Paediatric out-of-hospital cardiac arrests in Melbourne, Australia: improved reporting by adding coronial data to a cardiac arrest registry

Conor Deasy,1–3 David Hall,2,3 Janet E Bray,1 Karen Smith,1,2 Stephen A Bernard,1–3 Peter Cameron,2 on behalf of the VACAR Steering Committee

ABSTRACT

Aim We describe improved reporting of paediatric out-of-hospital cardiac arrest (OHCA) by adding coronial findings to a cardiac arrest registry.

Methods Non-traumatic OHCA occurring in paediatric patients aged less than 16 years were identified using the Victorian Ambulance Cardiac Arrest Registry and available coronial findings reviewed.

Results Between the years 2001 and 2009, emergency medical services (EMS) attended 26 974 non-traumatic OHCA of which 390 (1.4%) occurred in children less than 16 years of age. We successfully linked 301 patients with the coronial registry; excluding patients discharged alive from hospital (n=22) and patients with terminal illness (n=16), this represents 86% of OHCA attended by the ambulance. Agreement between the paramedic cause of OHCA and the coronal cause of death was 66.5% (κ=0.16) for presumed cardiac, 74.4% (κ=0.43) for sudden infant death syndrome (SIDS), 81.1% (κ=0.17) for respiratory, 92.7% (κ=0.18) for neurological and 98.3% (κ=0.27) for drug overdose precipitants to OHCA. Undiagnosed congenital heart disease was a rare cause of OHCA (n=3, 1%). Intentional injury was found on autopsy in 13 cases; six cases were clinically thought to be SIDS and two cases presumed cardiac. Co-sleeping was found in 35 cases (39%) of SIDS.

Conclusions This study highlights the limitations associated with ascribing the cause of OHCA on the basis of clinical details. Improved reporting is possible by linkage with coronial data. Such robust data inform EMS service providers but also the wider healthcare system where preventive, diagnostic and treatment strategies can be maximised.

INTRODUCTION

Paediatric patients represent a minority of those who experience an out-of-hospital cardiac arrest (OHCA).1 The aetiology of cardiac arrest is different to that of older patients in whom ischaemic heart disease is more common.2 The clinician’s perception of the cause of arrest can strongly influence management and the direction of treatment. OHCA is presumed to be of cardiac aetiology unless, as best determined by the rescuers, it is known or likely to have been caused by trauma, submersion, drug overdose, asphyxia, exsanguination or other non-cardiac cause.3 Autopsy remains the ‘gold standard’ for determining OHCA aetiology; however, there are few studies that link cardiac arrest registry data with coronial data and compare the final diagnosis. Such information could potentially be useful for planning preventive strategies, improving emergency medical service (EMS) treatment, planning intervention strategies and guiding future research. We describe improved reporting of paediatric OHCA by adding coronial findings to a cardiac arrest registry.

METHODS

The state of Victoria, Australia, has a population of 5.3 million, with approximately 4 million residing in metropolitan Melbourne, of whom approximately 310 000 are under 16 years of age. The 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 authorised to perform endotracheal intubation and administer a wider range of cardiac drugs. Paramedics in Victoria have a base qualification of a 3-year bachelor in health sciences degree. MICA paramedics are experienced paramedics who undergo a university-level postgraduate 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’s area.6 Theprehospital cardiac arrest protocols follow the recommendations of the Australian Resuscitation Council.7 8

Since December 2007, all patients attended by paramedics have patient care data collected in an electronic patient record. Previous years involved a paper patient care record. Selected data from patient care records are collected from patients in cardiac arrest and stored on the Victoria Ambulance Cardiac Arrest Registry (VACAR). When the paramedic has not indicated the aetiology of the OHCA clinical staff within the registry make a judgement based on the details provided. The VACAR also includes some data from the hospital record for those patients transferred to hospital, including the number of days in hospital, discharge direction and whether the patient survived to leave hospital. Hospital investigation results were not recorded in VACAR for the time period involved in this study. EMS response time is the time from ‘000’ telephone call to EMS arrival at the scene.

Ambulance Victoria paramedics are not obliged to start resuscitation when the injuries are inconsistent with life. This includes decapitation,
presence of rigour mortis, decomposition or post-mortem lividity, when death has been declared by a medical officer who is or has been at the scene and when the presenting rhythm was monitored as asystole for more than 30 s, and there has been more than 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 gasps or evidence of pupillary reaction and no evidence of hypothermia or drug overdose.

