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## Clinical paper

# A descriptive analysis of the epidemiology and management of paediatric traumatic out-of-hospital cardiac arrest



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## Abstract

**Aim:** Paediatric traumatic out-of-hospital cardiac arrest (OHCA) is a rare event with few survivors. We examined long-term trends in the incidence and outcomes of paediatric traumatic OHCA and explored the frequency and timing of intra-arrest interventions.

**Methods:** We retrospectively analysed data from the Victorian Ambulance Cardiac Arrest Registry for cases involving traumatic OHCA in patients aged  $\leq 16$  years arresting between January 2000 to December 2017. Trends were assessed using linear regression and a non-parametric test for trend.

**Results:** A total of 292 cases were attended by emergency medical services (EMS), of which 166 (56.9%) received an attempted resuscitation. The overall incidence of EMS-attended cases was 1.4 cases per 100,000 person-years, with no significant changes over time. Unadjusted outcomes also remained unchanged, with 23.5% achieving return of spontaneous circulation and 3.7% surviving to hospital discharge. The frequency of trauma-specific interventions increased between 2000–2005 and 2012–2017, including needle thoracostomy from 10.5% to 51.0% ( $p$  trend  $< 0.001$ ), crystalloid administration from 31.6% to 54.9% ( $p$  trend = 0.004) and blood administration from 0.0% to 6.3% ( $p$  trend = 0.01). The median time from emergency call to the delivery of interventions were: 12.9 min (IQR: 8.5, 20.0) for cardiopulmonary resuscitation, 19.7 min (IQR: 10.7, 39.6) for external haemorrhage control, 29.8 min (IQR: 22.0, 35.4) for crystalloid administration and 31.5 min (IQR: 21.0, 38.0) for needle thoracostomy.

**Conclusion:** The incidence and outcomes of paediatric traumatic OHCA remained unchanged over an 18 year period. Early correction of reversible causes by reducing delays to the delivery of trauma-specific interventions may yield additional survivors.

**Keywords:** Out-of-hospital cardiac arrest, Paediatrics, Injury, Trauma, Incidence, Survival

## Introduction

In children, traumatic out-of-hospital cardiac arrest (OHCA) is an uncommon event with a high mortality rate.<sup>1–3</sup> Although there is little research investigating the low survival rate following paediatric OHCA

due to trauma, arrest factors such as being witnessed by a bystander, receiving bystander cardiopulmonary resuscitation (CPR), and presenting in an initial shockable rhythm have been associated with an increase in survival.<sup>2</sup> However, the majority of paediatric traumatic OHCA do not present with an initial shockable rhythm, and patients are often not witnessed to arrest.<sup>4–6</sup> Therefore, community-specific

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interventions that focus on early access to bystander CPR and public access defibrillation may not lead to the improvements in survival observed in other OHCA populations.<sup>7–10</sup>

As the majority of paediatric traumatic OHCA are precipitated by major haemorrhage, head or chest injuries, or airway obstruction, early recognition and treatment of reversible causes by emergency medical services (EMS) could improve patient outcomes.<sup>8,11,12</sup> Current consensus guidelines recommend the prioritisation of bleeding control, ventilation, thoracostomy, splinting, and fluid or blood replacement ahead of conventional resuscitation strategies.<sup>8</sup> However, little is known about the frequency and timing of these interventions, and this reduces opportunities to improve the system response to paediatric traumatic OHCA.

In this study, we provide an epidemiological analysis of the long-term trends in the incidence and survival outcomes of paediatric traumatic OHCA in Victoria between 2000 to 2017. In addition, we investigated the frequency and timing of intra-arrest interventions performed by paramedics, including medical resuscitation and trauma-specific interventions.

