Clinical paper

Paediatric traumatic out-of-hospital cardiac arrests in Melbourne, Australia

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A R T I C L E   I N F O

Article history:
Received 9 September 2011
Accepted 8 November 2011

Keywords:
Trauma
Out-of-hospital cardiac arrest
Paediatric
Outcomes
Mechanism of injury

A B S T R A C T

Introduction: Many consider attempted resuscitation for traumatic out-of-hospital cardiac arrest (OHCA) futile. This study aims to describe the characteristics and profile of paediatric traumatic OHCA.

Methods: The Victorian Ambulance Cardiac Arrest Registry (VACAR) was used to identify all trauma related cases of OHCA in patients aged less than 16 years of age. Cases were linked with their coronial findings.

Results: Between 2000 and 2009, EMS attended 33,722 OHCA including 2187 adult traumatic OHCA. There were 538 (1.6%) OHCA in children less than 16 years of age of which n = 64 were due to trauma. The median age (IQR) of paediatric traumatic OHCA was 7 (4.5–13) years and 44% were male (64%). Bystander CPR was performed in 22 cases (34.4%). The first recorded rhythm by EMS was asystole seen in 42 (66%), PEA in 14 (22%) cases and VF in 2 cases (3%). Cardiac output was present in 7 (11%) cases who subsequently had an EMS witnessed OHCA. EMS attempted resuscitation in 35 (55%) patients of whom 7 (20%) achieved ROSC and were transported, and 1 (3%) survived to hospital discharge with severe neurological sequelae; 14 (40%) were transported to CPR of whom none survived. Coronial cause of death was multiple injuries in 35%, head injury in 33%, head and neck injury in 10%, chest injuries in 10% and other causes (12%)

Conclusions: Traumatic aetiology of OHCA when compared to the incidence of adult traumatic OHCA is uncommon. Resuscitation efforts are seldom effective and associated with poor neurological outcome.

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1. Introduction

Trauma is one of the most common causes of paediatric out-of-hospital cardiac arrest (OHCA) responsible for 22% of OHCA in this age group. Resuscitation of traumatic OHCA is considered by many to be futile and an inappropriate use of resources due to the associated low survival and poor neurological outcomes. While guidelines exist regarding the withholding or termination of resuscitation in out-of-hospital traumatic cardiopulmonary arrest in adults these cannot be extrapolated to the paediatric age group as supporting evidence is lacking. Prehospital trauma services where physicians attended the scene report better results for paediatric patients in traumatic OHCA than those where physicians were not present however there may be selection bias in the patients they attended.

This study aims to describe the characteristics and profile of paediatric traumatic OHCA in Melbourne.

2. Methods

The state of Victoria, Australia has a population of 5.3 million with approximately 4 million residing in metropolitan Melbourne of whom approximately 810,000 are <16 years of age. Victoria is served by a state-wide trauma system with triage of major trauma patients to designated major trauma services comprising two adult and one paediatric level 1 centres. The emergency medical service (EMS) comprises ambulance paramedics who have some advanced life support skills (laryngeal mask airway, intravenous epinephrine) and mobile intensive care ambulance (MICA) paramedics who are authorized to perform endotracheal intubation, rapid sequence induction, Pneumocath® insertion and administer a wider range of drugs. Paramedics in Victoria have a base qualification of a three year bachelor in health sciences degree. MICA paramedics are experienced paramedics who undergo a university-level post graduate diploma in Intensive Care Paramedical Practice. The Advanced Medical Priority Dispatch System® is operational in Melbourne. MICA paramedics are dispatched to patients with critical illness, including patients with cardiac arrest. In addition, fire-fighters are dispatched to patients with suspected cardiac arrest in the inner two thirds of Melbourne. EMS response time is the time from ‘000’ call to arrival at scene. The pre-hospital cardiac arrest protocols follow the recommendations of the Australian Resuscitation Council.© 2011 Elsevier Ireland Ltd. All rights reserved.

A Spanish translated version of this summary of this article appears as Appendix in the final online version at doi:10.1016/j.resuscitation.2011.11.009.

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On behalf of the VACAR Steering Committee.

