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ORIGINAL ARTICLE

Epidemiology and outcome analysis of children with traumatic out-of-hospital cardiac arrest compared to nontraumatic cardiac arrest

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Abstract
Purpose This study aimed to determine predictive factors for sustained return of spontaneous circulation (ROSC) in pediatric patients with traumatic out-of-hospital cardiac arrest (OHCA) and compared to those with nontraumatic OHCA.
Methods This was a retrospective prognostic study of children with OHCA presenting to the emergency department (ED) was conducted from 2005 to 2010. Related clinical factors that influenced sustained ROSC in traumatic OHCA patients were identified and compared to nontraumatic cases. Significant parameters in predicting sustained ROSC in traumatic OHCA children were also determined using multivariate logistic regression analysis, and etiologies of the ICU admissions were analyzed in patients with sustained ROSC.
Results Among 2,978 critically ill children admitted to the ED, 150 were pediatric OHCA patients, including 76 traumatic cases and 74 nontraumatic cases. Of children with OHCA, initial sustained ROSC was achieved in 51 cases (34.0 %), including 31 traumatic cases and 20 of nontraumatic cases. Head and neck injuries were the majority of traumatic cases in the traumatic OHCA children, followed by abdominal injuries and chest injuries. However, abdominal injuries accounted for the highest rate to gain sustained ROSC, while chest injuries had the lowest rate for successful sustained ROSC. Significant factors associated with sustained ROSC in traumatic OHCA

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included initial cardiac rhythm ($P < 0.05$), the period from scene to hospital ($P < 0.05$), and the duration of in-hospital cardiopulmonary resuscitation (CPR) ($P < 0.05$).
Conclusions Significant factors related to sustained ROSC have been identified as initial cardiac rhythm, duration of in-hospital CPR, and the period from scene to hospital. Head and neck injuries were the majority of traumatic cases and the prevention in head and neck trauma may play an important part in public health aspects.

Keywords Epidemiology · CPR · OHCA · Trauma · Children

Introduction

In children, out-of-hospital cardiac arrest (OHCA) is an uncommon event and the outcome of OHCA has been poor, with very high rates of mortality and severe neurological sequel [1, 2]. Few cases successfully achieve sustained return of spontaneous circulation (ROSC) after cardiopulmonary resuscitation (CPR) and finally survival to hospital discharge [3, 4], which is very stressful for medical teams, whose judgment and clinical management may influence outcome and prognosis [3–5]. Some studies reported that about 6 % of children suffering from an OHCA and 8 % of those receiving prehospital emergency response resuscitation survive, but many suffered serious permanent brain injury as a result of their cardiac arrest [6–11].

Children with OHCA can be initially categorized into traumatic and nontraumatic etiologies. Analyzing the factors related to successful initial CPR will significantly help primary clinicians to appropriately evaluate the condition and prognosis of pediatric OHCA patients. Understanding of the epidemiologic data of OHCA children in the emergency department (ED) may help expedite accurate clinical assessments and decision-making regarding intensive care unit (ICU) admission for sustained ROSC patients. In addition, epidemiologic patterns in pediatric trauma OHCA could help identify which causes to be the most prevalent in pediatric OHCA, and this information may have important implications in prevention programs.

This study investigated the epidemiologic patterns of pediatric traumatic OHCA patients presenting to the ED. In addition, we further analyze related factors associated with sustained ROSC in traumatic pediatric OHCA patients and compared with nontraumatic OHCA patients. Our hypothesis was that factors that have been shown to be associated with an increased chance of survival among children with nontraumatic OHCA in the ED also are associated with an increased chance of survival among those with traumatic OHCA presenting to the ED.