## Methods

### Study design

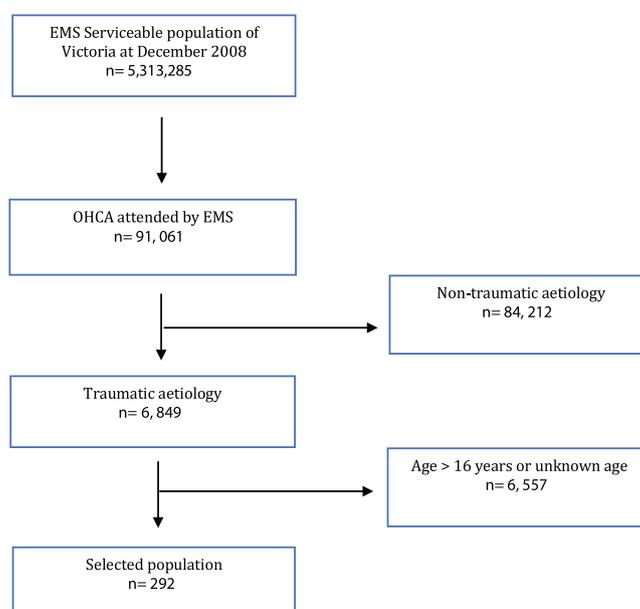
We retrospectively analysed EMS-attended traumatic OHCA cases involving patients aged  $\leq 16$  years from the Victorian Ambulance Cardiac Arrest Registry (VACAR) who arrested between January 2000 and December 2017. Patients with non-traumatic aetiology were excluded. The VACAR is a quality assurance initiative approved by the Victorian Government Department of Health and Human Research Ethics Committee. Ethical approval for this study was obtained from the Monash University Human Research and Ethics Committee (Reference number: 2018-14187-20025).

### Setting

Ambulance Victoria is a single state-wide EMS system operating in Victoria, Australia, serving a population of more than six million people of whom approximately 672,000 are 16 years or younger.<sup>5</sup> Victoria has a three-tier response for suspected cardiac arrest events, including basic life support first responders, advanced life support paramedics, and intensive care paramedics.<sup>13</sup> Cardiac arrest treatment protocols follow the recommendations of the Australian Resuscitation Council. First responders (including fire-fighters and community volunteers) are trained to deliver CPR and defibrillation using an automated external defibrillator (AED). In paediatric patients ( $<16$  years), advanced life support paramedics are authorised to perform manual and semi-automatic defibrillation and bag-valve-mask ventilation. Intensive care paramedics undertake additional interventions including intubation with or without drugs, needle thoracostomy, intravenous (IV) and intraosseous access (IO), as well as epinephrine and amiodarone administration. Helicopter Emergency Medical Services (HEMS) in Victoria are staffed by more highly-trained intensive care paramedics who are authorised to perform rapid sequence intubation,<sup>14</sup> arterial cannula insertion, in-field blood gas analysis, blood transfusion,<sup>15</sup> cricothyroidotomy and advanced analgesia including ketamine and parecoxib sodium.<sup>16</sup>

### Data sources

Data for this study were extracted from the VACAR.<sup>17</sup> All OHCA cases attended by ambulance personnel are identified and recorded in the registry according to international recommendations.<sup>18</sup> VACAR collects data from hospital records for those cases transported to hospital.<sup>17</sup> Since 2007, treatment records have been electronically recorded and stored in a clinical data warehouse using a computer tablet that is synchronised on a daily basis. The VACAR collects more than 150 data elements, including the Utstein-style descriptors<sup>19</sup> and patient discharge outcomes from over 100



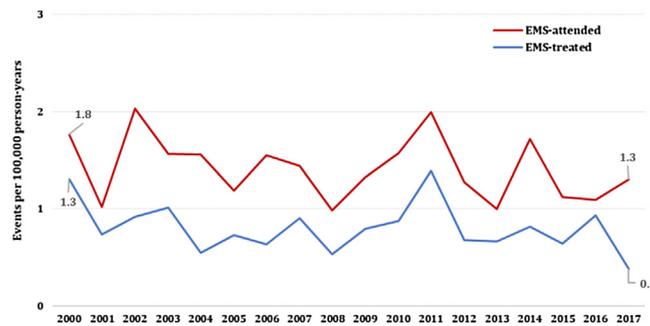
**Fig. 1 – Selection of paediatric traumatic OHCA between 1st January 2000 and 31st December 2017 in Victoria, Australia.**

participating hospitals. For this study, data from the VACAR was supplemented by hand-searching of patient care records to identify the relevant intra-arrest interventions and the time to their administration.

