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Outcome from paediatric cardiac arrest associated with trauma[☆]

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KEYWORDS

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resuscitation (CPR);
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Summary

Objective: To examine survival rates for paediatric trauma patients requiring cardiopulmonary resuscitation (CPR) in the pre-hospital setting, and to identify characteristics that may be associated with survival.

Design: Ten-year retrospective trauma database review.

Setting: An urban physician-led pre-hospital trauma service serving a population of approximately 7.5 million, in the United Kingdom.

Patients: Eighty paediatric trauma patients (15 years or less) who received pre-hospital resuscitation following cardiorespiratory arrest between July 1994 and June 2004.

Intervention: Pre-hospital cardiopulmonary resuscitation.

Main outcome measure: Survival to hospital discharge.

Results: Eighty children met inclusion criteria for the study. Nineteen (23.8%) were discharged alive from the emergency department and seven children (8.75%) survived to hospital discharge.

Of the seven survivors, one had spinal cord injury. Two suffered asphyxial injury associated with blunt trauma and three sustained hypoxic insults following drowning or burns/smoke inhalation. In one patient with known congenital cardiac disease the cause of cardiac arrest was likely to have been medical.

Conclusion: This study confirms the poor outcome for children requiring pre-hospital CPR following trauma. However, the results are better in this physician-attended group than in other studies where physicians were not present. They also suggest that cardiac arrest associated with trauma in children has a better outcome than in adults. In common with adults treated in this system, those patients with hypovolaemic cardiac arrest did not survive (Ann Emerg Med 2006;48:240–4). A large proportion of the survivors suffered hypoxic or asphyxial injuries. Targeted aggressive out-of-hospital resuscitation in certain patient groups can produce good outcomes.

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What we already know about this topic:

- Paediatric cardiac arrest in the community is an uncommon event.
- Published survival rates from outside the UK following traumatic cardiac arrest are poor in adults and children.
- Recent guidelines for withholding or terminating resuscitation in traumatic cardiac arrest do not include children because of the lack of data on the subject.¹

What the study adds:

- Survival rates following cardiac arrest associated with trauma in the UK are poor.
- Children who sustain traumatic cardiac arrest precipitated by hypoxaemia have the best chance of surviving.
- Children who have pre-hospital hypovolaemic cardiac arrest, particularly following penetrating trauma, have a poor chance of survival.

Introduction

Background

Paediatric cardiac arrest is an infrequent event, accounting for only 2% of all out-of-hospital cardiac arrests.² A recent review suggested that almost 22% of cardiac arrests in children are associated with trauma,³ making this one of the most common causes of pre-hospital cardiac arrest and death between the ages of 1 and 16 years.^{4,5} Traumatic injury is usually considered in subgroups of blunt trauma, penetrating trauma, and 'other', including hypoxic events such as electrocution, drowning, and hanging. There is minimal published information for all these patient groups but, in particular, few data exist on the efficacy of CPR following hypoxic insults.⁶

Importance

Survival following traumatic cardiac arrest is universally reported as poor for adults and children.⁵ Most successfully resuscitated paediatric cardiac arrest victims are those who receive CPR in the pre-hospital phase.⁷ Providers of emergency care should be aware of patient sub-groups in whom aggressive resuscitation efforts may produce a good outcome.

Goals

This study set out to identify survivors of paediatric traumatic cardiac arrest in a UK physician-led pre-hospital service, and characteristics that may be associated with survival.

Method

The London Helicopter Emergency Medical Service (HEMS) is a well-established physician-led pre-hospital trauma service operating from a London teaching hospital. Pre-determined dispatch criteria ensure the service is deployed only to major trauma, with rare exceptions. The London HEMS trauma database was reviewed retrospectively to identify all children (aged < 16 years) who required pre-hospital cardiopulmonary resuscitation during a 10-year period (July 1994 to June 2004). Cardiopulmonary resuscitation was identified by the use of high-dose adrenaline, external or internal cardiac compressions, and/or defibrillation on scene or during transfer to hospital. The primary outcome measure was survival to hospital discharge. Pre-hospital records of survivors were further examined to identify factors associated with their cardiac arrest.