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doi:10.1016/j.resuscitation.2011.11.009
commence resuscitation when the injuries are inconsistent with life. This includes decapitation, presence of rigor mortis, decomposition or post mortem lividity, where death has been declared by a Medical Officer who is or has been at the scene and where the presenting rhythm was monitored as asystole for >30 s, and there has been >10 min downtime with no evidence of hypothermia, drug overdose or family/bystander objections. Paramedics may discontinue resuscitation if advanced life support has been performed for 30 min without return of spontaneous circulation (ROSC), the rhythm is not Ventricular fibrillation (VF) or Ventricular Tachycardia (VT), there are no signs of life, no gases or evidence of pulmonary reaction and no evidence of hypothermia or drug overdose.10

Patient details and management are documented by paramedics in an electronic patient care record (PCR) since December 2007. Documentation in previous years involved a paper-based PCR. Selected data from PCRs is collected for all cases of OHCA and stored on the Victorian Ambulance Cardiac Arrest Registry (VACAR). VACAR also includes some data from the hospital record for those cases transferred to hospital, including length of stay, discharge direction from hospital and outcome.

The National Coroners Information System (NCIS) is a national internet based data storage and retrieval system for Australian coronial cases. Information about every death reported to an Australian coroner since July 2000 is stored within the system.

The Victorian Ambulance Cardiac Arrest Registry (VACAR) was searched for all OHCAs occurring due to trauma in those aged less than 16 years. This included OHCAs occurring in the presence of EMS. Hanging associated OHCA, though traumatic represent an individual group when following Utstein11 reporting and were excluded from this analysis. Traumatic OHCAs identified by VACAR were then searched for on the National Coronial Information System (NCIS) and ‘closed cases’ reviewed.

2.1. Ethics approval

VACAR has been classified as a quality assurance project by the ethics committee at the Department of Health. The collection of cardiac arrest outcome data by VACAR was approved by the ethics committees of Melbourne hospitals receiving cardiac arrests by ambulance. This study was approved by the Research Committee of Ambulance Victoria and Monash University Human Research Ethics Committee.

2.2. Statistical analysis

All data were entered into an Access software cardiac arrest registry database (version 2003, Microsoft, Redmond, WA, USA). Statistical calculations were performed on STATA software (version 10.0 Stata Corporation, College Station, TX, USA). Chi-Square was used to determine differences for categorical variables, with a p value <0.05 regarded as statistically significant. Continuous variables were compared using the t-test (normal distribution) or Mann–Whitney.

3. Results

Between the years 2000 and 2009, EMS attended n = 33,722 OHCAs of which n = 538 (1.6%) occurred in children aged less than 16 years of age. Fig. 1 shows the breakdown of paediatric OHCA aetiologies. There were n = 64 paediatric traumatic OHCAs during this time. Trauma ranked third in causes of paediatric OHCAs attended.

Table 1 details the characteristics of patients and the Utstein characteristics of the OHCAs sustained for both traumatic and ‘presumed cardiac’ paediatric OHCA. The median (IQR) length of resuscitation to achieve ROSC was 34 (4–51) minutes for traumatic OHCA and 27 (18–46) minutes for presumed cardiac (p = 0.24).

Table 2 details the mechanism of injuries causing the traumatic OHCA and the outcomes. The group ‘other’ comprises the following mechanisms of injury: homicide, self inflicted head injury, dog attack, fall from moving trailer, crush by another person, crush by electric door, boat accident, pony trampling, fall from a sofa, and house fire. There were eight cases of traumatic OHCA occurring related to children being hit by trains; the median (IQR) age was 14.5 (7.5–15) years and none had an attempted EMS resuscitation. The one and only survivor was a 5 year old who had a witnessed cardiac arrest when crushed under an electric door. On arrival of EMS the patient was receiving bystander CPR and was asystolic. EMS resuscitation lasted 33 min whereupon the patient was transported with ROSC. The patient suffered severe hypoxic ischaemic encephalopathy and was discharged from hospital with consequent spastic quadriplegia, cerebral palsy, severe scoliosis, epilepsy and swallowing dysfunction. He died three years later.

During the same period paramedics attended n = 2187 adult traumatic cardiac arrests. The median age (IQR) of adult cases was 36 (25–55) years and 77.5% were male. Bystander CPR was performed in 201 cases (10.2%). EMS attempted resuscitation in n = 545 (25%) adult patients of whom n = 84 (15%) were transported with ROSC, and n = 27 (5%) survived to hospital discharge; n = 107 were transported with CPR of whom n = 8 (7%) survived.

