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Acute paediatric asthma treatment in the prehospital setting: a retrospective observational study

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ABSTRACT

Objectives To describe the incidence of and patterns of 'escalated care' (care in addition to standard treatment with systemic corticosteroids and inhaled bronchodilators) for children receiving prehospital treatment for asthma.

Design Retrospective observational study.

Setting State-wide ambulance service data (Ambulance Victoria in Victoria, Australia, population 6.5 million)

Participants Children aged 1–17 years and given a final diagnosis of asthma by the treating paramedics and/or treated with inhaled bronchodilators from 1 July 2019 to 30 June 2020.

Primary and secondary outcome measures We classified 'escalation of care' as parenteral administration of epinephrine, or provision of respiratory support. We compared clinical, demographic and treatments administered between those receiving and not receiving escalation of care.

Results Paramedics attended 1572 children with acute exacerbations of asthma during the 1 year study period. Of these, 22 (1.4%) had escalated care, all receiving parenteral epinephrine. Patients with escalated care were more likely to be older, had previously required hospital admission for asthma and had severe respiratory distress at initial assessment.
Of 1307 children with respiratory status data available, at arrival to hospital, the respiratory status of children had improved overall (normal/mild respiratory distress at initial assessment 847 (64.8%), normal/mild respiratory distress at hospital arrival 1142 (87.4%), p<0.0001).

Conclusions Most children with acute exacerbations of asthma did not receive escalated therapy during their pre-hospital treatment from ambulance paramedics. Most patients were treated with inhaled bronchodilators only and clinically improved by the time they arrived in hospital.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Highly generalisable, with the use of a comprehensive electronic state-wide ambulance database.
⇒ Most ambulance cases were concentrated in metropolitan regions; this may limit generalisability to rural and regional settings.
⇒ Bias was minimised by direct download from electronic medical record, rather than abstraction by reviewers.
⇒ It is possible that a small number of critically ill cases were misclassified due to an ambulance diagnosis other than asthma.

Most children with asthma have mild or moderate exacerbations, and respond to first-line treatment with inhaled bronchodilator therapy and systemic steroids.[6–9] However, some children with severe asthma require more intensive therapies including intravenous medications, endotracheal intubation and/or admission to intensive care.[9–11] Management of acute severe asthma is complicated by a number of problems, including a large number of treatment options, wide variation in self-reported and actual physician practice,[12–15] and a weak evidence base.[16 17]

Early initiation of therapy in the prehospital setting may abort an asthma attack and prevent further escalation on arrival to the ED. This in turn may prevent the need for more invasive treatment and potential complications or side effects of medications used in escalation. The introduction of a new treatment protocol emphasising early use of systemic corticosteroids in a large Emergency Medical Services system was associated with reduced rates of hospitalisation, less need for critical care and shortened hospital length of stay.[18] Systemic corticosteroid administration has been the subject of successful improvement projects in the prehospital setting.[19] However, a separate study identified high rates of paramedic non-compliance with

INTRODUCTION

Asthma is a frequent reason for children to attend the emergency department (ED),[1 2] and one of the most common reasons for paediatric hospitalisation after an ED visit.[3] In the USA, the rate of paediatric ED visits for asthma increased by 13.3% between 2001 and 2010,[4] while in the UK, it is estimated that a child is admitted to hospital with an asthma attack every 20 min.[5]

prehospital treatment protocols recommending parenteral epinephrine for children with high-severity respiratory distress.[20]

There are little data available on treatment patterns or prehospital outcomes for children with acute asthma in the Australian setting. This study aimed to extract information from the electronic medical records of Ambulance Victoria (AV), Australia, on all children treated for asthma to understand the incidence of and patterns of 'escalated' care (care in addition to standard treatment with systemic corticosteroids and inhaled bronchodilators).

METHODS

Study design

This was a retrospective cohort study of all children who were either given a final diagnosis of asthma by the treating AV paramedics or treated with inhaled bronchodilators from 1 July 2019 to 30 June 2020. The project is reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[21] The study was approved by the Royal Children's Hospital Research Ethics and Governance Office, Melbourne, Australia (60707) and the Ambulance Victoria Research Governance Committee, Melbourne, Australia.

Study setting

AV is the single public emergency medical service for the state of Victoria, Australia (population of 6.5 million over 227 000 km^2).

