

ORIGINAL ARTICLE

Treatment of a simulated child with anaphylaxis: An in situ two-arm study

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Aim: This study aims to determine whether junior medical staff correctly identify and treat paediatric anaphylaxis and whether the presence or absence of hypotension influenced the treatment, using a standardised simulated patient encounter.

Methods: Junior medical staff from the emergency department of a large paediatric tertiary hospital were invited to participate in a two-armed cohort study to assess recognition and management of anaphylaxis in a standardised scenario using a simulated patient with and without hypotension. The primary outcome measure was administration of adrenaline. The secondary outcome measures included time to adrenaline administration, ability to seek and identify relevant features of history and clinical examination and use of other medications.

Results: Fifty-six junior medical staff participated (90% participation rate). Only 50% of participants administered adrenaline in scenarios of definite anaphylaxis. Adrenaline was more likely to be administered if the scenario included hypotension, where the junior medical officer had previous formal resuscitation training (Advanced Paediatric Life Support) and by medical officers with more years of training.

Conclusion: Anaphylaxis is a life-threatening presentation and requires prompt recognition and appropriate adrenaline administration. Junior medical staff may require more emphasis on recognition and prompt adrenaline administration in both undergraduate and in hospital training and education. Simulated scenarios may provide a platform to deliver this training to ultimately improve patient care.

Key words: anaphylaxis; paediatrics; patient simulation.

What is already known on this topic?

- 1 Delay or no adrenaline administration in anaphylaxis is associated with poor outcomes and death.
- 2 Presentations of paediatric anaphylaxis to Australian emergency departments have risen significantly over the past 10 years.
- 3 Scenario-based systems are a useful tool for teaching in the emergency department setting.

What this paper adds

- 1 Anaphylaxis in the paediatric setting is under recognised particularly when hypotension is not a clinical feature.
- 2 Significant improvements are required in training junior medical staff in the recognition of anaphylaxis and timely administration of adrenaline.
- 3 The mini-clinical evaluation exercise format is a useful tool in the assessment and education of junior medical staff in the paediatric emergency department.

Presentations of paediatric anaphylaxis to emergency departments have risen significantly in the past 10 years, in line with increases in food allergy in the paediatric population.^{1–3} Food-related anaphylaxis most commonly presents with cutaneous and/or gastrointestinal symptoms and respiratory compromise without initial hypotension.^{4,5} In the hospital setting, junior doctors are often involved in the initial assessment and management of anaphylaxis. It is therefore important that they are familiar with diagnosis and management of anaphylaxis and recognise the potential for rapid patient deterioration.

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International guidelines advise the rapid and early administration of parenteral adrenaline for the treatment of anaphylaxis.⁶ The delayed administration of parenteral adrenaline and/or misdiagnosis of severe allergic reactions as asthma presentations are associated with poor outcome including death.⁶ Previous studies have examined the management of anaphylaxis;^{5,7–10} however, they have been based on surveys or retrospective chart review methodology. These methodologies are unable to examine real-time decision-making or the sequence of management steps, which impairs the capacity to use these previous study results to inform best practice anaphylaxis education and training.

Simulation-based teaching is increasingly becoming an important part of medical education at all levels. Many hospitals now have formal simulation centres. Simulation also allows the development of skills in a non-clinical setting, rather than real patients, and clinical errors can be used as a learning tool, rather than leading to detrimental clinical outcomes. Simulation

training has been shown to improve overall retention of information. In paediatrics, simulation has been used to assess a variety of clinical scenarios including resuscitation, trauma, airway skills, procedural techniques and crisis management.¹¹ There are no published studies examining the use of simulators in acute management of anaphylaxis.

Methods

A two-armed cohort study using the mini-clinical evaluation exercise (mini-CEX) format within a standardised scenario was conducted in the Emergency Department of the Children's Hospital at Westmead, Sydney, a major tertiary referral paediatric centre in 2010.