### Definitions

Definitions used in this study follow the recommendations of the Utstein guidelines.<sup>18</sup> EMS-treated cases are defined as those receiving any attempt at CPR or defibrillation by EMS personnel.

The mechanism of injury (MOI) was categorised into four groups, including traffic accidents, falls, shooting/stabbing, and other (includes crush injuries, animal-related injuries, environmental exposure, industrial events, and strike by an object). The level 1 major trauma centres in Victoria include the Royal Children's Hospital for children aged <16 years, and the Royal Melbourne Hospital, and the Alfred Hospital for adults. Intra-arrest interventions included any intervention performed during the resuscitation attempt and before ROSC. Intra-arrest interventions were categorised into medical resuscitation interventions (CPR, defibrillation, airway suctioning,



**Fig. 2 – Crude incidence of EMS-attended and EMS-treated paediatric traumatic OHCA.**

**Table 1 – Characteristics of EMS-attended paediatric traumatic OHCA cases, stratified by EMS-treated and not-treated cases.**

	Overall n = 292	EMS-treated n = 166	Not EMS-treated n = 126	p-Value	Missing n (%)
<b>Age in years, median (IQR)</b>	9.0 (4.0, 14.0)	7.5 (3.0, 13.0)	12.0 (4.0, 15.0)	0.008	0
<b>Male sex, n (%)</b>	189 (64.7)	113 (68.1)	76 (60.3)	0.17	0
<b>Arrest location, n (%)</b>					0
Private residence	72 (24.7)	41 (24.7)	31 (24.6)	0.99	
Public location	209 (71.6)	114 (68.7)	95 (75.4)	0.21	
Other	11 (3.8)	11 (6.6)	0	0.003	
<b>Mechanism of injury, n (%)</b>					8 (2.7)
Traffic accident	214 (75.4)	119 (73.5)	95 (77.9)	0.39	
Fall	23 (8.1)	21 (13.0)	2 (1.6)	0.001	
Shooting or stabbing	18 (6.3)	4 (2.5)	14 (11.5)	0.002	
Other	29 (10.2)	18 (11.1)	11 (9.0)	0.56	
<b>Initial rhythm, n (%)</b>					0
VF/VT	8 (2.7)	8 (4.8)	0	–	
PEA	68 (23.3)	65 (39.2)	3 (2.4)	<0.001	
Asystole	212 (72.6)	89 (53.6)	123 (97.6)	<0.001	
Pulse present	4 (1.4)	4 (2.4)	0	–	
<b>Metropolitan region, n (%)</b>	142 (48.6)	86 (51.8)	56 (44.4)	0.21	0
<b>Witnessed status, n (%)</b>					6 (2.1)
Bystander witnessed	195 (68.2)	107 (64.5)	88 (73.3)	0.11	
EMS witnessed	38 (13.3)	36 (21.7)	2 (1.7)	<0.001	
Not witnessed	53 (18.5)	23 (13.9)	30 (25.0)	0.02	
<b>Bystander CPR, n (%)<sup>a</sup></b>	105 (41.3)	85 (65.4)	20 (16.1)	<0.001	0
<b>Scene outcomes, n (%)</b>					0
Died at scene or transit	215 (73.6)	89 (53.6)	126 (100.0)	<0.001	
Transported with CPR	49 (16.8)	49 (29.5)	–	–	
Transported with ROSC	28 (9.6)	28 (16.9)	–	–	
<b>Transported to a major-trauma centre, n (%)<sup>b</sup></b>	39 (50.7)	39 (50.7)	–	–	0
<b>Prehospital ROSC, n (%)</b>	39 (13.4)	39 (23.5)	–	–	0
<b>Event survival, n (%)</b>	34 (11.6)	34 (20.5)	–	–	0
<b>Discharged alive, n (%)</b>	6 (2.1)	6 (3.7)	–	–	2 (0.7)

CPR stands for cardiopulmonary resuscitation; VF, ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity; ROSC, return of spontaneous circulation; IQR, interquartile range. Proportion excluded the missing value.

<sup>a</sup> Excludes EMS witnessed cases (n = 38).