Under Victorian law, patients who experience sudden death are referred to the coroner unless a medical practitioner is able to complete a death certificate with knowledge of the cause of death. Patients referred to the coroner generally undergo an autopsy unless there is an objection by the next of kin. Deaths were matched with coroner’s office records and all autopsies and coroners’ investigation notes reviewed. Cases that could not be matched included cases with missing identity or registered with alternative names and cases not reported to the coroner.

VACAR was searched for all OHCA occurring in patients aged less than 16 years. Cases of hanging and trauma-precipitated OHCA were excluded. Cases were then linked to the coronal database and their autopsies reviewed.

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 Victorian hospitals receiving cardiac arrests by ambulance. This study was approved by the Research Committee of Ambulance Victoria and Monash University Human Research Ethics Committee.

Statistical analysis
All data were entered into an Access software cardiac arrest registry database (V2003). Statistical calculations were performed on STATA software (V10.0). Chi-squared analyses were used for categorical variables. Continuous variables were compared using the t test (normal distribution) or Mann–Whitney.

RESULTS
Between the years 2001 and 2009, EMS attended 26 974 non traumatic OHCA of which 390 (1.4%) occurred in children less than 16 years of age. Twenty-two patients were discharged alive from hospital; we were unable to ascertain discharge status on a further three patients who had been transported with ROSC to hospital; two of these patients were newborn babies brought to maternity hospitals and the third case was a patient in a vegetative state with severe congenital abnormalities before arrest. We successfully linked 301 patients with the coronal registry; excluding patients discharged alive from hospital (n=22) and patients with terminal illness (n=16), this represents 86% of OHCA attended by the ambulance (figure 1).

Figure 1 shows the aetiology of the non-traumatic OHCA for whom autopsies were performed. Figure 2 shows the autopsy cause of death for these cases.

Agreement between the paramedic cause of OHCA and the coronal cause of death was 66.5% (κ 0.16) for presumed cardiac, 74.4% (κ 0.43) for sudden infant death syndrome (SIDS), 81.1% (κ 0.17) for respiratory, 92.7% (κ 0.18) for neurological and 98.3% (κ 0.27) for drug overdose precipitants to OHCA. Table 2 details the clinically presumed aetiology of OHCA and subsequent autopsy finding.

There were 114 cases that were ‘presumed cardiac’ OHCA for whom autopsies were performed. Figure 4 shows the autopsy cause of death for these cases.

The group of patients found to have a cardiac cause of death at autopsy (n=25) had a median age of 5 years (2–9) and 64% were male. Of these, 11 (44%) had a known structural heart condition and five (20%) had a structural heart condition diagnosed at autopsy. The first cardiac rhythm found on arrival by EMS was asystole (n=17, 68%), VF/pulseless VT (n=5, 12%) and pulseless electrical activity (PEA) (n=5, 12%); two patients (8%) had an EMS witnessed arrest. The cases of unknown structural heart condition as the cause of death included two cases of cardiomyopathy (aged 9 and 11 years), one case each of anomalous left coronary artery (aged 7 years), anomalous pulmonary venous connection (aged 10 months) and a case of complete interruption of the aortic arch (with truncus arteriosus and a ventricular septal defect aged 9 years). There were six patients whose cause of death was considered to be myocarditis.

SIDS was considered the cause of OHCA clinically in 115 patients, with autopsy agreement in 63 cases (55%); respiratory (n=17, 15%), intentional injury (n=6, 5%) and sepsis (n=4, 5%) were the most common other causes of death in this group at autopsy. The median (IQR) age of autopsy-defined
The median (IQR) age of deaths due to pneumonia was 0.9 years (0.3–3.5%), bronchiolitis (n=2, 4%) and other (n=6, 11%). The median death included pneumonia (n=24, 44%), asphyxia (n=10, 18%), respiratory cause in 55 cases. The autopsy respiratory causes of 32 cases; however, the coroner attributed death as due to a time of OHCA.

Co-sleeping was noted in 35 cases (39%) at the found on arrival by EMS was asystole (n=88, 99%) and PEA syndrome.


and seven patients had been seen by a doctor in the preceding 24 h. The median (IQR) age of those who died due to asphyxia was 0.7 years (0.4–3.0); these included asphyxia due to entrapment in a bed or mattress or bedding (n=5) and tracheotomy issues (n=2). Choking on a foreign body was responsible for OHCA in six cases, median (IQR) age 1 years (1–1); in three of these cases the foreign body involved was a food bolus. When autopsy subsequently defined the cause of death as respiratory the first cardiac rhythm found on arrival by EMS was asystole (n=47, 85%), PEA (n=5, 9%) and VF/pulseless VT (n=2, 4%); one patient had an EMS witnessed arrest.