Patients and methods

Patient population

This retrospective study of children aged 0–18 years presenting with OHCA to the ED was conducted in three medical hospitals in Taiwan from January 2005 to December 2010. Prehospital information was obtained from the public emergency medical services (EMS) records and included the time the call was received, the time of arrival and departure from the scene, the time the patient arrived at the ED, and the duration of prehospital basic life support (BLS). All pediatric patients transferred to the ED from the EMS were included without distinction. The condition of the OHCA patients was classified as either trauma or nontrauma based on clinical assessment and bystander information. Patients presenting to the ED underwent resuscitation based on the pediatric advanced life support (PALS) and the advanced pediatric life support (APLS) protocols. In-hospital CPR was defined as resuscitation attempts performed in the ED. All treatments and decisions regarding the termination of resuscitation efforts were made at the discretion of the treating physician. Patients with do-not-resuscitate orders and those with terminal illnesses not expected to survive their current admission were excluded. The study was approved by the institution's Human Subjects Review Committee.

Methods

Demographic data gathered from the ED sheets included initial vital signs, age, gender, the transfer period from scene to hospital, the period from collapse to ROSC, prehospital BLS, initial cardiac rhythm on ED presentation [asystole, pulseless electrical activity (PEA), and ventricular fibrillation (VF)], duration of in-hospital CPR, and length of stay and diagnosis in the ED and ICU. The ICU admissions were also divided into neonatal ICU (NICU), pediatric ICU (PICU), and surgical ICU (SICU). The children were categorized into three age groups: young-aged (≤5 years), elementary school-aged (6–12 years), and adolescents (13–18 years).

In traumatic pediatric OHCA patients, we classified them into five main groups according to the site of main injury: (1) head and neck injuries, (2) abdominal injuries, (3) chest injuries, and (4) multi-site traumatic injuries. Moreover, the mechanisms for anatomical classifications of trauma were mainly divided into three causes, including MVC or RTI (motor vehicle crash or road traffic injuries), falls, and crush in our series. In addition, nontraumatic pediatric OHCA patients were classified into six groups according to the possible etiologies of their conditions: (1) cardiovascular disease, (2) respiratory diseases, (3) infections, (4) neurological disorders, (5) malignancy, and (6)

sudden infant dearth syndrome (SIDS). In this study, sustained ROSC was achieved when chest compressions were not required for 20 consecutive minutes and signs of a circulation continued.

Statistical analysis

The Chi-square test, Fisher's exact test, Mann–Whitney *U* test, and multivariate logistic regression analysis were used where appropriate. In the descriptive analysis, values were presented as mean ± standard deviation (SD). The difference between groups was presented as 95 % confidence intervals (CIs). For comparison of dichotomous variables between groups, Chi-square test or Fisher's exact test was used. Comparisons of continuous variables between two groups were made with the Mann–Whitney *U* test. Factors that may be associated with a sustained ROSC were analyzed according to Fisher exact test and the Mann–Whitney *U* test. A stepwise logistic regression analysis was used to select independent predictors of the dichotomous dependent variables, sustained ROSC and nonsustained ROSC. Possibility levels <0.05 were considered significant. Statistical analyses were performed using SPSS software (version 15.0; SPSS Inc., Chicago, IL, USA).

Results

Patients population

During the 5-year study period, 129,540 pediatric ED visits were recorded, of which 3,078 were critically ill children and 150 were pediatric OHCA patients who received immediate emergency care in the ED, including 76 traumatic cases and 74 nontraumatic cases. Thus, the incidence of OHCA in children admitted to the pediatric ED was 0.115 %, and around 4.873 % of critically ill children admitted to the ICUs from the EDs. The characteristics of OHCA patients admitted to the ED are presented in Table 1. The mean age was 7.36 ± 6.93 years. Of 150 children with OHCA, initial sustained ROSC was achieved in 51 cases (34.0 %), including 31 traumatic cases and 20 nontraumatic cases. However, only four of those with sustained ROSC were eventually discharged home from the hospital, with a total mortality rate of 98.0 % in pediatric OHCA patients in the ED (98.6 % for trauma vs. 95.9 % for nontrauma).