<sup>b</sup> For transported cases (n = 77).

advanced airway, IV/IO access, epinephrine administration, and sodium bicarbonate administration) and trauma-specific interventions (external bleeding control, needle thoracostomy, crystalloid administration, blood administration, splinting, and spinal motion restriction). Advanced airway includes the insertion of a tracheal tube or supraglottic airway device.

### Data analysis

Statistical analyses were undertaken using Stata Statistical Software 14 (StataCorp, 2015, College Station, TX). A two-sided significance level of less than 0.05 was considered statistically significant. Baseline characteristics and survival outcomes are reported using descriptive statistics stratified by EMS-treated and not-treated groups. Differences in baseline characteristics and survival outcomes were assessed using the  $\chi^2$  test, Fisher's exact test and the Kruskal–Wallis test, as appropriate.

The annual incidence of paediatric OHCA was calculated using data from the Australian Bureau of Statistics for people aged  $\leq 16$  years.<sup>20</sup> Trends in incidence over the study period were assessed for the EMS-attended and EMS-treated populations using linear regression. To assess trends over time for intra-arrest

interventions and survival outcomes, we used a non-parametric test for trend.<sup>21</sup> The time to administration of intra-arrest interventions were reported as medians and interquartile ranges (IQR) and calculated from the time of emergency call and initial patient contact.

## Results

### Sample population

From January 2000 to December 2017 EMS-attended 292 cases of paediatric traumatic OHCA of which 166 (56.9%) received an attempted resuscitation (Fig. 1).

### Incidence

The crude incidence of EMS-attended and EMS-treated paediatric traumatic OHCA over the study period are presented in Fig. 2. The overall incidence of EMS-attended and EMS-treated events were 1.4 and 0.8 cases per 100,000 person-years, respectively, with no significant change in trend over time ( $p$  trend = 0.2 and 0.3, respectively).

**Table 2 – Characteristics of EMS-treated paediatric traumatic OHCA cases, stratified by age groups.**

	( $\leq 4$ years) n = 54	(5–11 years) n = 55	(12–16 years) n = 57	p-Value	Missing n (%)
<b>Age in years, median (IQR)</b>	–	–	–	–	–
<b>Male sex, n (%)</b>	30 (55.6)	42 (76.4)	41 (71.9)	0.05	0
<b>Arrest location, n (%)</b>					0
Private residence	19 (35.2)	14 (25.5)	8 (14.0)	0.04	
Public location	30 (55.6)	39 (70.9)	45 (79.0)	0.03	
Other	5 (9.3)	2 (3.6)	4 (7.0)	0.49	
<b>Mechanism of injury, n (%)</b>					4 (2.4)
Traffic accident	38 (71.7)	39 (75.0)	42 (73.7)	0.93	
Fall	5 (9.4)	8 (15.4)	8 (14.0)	0.63	
Shooting or stabbing	0	0	4 (7.0)	0.03	
Other	10 (18.9)	5 (9.6)	3 (5.3)	0.07	
<b>Initial rhythm, n (%)</b>					0
VF/VT	1 (1.9)	2 (3.6)	5 (8.8)	0.28	
PEA	19 (35.2)	18 (32.7)	28 (49.1)	0.16	
Asystole	32 (59.3)	33 (60.0)	24 (42.1)	0.10	
Pulse present	2 (3.7)	2 (3.6)	0	0.40	
<b>Metropolitan region, n (%)</b>	33 (61.1)	21 (38.2)	32 (56.1)	0.04	0
<b>Witnessed status, n (%)</b>					0
Bystander witnessed	35 (64.8)	38 (69.1)	34 (59.7)	0.58	
EMS witnessed	13 (24.1)	8 (14.6)	15 (26.3)	0.28	
Not witnessed	6 (11.1)	9 (16.4)	8 (14.0)	0.73	
<b>Bystander CPR, n (%)<sup>a</sup></b>	30 (73.2)	31 (66.0)	24 (57.1)	0.31	0
<b>Scene outcomes, n (%)</b>					0
Died at scene or transit	24 (44.4)	30 (54.6)	35 (61.4)	0.20	
Transported with CPR	22 (40.7)	15 (27.3)	12 (21.1)	0.07	
Transported with ROSC	8 (14.8)	10 (18.2)	10 (17.5)	0.88	
<b>Transported to major-trauma centre, n (%)<sup>b</sup></b>	16 (53.3)	12 (48.0)	11 (50.0)	0.92	
<b>ROSC, n (%)</b>	11 (20.4)	11 (20.0)	17 (29.8)	0.38	0
<b>Event survival, n (%)</b>	9 (16.7)	11 (20.0)	14 (24.6)	0.59	0
<b>Discharged alive, n (%)</b>	0	1 (1.9)	5 (8.8)	0.04	2 (1.2)