Neurological cause of death was found in 17 cases; these included death due to sudden unexplained death in epilepsy (n=7, 41%), death due to seizures (n=4, 24%), death due to intracranial bleed (n=2, 12%) and other (n=4, 24%). In addition, there were three deaths caused by central nervous system infection.

There were 21 cases of death due to drowning, with three further cases of intentional death by drowning. Of these 15 (54%) had an autopsy performed. The median (IQR) age was 4 years (2–9) and 12 (57%) were male. The drownings occurred in domestic pools (n=8), in a domestic bath (n=7), in the sea (n=4), in a lake/pond (n=2), and one each in a commercial pool, an animal trough and a dam.

SIDS cases was 0.25 years (0.08–0.42). The first cardiac rhythm found on arrival by EMS was asystole (n=88, 99%) and PEA (n=1, 1%). Co-sleeping was noted in 35 cases (59%) at the time of OHCA.

Respiratory was considered the Utstein aetiology of OHCA in 32 cases; however, the coroner attributed death as due to a respiratory cause in 55 cases. The autopsy respiratory causes of death included pneumonia (n=24, 44%), asphyxia (n=10, 18%), foreign body (n=6, 11%), aspiration (n=4, 7%), asthma (n=5, 5%), bronchiolitis (n=2, 4%) and other (n=6, 11%). The median (IQR) age of deaths due to pneumonia was 0.9 years (0.3–3.5)

DISCUSSION

This study highlights the limitations associated with ascribing cause of OHCA on the basis of clinical details, with κ scores

Figure 3 Coronal cause of death. SIDS, sudden infant death syndrome.
showing fair to poor agreement between clinical and autopsy diagnosis. Accurate data are important in this area as they inform treatment and preventive strategies. Furthermore, when measuring system performance or trying to establish the impact of initiatives such as the 2005 CPR guidelines on survival comparing homogenous datasets it is important to avoid misrepresentation.

There were 89 cases of SIDS diagnosed on autopsy. SIDS is a diagnosis of exclusion and is defined as the sudden unexpected death of an infant less than 1 year of age, with onset of the fatal episode apparently occurring during sleep that remains unexplained after a thorough investigation including performance of a complete autopsy and review of the circumstances of death and the clinical history. There has been some debate regarding the inclusion of co-sleeping as a risk factor for SIDS; however, a recent meta-analysis of 11 case–control studies that included 2464 cases and 6495 controls concluded that bed sharing was a risk factor for SIDS and was especially enhanced in smoking parents and in very young infants. Co-sleeping was found to be present in 59% of cases of SIDS in this study. This study also shows that the term SIDS is over-used clinically, with only 55% of clinically presumed SIDS meeting the SIDS definition at autopsy and six cases of intentional injury categorised clinically as SIDS. The non-accidental nature of a traumatic brain injury diagnosis may be missed frequently in the hospital setting, and given the dynamic and challenging environment associated with a paediatric OHCA it is more likely to be missed by paramedics.

There were an additional 33 cases (15.5%) of the 244 autopsies performed in which the pathologist was unable to ascertain the cause of death. A ‘negative’ post-mortem may yield a default diagnosis of sudden arrhythmic death syndrome or sudden unexplained death syndrome after the first year of life, in which there are no discernible abnormalities on histopathology and a negative toxicology screen. Death ascribed to drowning on autopsy may actually represent death due to a fatal arrhythmia occasionally. The inherited arrhythmia syndromes (long QT, short QT, and Brugada syndromes and familial catecholaminergic polymorphic VT) may be implicated in sudden arrhythmic death syndrome, as a result of their propensity for producing ventricular tachyarrhythmia in the structurally normal heart. In cases in which a morphological explanation for cardiac arrest is lacking, a growing number of forensic experts now perform post-mortem genetic testing, called ‘molecular autopsy’, however, at present there is no internationally established best practice concerning post-mortem genetic testing in the clinical or forensic setting. In at least 10% and perhaps as many as 50% of sudden deaths involving previously healthy children, adolescents and young adults, no abnormalities are evident at autopsy, leaving coroners, medical examiners and forensic pathologists only to suggest that a fatal arrhythmia might be responsible for the event. The actual extent of inherited arrhythmia syndromes causing OHCA is therefore at best speculative.

