

An Overview of Paediatric Advanced Life Support

Introduction

Paediatric advanced life support (PALS) includes the knowledge and skills necessary to identify and effectively treat infants and children who have potential respiratory or circulatory failure, and to provide the appropriate early treatment for a paediatric cardiac arrest.

The aim of this chapter is to provide an overview of PALS.

Learning objectives

At the end of this chapter, the reader will be able to:

- Discuss the causes of death in childhood
- Discuss survival rates following paediatric resuscitation
- Outline the pathophysiology of paediatric cardiac arrest
- Discuss the importance of treating children differently from adults
- Outline the provision of a resuscitation service in hospital

Causes of death in childhood

The most common causes of death in children under 6 years of age worldwide are detailed in Table 1.1.

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Table 1.1 Most common causes of death worldwide in children under 6 years of age

Neonates aged 0–27 days		Children aged 1–59 months	
Preterm birth complications	12%	Diarrhoea	14%
Birth asphyxia	9%	Pneumonia	14%
Sepsis	6%	Other infections	9%
Other	5%	Malaria	8%
Pneumonia	4%	Other non-communicable disease	4%
Congenital abnormalities	3%	Injury	3%
Diarrhoea	1%	AIDS	2%
Tetanus	1%	Pertussis	2%

Reproduced from Stevenson & Tedrow (2010).

Table 1.2 Causes of death by age in England and Wales, 2008

	0–4 weeks	1–12 months	1–4 years	5–14 years
Number of deaths	3918	1023	506	590
Perinatal conditions and prematurity	62%	22%	3%	1%
Congenital	25%	20%	15%	7%
Sudden unexplained deaths	1%	19%	3%	1%
Respiratory infections	Included in 'Other infections'	6%	11%	8%
Other infections	1%	7%	11%	3%
Trauma including asphyxia	10%	4%	13%	19%
Other	1%	6%	2%	1%

Reproduced from Office for National Statistics (2010).

According to the Office for National Statistics (2009), the highest death rates in childhood occur during the first year of life, particularly the first month (Table 1.2). Causes of death in childhood vary according to age. The most common causes are:

- *Newborn period* – congenital abnormalities and factors associated with prematurity
- *1 month to 1 year* – cot death, infection and congenital abnormality
- *From 1 year* – trauma

In England and Wales, infant mortality rates (number of deaths of children under 1 year of age in one calendar year per 1000 live

births in the same calendar year) have fallen by more than 50% in the last 28 years, from 12 in 1980 down to 4.5 in 2008, the lowest on record (Advanced Life Support Group, 2011).

Survival rates following paediatric resuscitation

Paediatric cardiac arrest is rarely caused by a primary cardiac problem. It is also rarely a sudden event (Klitzener, 1995), often being the end result of a progressive deterioration in respiratory and circulatory function (American Academy of Paediatrics, 2000). If cardiac arrest ensues, the prognosis is dismal (O'Rourke, 1986); the survival rate of patients in asystole has been reported to be as low as 3% (Zaritsky *et al.*, 1987).

The early diagnosis and aggressive management of respiratory or cardiac insufficiency aimed at preventing deterioration to cardiac arrest are the key to improving survival without neurological deficit in seriously ill children (Zideman & Spearpoint, 1999). Prompt resuscitation in the event of a respiratory arrest is associated with a favourable outcome – survival rates of over 50% have been reported (Zaritsky *et al.*, 1987; Spearpoint, 2002). Recognition of respiratory failure and shock is discussed in Chapter 3.

Pathophysiology of cardiac arrest

There are three basic mechanisms of paediatric cardiac arrest – asystole, pulseless electrical activity (PEA; formerly known as electromechanical dissociation) and ventricular fibrillation (VF). Pulseless ventricular tachycardia (VT) is another mechanism, but this is usually classified with VF because the causes and treatment are similar.

Asystole

Asystole (Fig. 1.1) is the most common presenting rhythm in paediatric cardiac arrests (Sirbaugh *et al.*, 1999; Young & Seidel, 1999). It is the final common pathway of respiratory or circulatory failure (Zideman, 1997). Prolonged severe hypoxia and acidosis leads to progressive bradycardia and asystole (Advanced Life

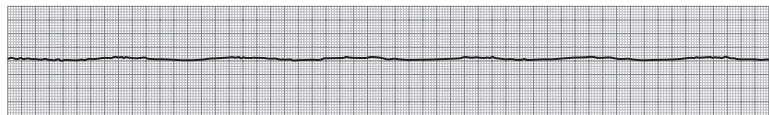


Fig. 1.1 Non-shockable rhythm: asystole.



Fig. 1.2 Non-shockable rhythm: pulseless electrical activity.