Participants were junior medical officers (JMOs) working in training positions within the emergency department between January and July 2010. All JMOs in training positions were invited to participate. Participation was voluntary and promoted as a positive educational opportunity. JMOs not currently working in the department or those working in the department in non-training positions were excluded. Residents were generally 3 years or less postgraduation, and registrars were more than 4 years postgraduation. Participants were divided into two groups: January to April 2010 (group 1) and April to July 2010 (group 2). Group 1 completed a standard scenario of child with anaphylaxis (generalised urticarial, shortness of breath and wheeze) including hypotension (Appendix I). Group 2 completed the same standard anaphylaxis scenario (as above) with normotension. Data were collected by one of two observers trained in the use of the mini-CEX model and was recorded on a standardised proforma (Appendix I). There was one observer per participant. An independent senior medical practitioner administered the mini-CEX as an educational activity for participants; the scenario was terminated at either 10 min or if the independent medical practitioner felt that the scenario was not progressing. Participants received constructive formative feedback at the completion of the scenario.

The anaphylaxis scenarios used a Megacode Kid (Laerdal Medical, Stavanger, Norway), as the standardised simulated patient. A faculty instructor played the role of patient's voice, parent and nurse. Physiological parameters were displayed on a monitor using Simbaby software (Laerdal Medical). The definition of anaphylaxis is any acute onset illness with typical skin features (urticarial rash or erythema/flushing and/or angioedema), PLUS involvement of respiratory and/or cardiovascular and/or persistent severe gastrointestinal symptoms, OR any acute onset of hypotension or bronchospasm or upper airway obstruction where anaphylaxis is considered possible, even if typical skin features are not present,¹² as defined by The Australasian Society of Clinical Immunology and Allergy (ASCIA).

The primary outcome measure was administration of parenteral adrenaline. The correct dose was defined as per ASCIA.¹² Secondary measures were pre-defined clinical assessments of the patient (measurement of respiratory rate, work of breathing, blood pressure, oxygen saturation, heart rate, presence of angioedema, wheeze or stridor), patient management (time taken to complete tasks and the sequence of tasks) and a questionnaire survey on the usefulness of the scenario. Time to

prescription (administration) was taken from the commencement of the scenario. Additional secondary outcome was feedback from participants, via a self-administered questionnaire survey, on their perception of whether the session had improved their knowledge of anaphylaxis and general satisfaction with the session.

The scenario and questionnaire were tested on a small sample prior to commencement of the project. Ethics approval was obtained from the hospital ethics committee prior to commencement of the study.

Data were analysed using Pearson χ^2 test using SPSS (v 16.0) software (SPSS Inc., Chicago, IL, USA). Parametric data were expressed as mean and standard deviation, and non-parametric data were expressed as median and inter-quartile range. A power calculation prior to commencement showed that 23 participants would be required in each arm to detect a difference of 40%, with a power of 80% and $P < 0.05$.

Results

Participant characteristics

A total of 56 out of 62 (90%) JMOs completed the scenario. There were 28 in each cohort. The two cohorts were similarly matched for training status, postgraduate year and completion of Advanced Paediatric Life Support (APLS) training (Table 1). There was no significant difference between groups 1 and 2 in terms of time from completion of APLS.

Primary outcome: administration of adrenaline

A total of 28 (50%) participants administered parenteral adrenaline. Significantly more participants from group 1 (hypotensive patient) (21/28; 75%) gave parenteral adrenaline compared with group 2 (normotensive patient) (7/28; 25%) ($P < 0.001$).

Only three participants knew and prescribed the correct dose of adrenaline, 23 looked up the dose and two prescribed the incorrect dose. Adrenaline was prescribed intramuscularly by 24 participants, intravenously by three participants and subcutaneously by one participant.

Parenteral adrenaline was significantly more likely to be prescribed by a registrar ($P = 0.004$) and those who were APLS providers ($P = 0.007$). The measurement of blood pressure and capillary refill during the simulation scenario was also significantly associated with the prescription of parenteral adrenaline ($P < 0.001$ and $P = 0.002$, respectively).