It was possible to link n = 57 (89%) cases using NCIS to coronial findings of which five remained ‘open cases’. There were five cases that occurred prior to the NCIS database being established and two cases that did not appear on NCIS though had been transported with ROSC to hospital. Coronial cause of death was head injury in n = 21 (37%), head and neck injuries in n = 5 (9%), multiple injuries in n = 23 (40%), chest injuries in n = 5 (9%), and there was one case each of head and abdominal injuries, head and chest injuries, and exsanguination. There were three patients whose mechanism of injury was fall from height. Two of these involved an intentional injury caused by a parent. All cases were asystolic on initial assessment by paramedics and had an EMS attempted resuscitation. Two of the three were declared dead at the scene, one was transported with ongoing CPR to the nearby hospital. There were two cases described as ‘struck by object’. The first case was due to a wall holding a basketball ring collapsing onto the patient causing fatal chest injuries; the second case occurred when a wall the child was jumping over collapsed on him causing fatal head injuries.

Table 3 details the traumatic OHCAs where paramedics attempted resuscitation comparing them to the traumatic OHCAs where no attempted resuscitation was performed. A greater proportion of patients that received EMS attempted resuscitation had received bystander CPR.

There were five traumatic OHCAs witnessed by EMS; their median (IQR) age was 9 (6–13) years, the youngest being two months. Of these, one was a passenger in a Road Traffic Accident
(RTA) transported with ROSC however did not survive to leave hospital. Two EMS witnessed OHCAs were passengers in an RTA, one of whom, with obvious skull and base of skull fractures was declared dead at the scene by paramedics after an attempted resuscitation, never achieving ROSC, the other did achieve ROSC but had atlanto-occipital dislocation and a compound skull fracture and was declared dead at the hospital. Neither had an autopsy due to family objections and their cause of death was reported by the coroner as being from ‘injuries sustained in motor vehicle accident.’ Case three was an infant who sustained injuries inflicted in a dog attack; paramedics attempted resuscitation placing a guedel airway and intrasosseus access however death was declared at the scene. Autopsy found death to be due to compound fracturing of the skull, subarachnoid and subdural haemorrhage and extensive parenchymal brain injury. Case four was a multiply injured passenger in a road traffic accident who after extrication initially had signs

**Table 1**

<table>
<thead>
<tr>
<th>Description of traumatic OHCA compared with ‘presumed cardiac’ paediatric OHCA.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traumatic OHCA (n = 64)</strong></td>
</tr>
<tr>
<td>Age (Median IQR)</td>
</tr>
<tr>
<td>Male sex (n, %)</td>
</tr>
<tr>
<td>Response time (Median IQR) min</td>
</tr>
<tr>
<td>Time to 1 at ROSC (Median IQR) min</td>
</tr>
<tr>
<td>Lay witnessed (n, %)</td>
</tr>
<tr>
<td>EMS witnessed (n)</td>
</tr>
<tr>
<td>Bystander CPR (n, %)</td>
</tr>
<tr>
<td>Missing data (n)</td>
</tr>
</tbody>
</table>

**Table 2**

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>n (%)</th>
<th>EMS Attempted Resuscitation n (%)</th>
<th>Died at scene n (%)</th>
<th>Transported with ROSC n (%)</th>
<th>Transported with ongoing CPR n (%)</th>
<th>Discharged from hospital alive n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>64 (100)</td>
<td>35 (55)</td>
<td>43 (67)</td>
<td>7 (11)</td>
<td>14 (22)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>RTA passenger</td>
<td>11 (17)</td>
<td>6 (55)</td>
<td>6 (55)</td>
<td>2 (18)</td>
<td>3 (27)</td>
<td>0</td>
</tr>
<tr>
<td>RTA pedestrian</td>
<td>20 (31)</td>
<td>13 (65)</td>
<td>11 (55)</td>
<td>2 (10)</td>
<td>7 (35)</td>
<td>0</td>
</tr>
<tr>
<td>Cyclist</td>
<td>4 (6)</td>
<td>1 (25)</td>
<td>4 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0</td>
</tr>
<tr>
<td>RTA motorcyclist</td>
<td>2 (3)</td>
<td>1 (50)</td>
<td>1 (100)</td>
<td>1 (50)</td>
<td>0 (0)</td>
<td>0</td>
</tr>
<tr>
<td>Struck by object</td>
<td>2 (3)</td>
<td>2 (100)</td>
<td>1 (100)</td>
<td>0 (0)</td>
<td>1 (50)</td>
<td>0</td>
</tr>
<tr>
<td>Struck by Train</td>
<td>8 (12)</td>
<td>0 (0)</td>
<td>8 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0</td>
</tr>
<tr>
<td>Gun Shot to Head</td>
<td>2 (3)</td>
<td>1 (50)</td>
<td>2 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0</td>
</tr>
<tr>
<td>Crushed by machinery</td>
<td>2 (3)</td>
<td>1 (50)</td>
<td>2 (100)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>10 (16)</td>
<td>7 (70)</td>
<td>10 (100)</td>
<td>2 (20)</td>
<td>2 (20)</td>
<td>1 (10)</td>
</tr>
</tbody>
</table>