AV clinical practice guidelines[22] provide recommendations for asthma management according to severity (Box 1), which include: inhaled salbutamol via a

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> **Box 1** **Asthma severity assessment and treatment according to Ambulance Victoria clinical practice guidelines**
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> **Mild/moderate:** normal conscious state, some increased work of breathing, tachycardia, speaking in phrases/sentences
> Salbutamol pMDI and spacer:
> 6 or more years: 4–12 doses
> 2–5 years: 2–6 doses
> **Severe:** agitated/distressed, markedly increased work of breathing, including accessory muscle use/retraction, tachycardia, speaking in words.
> Salbutamol nebulised (repeated at 20 min if required)
> 2–4 years: 2.5 mg
> 5–11 years: 2.5–5 mg
> Ipratropium bromide nebulised 250 mcg
> **Critical:** altered conscious state, maximal work of breathing, marked tachycardia and unable to talk.
> Salbutamol nebulised 10 mg (repeated at 5 min if required)
> Ipratropium bromide nebulised 250 mcg
> Epinephrine 10 mcg/kg IM (repeated at 5 min if required)
> Dexamethasone 0.6 mg/kg intravenous or oral (max 12 mg)
> Epinephrine intravenous boluses and infusion (for Mobile Intensive Care Paramedics)
> IM, intramuscular; pMDI, pressurised metered dose inhaler.

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pressurised metered dose inhaler (pMDI) as initial treatment for mild/moderate asthma; nebulised salbutamol and ipratropium reserved for severe or critical illness, or failure of moderate asthma to respond to treatment after 20 min; corticosteroids (intravenous or oral dexamethasone) for critical asthma in children and for severe and critical asthma in adults; parenteral epinephrine (intramuscular (IM), intravenous infusion or titrated boluses) for critical asthma and assisted ventilation and/or intubation for unconsciousness or respiratory arrest. Children aged 12 years or more are managed according to an 'adult' algorithm, which has a lower threshold for corticosteroids compared with the paediatric algorithm (recommended for all severe cases, rather than only in critical illness).[22]

Selection of participants

We searched the AV electronic patient care system for presentations of children aged more than 1 year and less than 18 years matching the following criteria: final primary assessment of asthma or cough or shortness of breath. We excluded children with a paramedic diagnosis of cough or shortness of breath if they were not administered any inhaled bronchodilator (salbutamol or ipratropium). Records of cases assessed by multiple ambulance teams during the same incident were unified as a single paramedic attendance. Interhospital transports and patients managed for cardiac arrest were excluded.

Data collection

Data were extracted directly from the AV medical record database into a purpose-designed spreadsheet and analysed. Exact medication doses were not extracted, as treatment is highly protocolised (box 1).

We defined 'respiratory support' as the use of continuous positive airway pressure, bi-level positive airway pressure, assisted ventilation, intubation and mechanical ventilation, or application of a bag-valve-mask device.

We defined 'escalation' of care as parenteral administration of epinephrine, or provision of respiratory support. Although AV protocols recommend oral (or parenteral) corticosteroids for severe and critical asthma, corticosteroids are usually considered part of routine asthma care (rather than reserved for critical illness). We did not include nebulised epinephrine for suspected croup/upper airway obstruction. The case notes were reviewed and verified by a second paramedic abstractor (BD) for all patients where escalation was identified through electronic medical record data.

Analysis

Descriptive statistics were used to summarise patient characteristics, clinical features and treatments administered. Non-parametric data are reported using median and IQR, while categorical data are presented as count and percentage. We did not impute any missing data.

Comparisons were made between those requiring escalation of care to those not requiring escalation of care.

Figure 1 Flow chart—prehospital management of acute asthma in children. AV, Ambulance Victoria.

Categorical data are compared using χ^2 test or Fisher's exact test as appropriate. Non-parametric data are compared using Mann-Whitney U test.

All analyses were performed using SPSS for Windows (IBM Corp. Released 2021. IBM SPSS Statistics for Windows, V. 28.0. Armonk, NY: IBM Corp.).

Patient and public involvement

Patients were not involved in the design of this study.

RESULTS

Over the study period, the service responded to 633 950 on-road emergency cases,[23] mainly using advanced life support or mobile intensive care ambulance paramedics. We identified 3587 children who had been assessed by AV with a primary assessment diagnosis of asthma, cough or shortness of breath, 1520 were excluded, leaving 1572 children managed by AV with asthma (figure 1).

