CHAPTER 1

Introduction

Learning outcomes

After reading this chapter, you will be able to:
- Describe the focus of the APLS course
- Identify the important differences in children and their impact on the management of emergencies

1.1 Introduction

Over the last two decades there has been a substantial reduction in childhood mortality across the world. This has been related to improvements in many areas such as maternal education, access to clean water, access to food, immunisation against an increasing number of infectious conditions, and improved access to healthcare services. Even conditions such as human immunodeficiency virus infections have potentially come under control with the development of highly effective antiretroviral therapeutic regimes. However, children across the world continue to suffer potentially life-threatening acute illness (sometimes on a background of chronic illness) and injury. The Advanced Paediatric Life Support (APLS) course is directed at training healthcare workers to recognise life-threatening illness or injury in children; provide effective emergency intervention; and ensure that children receive the appropriate definitive management of the condition as soon as possible. This approach is potentially applicable in many different settings across the world.

1.2 Principles

There are a number of principles that underpin this approach.

Physiological differences

Most clinical medicine is taught with the underlying assumption that adults best exemplify ‘normal’ in health. This is perhaps justified by the reality that in most parts of the world the majority of the population is made up of adults, but in poorer countries up to 40% of the population may be made up of children (depending on how children are defined). Thus it is important to highlight where children are different to adults in terms of physiology, pathophysiology and responses to various interventions (see Section 1.3). Among the most important differences are the substantially lower physiological reserves in children, particularly young children. A consequence of this is that in the face of injury or severe illness their condition may deteriorate more rapidly than would be expected for adult patients. Thus particular attention has to be paid to timeliness and effective support of the respiratory and cardiovascular systems.

Children come in a range of sizes, and a consequence of this is the constant requirement to adjust all therapy, interventions and selection of equipment or consumable to the size of the particular patient (see Table 1.1 in Section 1.3).
**Relationship between disease progression and outcomes**

The further a disease process is allowed to progress, the worse the outcome is likely to be. The outcomes for children who have a cardiac arrest out of hospital are generally poor (this may be related to the fact that in children cardiac arrest is rarely related to cardiac arrhythmia, but more commonly is a sequel of hypoxaemia and/or shock with associated organ damage and dysfunction). By the time that cardiac arrest occurs, there has already been substantial damage to various organs. This is in contrast to situations (more common in adults) where the cardiac arrest was the consequence of cardiac arrhythmia – with preceding normal perfusion and oxygenation. Thus the focus of the course is on early recognition and effective management of potentially life-threatening problems before there is progression to respiratory and/or cardiac arrest (Figure 1.1).

**Standardised structure for assessment and stabilisation**

The use of a standardised structure for resuscitation provides benefits in many areas. Firstly it provides a structured approach to a critically ill child who may have multiple problems. The standardised approach enables the provision of a standard working environment, ensuring that all the necessary equipment is available as required. By focusing attention on life-threatening issues and dealing with those in a logical sequence it is possible to stabilise the child’s condition as quickly as possible. The use of the standardised structure enables the entire team to know what is likely to be expected of them and in what sequence.

There may well be discussion around the optimum sequence of resuscitation, but in this course a particular approach has been accepted as being reasonable, and most in keeping with the available research information. It is likely that aspects of this approach will change over time, and in fact it may be appropriate to modify the approach in particular working environments and contexts.

Once basic stabilisation has been achieved, it is then appropriate to investigate the underlying diagnoses and proceed to definitive therapy. Occasionally, definitive therapy (such as surgical intervention) may be a component of the resuscitation.

**Resource management**

There is increasing realisation that provision of effective emergency treatment depends on the development of teams of healthcare providers who are able to work together in a coordinated and appropriately directed way (Figure 1.2). Thus part of training in paediatric life support must focus on understanding how the human resources available for a particular resuscitation episode can be utilised most effectively.
Early referral to appropriate teams for definitive management

It is clear that emergency areas are unlikely to be able to provide definitive management for all paediatric emergencies, and a component of stabilisation of critically ill or injured children is the capacity to call for help as soon as possible, and where necessary transfer the child to the appropriate site safely.

Ongoing care until admission to appropriate care

In most parts of the world it is impossible to transfer critically ill children into intensive care units or other specialised units within a short time of their arrival in the emergency area. Thus it is important to provide training in the ongoing therapy that is required for a range of relatively common conditions once initial stabilisation has been completed.

1.3 Important differences in children

Children are a diverse group, varying enormously in weight, size, shape, intellectual ability and emotional responses. At birth a child is, on average, a 3.5 kg, 50 cm long individual with small respiratory and cardiovascular reserves and an immature immune system. They are capable of limited movement, have immature emotional responses though still perceive pain and are dependent upon adults for all their needs. At the other end of childhood, the adolescent may be a 50 kg, 160 cm tall person who looks physically like an adult, often exhibiting a high degree of independent behaviour but who may still require support in ways that are different to adults.

Competent management of a seriously ill or injured child who may fall anywhere between these two extremes requires a knowledge of these anatomical, physiological and emotional differences and a strategy of how to deal with them.

Weight

The most rapid changes in weight occur during the first year of life. An average birth weight of 3.5 kg will have increased to 10 kg by the age of 1 year. After that time weight increases more slowly until the pubertal growth spurt. This is illustrated in the weight charts shown in Figure 1.3.

