of the cardiac arrests were witnessed and the bystander CPR rate was 22.9%. Though our witnessed arrest rate is similar to that reported by a previous collective study (approximately one-third of arrests were witnessed), our bystander rate is lower than previously reported (one-third of cardiac arrest patients)[7]. This could be due to a lower public awareness in the importance of learning basic life support skills. The results of our study further reinforced that one of the most crucial factors in strengthening the links in the chain of survival is public education, to encourage parents and caregivers of young children to learn basic CPR skills. In addition, for lay rescuers, CPR instruction must remain simple. Retention of current CPR skills and knowledge is now suboptimal. More complex instruction is more difficult to teach, learn, remember, and perform[13].

Our study has also shown that most of the patients who sustained cardiac arrest at home were also less likely to be witnessed, leading to delay in starting CPR, and thus contributing to the poorer outcome as compared to those who collapsed elsewhere. Similar results were demonstrated by another study done in Sweden, including patients of all age groups, showing arrest at home as an independent predictor of adverse outcome[15]. However, the scope of our study did not allow us to further analyse the factors leading to the observation of less witnessed cardiac arrest at home than elsewhere. A prospective population-based epidemiological study may be able to address the concerns.

Another weak link identified in our study was that EMS was activated in only 63.5% of the cardiac arrests, with the remaining 36.5% arriving in private transport. This may reflect public unfamiliarity with the local emergency access number (995). In a previous study done in Singapore, 11% of the public surveyed did not know the correct local emergency access number[16]. Another possibility is the public perception that it is faster to arrive to hospital in their private vehicle than to wait for the ambulance. The cardiac arrest and resuscitation epidemiology (CARE) study, which was done in Singapore, reported ambulance response mean time as 10.2 (SD +/- 4.3) min[17]. This response time may still allow CPR to be provided earlier than if patients were to arrive to hospital in private transport without any form of CPR. In another study done in Michigan to look at impact of lay responder actions on out-of-hospital cardiac arrest outcome, the authors found that when a lay responder called to EMS (911) first, there appeared to be associated with improved survival. When a phone call other than 911 was made first, there were no survivors[18]. This shows that more work is needed to educate the public regarding the emergency access number 995 and to “phone fast”.

In our study, almost all the patients who received CPR prior to hospital arrival, including all those who were brought to hospital by ambulance, received only basic CPR. Only one patient who survived received advanced CPR from his father who was a medical doctor. Immediate on-site endotracheal intubation has been indicated as the only positive predictor for ROSC in a population-based study done in Houston, Texas involving 300 children with out-of-hospital cardiac arrest[5]. However, in another study by Pitetti et al[19], the authors found that the use of ALS by pre-hospital personnel did not improve survival to discharge from the hospital when compared with the use of basic life support (BLS). Thus, whether starting advanced CPR early in the chain of survival (pre-hospital) truly improves the survival rates is debatable. Further prospective pre-hospital studies are needed to explore whether the training of ambulance officers in advanced CPR, will increase the chances of survival in children with cardiac arrest.

The initial cardiac rhythm has been increasingly recognised to be an important factor of survival in paediatric cardiac arrest. Approximately 10% of the paediatric cardiac arrest patients were in ventricular fibrillations/ventricular tachycardia (VF/VT), and 30% of them survived to discharge from hospital according to a collective review. This compares favourably with bradyasystolic patients who had survival rate of 5%[7]. The International Liaison Committee on Resuscitation (ILCOR) in 2003 has recommended that automated external defibrillators (AEDs) may be used for children between one to eight years of age who have no signs of circulation. This further expanded the 2000 ILCOR recommendations about use of AEDs in children above eight years of age[20]. In our study, we were not able to analyse the predictive value of ECG rhythm as only two (2.4%) of the patients had initial rhythm of VF/pulseless VT, and both died in the ICU after initial ROSC. This disappointing low rate of initial VF/VT could be due to delay in recognition of cardiac arrest by the family members and the high percentage of patients that arrived to ED in private transports. This may cause the VF to degenerate into asystole. The authors from the CARE study found that the initial presenting rhythm to EMS is greatly dependent on the time from collapse that the patient is seen, with mean time of 6.3 (SD +/- 20.8) minutes for VT, 13.8 (13) minutes for pulseless electrical activity and 19.3 (SD +/- 16.1) minutes for asystole[17]. Thus, it is important to activate EMS early so that effective defibrillation can be delivered as early as possible when the presenting rhythm is VT/VF.

Another important predictor of ROSC and survival to hospital discharge in our study is the duration of resuscitation at the ED. Most studies have shown that resuscitation of more than 20 to 30 minutes of resuscitation had very poor prognosis[3,7,13]. In our study, attempts beyond 30 minutes of resuscitation in the ED are futile. This is in keeping with the paediatric advanced life support (PALS) 2000 guidelines, which state that resuscitative efforts may be discontinued after no more than 30 minutes of resuscitation, if there is no ROSC despite advanced life support intervention[13]. Though a previous study done had shown that the use of more than two doses of adrenaline is associated with poor prognosis[3], the maximum number of doses of adrenaline used in our survivors was 9 doses, and this patient had 30 minutes of resuscitation at the ED.

The poor neurological outcome of survivals of paediatric cardiac arrest had been highlighted in several studies[2,3,5,7]. Our study showed similar dismal results (Fig. 1). Emphasis must be placed on improving neurological outcome in addition to survival. Prevention of cardiac arrest and injury by educating the primary caregivers of children, especially parents, regarding: firstly, the recognition of the early signs of a sick child before deterioration to cardiopulmonary failure; and secondly, safe childcare practices; may help to decrease morbidity and mortality in paediatric cardiac arrests.

In conclusion, the results of our study and previous studies suggest that cardiac arrest among children has a very poor prognosis, especially when the efforts of resuscitation continue for longer than 30 minutes. The presence of a witnessed arrest and early effective bystander CPR are important in improving the outcome of cardiac arrest in children. As more than one-third of the patients were transported in private transport, there is a need to increase public awareness regarding early activation of EMS in paediatric cardiac arrest.

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