The median age of the cohort was 6 years (IQR 4–10 years) and 888 (56.5%) were male. Most (87.6%) patients had a documented history of asthma, 115 (7.3%) had been hospitalised, 63 (4%) had required intensive care admission and 19 (1.2%) had been intubated for a previous asthma exacerbation. Information on usual asthma medications was not available. The median initial respiratory

rate was 32 breaths/min (IQR 24–40 breaths/min). Of the 1460 patients who had initial work of breathing documented, 978 (67.0%) had normal or mild work of breathing, and 166 (7.7%) had severe work of breathing.

Ambulance response time was a median of 11.9 min (IQR 8.2 to 15.2 min); paramedics were on the scene with the patient for a median of 17 min (IQR 12.7 to 25.1 min). Patients were transported by ambulance in 90% (n=1419) of attendances.

Paramedics administered inhaled bronchodilators in 946 (60.2%) of cases. Of those, 493 (52.1%) received salbutamol alone, 13 (1.4%) received ipratropium alone and 440 (46.5%) received salbutamol and ipratropium. For those receiving bronchodilators, a median (IQR) of 1 (1–2) administrations were recorded. Oxygen administration was documented in 306 (19.4%) patients, most commonly by nebuliser mask, nasal cannulae or an oxygen mask; however, 514 (32.6%) received nebulised medication, driven by oxygen. Oral corticosteroids were administered to 141 (9.0%) patients.

Twenty-six records were reviewed for escalation of care; in four patients, the electronic record was incorrectly coded, due to inadvertent selection of intravenous salbutamol (used by AV for preterm labour) instead of nebulised salbutamol, leaving 22 (1.4%) patients with escalated care (figure 1). Patients with escalated care were more likely to be older, had previously required hospital admission for asthma and had severe respiratory distress at initial assessment (table 1). Those receiving escalated care were more likely to be treated with inhaled bronchodilators, corticosteroids and oxygen (table 2). With increasing severity of illness, children were more likely to be administered nebulised salbutamol, less likely to be administered salbutamol by a pMDI, more likely to receive ipratropium and more likely to receive systemic corticosteroids (online supplemental table).

All patients who received escalated care received parenteral epinephrine. No patients received non-invasive ventilation, assisted ventilation or intubation. Four children (aged 2, 14, 16 and 17 years) received an epinephrine infusion. One patient who received IM epinephrine also had a bag-valve-mask applied, however, did not receive positive pressure ventilation. They were a 2 year-old child who had difficulty in breathing and cough that was not improving with salbutamol administered at home. They became unresponsive after a coughing episode and bystander cardiopulmonary resuscitation was initiated. They were breathing spontaneously and responsive on initial paramedic assessment.

Reports of respiratory status at initial assessment and hospital arrival were available for 1307 (85.5%) of the cohort. On arrival to hospital, the respiratory status of children had improved overall (normal/mild respiratory distress at initial assessment 847 (64.8%), normal/mild respiratory distress at hospital arrival 1142 (87.4%), p<0.0001). One hundred and thirty-one (81.2%) of the 160 children with severe respiratory distress at initial assessment had improved. Of the 847 children with

Table 1 Demographics and clinical characteristics of children treated or assessed for asthma by AV