Support Group, 2011). The most common cause is hypoxia, and the most effective treatment is to establish a clear airway and effective ventilation (Zideman, 1997).

Management of asystole is less commonly successful than when the rhythm is VF (Dieckmann & Vardis, 1995), but survival to discharge has been reported (Spearpoint, 2002).

Pulseless electrical activity

‘Pulseless electrical activity’ is a term used to signify the features of cardiac arrest associated with a normal (or near-normal) ECG (Fig. 1.2). The diagnosis is made on clinical grounds by the combination of the absence of a cardiac output with a ECG rhythm on the monitor that would normally be associated with a good cardiac output.

The causes of PEA can be classified into one of two broad categories:

- *Primary PEA* – there is failure of excitation contraction coupling in the cardiac myocytes resulting in a profound loss of cardiac output. Causes include hypoxia, poisoning, for example due to beta-blockers, calcium channel blockers or toxins, and electrolyte disturbance (hyperkalaemia or hypocalcaemia).
- *Secondary PEA* – there is a mechanical barrier to ventricular filling or ejection. Causes include hypovolaemia, cardiac tamponade and tension pneumothorax.

In all cases, treatment is directed towards the cause.

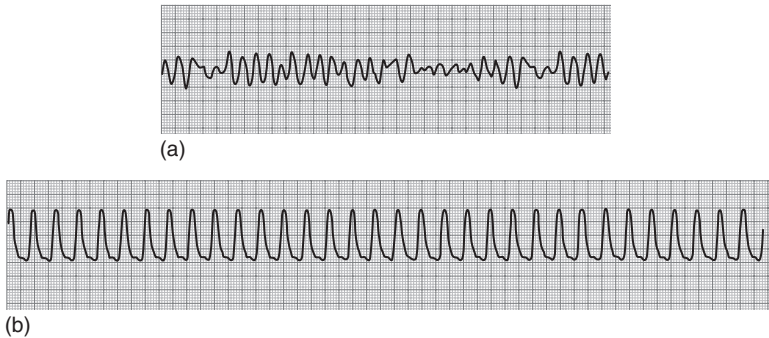


Fig. 1.3 Shockable rhythms: ventricular fibrillation (a) and pulseless ventricular tachycardia (b).

Ventricular fibrillation/pulseless ventricular tachycardia

VF/pulseless VT (Fig. 1.3) is uncommon in children (Zideman, 1997; Spearpoint, 2002). However, clinical situations when it may occur include after cardiac surgery or with cardiomyopathy, congenital heart disease, hypothermia or drug intoxication.

The ECG displays a bizarre irregular waveform, apparently random in both frequency and amplitude, which reflects disorganised electrical activity in the myocardium. This is an eminently treatable arrhythmia, but the only effective treatment is early defibrillation, and the likelihood of success is crucially time-dependent (Jevon, 2009).

Conditions for defibrillation are optimal for as little as 90 seconds after the onset of the rhythm, and the chances of success fall by about 10% with every minute that treatment is delayed (Waalewijn *et al.*, 2001). Untreated VF will inevitably deteriorate into asystole as myocardial energy reserves and oxygen are exhausted; successful cardiopulmonary resuscitation (CPR) at this late stage is almost impossible (Waalewijn *et al.*, 2001).

Importance of treating children differently from adults

Children are not small adults. Children are a diverse group of the population. They vary dramatically in weight, size, shape, intellectual ability and emotional responses.

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At birth, a child is, on average, 3.5 kg, with a small respiratory and cardiovascular reserve and an immature immune system. At this stage, children are capable of limited movement, exhibit limited emotional responses and are dependent upon adults for their needs. Fourteen or more years later, at the other end of childhood, the adolescent is a 50 kg, 160 cm tall person who looks like an adult. Therefore, the competent management of the critically ill child, who may fall anywhere between these two extremes, requires a knowledge of these anatomical, physiological and emotional differences (Advanced Life Support Group, 2011).

Weight

The most dramatic changes in a child's weight occur during the first year of life: an average birth weight of 3.5 kg will increase to 10 kg by the child's first birthday. After this time, the weight increases more slowly until puberty. In paediatric resuscitation, most drugs and fluids are given per kilogram of body weight, so it is important to determine a child's weight as soon as possible during the treatment process.

The most accurate method is to weigh the child, but this may not always be possible, so in this situation a child's weight can be estimated in a number of methods. Examples of these are the Broselow tape, which relates the length of the child to the body weight, or centile charts that estimate weight against age. If a child's age is between 1 and 10 years, the most commonly used formula to determine weight (Resuscitation Council (UK), 2011) is:

$$\text{Weight (kg)} = \text{age (years)} + 4 \times 2$$

This formula is not, however, suitable for use in a child under 1 year of age: a term newborn infant averages 3.5 kg, and by 6 months the birth weight has usually doubled, trebling at 1 year.