CPR stands for cardiopulmonary resuscitation; VF, ventricular fibrillation; VT, ventricular tachycardia; PEA, pulseless electrical activity; ROSC, return of spontaneous circulation; IQR, interquartile range. Proportion excluded the missing value.

<sup>a</sup> Excludes EMS witnessed cases (n = 36).

<sup>b</sup> For transported cases (n = 77).

**Table 3 – The intra-arrest out-of-hospital interventions of EMS-treated paediatric traumatic OHCA cases, stratified by years.**

	Overall n = 166	2000–2005 n = 57	2006–2011 n = 58	2012–2017 n = 51	p-Value for trend	Missing
<b>Medical resuscitation interventions, n (%)</b>						
CPR	165 (99.4)	56 (98.3)	58 (100.0)	51 (100.0)	0.11	0
Defibrillation	18 (10.8)	4 (7.0)	8 (13.8)	6 (11.8)	0.38	0
Airway suctioning	89 (60.5)	34 (77.3)	24 (43.6)	31 (64.6)	0.29	19 (11.5)
Advanced airway	109 (65.7)	37 (64.9)	40 (69.0)	32 (62.8)	0.89	0
Intravenous/intraosseous access	85 (57.8)	24 (54.6)	30 (54.6)	31 (64.6)	0.18	19 (11.5)
Epinephrine administration	96 (57.8)	28 (49.1)	36 (62.1)	32 (62.8)	0.10	0
Sodium bicarbonate administration	26 (15.7)	5 (8.8)	11 (19.0)	10 (19.6)	0.17	0
<b>Trauma-specific interventions, n (%)</b>						
External haemorrhage control	14 (9.5)	2 (4.6)	6 (10.9)	6 (12.5)	0.10	19 (11.5)
Needle thoracostomy	49 (29.5)	6 (10.5)	17 (29.3)	26 (51.0)	<0.001	0
Crystalloid administration	74 (44.6)	18 (31.6)	28 (48.3)	28 (54.9)	0.004	0
Blood administration	3 (2.0)	0	0	3 (6.3)	0.01	19 (11.5)
Spinal motion restriction	43 (29.3)	16 (36.4)	12 (21.8)	15 (31.3)	0.52	19 (11.5)
Splinting	9 (6.1)	1 (2.3)	0	8 (16.7)	0.003	19 (11.5)
Any trauma-specific intervention	102 (61.5)	28 (49.1)	36 (62.1)	38 (74.5)	0.001	0
<b>Time intervals, median (IQR)</b>						
Call to EMS arrival on scene <sup>a</sup>	10.5 (7.7, 16.4)	9.0 (5.0, 12.0)	11.5 (8.0, 16.5)	14.7 (8.2, 18.3)	<0.001	7 (5.4)
Call to HEMS arrival on scene <sup>b</sup>	37.1 (32.8, 54.6)	59.0 (24.0, 67.7)	37.1 (24.0, 45.9)	40.4 (32.8, 54.6)	0.34	3 (6.1)
Resuscitation duration	21.0 (9.0, 35.0)	19.5 (9.0, 32.0)	21.5 (7.0, 35.0)	22.0 (9.0, 43.0)	0.34	7 (4.2)
<b>Highest EMS skill level on scene, n (%)</b>						
HEMS	49 (29.5)	6 (10.5)	23 (39.7)	20 (39.2)	0.001	0
Intensive care paramedic	91 (54.8)	36 (63.2)	29 (50.0)	26 (51.0)	0.13	0
Basic/advanced paramedic	26 (15.7)	15 (26.3)	6 (10.3)	5 (9.8)	0.02	0

CPR stands for cardiopulmonary resuscitation; EMS, emergency medical services; HEMS, helicopter emergency medical services. Proportion and median excluded the missing value.