	Total (n=1572)	Escalation of care (n=22)	No escalation of care (n=1550)	P value (escalation vs no escalation)
Age, years, n (%)				
1–4	561 (36.3)	6 (27.3)	555 (35.8)	0.38
5–11	690 (43.9)	9 (40.9)	681 (43.9)	
12–17	321 (20.4)	7 (31.8)	314 (20.3)	
Median age, years (IQR)	6 (4–10)	10.5 (3.8–14.3)	6 (3.8–10)	0.045
Female sex, n (%)	684 (43.5)	11 (50)	877 (43.4)	0.54
Pre-existing conditions, n (%)				
Asthma	1377 (87.6)	20 (90.9)	1357 (87.5)	0.64
Requiring hospital admission	115 (7.3)	5 (22.7)	110 (7.1)	0.005
Requiring intensive care	63 (4)	1 (4.5)	62 (4)	0.89
Requiring intubation	19 (1.2)	1 (4.5)	18 (1.2)	0.15
With cardiac/respiratory arrest	5 (0.3)	0 (0)	5 (0.3)	0.79
Other respiratory illness				
Croup	94 (6)	1 (4.5)	93 (6)	0.78
Bronchiolitis	80 (5.1)	1 (4.5)	79 (5.1)	0.91
Pneumonia	44 (2.8)	1 (4.5)	43 (2.8)	0.62
Chest infection	32 (2)	1 (4.5)	31 (2)	0.40
Other	8 (0.5)	0 (0)	8 (0.5)	0.64
Initial physiological parameters				
Respiratory rate (breaths/min), median (IQR)	32 (24–40)	35.5 (28–48.5)	32 (24–40)	0.09
Pulse rate (beats/min), median (IQR)	130 (112–146)	134.5 (120–150.5)	130 (112–146)	0.24
Initial respiratory status, n (%)				
Normal	615 (39.1)	3 (13.6)	612 (39.5)	<0.001
Mild respiratory distress	363 (23.1)	1 (4.5)	362 (23.4)	
Moderate respiratory distress	315 (20)	2 (9.1)	313 (20.2)	
Severe respiratory distress	166 (10.6)	16 (72.7)	150 (9.7)	
Depressed respirations	1 (0.1)	0 (0)	1 (0.1)	
Final physiological parameters				
Respiratory rate (breaths/min), median (IQR)*	28 (22–36)	28 (22–36)	30 (27–40)	0.06
Pulse rate (beats/min), median (IQR)*	126 (108–142)	126 (108–142)	126 (112–162)	0.29
Final respiratory status, n (%)†				
Normal	742 (56.8)	4 (18.2)	738 (57.4)	<0.001
Mild respiratory distress	400 (30.6)	4 (18.2)	396 (30.8)	
Moderate respiratory distress	127 (9.7)	6 (27.3)	121 (9.4)	
Severe respiratory distress	38 (2.9)	8 (36.4)	30 (2.4)	

All P values calculated using χ^2 tests, except for continuous variables where Mann-Whitney U tests* were used.
*Data were not available for final pulse rate and respiratory rate for 54 patients in the 'No escalation of care' group.
†Data were not available for final respiratory status for 265 patients in the 'No escalation of care' group.
AV, Ambulance Victoria.

normal/mild respiratory distress at initial assessment, only 24 (2.8%) were documented as having moderate or severe respiratory distress at hospital arrival; and only 9 (0.8%) of the 1146 children with normal/mild/moderate respiratory distress at initial assessment were documented as having severe respiratory distress at hospital arrival (figure 2).

DISCUSSION

This study provides a population-based state-wide assessment of prehospital asthma management in children. Most children with acute exacerbations of asthma in Victoria, Australia, did not receive escalated therapy during their prehospital treatment from ambulance paramedics. Although more than 60% had either mild or no

Table 2 Treatment provided by AV paramedics

	Total (n=1572)	Escalation of care (n=22)	No escalation of care (n=1550)	P value (escalation vs no escalation)
Respiratory support, n(%)				
Bag-valve-mask applied	1 (0.1)	1 (4.5)	0 (0)	<0.001
Oxygen delivery				
Nasal cannulae	46 (2.9)	4 (18.2)	42 (2.7)	<0.001
Nebuliser mask	258 (16.4)	10 (45.5)	248 (16)	<0.001
Oxygen mask	48 (3.1)	0 (0)	48 (3.1)	0.40
Non-rebreather mask	8 (0.5)	0 (0)	8 (0.5)	0.74
Other oxygen therapy (not otherwise specified)	2 (0.1)	0 (0)	2 (0.1)	0.87
Parenteral bronchodilator				
Epinephrine IM injection	20 (1.3)	20 (90.9)	0 (0)	<0.001
Epinephrine infusion	4 (0.3)	4 (18.2)	0 (0)	<0.001
Dexamethasone				
Intravenous injection	25 (1.6)	4 (18.2)	21 (1.4)	<0.001
Oral	141 (9)	11 (50)	130 (8.4)	<0.001
Inhaled bronchodilator				
Any inhaled bronchodilator	946 (60.2)	21 (95.5)	925 (59.7)	<0.001
Any Ipratropium bromide nebulisation	453 (28.8)	17 (77.3)	436 (28.1)	<0.001
Any salbutamol pMDI	465 (29.6)	3 (13.6)	462 (29.8)	0.10
Any salbutamol nebulisation	513 (32.6)	20 (90.9)	493 (31.8)	<0.001
Single administration of inhaled salbutamol	348 (22.1)	3 (13.6)	345 (22.3)	
Single administration of inhaled ipratropium bromide	13 (0.8)	1 (4.5)	12 (0.8)	
Single administration of inhaled salbutamol and single administration of inhaled iptratropium bromide	280 (17.8)	6 (27.3)	274 (17.7)	
Two administrations of inhaled salbutamol alone	114 (7.3)	1 (4.5)	113 (7.3)	
Two administrations of inhaled salbutamol and at least one administration of ipratropium bromide	112 (7.1)	3 (13.6)	109 (7)	
Three or more administrations of inhaled salbutamol alone	31 (2.0)	0 (0)	31 (2)	
Three or more administrations of inhaled salbutamol and at least one administration of ipratropium bromide	48 (3.1)	7 (31.8)	41 (2.6)	
Total instances of inhaled bronchodilator administration, median (IQR)	1 (0–2)	2 (1.8–4)	1 (0–2)	<0.001
Intravenous access				
Intravenous access attempt	39 (2.5)	7 (31.8)	32 (2.1)	<0.001
Successful intravenous attempt	34 (2.2)	7 (31.8)	27 (1.7)	<0.001