Whichever method has been used to establish body weight, it is essential that healthcare professionals are familiar with and competent in its use.

Anatomical

A child's airway goes through many changes. In the younger child, the head is large and the neck short, which causes neck

flexion and airway narrowing. The face and mandible are small, and the tongue is relatively large and can easily obstruct the airway. In addition, the floor of the mouth is easily compressible and can be obstructed by the positioning of the fingers during airway manoeuvres.

The anatomy of the airway itself also changes with age. Infants less than 6 months of age are nose-breathers, and as upper respiratory tract infections are common in this age group, their airways are commonly obstructed by mucous secretions. In all young children, the epiglottis is horseshoe-shaped and the larynx high and anterior, making tracheal intubation much more difficult.

Physiological

There are many differences between the respiratory and cardiovascular systems of infants and those of adults (Tables 1.3–1.5). Infants have a greater metabolic rate and oxygen consumption, which is the reason for their increased respiratory rates. Stroke volume is also relatively small in infancy and increases with heart size. However, cardiac output is the product of stroke volume and heart rate so high cardiac outputs in infants and young children are achieved by rapid heart rates.

Table 1.3 Normal respiratory rate according to age

Age (years)	Respiratory rate (breaths/min)
<1	30–40
1–2	26–34
2–5	24–30
5–12	20–24
>12	12–20

Reproduced from Advanced Life Support Group (2011).

Table 1.4 Normal heart rate according to age

Age	Mean	Awake	Deep sleep
Newborn – 3 months	140	85–205	80–140
3 months – 2 years	130	100–180	75–160
2–10 years	80	60–140	60–90
>10 years	75	60–100	50–90

Reproduced from Advanced Life Support Group (2011).

Table 1.5 Normal blood pressure according to age

Age	Systolic blood pressure (mmHg)	
	Normal	Lower limit
0–1 month	>60	50–60
1–12 months	80	70
1–10 years	90 + $2 \times \text{age in years}$	70 + $2 \times \text{age in years}$
>10 years	120	90

Reproduced from Advanced Life Support Group (2011).

Immune function

At birth, the immune system is immature so babies are much more susceptible to illness.

Psychological

Children vary greatly in their intellectual ability and emotional response, and a knowledge of the child development is of great benefit to the practitioner. Infants and young children find it very difficult to communicate, and the importance of non-verbal communication and fear must be considered.

Cardiopulmonary resuscitation: standards for clinical practice and training

Cardiopulmonary Resuscitation: Standards for Clinical Practice and Training (Royal College of Anaesthetists *et al.*, 2008) is a joint statement from the Royal College of Anaesthetists, Royal College of Physicians of London, Intensive Care Society and Resuscitation Council (UK). It has been endorsed by a number of national bodies, including the Royal College of Nursing. The joint statement makes a numbers of recommendations relating to:

- The resuscitation committee
- The resuscitation officer
- Resuscitation training
- The prevention of cardiopulmonary arrest
- The resuscitation team

- Resuscitation in children, pregnancy and trauma
- Resuscitation equipment
- Decisions relating to CPR
- Patient transfer and post-resuscitation care
- Audit and reporting standards
- Research

Resuscitation committee

Each hospital should have a resuscitation committee that meets on a regular basis and is responsible for implementing operational policies relating to resuscitation practice and training. The chairperson should be a senior clinician who is actively involved in resuscitation. Membership of the committee should include:

- A physician
- A senior resuscitation officer
- An anaesthetist/intensivist
- A senior manager
- Representatives from appropriate departments, including paediatrics, based on local needs

The responsibilities of the resuscitation committee include:

- Advising on the composition and role of the resuscitation team
- Ensuring that resuscitation equipment and resuscitation drugs are available
- Ensuring the adequate provision of resuscitation training
- Ensuring that Resuscitation Council (UK) guidelines and standards for resuscitation are followed
- Updating resuscitation and anaphylaxis policies
- Recording and reporting clinical incidents related to resuscitation
- Auditing resuscitation attempts and Do Not Attempt Resuscitation (DNAR) orders

Resuscitation officer

Each hospital should have a resuscitation officer responsible for resuscitation training, ideally one for every 750 members of clinical staff. The resuscitation officer should possess a current

Resuscitation Council (UK) Advanced Life Support (ALS) certificate and should ideally be a Resuscitation Council (UK) ALS Instructor. Adequate training facilities, training equipment and secretarial support should be provided. Responsibilities of the resuscitation officer include:

- Implementing Resuscitation Council (UK) guidelines and standards in resuscitation
- Providing adequate resuscitation training for relevant hospital personnel
- Ensuring that there are systems in place for checking and maintaining the resuscitation equipment
- Auditing resuscitation attempts following national guidelines
- Attending resuscitation attempts and providing feedback to team members
- Coordinating participation in resuscitation-related trials
- Keeping abreast of current resuscitation guidelines

Resuscitation training

Clinical staff should receive regular (at least annual) resuscitation training appropriate to their level and expected clinical responsibilities. This should also be incorporated into the induction programme for new staff. Where appropriate, this training should include paediatric resuscitation training, incorporating the recognition and effective treatment of critical illness and providing effective treatment to prevent cardiopulmonary arrest. Some staff, for example members of the paediatric cardiac arrest team, will require appropriate advanced resuscitation training, such as a European Paediatric Life Support (EPLS) course or Advanced Paediatric Life Support (APLS) course (see Chapter 15).

The resuscitation officer is responsible for organising and coordinating the training; a cascade system of training may be needed to meet training demands, particularly in paediatric basic life support. Help should be sought from other medical and nursing specialties to provide specific training. See Chapter 15 for more detailed information on resuscitation training.

Prevention of cardiopulmonary arrest

Systems should be place to identify patients who are critically ill and therefore at risk of cardiopulmonary arrest (Royal College of

Anaesthetists *et al.*, 2008). Every hospital should have an early warning scoring system in place to identify these patients. Adverse clinical indicators or scores should elicit a response to alert expert help, for example the critical care outreach service or medical emergency team.

Each healthcare organization should have a patient observation chart that facilitates the regular measurement and recording of early warning scores. There should be a clear and specific policy that requires a clinical response to 'calling criteria' or early warning systems ('track and trigger'), including the specific responsibilities of senior medical and nursing staff (Royal College of Anaesthetists *et al.*, 2008).

Paediatric resuscitation team

The composition of the paediatric resuscitation team should be determined by the resuscitation committee. All staff who are involved with paediatric resuscitation should be encouraged to attend national paediatric courses such as the EPLS, APLS or Newborn Life Support course.

The resuscitation team should be alerted within 30 seconds of dialling 2222 (the recommended telephone number for contacting the switchboard following an in-hospital cardiac arrest) (National Patient Safety Agency, 2004). The system should be tested on a daily basis.

Resuscitation equipment

The resuscitation committee is responsible for advising on resuscitation equipment, which will largely be dependent upon local requirements and facilities. Ideally, it should be standardised throughout the hospital. The Resuscitation Council (UK) (2011) has made suggestions regarding resuscitation equipment for paediatric resuscitation, and these are discussed in detail in Chapter 2.

Do Not Attempt Resuscitation orders

Every hospital should have a DNAR policy, which should be based on national guidelines (BMA *et al.*, 2007). Only a minority

of childhood deaths, such as those due to end-stage neoplastic disease, are expected and 'managed'. There should be timely discussions between the child, family and health carers to identify whether and in what manner resuscitation should be carried out to prevent unwanted and inappropriate resuscitation and interventions (Advanced Life Support Group, 2011).

Transfer of the child and post-resuscitation care

Complete recovery from a cardiac arrest is rarely immediate, and the return of spontaneous circulation is just the start, not the end, of the resuscitation attempt. The immediate post-resuscitation period is characterised by high dependency and clinical instability (Jevon, 2009), with most children requiring transfer to a paediatric intensive therapy unit. The principles of transfer of the child and post resuscitation care are discussed in Chapter 11.

Auditing and reporting standards

The resuscitation committee should ensure that all resuscitation attempts are audited. Acute NHS Trusts that are affiliated to the National Cardiac Arrest Audit (NCAA) initiative will submit data from paediatric resuscitation attempts to this audit. For further information, see Chapter 13.

To help ensure a high-quality resuscitation service, each hospital should audit:

- The resuscitation attempt, including outcomes
- The availability and use of resuscitation equipment
- The availability of emergency drugs
- DNAR orders
- Critical incidents that cause, or occur during, cardiopulmonary arrests
- Health and safety issues, including the cleaning and decontamination of resuscitation training manikins (following each training session)

Hospital management should be informed of any problems that arise, and the local clinical governance lead should support the resuscitation committee to rectify any deficiencies in the service.

Research

Healthcare practitioners interested in undertaking resuscitation-related research should be encouraged to do so. They should be advised to seek the advice and support of the local research ethics committee.

Summary

In this chapter, an overview of PALS has been provided. The causes of death in childhood have been discussed, together with the survival rates following paediatric resuscitation. The pathophysiology of paediatric cardiac arrests has been outlined, and the provision of a resuscitation service in hospital has been discussed.

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