All patients triaged directly from the accident scene to the receiving hospital were included in the study; interhospital transfers were excluded. Patients suffering cardiac arrest secondary to hypoxia from drowning, burns/smoke inhalation, and electrocution were included.

London HEMS is staffed by a physician and flight paramedic with specialist training in pre-hospital care. The arrival of London HEMS on scene is often preceded by a ground ambulance crew who will usually commence immediate basic life support. Advanced life support may be initiated where the necessary skill levels exist. Interventions undertaken on scene by HEMS personnel include:

- Oxygenation/establishment of a definitive airway.
- Formal bilateral chest decompression.
- Intravenous or intraosseous access/appropriate fluid administration.
- Paediatric advanced life support.

If the patient has a witnessed arrest following penetrating chest trauma, and surgical intervention is estimated to be more than 10 min away, thoracotomy is carried out on scene. Resuscitative efforts are not usually terminated on children until arrival in the emergency department.

Results

In the 10-year study period a total of 12,086 trauma patients were attended by London HEMS. Eighty children required pre-hospital CPR on scene or during transport to hospital. Of these, 19 (23.75%) survived to discharge from the emergency department. Seven children (8.75%) survived to be discharged from hospital; their mean age was 5.7 years (range 2–11). Three children were functionally normal at the time of discharge. Full neurological outcome data was unavailable for the remaining survivors. Twelve children died during the inpatient stay. The average survival of this subgroup was 2 days; five patients died within the first 24h.

Fifty patients (62.5%) sustained blunt trauma, including two patients who were suspected to have had a medical cardiac arrest, which most likely occurred before, and resulted in, their trauma. Road traffic collision (RTC) was the mechanism of injury in 33 children (41.3%). Other mechanisms of blunt trauma were fall from height, air crash, assault, struck by a falling object, and a case of non-accidental injury. All seven patients (8.75%) with penetrating trauma had stabbing injuries. Twenty-three patients (28.75%) sustained hypoxic insults (hanging, drowning, and burns/smoke inhalation) (Figure 1).

Four patients (5.0%) survived to hospital discharge following blunt trauma. One survivor had spinal cord injury, and two patients sustained traumatic asphyxia following crush injury to the chest or airway obstruction. In one survivor with a background of congenital heart disease it is probable that the cardiac arrest was medical in origin but it is unclear whether it was the cause, or a consequence, of his trauma.

Three children (3.75%) survived following a hypoxic mechanism of injury which resulted in car-

diac arrest. The mechanism of injury in one of these cases was near drowning; the other two children arrested following burns/smoke inhalation.

There were no survivors of penetrating trauma. Thoracotomy was performed in four of the seven patients with penetrating injury. It was not carried out in the remaining three children because they did not meet local indications for this procedure.⁸

Of note, the mean scene time for the study population was 26.4 min and mean transport time was 6.4 min.

Discussion

Few data are available regarding the aetiology and outcome of cardiac arrest in children. A recent comprehensive review documented a long-term survival rate of 6.7% for children sustaining out-of-hospital cardiac arrest of any cause. The same study concluded that only 1.1% of trauma patients in cardiac arrest survived to hospital discharge. In this review, the term 'trauma' describes blunt or penetrating injury, child abuse, burns and smoke inhalation.³ Drowning is the most common cause of accidental death in children,⁹ and a survival rate of 22.7% was recorded for this patient subgroup.³

Other studies of out-of-hospital paediatric cardiac arrest have demonstrated survival rates ranging from 0% to 22.6% (Table 1) The casemix of the studies varies widely in terms of definition of cardiac arrest, and the upper age limit of subjects. Many studies exclude patients in whom resuscitative efforts were terminated in the pre-hospital phase and those in whom resuscitation was not attempted at scene or after arrival in the emergency department. Patients in a peri-arrest state have been included in some studies. Where traumatic cardiac arrest was the primary focus, patients with a hypoxic mechanism of injury (electrocution, drowning, burns/smoke inhalation) were used in the analysis of some studies but not others.