No patients received any of: BiPAP, manual ventilation, mechanical ventilation, intravenous salbutamol infusion, IM dexamethasone.
AV, Ambulance Victoria; BiPAP, bi-level positive airway pressure; IM, intramuscular; pMDI, pressurised metered dose inhaler.
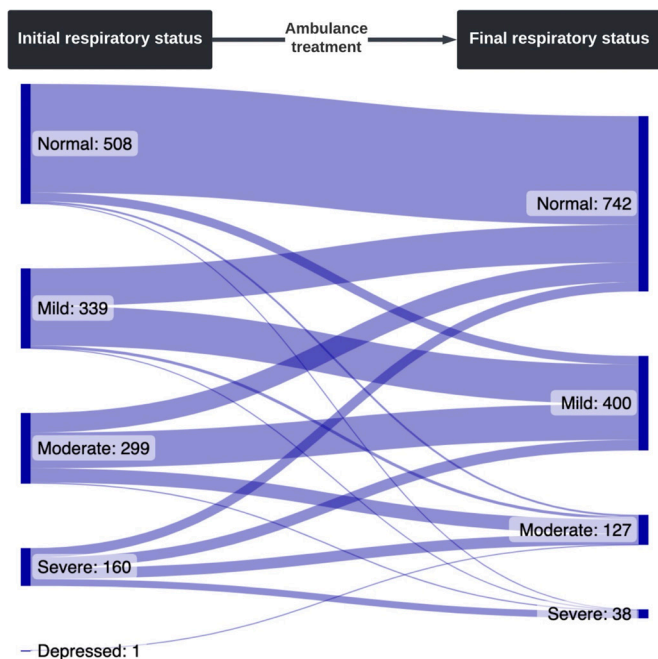
Figure 2 Initial and final respiratory status documented by AV paramedics. 111 patients missing initial respiratory status, and 265 missing final respiratory status. AV, Ambulance Victoria.

respiratory distress, over 90% of all patients were transported to hospital. Overall, the respiratory status of children improved from ambulance arrival to hospital arrival in all severity categories.

The overall rate of parenteral bronchodilator (epinephrine) administration was 1.6%. No patients received non-invasive ventilation, assisted ventilation or intubation and most patients were treated with inhaled bronchodilators and clinically improved by the time they arrived in hospital. Those receiving escalated care were older, were more likely to have a history of asthma requiring hospital admission and/or intubation and have severe respiratory distress on ambulance arrival.

A recent large study described in-hospital management of acute asthma exacerbations in Australia and New Zealand. In 14029 children, there was a higher overall rates of escalated therapy (7.3% overall, with 4.2% receiving parenteral bronchodilators and 4.3% respiratory support).[12] A common indication for escalation of care is failure to adequately respond to first-line therapy. The relatively low rates of treatment escalation in the prehospital setting (1.6%) suggest that a small proportion of children are seriously ill, while most are early in their treatment, and may not have had sufficient time to demonstrate improvement (or lack of improvement) prior to hospital arrival.