<sup>a</sup> Excludes EMS witnessed cases (n = 36).

<sup>b</sup> For cases receiving HEMS response (n = 49).

### Characteristics and outcomes

Table 1 shows the baseline characteristics of the overall population and across EMS-treated and not-treated cases. The median age of the overall population was nine years (IQR: 4.0, 14.0), with 64.7% being male. The majority of cases occurred in a public place (71.6%), were caused by traffic accidents (75.4%), and were witnessed by bystanders (68.2%). When compared to EMS-treated cases, not-treated cases had a higher proportion of initial asystole (53.6% vs 97.6%;  $p < 0.001$ ) and a lower proportion of bystander CPR (65.4% vs 16.1%;  $p < 0.001$ ).

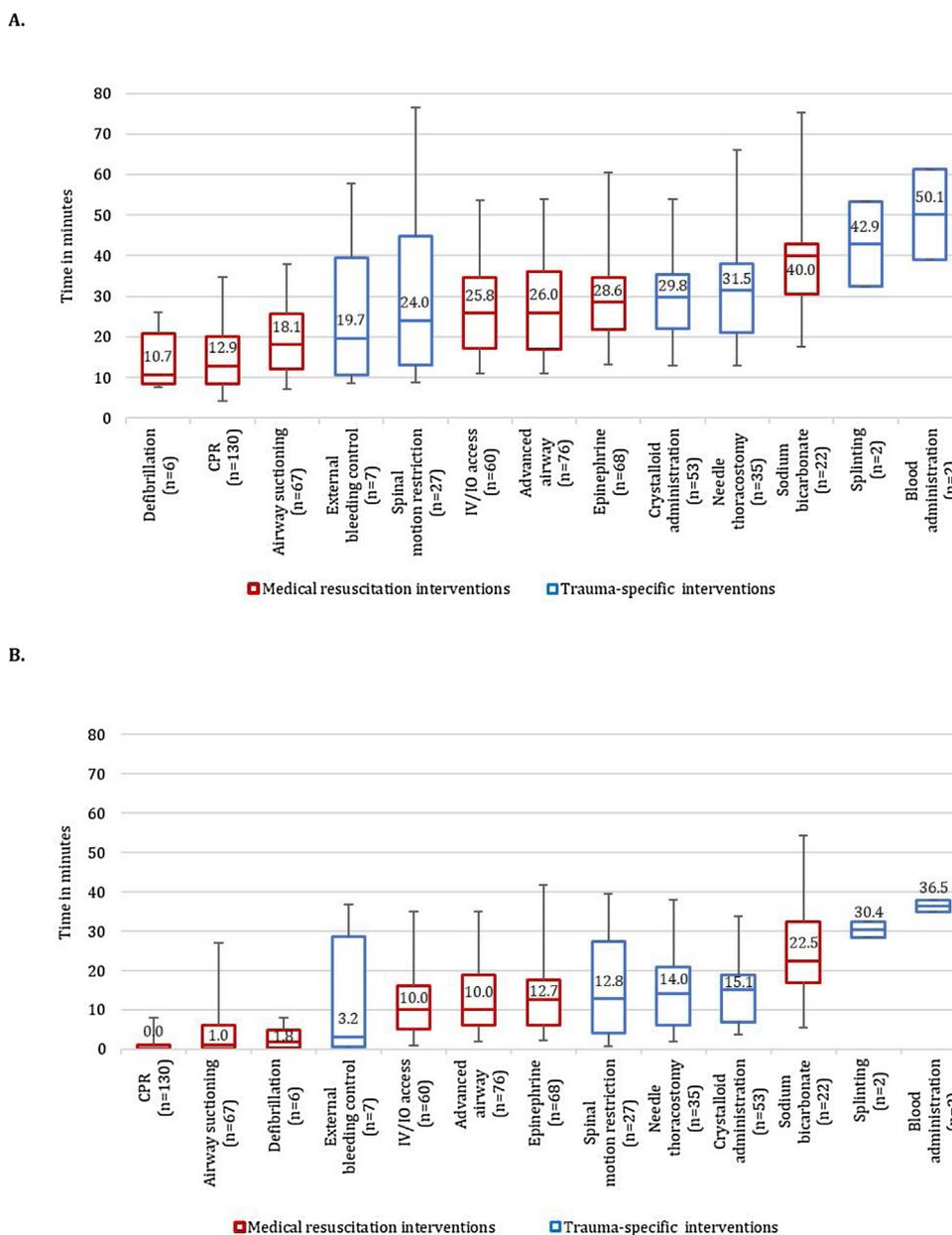
In EMS-treated cases, 23.5% achieved ROSC, 20.5% survived the event, and 3.7% survived to hospital discharge. There were no significant trends for ROSC ( $p$  trend = 0.18), event survival ( $p$  trend = 0.62) or survival to hospital discharge ( $p$  trend = 0.63) over the study period. Survival to hospital discharge was higher among children aged 12–16 years (8.8%) compared to children aged 5–11 years (1.9%) (Table 2). There were no survivors in children aged  $\leq 4$ . Additionally, there were no survivors among the patients transported to non-major trauma centres (n = 37).