The mean time to adrenaline prescription/administration (where prescribed) was 5 min 30 s (group 1) and 4 min 44 s (group 2) (Table 2).

Secondary outcomes: patient assessment and treatment

The majority of participants were able to elicit relevant history using the standardised simulated patient and faculty actor (Table 3). A history of asthma was obtained in 98% of cases, whereas only 75% obtained a history of relevant allergen exposure. Oxygen saturation and auscultation was performed in

Table 1 Characteristics of participants

	Cohort 1 (hypotensive)	Cohort 2 (normotensive)	Total	(P value)
Number of participants	28	28	56	
Males	10	10	20	1
Residents : Registrars	8:20	10:18	18:38	0.576
RACP advanced trainee†	2	2	4	0.741
RACP basic trainee	15	10	25	
Paediatric resident	4	4	8	
ACEM advanced trainee‡	3	6	9	
ACEM provisional trainee	1	2	3	
RACGP trainee§	1	1	2	
Unstreamed resident	2	3	5	
Median postgraduate year (inter-quartile range)	4.5 (2.25)	4 (3)	4 (3)	0.678
APLS provider¶	19	16	35	0.508

†Royal Australasian College of Physicians. ‡Australasian College of Emergency Medicine. §Royal Australasian College of General Practitioners. ¶Advanced Paediatric Life Support.

Table 2 Comparison of adjunctive therapy between cohort 1 and cohort 2

Interventions	Cohort 1		Cohort 2		Cohorts 1 & 2	Significance between groups for intervention P=	Significance between groups for time to intervention P=
	n	Mean (SD) time to intervention (seconds)	n	Mean (SD) time to intervention (seconds)	n		
Parenteral adrenaline	21	319 (117)	7	284 (90)	28	<0.001	0.425
Oxygen	16	258 (114)	9	245 (137)	25	0.06	0.812
Steroid administration	25	337 (118)	17	247 (57)	42	0.005	0.003
Salbutamol administration	28	169 (79)	28	204 (89)	56	1	0.133
Antihistamine administration	11	404 (58)	8	253 (51)	19	0.397	<0.001
Insertion of intravenous cannula	24	246 (81)	13	330 (103)	37	0.002	0.02
Administration of intravenous fluid	21	266 (102)	2	340 (14)	23	<0.001	0.009

most or all instances; however, only 60% of participants measured a blood pressure and only 37% assessed for capillary refill.

Salbutamol was generally the first medication prescribed, with a mean time to administration of 2 min 49 s (group 1) and 3 min 24 s (group 2) (Table 2). The time to administration of steroids and antihistamine was significantly shorter in those participants assessing the normotensive anaphylaxis scenario (group 2), whereas time to insertion of the intravenous cannula and administration of intravenous fluids was significantly shorter in those assessing the hypotensive anaphylaxis scenario (group 1). Participants treating the hypotensive patient were significantly more likely to give steroids, insert an intravenous cannula and give intravenous fluids (Table 2).

Secondary outcomes: participant feedback

All participants completed feedback questions. The mini-CEX was generally well received, with all participants indicating that they believed the session had improved their ability to

Table 3 Participants ability to elicit history and examination findings

History and examination finding	Number of participants eliciting (%)
History of asthma	55 (98.2)
History of exposure to allergen	42 (75)
Respiratory rate	48 (85.7)
Ability to speak	55 (98.2)
Presence of angioedema	39 (69.6)
Hear rate	52 (92.8)
Blood pressure	34 (60.7)
Work of breathing	48 (85.7)
Auscultation of chest	56 (100)
Oxygen saturation	54 (96.4)
Capillary refill time	21 (37.5)