The two studies led by Li et al. and Perron et al. documented relatively high survival rates, 22.6% and 23.5%, respectively.^{4,11} Both studies used the National Paediatric Trauma Registry (NPTR) as their data source. These survival rates may be spuriously high because some patients described as 'receiving CPR' may have received only other pre-hospital interventions such as intravenous fluid therapy or inotropic drug support and not sustained cardiac arrest.³ Perron et al. also included all patients aged less than 19 years. The main outcome measure for the study was survival to trauma centre discharge rather than hospital discharge.¹¹ Li et al. excluded children pronounced dead on scene.

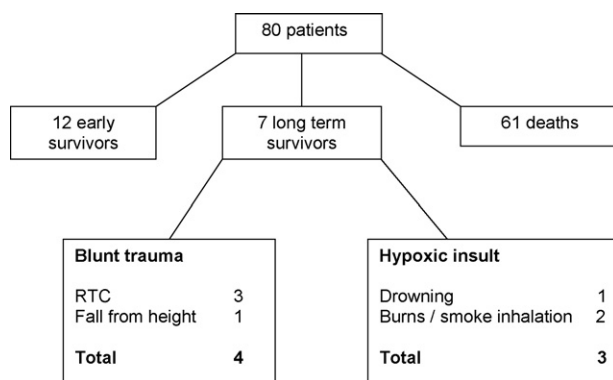


Figure 1 Outcome of study population.

Table 1 Survival from out-of-hospital paediatric cardiac arrest

Study	Cause of arrest	Patients	Survivors (%)
Calkins et al. ¹⁰	Trauma	25	2 (8.0)
Perron et al. ¹¹	Trauma	729	165 (22.6)
Fisher and Worthen ¹²	Trauma	65	1 (1.5)
Li et al. ⁴	Trauma	269	4 (1.5)
		957	225 (23.5%)
Suominen et al. ⁶	Trauma	41	3 (7.3)
Hazinski et al. ⁵	Trauma	30	0 (0)
Gerein et al. ¹³			
Ong et al. ⁹	All	474	9 (1.9)
Engdahl et al. ²	All	98	5 (5.1)
Sirbaugh et al. ¹⁴	All	300	6 (2.0)
Schindler et al. ¹⁵	All	80	6 (7.5)
Hickey et al. ⁷	All	95	15 (15.8)
Mogayzel et al. ¹⁶	All	438	15 (3.4)
Kuisma et al. ¹⁷	All	79	5 (6.3)
Losek et al. ¹⁸	All	114	9 (7.9)

If analysis is performed for only those patients who were pulseless at time of presentation to the emergency department, the survival rate decreases from 23.5% to 1.5%.⁴ One study reported no survivors among children presenting to an emergency department in cardiac arrest.⁵ An 8% survival rate was recorded in another study but the two survivors had vital signs in the pre-hospital setting and CPR was started in the emergency department.¹⁰ Hickey et al. reported a survival rate of 15.8%. Their study included children who received initial treatment in the emergency department as well as those who underwent resuscitation at other hospitals and were subsequently transferred to their centre. The authors acknowledge that, in general, only successfully resuscitated patients were transferred; 12.5% of patients who were pulseless on EMS arrival survived. Patients who died in the pre-hospital phase were excluded.⁷

The survival rate for children sustaining cardiac arrest associated with trauma in our study is 8.75%. Although this figure confirms the generally poor outcome for these patients, the survival rate is at least comparable with that generally observed for survival from out-of-hospital cardiac arrest of all causes (5–8.4%).^{19,20} Three patients survived without neurological deficit. Two of the neurologically intact survivors sustained an asphyxial mechanism of injury secondary to blunt trauma. The third intact survivor suffered burns/smoke inhalation. In the other survivors full details of neurological outcome could not be obtained (all were taken to hospitals which were not the base hospital for this service).