Three (1%) cases of OHCA (1%) were caused by a previously undiagnosed congenital heart disease (CHD). The overall birth prevalence of diagnosed CHD in Victoria, Australia, is 7.8 per 1000 births; it is the most common birth defect comprising 93.6% of all births and 93% of CHD births, although almost half of children with severe CHD do not have an antenatal diagnosis. The inherited arrhythmia syndromes causing OHCA are therefore at best speculative.

**Table 2** Clinically presumed aetiology of OHCA and subsequent autopsy finding

<table>
<thead>
<tr>
<th>Autopsy aetiology, n (%)</th>
<th>Cardiac</th>
<th>SIDS</th>
<th>Respiratory</th>
<th>Unascertained</th>
<th>Sepsis</th>
<th>Neurological</th>
<th>Overdose</th>
<th>Intentional injury</th>
<th>Diabetes</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presumed aetiology, n (%)</td>
<td>19 (16.6)</td>
<td>22 (19.3)</td>
<td>23 (20.2)</td>
<td>18 (15.9)</td>
<td>11 (9.6)</td>
<td>8 (7)</td>
<td>3 (2.6)</td>
<td>2 (1.7)</td>
<td>2 (1.7)</td>
<td>6 (5.3)</td>
</tr>
<tr>
<td>SIDS</td>
<td>1 (0.9)</td>
<td>63 (55.3)</td>
<td>17</td>
<td>18</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>6</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Respiratory</td>
<td>3 (14.3)</td>
<td>1 (4.8)</td>
<td>10 (47.6)</td>
<td>3 (14.3)</td>
<td>1 (4.8)</td>
<td>1 (4.8)</td>
<td>0</td>
<td>0</td>
<td>1 (4.8)</td>
<td>1 (4.8)</td>
</tr>
<tr>
<td>Neurological</td>
<td>1 (9)</td>
<td>1 (9)</td>
<td>1 (9)</td>
<td>4 (36)</td>
<td>0</td>
<td>3 (27)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1 (9)</td>
</tr>
<tr>
<td>Overdose</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1 (33)</td>
<td>2 (66)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

OHCA, out-of-hospital cardiac arrest; SIDS, sudden infant death syndrome.

**Figure 4** Autopsy cause of death of Utstein ‘presumed cardiac’ paediatric out-of-hospital cardiac arrests. SIDS, sudden infant death syndrome.

**Limitations**

This study has a number of limitations due to its retrospective nature. The priority of paramedics is not the accurate diagnosis of the cause of OHCA but rather the management of airway, breathing and circulation; arguably, management of the arrested child or infant does not alter based on the underlying diagnosis. Comparing paramedic diagnosis with autopsy
findings may then seem disingenuous. However, integral to improving resuscitation outcomes is tailoring resuscitation to the patient; there are certain cases in which resuscitation was always going to be futile, yet attempted resuscitation forms part of the denominator that measures performance. Likewise, there may be other patients in whom different management or a more aggressive approach is warranted. Further population-based multi-agency research linking cardiac arrest registry data with hospital and coronial data to create a more complete picture may help in streamlining our resuscitation strategies so the ‘right care is delivered to the right patient’.

We were unable to match a proportion of OHCA to coroners’ autopsies (14%). Some of these patients had achieved ROSC and were transported to hospital but subsequently died. It is possible that an autopsy was not performed in these cases as the cause of death was sufficiently evident from the hospital investigations for it to be recordable on the death certificate. Reporting the aetiology of OHCA when the patient survived to reach hospital and had diagnostic investigations was beyond the scope of this study. Decisions to perform or withhold a complete autopsy are not standardised between coroners; however, in the context of pediatrics the threshold to perform such an investigation is low.

CONCLUSIONS
This study highlights the limitations associated with ascribing the cause of OHCA on the basis of clinical details. Linking OHCA registries with coronial databases for aetiology of the arrest will improve the quality of the data and deepen our understanding of the factors associated with these rare events. The lessons learned from such linked data are valuable not only in informing EMS service providers but also the wider healthcare system in which preventive, diagnostic and treatment strategies can be maximised.

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Contributors All authors have made substantial contributions to the conception and design of the study, drafting the article or revising it critically for important intellectual content and final approval of the version to be submitted.

Competing interests None.

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