Characteristics and etiologies between patients with traumatic OHCA and nontraumatic OHCA

In the 76 traumatic OHCA patients, head and neck injuries were the majority of traumatic cases, followed by abdominal injuries and chest injuries. Comparison of the mechanisms for anatomical classifications of trauma is shown in Table 2. The most common mechanism of trauma was MVC or RTI (75.0 %) which caused 81.1 % of head and neck injuries, 78.6 % of thoracic injuries and 72.2 % of abdominal injuries. However, there is no significant difference of causes, process of transport and resuscitation among different mechanisms of trauma. For etiologies of patients with nontrauma, SIDS was the most common cause leading to OHCA, followed by cardiovascular diseases, infections, and respiratory diseases. Comparison of characteristics between patients with traumatic and nontraumatic OHCA is shown in Table 3. Traumatic OHCA

Table 1 Demographics of OHCA children admitted to the ED

Variables	OHCA patients	
	N	%
Gender		
Female	64	42.6
Male	86	57.4
Causes		
Trauma	76	50.1
Nontrauma	74	49.9
Initial cardiac rhythm		
Asystole	92	61.3
PEA	35	23.3
VF[a]	23	15.4
Sustained ROSC		
Yes	51	34.0
No	99	66.0
Mode of transportation		
Family	73	48.7
EMTs	77	51.3
Prehospital BLS		
Yes	80	53.3
No	70	46.7
Age		
0–5 years	78	52.1
6–12 years	29	19.3
13–18 years	43	28.6
The period from scene to hospital (mean ± SD) (min)	23.36 ± 13.19	
The period from collapse to ROSC (mean ± SD) (min)	35.68 ± 16.50	
The duration of prehospital BLS (mean ± SD) (min)	2.33 ± 3.82	
The duration of in-hospital CPR (mean ± SD) (min)	29.10 ± 15.60	

EMTs emergency medical technicians, *BLS* basic life support

[a] VF includes patients with pulseless VT

Table 2 Categorizing mechanisms for anatomical classifications of trauma

Anatomical classifications of trauma	Mechanisms			*P* value
	MVC or RTI ($n = 57$)	Falls ($n = 9$)	Crush ($n = 10$)	
Head and neck	30	4	3	0.505
Thoracic	11	1	2	
Abdomen	13	2	3	
Multiple	3	2	2	

MVC motor vehicle crash, *RTI* road traffic injuries

Table 3 Characteristics between patients with traumatic and nontraumatic OHCA

Variables	Trauma ($N = 76$)	Nontrauma ($N = 74$)	*P* value
Gender			
Female	28	36	0.147
Male	48	38	
Initial cardiac rhythm in the ED			
Asystole	45	47	0.466
PEA	21	14	
VF/pulseless VT	10	13	
Sustained ROSC			
Yes	31	20	0.109
No	45	54	
Mode of transportation			
Family	15	58	< 0.05
EMTs	61	16	
Prehospital BLS			
Perform	56	24	<0.05
Not perform	20	50	
The period from scene to hospital (mean ± SD) (min)	17.98 ± 7.97	29.05 ± 12.71	<0.05
The duration of prehospital BLS (mean ± SD) (min)	5.22 ± 3.12	1.82 ± 4.22	<0.05

EMTs emergency medical technicians, *BLS* basic life support

patients were more commonly transferred by EMTs and more commonly received prehospital BLS than those with nontraumatic OHCA (both $P < 0.05$). In addition, the period from scene to hospital in the traumatic cases was significantly shorter than that in nontraumatic cases ($P < 0.05$). The duration of prehospital BLS in the traumatic cases was significantly longer than that in nontraumatic cases ($P < 0.05$). Although the rate of sustained ROSC in traumatic OHCA patients (40.78 %) was higher than that in nontraumatic OHCA cases (27.02 %); this result showed no significantly statistical difference.