**Table 3**

<table>
<thead>
<tr>
<th>Traumatic OHCAs; paramedic attempted resuscitations compared to those where no attempted resuscitation was made.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resuscitation attempted n (%)</td>
</tr>
<tr>
<td>35 (54)</td>
</tr>
<tr>
<td>Age Median (IQR) years</td>
</tr>
<tr>
<td>Male n (%)</td>
</tr>
<tr>
<td>Witnessed OHCA</td>
</tr>
<tr>
<td>Bystander CPR</td>
</tr>
<tr>
<td>Missing data n = 6</td>
</tr>
</tbody>
</table>

**Pick up location**

| Home | 10 (29) | 5 (17) |
| Street/public place | 19 (54) | 19 (66) |
| Car/road vehicle | 4 (11) | 5 (17) |
| Other | 2 (6) | 0 |

<sup>1</sup> Indicates p < 0.005.
of life but lost cardiac output and after a period of resuscitation was declared dead at the scene. This remains an ‘open case’ therefore details of the coronial autopsy findings were not available. The fifth EMS witnessed OHCA was precipitated by acute blood loss sustained when the patient lost control of his bicycle landing on the handlebar which penetrated the lower abdomen lacerating the external iliac vein. Death was declared at the scene.

4. Discussion

This is the largest case series describing traumatic OHCA from a paramedic provided EMS. Traumatic aetiology of OHCA was relatively frequent when compared to other causes of paediatric OHCA however when compared to the incidence of adult traumatic OHCAs is uncommon. Traumatic and presumed cardiac aetiology OHCA in the paediatric age group differed significantly with lower of rates of bystander CPR and attempted resuscitation by paramedics but higher rates of witnessed arrests. Attempted resuscitation for traumatic paediatric OHCA had poor outcomes with only one patient, with severe neurological sequelae, surviving to leave hospital alive.

The survival to leave hospital rate of children sustaining traumatic OHCA has been reported elsewhere as 1.1%.1 Other studies have reported varying resuscitation success however there is heterogeneity in the patients represented and in the definitions of traumatic cardiac arrest comprising the denominator from which survival is calculated.1,5,12-14 For example, many studies do not include cases where resuscitation efforts were terminated in the field or in whom resuscitation was not attempted at scene or after arrival in the emergency department. Patients in peri-arrest states have been included in other studies. This Melbourne study uses a population based cardiac arrest registry and therefore the denominator is all traumatic cases of OHCA to which the ambulance responds; paramedics may or may attempt resuscitation; however the patient is none the less entered on the registry as an OHCA. This differs in particular from many trauma registries, where the patient is entered onto the registry if they reached hospital.

Crowdson et al.,6 describing the London HEMS experience report an overall survival of 8.75% (7 of 80 patients) for paediatric traumatic OHCA however they include a case of near drowning and a further two cases of burns/smoke inhalation induced OHCA. This is a physician led prehospital care service and there may be a selection bias in the patients to whom they respond. Nonetheless, their results are impressive; of 50 cases of blunt trauma OHCA they had four patients that survived to hospital discharge (8% survival). Unfortunately, while they report one survivor as having sustained a spinal cord injury they do not report the cognitive and functional outcomes of survivors.

The establishment of an integrated inclusive regionalised trauma system in our jurisdiction has been associated with progressively improving risk-adjusted mortality for paediatric patients with major trauma. Treatment at a Major Trauma Service (Level 1 trauma centre) has been associated with lower adjusted odds of mortality.29 We suggest that the low volume of paediatric traumatic OHCA, relative to adult, creates a challenging environment for maintaining skills and institutional preparedness. Improvements in system performance may require innovative solutions to maintain proficiency, interest and team experience. Potential strategies may involve simulation, transfer of skills from related procedural work and perhaps rotations to other clinical or adult units. However, the fruits of such endeavors may not be reflected in outcome measures such as mortality for paediatric traumatic OHCA given its dismal survival.

Papers describing physician delivered prehospital care in traumatic OHCA have emphasized the importance of chest decompression. Huger-Wagner et al.,30 report a tension pneumothorax rate of 5.7%, with 25.1% of traumatic OHCA patients receiving a chest drain at the scene. Lockey et al.,31 described return of circulation after chest decompression in n = 6 adult patients (0.7%). MICA paramedics in Victoria are trained to decompress the chest using needles and/or pneumothorax® devices however published4 and anecdotal reports of ineffective needle decompression as well as ineffective placement and migration of pneumothorax® devices suggest that paramedic performed, on scene bilateral thoracostomies may have a role.27 While it may be that pre-hospital interventions such as chest decompression to treat life-threatening events may significantly decrease mortality28 an evidence base is lacking, particularly in the paediatric age group.