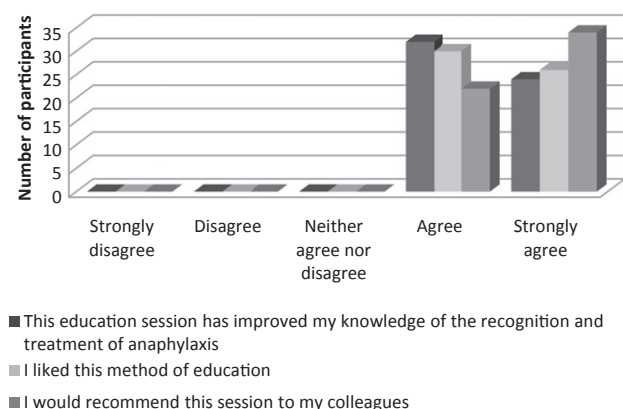


Fig. 1 Participants self-reported feedback on their satisfaction with the anaphylaxis simulation.

recognise and treat anaphylaxis. There was no significant difference between the hypotensive and normotensive groups (Fig. 1).

Discussion

This study demonstrates that there remains a significant deficiency in the recognition and management of paediatric anaphylaxis by junior medical staff in our setting and that standardised simulated scenarios can assist with both the assessment of and the education in management of anaphylaxis in the emergency department.

Consistent with our findings, previous surveys^{7,8} and retrospective case review studies^{4,5,9} that have examined administration of adrenaline in anaphylaxis have also reported undertreatment of anaphylaxis. Most reported that less than half of children requiring adrenaline, according to accepted anaphylaxis criteria, had it administered.^{4,13} We observed an increasing likelihood of adrenaline administration in doctors with greater years of postgraduate experience and in those who were APLS providers. Previous studies have focused on presentation of anaphylaxis, triggering agents and differences between adults and children and not on the experience or training of the treating doctor. In a survey of UK-based JMOs' knowledge of anaphylaxis management,⁸ only 61% of 1981 juniors surveyed knew which drugs to use and less than 50% knew the appropriate dose. We also found only a small number of participants (three) knew the correct dose of adrenaline, while 23 looked up the dose. Based on this UK survey, recommendations were made to improve training programmes. As formal APLS training in Australia is currently compulsory for those undertaking paediatric (Fellowship of the Royal Australasian College of Physicians) but not emergency training (Fellowship of the Australasian College of Emergency Medicine), consideration of broader mandatory APLS (or similar) is merited.

The rate of overall adrenaline provision for anaphylaxis in our simulated scenario is in line with previous case note reviews from emergency departments, both in Australia and the USA, where between 19% and 76% of paediatric patients presenting

with anaphylaxis had adrenaline administered.^{4,13} A review of an Australian centre reported a higher rate of 85%; however, only half of these children had had adrenaline administered by the recommended intramuscular route; the remainder was subcutaneously administered, which may delay rapid distribution of the adrenaline.⁵

One of the most worrying and novel aspects of this study was our finding of the under recognition of anaphylaxis in the absence of hypotension. We report a significant difference between the numbers of participants prescribing adrenaline between the groups, with significantly more participants prescribing adrenaline in the presence of hypotension. This suggests that the majority of participants may have been unable to make the diagnosis of anaphylaxis in this scenario in the absence of hypotension and that JMOs may not have realised that wheeze without cardiovascular compromise can be anaphylaxis. Of further concern is that only 34 (60.7%) of participants measured blood pressure overall during either scenario. Respiratory compromise, in the absence of hypotension, has been consistently reported to be the most common form of paediatric food-related anaphylaxis presentation, with only 17% of children presenting with hypotension or evidence of cardiovascular compromise in a recent Australian review.⁵ This misconception may explain some of the low published rates of adrenaline provision for paediatric food-related anaphylaxis world-wide.