Related clinical factors associated with sustained ROSC

The mean durations of in-hospital CPR were 33.36 ± 17.12 and 32.86 ± 18.45 min in children with nontraumatic and traumatic OHCA, respectively. For emergency care and managements, intubation was performed in all of our OHCA children, and epinephrine was the most common drug used during in-hospital resuscitation. Among all patients, the total treating dose during CPR was 0.32 ± 0.25 mg/kg in survivors and 0.48 ± 0.32 mg/kg in nonsurvivors. After analyzing the results, the total treating dose of epinephrine was not a significant factor associated with survival. In the 76 pediatric traumatic OHCA patients with sustained ROSC, abdominal injuries accounted for the highest rate to gain sustained ROSC, while chest injuries had the lowest rate for successful sustained ROSC (Table 4). But in nontraumatic cases, respiratory diseases accounted for the highest rate to gain sustained ROSC, while malignancy had the lowest rate for successful sustained ROSC. In the traumatic OHCA patients, sustained ROSC was significantly related to initial cardiac rhythm ($P < 0.05$), and the period from scene to hospital ($P < 0.05$). Pediatric patients with PEA and VF had higher rates to gain sustained ROSC than those with asystole. In the 74 pediatric nontraumatic OHCA patients, sustained ROSC was correlated to initial cardiac rhythm ($P < 0.05$), prehospital BLS ($P < 0.05$), mode of transportation ($P < 0.05$), the transfer period from scene to hospital ($P < 0.01$), and the duration of prehospital BLS ($P < 0.05$). The total durations of CPR (in/prehospital) were 41.42 ± 19.12 and 40.85 ± 17.32 min in children with nontraumatic and traumatic OHCA, respectively. Of all, the total durations of CPR were shorter in survivors (23.12 ± 15.13 min) than in nonsurvivors (45.33 ± 20.17 min). For mode of transportation and prehospital BLS, in patients with traumatic OHCA transported by family, no BLS was performed, but in nontraumatic cases, 13.7 % of patients transported by family had BLS. In contrast, the nontraumatic cases transported by EMTs all had BLS, and in traumatic cases, 91.8 % of patients transported by EMTs had BLS.

Clinical outcomes of OHCA patients with sustained ROSC

In the 51 pediatric patients with sustained ROSC, only 12 patients had been successfully resuscitated by performing CPR and survived more than 72 h. Among the 12 patients with sustained ROSC, 7 patients survived for more than 168 h after intensive care in the ICUs but only 4 cases were finally discharged home from the hospitals. For etiologies of the four cases, one was respiratory disease, one was cardiovascular disease, one was neurological disease, and

Table 4 Related factors associated with sustained ROSC in traumatic and nontraumatic OHCA children

	Sustain ROSC of traumatic OHCA			Sustain ROSC of nontraumatic OHCA		
	Success	Fail	*P* value	Success	Fail	*P* value
Gender						
Female	11	17	ns	6	30	ns
Male	20	28		14	24	
Initial cardiac rhythm						
Asystole	11	34	0.004	7	40	<0.05
PEA	15	6		9	5	
VF	5	5		4	9	
Mode of transportation						
Family	8	7	ns	11	47	<0.05
EMTs	23	38		9	7	
Prehospital BLS						
Yes	24	32	ns	15	9	<0.05
No	7	13		5	45	
Etiologies						
Traumatic						
Head and neck injury	15	22	ns			
Abdominal injury	9	9				
Thoracic injury	4	10				
Multiple trauma	3	4				
Nontraumatic						
Sudden infant death syndrome				5	16	ns
Cardiovascular disease				5	12	
Respiratory failure				6	6	
Infections				2	11	
Neurology problem				2	6	
Malignancy				0	3	
The period from scene to hospital (mean ± SD) (min)	15.64 ± 8.00	32.33 ± 13.13	<0.05	17.36 ± 4.13	33.00 ± 16.13	<0.05
The duration of prehospital BLS (mean ± SD) (min)	3.76 ± 3.21	3.50 ± 4.69	ns	5.70 ± 5.46	0.18 ± 0.87	<0.05

ns not significant

one was abdominal injury. Furthermore, of all children with OHCA, two cases (1.33 %) eventually became donors after suffering a traumatic OHCA.