We have excluded cases of drowning and hanging from this analysis. They are considered as separate entities by the Utstein definitions of OHCA and their survival characteristics are likely to be different.11 Intentional injury was documented as the precipitating cause of OHCA by paramedics in two cases, however, this is an underestimation of the incidence. The non accidental nature of the traumatic brain injury (TBI) diagnosis may be missed frequently.15,16 In a related study where we have accessed the coronal data on other Utstein precipitants to paediatric cardiac arrest we have found two cases of Intentional Injury which paramedics documented as presumed cardiac and six cases which they documented as SIDS (sudden infant death syndrome). Given the acknowledged difficulties with this diagnosis being made in hospital, it is not surprising that prehospital diagnosis may be challenging.

Other studies have noted differences in bystander CPR rates between traumatic and presumed cardiac aetiology OHCAs. Dami et al.,17 found non-traumatic cardiac arrest more likely to receive bystander CPR than traumatic cardiac arrests OR 1.5 (95% CI = 1.15–1.95). While bystander CPR in traumatic arrests is higher for paediatric traumatic OHCA than in adults in Melbourne (34.4% vs 10.2%) it may well be that a focus on increasing bystander CPR and bystander first aid may save lives given that airway obstruction has been proposed as contributing to adult traumatic OHCA in motor vehicle collisions.18-20 First aid would not have prevented any deaths in the autopsies or patient care records reviewed in this study however.

Penetrating injuries have previously been associated with an improved chance of survival21,22 from OHCA possibly due to more localised organ injury. There were was only one case of penetrating injury and that was sustained when a young teenager landed on his handlebars which penetrated through his right lower quadrant to a depth of 7 cm to lacerate his external iliac vessel. Of note, there was no case of OHCA precipitated by knife injury. There were two cases of death due to gun shot injury to the head; both were self inflicted intentional injuries in teenagers; there were no other cases of gun related traumatic OHCA in this case series.

There were eight cases of traumatic OHCA occurring related to children being hit by trains one of which was a suicide. Other studies have shown a significant increase in tram related trauma in this jurisdiction when adjusted for population growth.23 Some coronial recommendations resulting from these fatalities included making a traffic safety education program with parent participation a compulsory component of the primary school curriculum; a recommendation that an advertising campaign be launched aimed at highlighting developmental limitations of young children and the need for parental supervision of the young and ‘role modelling’ of safe traffic behaviours; and provision of railway crossing supervisors similar to school crossing supervisors. The focus of primary prevention should be on separating pedestrians from trains, in particular developing safe pedestrian crossings.

Neurological consequences and quality of life outcomes for patients who survive traumatic OHCA are a significant concern.2,4
and contributed to the development of the somewhat controversial National Association of EMS physicians/American College of Surgery Committee guidelines on withholding of CPR in the adult traumatic OHCA setting. The only survivor in this case series had severe neurological injury with spastic quadriplegia, cerebral palsy, severe scoliosis, epilepsy and swallowing dysfunction resulting from his traumatic OHCA.

5. Limitations

There are limitations due to the retrospective nature of this study. Recognition of pulselessness has been shown to be unreliable for children. Patients in this study however had an ECG recording determining their cardiac arrest rhythm. On reviewing the individual patient case records of each incident we are satisfied that patients documented as being in cardiac arrest were in fact in cardiac arrest and our only survivor was in fact asystolic at the time of EMS arrival and assessment.

There has been significant investment in preventive measures such as mandatory child restraints, reduction of speed limits in residential and school zones, enforcement of children crossings, compulsory helmets for cyclists to name a few. These are measures that potentially reduce mortality more than medical interventions in this jurisdiction; capturing whether these strategies impacted on injury severity or mortality is challenging and beyond the scope of this paper.

6. Conclusions

Traumatic aetiology of OHCA when compared to the incidence of adult traumatic OHCA is uncommon. Resuscitation efforts are seldom effective and associated with poor neurological outcome.

Conflict of interest statement

There are no conflicts of interest to declare.

Acknowledgements

The families of the victims. Ambulance Victoria paramedics. Vanessa Barnes and Marian Lodder and staff at VACAR, Ambulance Victoria.

Dr Conor Deasy was supported by a Monash University overseas PhD student scholarship during this project. Ambulance Victoria provided in kind support with data extraction.

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