Delayed administration of adrenaline in the setting of anaphylaxis is a known risk factor for death.¹⁴ All international guidelines highlight the importance of rapid administration of adrenaline for the acute management of anaphylaxis, although targets for door-to-treatment times are not suggested.¹⁵ In rapidly progressing anaphylactic reactions, cardiorespiratory arrest may occur within 5 min of parenteral allergen exposure and less than 30 min of food allergen exposure. Even in patients undertaking a more prolonged course, they are more likely to make a full recovery if adrenaline is administered within 30 min of the onset of symptoms.¹⁶ Previous case review of anaphylaxis management in an Australian paediatric emergency department estimated a mean time between presentation and administration of adrenaline of up to 40 min.⁵ Our study used the decision to administer treatment as the recorded time, thus real times to administration may be longer. The time data in our study does however give an indication of the sequence of priorities of treating medical staff, where both groups gave salbutamol prior to first-line adrenaline. Current guidelines allow for administration of selective beta-2 agonists as adjunctive therapy in those patients where lower respiratory tract symptoms occur, but there administration should not be a substitute for or delay administration of adrenaline.¹⁵ As anaphylaxis training and awareness programmes within schools,¹⁷ for patients prescribed adrenaline auto-injectors¹⁸ and for ambulance staff all emphasise pre-hospital administration and the importance of minimising delay to adrenaline administration, the same vigilance should also be applied within the hospital setting to ensure recognition and prompt treatment of anaphylaxis. To examine real delays in more depth, a full high-fidelity simulation with multiple participants where drugs are actually drawn up would provide more accurate information.

There is good consensus regarding route of administration of adrenaline for first-line treatment of treatment of anaphylaxis,

and 24 of 28 of the participants in this study who decided to give adrenaline selected the intramuscular route of delivery, in accordance with accepted guidelines. Current guidelines recommend that intramuscular adrenaline should be given in the initial setting, and infusion of adrenaline should be initiated in the presence of shock or inadequate response from intramuscular adrenaline.¹⁵ There are multiple published case reports of either adverse outcomes or patient fatality from inappropriate use of intravenous adrenaline or adrenaline overdose.^{16,19}

The ability of medical officers to gain relevant clinical history and examination during the patient assessment was in general good, with 80–100% of candidates determining history of asthma and clinical variables of oxygen saturation, signs of respiratory disease and distress. Only 75% obtained a history of allergen exposure. From the history in the scenario, the presentation was atypical of asthma with rapid onset of dyspnoea in the absence of prodromal viral illness. This should prompt the clinician to consider other differential diagnoses such as anaphylaxis or foreign body inhalation. Asthma is a known risk factor for fatal anaphylaxis,²⁰ and fatality is rare in its absence in children. As a percentage of fatal asthma attacks may also be secondary to unrecognised anaphylaxis,²¹ a high index of suspicion should be maintained in this paediatric population.

Potential weaknesses of the study include that it was not multicentre and may not reflect paediatric training and skills across the whole country, although comparison with similar UK knowledge-based questionnaire responses and emergency department audits suggest this is a wide problem. Furthermore, the study utilised a simulated patient with faculty actors and as such the results may not be valid in real patient encounters where JMOs may perform differently. The study is unlikely to be confounded by the two time periods in which the study was undertaken, as trainees in the emergency department were exposed to the same training programme that runs on a term basis. Results could have been strengthened by the use of two blinded observers and measuring inter-observer variability; however, blinding is extremely difficult in the simulation environment as the observers have to be present and aware of the physiological parameters in order to document the outcomes and may also be a source of measurement bias. Past research has shown that these biases both tend to favour the positive outcome²² that would have led to an overestimation of adrenaline prescription. Assuming that this bias would affect each group equally, it should not significantly alter the difference observed between groups.

Conclusion

We found that the administration of adrenaline in management of simulated paediatric anaphylaxis is suboptimal, and improved teaching aimed at JMOs should highlight case definition and the role of intramuscular adrenaline in anaphylaxis. We believe this study highlights the importance of formalised paediatric advanced life support courses and requirement for enhanced education surrounding the management of paediatric anaphylaxis. It also highlights the utility of in situ simulated learning systems for the assessment and teaching, especially in high stakes emergency presentations, where opportunistic teaching during the clinical episode is difficult.