There is little evidence to guide escalated therapy for asthma. A recent Overview of Cochrane reviews of clinical trials on escalated therapy for asthma[16] assessed the evidence for parenteral bronchodilators, Heliox, respiratory support and inhaled magnesium. The review found that the majority of comparisons involved between one

and three trials and fewer than 100 participants, making it difficult to assess the balance between benefits and potential harms. The authors were unable to make firm practice recommendations.[16]

There is little evidence to support IM epinephrine as first-line treatment for seriously ill children with asthma,[24] although it has a number of advantages, including ease of administration and paramedic familiarity. Parenteral epinephrine is also used for anaphylaxis, cardiac arrest and management of hypotension, while nebulised epinephrine is used for severe upper airway obstruction in croup. In addition, it can be easily and rapidly administered as there is no need for dilution prior to administration, and no requirement for a prolonged infusion.[22]

Prehospital treatment of asthma rarely results in escalation of therapy beyond inhaled bronchodilators and systemic corticosteroids. In addition, the use of parenteral bronchodilators is often reserved for those who do not improve after initial inhaled bronchodilators, and is administered relatively late in the course of an ED visit.[15] Given that most children with asthma will improve with prehospital treatment, and/or will not have sufficient time to 'fail to improve' with standard therapy, it appears that any comparative clinical trials to determine the superiority of one parenteral bronchodilator over another should be reserved for the in-hospital rather than prehospital setting.

Limitations

Inclusion in the study was based on a combination of paramedic diagnosis of asthma and administration of inhaled bronchodilators. While only 89% had a diagnosis of asthma recorded in the ambulance notes, it seems that the cohort is reflective of the asthma population as over 87% of cases had a previous diagnosis of asthma.

Due to state-wide data collection and large numbers of patients, our study is likely to be generalisable to other settings with similar prehospital care systems. However, most ambulance cases within Victoria are concentrated in the metropolitan area of Melbourne (the capital city), which may limit generalisability to rural and regional settings. Approximately 10% of children were not transported to hospital; this is similar to the rate identified in a study of children with seizures from the same ambulance service.[25]

This study is a retrospective review of a comprehensive electronic database. We optimised data extraction and minimised bias through the collection of variables using a piloted data collection instrument, and application of predefined inclusion and exclusion criteria.[26 27] Due to the nature of record-keeping within the ambulance service (all cases are documented using the electronic system), it is unlikely that any cases of escalated care were missed. As we downloaded fields directly from the electronic medical record system, we did not independently abstract any variables. However, we verified all instances of documented escalation of care through consultation with a second (paramedic) reviewer and identified four cases of misclassification. It is possible that we missed

some children who were not classified as asthma, were critically ill, not given inhaled bronchodilators and only given parenteral epinephrine. However, this is likely to be a very small number of cases. There was some missing data on final observations on arrival to hospital, however, this was not a primary objective of our study.

CONCLUSIONS

Most children with acute exacerbations of asthma did not receive escalated therapy during their prehospital treatment from ambulance paramedics. Most patients were treated with inhaled bronchodilators only and clinically improved by the time they arrived in hospital. Due to the very low incidence of treatment escalation or clinical deterioration, any comparative clinical trials to determine the superiority of one parenteral bronchodilator over another should be reserved for the in-hospital rather than prehospital setting.

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Contributors SC, CW and FEB identified the research question. SC and CW were responsible for the study design and research protocol. BD and ZN obtained data and input into data cleaning and analysis. SC was responsible for statistical analysis. SC drafted the initial manuscript. SC, BD, ZN, CW, SD, GMN, CP, AG and FEB contributed equally to writing, reviewing and editing the manuscript. All authors provided comments on the drafts and have read and approved the final version of the article. All authors have full access to all of the data (including statistical reports and tables) at the conclusion of the study and take responsibility for the integrity of the data and the accuracy of the data analysis. SC is the guarantor for the paper, accepts full responsibility for the work and/or the conduct of the study, had access to the data and controlled the decision to publish.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval This study involves human participants. The project was approved by the Royal Children's Hospital Research Ethics and Governance Office, Melbourne, Australia (60707), and the Ambulance Victoria Research Governance Committee, Melbourne, Australia. A waiver of consent for review of existing medical records was granted as per ethics approval in accordance with the National Statement on Ethical Conduct in Human Research (National Health and Medical Research Council, Australia).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. Deidentified participant data will be available for sharing from 1 July 2024. Any data access requests should be sent to SC (simon.craig@monash.edu), and should include a proposal from the individual or organisation regarding their plan for use of the data.The study team will review the request and consider the scientific merit of the proposed use of the data, and the legal, regulatory and ethical issues pertinent to the request. Presuming all constraints are addressed, the data will be shared using a secure file transfer platform.

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