### Arrest interventions

Table 3 shows the frequency of EMS intra-arrest interventions over the study period. Medical resuscitation interventions, such as CPR and

defibrillation were performed more frequently than trauma-specific interventions. However, the frequency of trauma-specific interventions increased significantly between 2000–2005 and 2012–2017, including an increase in needle thoracostomies (from 10.5% to 51.0%;  $p$  trend < 0.001), crystalloid administration (from 31.6% to 54.9%;  $p$  trend = 0.004), blood administration (from 0.0% to 6.3%;  $p$  trend = 0.01), and splinting (from 2.3% to 16.7%,  $p$  trend = 0.003). There was also an increase in the frequency of HEMS attendance on scene from 10.5% in 2000–2005 to 39.2% in 2012–2017 ( $p$  trend = 0.001) with an overall median response time of 37.1 min (IQR: 32.8, 54.6).

The timing of intra-arrest interventions from the emergency call and initial patient contact are shown in Fig. 3. Defibrillation for initial shockable rhythms and CPR were prioritised before other resuscitation and trauma-specific interventions [median time from emergency call, 10.7 min (IQR: 8.4, 20.9) and 12.9 min (IQR: 8.5, 20.0), respectively]. The median time to delivery of trauma-specific interventions from emergency call were: 19.7 min (IQR: 10.7, 39.6) for external haemorrhage control, 29.8 min (IQR: 22.0, 35.4) for crystalloid administration, and 31.5 min (IQR: 21.0, 38.0) for needle thoracostomy. From arrival at the patients' side, the median time to delivery of trauma-specific interventions were: 3.2 min (IQR: 0.7, 28.6) for external haemorrhage control, 14.0 min (IQR: 6.0, 21.0) for needle thoracostomies, 15.1 min (IQR: 6.9, 19.0) for crystalloid administration, and 36.5 min (IQR: 35.0, 38.0) for blood administration.



**Fig. 3 – The time (5th, 25th, 50th, 75th, and 95th percentiles) to administration of intra-arrest interventions for paediatric traumatic OHCA from (A) emergency call and (B) arrival at patient's side. Arrests witnessed by EMS are excluded.**

## Discussion

The findings of this study show that the incidence and outcomes of paediatric traumatic OHCA did not change over an 18 year period in Victoria, Australia. Although the majority of the cases occurred in public places and were witnessed by bystanders, the proportion of patients receiving bystander CPR were low. Our findings suggest that paramedics were less likely to commence resuscitation in patients with an initial rhythm of asystole and if bystander CPR was not initiated prior to their arrival. Additionally, we found that medical resuscitation interventions such as CPR and defibrillation were performed before trauma-specific interventions. An increase in the frequency of trauma-specific interventions such as needle thoracostomy, fluid

administration, and splinting was observed over the study period; however, there were considerable delays to their administration.