Previous work has suggested that cardiac arrest in children with trauma is often caused by bleeding or prolonged hypoxaemia.⁶ This reflects the lower incidence of primary cardiac disease in children compared with adults. Our data also revealed survivors in other categories of traumatic injury such as neurological injury and traumatic asphyxia. The patient group with the highest survival rate (13.0%, 3 of 23 children) included those children who appeared to suffer cardiac arrest after becoming hypoxic. This finding is confirmed by another study, where four of the five surviving children had a hypoxic mechanism of injury (near drowning and hanging).¹⁷ Similar results have been observed in studies of adults.^{21,22} Patients sustaining blunt trauma may experience a period of apnoea precipitating a respiratory arrest, which progresses to cardiac arrest. If our 'hypoxic' subgroup is extended to cover all hypoxic insults including hanging, drowning, burns/smoke inhalation, and those with traumatic asphyxia secondary to blunt trauma, the survival rate increases to 71.4% (5 of the 7 survivors). Children in this subgroup may particularly benefit from aggressive pre-hospital resuscitation.

In our series, no patients who had a cardiac arrest following penetrating trauma survived. Hypovolaemic cardiac arrest is often associated with a poor outcome.^{4,6,22} The high rate of bleeding associated with hypovolaemic cardiac arrest in the pre-hospital phase is unlikely to respond to conventional CPR. In contrast, when apnoea precedes cardiac arrest, provision of adequate oxygenation may restore a spontaneous circulation. The survival rate for children who sustained blunt trauma

was 5.0%, which is comparable to other studies (0–4.8%).^{5,6,10}

It has been suggested that the requirement of more than two doses of adrenaline, or duration of CPR longer than 20–30 min, are poor predictors of outcome in normothermic patients.^{15,23} Our results do not entirely support this. Two survivors in our series required two or more doses of adrenaline. Although the exact duration of CPR was not recorded specifically, the combined total of scene and transport times for the long-term survivors was greater than 20 min in 86% of cases, and longer than 30 min in 57%. It is likely that a number of survivors experienced a prolonged period of resuscitation.

The survival rate of 8.75% in this study suggests possible benefit from a physician-led pre-hospital response. The majority of paramedics rarely encounter children in cardiac arrest because it is an uncommon event. The presence of a physician on scene enables interventions, which are outside the scope of paramedic practice, to be undertaken early after injury. The scene times documented in this study (mean 26.4 min) are no longer than those reported by paramedic only systems.²⁴ Thus, the time taken for the patient to receive advanced treatment is reduced without delaying transfer to hospital.

There are no specific guidelines for the management of children in cardiac arrest secondary to trauma. The most recent guidelines from the United States regarding withholding or termination of resuscitation in pre-hospital traumatic cardiopulmonary arrest should not be applied to children because supporting evidence is lacking.² Throughout the 10-year study period, paediatric advanced life support undertaken by London HEMS personnel complied with the European Resuscitation Council (ERC) guidelines.^{25–27} The latest edition of the ERC guidelines has included a simple algorithm for paediatric basic life support which is directed at healthcare professionals.²⁸ The section from these guidelines focussing on cardiac arrest in special circumstances also addresses the management of trauma patients in cardiac arrest.²⁹

Limitations

Although this study is the largest of its type from the UK it includes relatively few subjects. Any conclusions must therefore be cautious. Unfortunately, data on the neurological outcome of the survivors was incomplete. The presenting cardiac rhythm was not always documented. We could not therefore correlate presenting rhythm with survival (previ-

ous work has shown that ventricular fibrillation is associated with a more favourable outcome¹⁷).

Conclusion

Though this study confirms the poor outcome for children receiving pre-hospital CPR for cardiac arrest associated with trauma, the survival rate is at least as good as previously reported by most other similar studies. Children with hypoxic insults appear to have a better chance of survival, and those with hypovolaemic arrest rarely survive. Three of seven surviving children had a good neurological outcome. Targeted aggressive out-of-hospital resuscitation may produce good outcomes in some identifiable patient groups.

Competing interests

None declared.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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