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Appendix I

Case scenario worksheet

Page 1 – to be completed by participant AFTER the scenario and education session

Page 2 – to be completed by the instructor DURING the scenario

Current position: Registrar ☐ Resident ☐

Training status: Paediatric Advanced trainee ☐ Basic trainee ☐ Resident ☐
 Emergency Advanced trainee ☐ Provisional trainee ☐ Resident ☐
 General practice trainee ☐
 PGY2 ☐ Unstreamed RMO ☐ Other _____

I am in my _____ postgraduate year Sex: Male ☐ Female ☐

Have you completed an APLS course? Yes ☐ No ☐

If yes how long ago <6 months ☐ 6 months to 1 year ☐ 1–3 years ☐ > 3 years ☐

Please complete the following as truthfully as possible:

After this education session my knowledge of the recognition and treatment of anaphylaxis is:

☐ Very poor ☐ Poor ☐ Adequate ☐ Good ☐ Excellent

This education session has improved my knowledge of the recognition and treatment of anaphylaxis

☐ Strongly disagree ☐ Disagree ☐ Neither agree nor disagree ☐ Agree ☐ Strongly agree

I liked this method of education:

☐ Strongly disagree ☐ Disagree ☐ Neither agree nor disagree ☐ Agree ☐ Strongly agree

I would recommend this session to my colleagues:

☐ Strongly disagree ☐ Disagree ☐ Neither agree nor disagree ☐ Agree ☐ Strongly agree

Comments:

Thank you, please remember to keep this session confidential so your colleagues can also benefit

Case scenario

7 years old (25 kg); Sitting up in bed, with parent Attached to monitor.

Parent history: A seven year old boy with his parent. He has been attending a birthday party for a friend when he has become a bit short of breath and has also developed a rash. Feels nauseous. Past history of mild asthma well controlled with prn ventolin, mild childhood eczema. No family history of asthma. Fully immunised.

Had been eating chocolates at the party, symptoms commenced within 15 min of eating the chocolate

Scenario set up: Megacode kid, sitting up, dressed. Able to speak in short sentences. RR 35, bilateral wheeze on auscultation, Sats 95% RA, HR 120, CR 2 s, BP 100/65 (when cuff placed). Rash – generalised urticarial

Scenario progress: If no adrenaline within 5 min will become more short of breath. Responds to first dose of Adrenaline with improvement and HR

Participant briefing:

‘As we have already discussed we would like to assess your practical skills in a mock clinical situation. We will explain the scenario to you and then ask you to act as you would in a real clinical situation. It is important that you DO what you would normally do in a real clinical situation, rather than saying what you would do. This person is the child’s mother/father and will be able to answer any questions you have. All the physiology is available on the monitor and please I will give you other feedback that the manikin can’t give you, e.g. work of breathing, as you do your clinical examination. All the equipment you will need will be provided. At the end of the scenario we will give you feedback and you will then have the opportunity to discuss the case and their management. Is that clear?’

‘Doctor, could you see the child in bed 2 please. They have been brought in from triage with shortness of breath’

‘Are you ready’ – **START CLOCK**

Call for help	☐	Time		Comments
History and Examination				
PHx asthma	☐	Exposure to allergen	☐	
RR	☐	Work of breathing	☐	
Speaking	☐	Listen to chest/wheeze	☐	
Oral mucosa/tongue	☐	SaO ₂	☐	
HR	☐	Capillary refill	☐	
BP	☐			
1st dose adrenaline	Time	Dose	Route	Comments
Knows dose of adrenaline	☐	Looks up dose of adrenalin	☐	
Oxygen	Time	Rate	Device	Comments
Steroids	Time	Dose	Route	Name
Ventolin	Time	Dose	Route	Comments
Antihistamine	Time	Dose	Route	Name
Cannula	Time	Volume	Rate	Comments
IV Fluids	Time	Volume	Rate	Comments

Now your patient has recovered what is diagnosis and your plan for disposition?