Discussion

Our data showed that the prevalence of pediatric OHCA in the pediatric ED was 0.115 %. The data differ from those in adult studies, in which the estimated prevalence of adults OHCA (5–10 %) [12, 13] was much higher than that in children. In addition, the rate of survival to hospital discharge in children requiring CPR in the ED was only 2.67 %. This disappointingly low survival rate is similar to the rates in previous studies of CPR in children, which range from 0 to 24 % [6, 10, 11, 14–17]. This rate is also similar to adult studies whose survival rates were 5–10 % [12, 13]. Clinical parameters for sustained ROSC in

pediatric OHCA patients are important but not well investigated. This study has determined some clinical parameters associated with sustained ROSC in the ED. Initial cardiac rhythm in pediatric traumatic OHCA patients in the ED is significantly associated with sustained ROSC. Asystole is a more common cardiac initial rhythm than PEA and VF, but PEA and VF appear to be better predictors of sustained ROSC than asystole. VF may develop during resuscitation attempts. In addition, VF is referred to as "shockable rhythms" because they respond to electric shocks (defibrillation). For patients with VF, defibrillators either manually or automated external defibrillator (AED) may play an important role in institutions caring for children at risk for arrhythmias and traumatic cardiac arrest in the ED and prehospital care [18, 19]. However, according to pediatric BLS guidelines, pediatric chain of survival does not include early defibrillation [18, 19], but for the patients with VF, sustained ROSC could not be achieved without defibrillation. Thus, to get AED as early as possible could be considered as an important part in performing prehospital pediatric resuscitation.

Other factors associated with sustained ROSC include the performance of prehospital BLS and time-related factors. Time-related factors such as the transfer period from scene to hospital, and the period from collapse to ROSC, are important for pediatric patients with traumatic OHCA to gain sustained ROSC. In our study, children with nontrauma were more commonly transported by family than EMTs. It also took more time to the hospital in children with nontrauma than those with trauma. Notably, children transported by EMTs could have prehospital BLS more commonly than those transported by family, and the time from scene to hospital would be shorter in children transported by EMTs than by family. Therefore, the reason may explain why nontraumatic OHCA children may take more time to get to the hospital in our study. Moreover, we also noticed that the duration of prehospital BLS in patients with OHCA in our analysis was short despite the EMT on the scene. All patients with OHCA were transported by family or EMTs. However, when patients were transported by family, prehospital BLS was performed briefly and interruptedly. The conditions may lead to the results of very short duration of BLS performed in patients with OHCA in our study. Decreasing the transfer period of time from the scene to the hospital and performing prehospital BLS more could obviously increase the chance for sustained ROSC in pediatric OHCA patients in the ED.

In this study, traumatic injuries were commonly caused by MVC or RTI. Patients with head and neck injury comprised the majority of those in traumatic OHCA patients. Sustained ROSC could be gained in patients with head and neck injuries, but the prognosis remains quite poor. Notably, survival from traumatic OHCA caused by head and neck injuries is quite rare, emphasizing the importance of head and neck injuries prevention such as helmets in reducing deaths. Moreover, sustained ROSC may serve as a bridge to possible organ donation. If organ donation is available, sustained ROSC is necessary to prevent organ failure before organ donation intervention. In contrast, sustained ROSC could be achieved in 9 (50.0 %) patients with abdominal traumatic injuries and one of them could be discharge home from the hospital after critical care. Therefore, primary clinicians should pay attention to pediatric patients with traumatic OHCA caused by abdominal injuries and treat them more aggressively.

Conclusion

More BLS should be taught to care givers of home patients with chronic illness and EMT should be called rather than family members driving patients to the hospital. Head and neck injuries were the majority of traumatic cases and the prevention in head and neck trauma may play an important part in public health aspects. In addition, primary clinicians should pay attention to children with abdominal injuries for the higher survivability among traumatic OHCA children.

Conflict of interest There is no conflict of interest related to this study.

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