Our study showed no significant changes in the incidence rate of paediatric traumatic OHCA over the study period. This finding is difficult to compare with other regions because the incidence of EMS-attended cases are rarely reported in the literature. However, our incidence rate of EMS-treated cases of 0.8 cases per 100,000 person-years is lower than that reported in Osaka, Japan (1.3 cases per 100,000 person-years)<sup>22</sup> and in the United States and Canada (2.3 cases per 100,000 person-years).<sup>23</sup> The reasons for the unchanged incidence of paediatric traumatic OHCA over time are uncertain. Although all-cause paediatric mortality has reduced in Victoria over time,<sup>24</sup> the incidence of major trauma involving paediatrics has not changed over the last decade.<sup>25</sup> Despite this, there have been a

number of legislative reforms targeting the prevention of major trauma in children, including mandatory child restraints in vehicles, reduced speed limits in residential and school zones, and compulsory helmets for cyclists.<sup>26</sup>

Survival rates from paediatric traumatic OHCA vary considerably in published literature, and this is often related to differences in included populations. Our survival rate of 3.7% is lower than recently reported by a study from England and Wales (4.7%),<sup>27</sup> and the United States and Canada (5.7%).<sup>23</sup> However, the higher survival rate in these studies is likely due to the exclusion of patients who were not conveyed to hospital and died at scene,<sup>27</sup> or the inclusion of cases associated with drowning, hanging, and electrocution<sup>23</sup> which have been associated with higher rates of survival.<sup>3,27,28</sup> Importantly, the definition of trauma used in our report is consistent with Utstein reporting guidelines.<sup>18</sup> The causes of traumatic OHCA may also explain the differences in the survival rate between the studies. For instance, our population had a higher proportion of traumatic OHCA precipitated by traffic accidents (75.4%) compared to the study from England and Wales (56.6%).<sup>27</sup>

Current guidelines suggest that to enhance survival from traumatic cardiac arrest, rescuers should prioritise the treatment of potentially reversible causes with trauma-specific interventions before CPR.<sup>10,29</sup> We found that paramedics delivered medical resuscitation interventions such as CPR and epinephrine administration more frequently in the past 18 years compared to trauma-specific interventions. Although the frequency of trauma-specific interventions increased over time, key interventions such as needle thoracostomy, advanced airway, and fluid administration were often performed 25 min after the emergency call. Delays in performing these interventions are partly the result of long EMS-response times to rural cases (which represented over half of all events in our population), and comparatively fewer intensive care paramedics compared to basic/advanced paramedics in our EMS. Importantly, children with traumatic OHCA who receive more than 20 min of resuscitation and survive have been shown to be neurologically impaired,<sup>2</sup> and this would suggest that new strategies are required to improve the frequency and timing of trauma-specific interventions in our population.

In an 'ideal' trauma resuscitation there would be sufficient rescuers to perform both traumatic and medical resuscitation interventions simultaneously. However, the results of our study reflect the environment, where half of the cases occurred in a rural population with long response times and where the first arriving crew was as almost always not authorised to perform trauma interventions in children. When the first arriving crew was authorised to perform trauma interventions, there has traditionally been an emphasis on performing good quality CPR, at the expense of delaying the administration of trauma interventions until the arrival of further EMS crews. This approach has led to long delays in addressing reversible causes, and highlights a clear opportunity to improve care. Treatment protocols which focus on the early correction of reversible causes, the early dispatch of HEMS, and improved resourcing of appropriately skilled paramedics may also potentially lead to improvements in survival in this population.

## Limitations

Our study has several limitations. The study is retrospective in design. Some variables such as the recording of intra-arrest interventions were self-reported by paramedics on the treatment record, and these

are subject to errors or recall bias. Although our study includes all paediatric traumatic OHCA over an 18-year period, sample sizes remained relatively small. As such, we were underpowered for multivariable analysis. In addition, some interventions such as splinting and blood administration were performed infrequently, and this increases the uncertainty around their time estimates.

## Conclusion

In Victoria, no significant changes in the incidence and outcomes of paediatric traumatic OHCA were observed over an 18-year period. Importantly, medical resuscitation interventions such as CPR and defibrillation were prioritised before trauma-specific interventions that address the possible reversible causes of arrest. Although the frequency of trauma-specific interventions increased over the study period, the majority were performed more than 25 min after the emergency call. Treatment protocols which focus on the early correction of reversible causes, the early dispatch of HEMS, and improved resourcing of appropriately skilled paramedics may potentially lead to improvements in survival in this population.

## Conflict of interest

The authors declare no conflict of interest.

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