As most drugs and fluids are given as the dose per kilogram of body weight, it is important to determine a child’s weight as soon as possible. Clearly the most accurate method for achieving this is to weigh the child on scales; however, in an emergency
this may be impracticable. Very often, especially with infants, the child’s parents or carer will be aware of a recent weight. If this is not possible, various formulae or measuring tapes are available. The Broselow or Sandell tapes use the height (or length) of the child to estimate weight. The tape is laid alongside the child and the estimated weight read from the calibrations on the tape. This is a quick, easy and relatively accurate method. Various formulae may also be used although they should be validated to the population in which they are being used.

Figure 1.3 Centile chart for weight in (a) boys (0–5 years) and (b) girls (5–20 years)
If a child’s age is known, the normal ranges table will provide you with an approximate weight (Table 1.1). This will allow you to then prepare the appropriate equipment and drugs for the child’s arrival in hospital. Whatever the method, it is essential that the carer is sufficiently familiar with it to be able to use it quickly and accurately under pressure. When the child arrives, you should quickly review their size to check if it is much larger or smaller than predicted. If you have a child that looks particularly large or small for their age, you can go up or down one age group.

### Table 1.1 Normal ranges: respiratory rate (RR), heart rate (HR) and blood pressure (BP)

<table>
<thead>
<tr>
<th>Age</th>
<th>Guide weight (kg)</th>
<th>RR At rest</th>
<th>HR</th>
<th>BP Systolic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
<td>Breaths per minute</td>
<td>5th–95th centile</td>
</tr>
<tr>
<td>Birth</td>
<td>3.5</td>
<td>3.5</td>
<td>25–50</td>
<td>120–170</td>
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<tr>
<td>1 month</td>
<td>4.5</td>
<td>4.5</td>
<td>25–45</td>
<td>115–160</td>
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<tr>
<td>3 months</td>
<td>6.5</td>
<td>6</td>
<td>20–40</td>
<td>110–160</td>
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<tr>
<td>6 months</td>
<td>8</td>
<td>7</td>
<td>70–75</td>
<td>80–95</td>
</tr>
<tr>
<td>12 months</td>
<td>9.5</td>
<td>9</td>
<td>20–35</td>
<td>100–155</td>
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<tr>
<td>18 months</td>
<td>11</td>
<td>10</td>
<td>20–30</td>
<td>100–150</td>
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<tr>
<td>2 years</td>
<td>12</td>
<td>12</td>
<td>20–30</td>
<td>100–150</td>
</tr>
<tr>
<td>3 years</td>
<td>14</td>
<td>14</td>
<td>20–30</td>
<td>90–140</td>
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<td>4 years</td>
<td>16</td>
<td>16</td>
<td>20–30</td>
<td>80–135</td>
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<tr>
<td>5 years</td>
<td>18</td>
<td>18</td>
<td>20–30</td>
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<td>22</td>
<td>15–25</td>
<td>70–120</td>
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<td>70–120</td>
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<tr>
<td>9 years</td>
<td>28</td>
<td>28</td>
<td>15–25</td>
<td>70–120</td>
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<td>10 years</td>
<td>31</td>
<td>32</td>
<td>15–25</td>
<td>70–120</td>
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<tr>
<td>11 years</td>
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<td>70–120</td>
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<td>12 years</td>
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<td>14 years</td>
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<td>50</td>
<td>12–24</td>
<td>60–110</td>
</tr>
<tr>
<td>Adult</td>
<td>70</td>
<td>70</td>
<td>12–24</td>
<td>60–110</td>
</tr>
</tbody>
</table>

### Anatomical

As the child’s weight increases with age the size, shape and proportions of various organs also change. Particular anatomical changes are relevant to emergency care.

### Airway

The airway is influenced by anatomical changes in the tissues of the mouth and neck. In a young child the occiput is relatively large and the neck short, potentially resulting in neck flexion and airway narrowing when the child is laid flat in the supine position. The face and mandible are small, and teeth or orthodontic appliances may be loose. The tongue is relatively large and not only tends to obstruct the airway in an unconscious child, but may also impede the view at laryngoscopy. Finally, the floor of the mouth is easily compressible, requiring care in the positioning of fingers when holding the jaw for airway positioning. These features are summarised in Figure 1.4.
The anatomy of the airway itself changes with age, and consequently different problems affect different age groups. Infants less than 6 months old are primarily nasal breathers. As the narrow nasal passages are easily obstructed by mucous secretions, and as upper respiratory tract infections are common in this age group, these children are at particular risk of airway compromise. Adenotonsillar hypertrophy may be a problem at all ages, but is more usually found between 3 and 8 years. This not only tends to cause obstruction, but also may cause difficulty when the nasal route is used to pass pharyngeal, gastric or tracheal tubes.

In all young children the epiglottis is horseshoe-shaped, and projects posteriorly at 45°, making tracheal intubation more difficult. This, together with the fact that the larynx is high and anterior (at the level of the second and third cervical vertebrae in the infant, compared with the fifth and sixth vertebrae in the adult), means that it is often easier to intubate an infant using a straight-blade laryngoscope. The cricoid ring is oval in shape, and thus passage of a round endotracheal tube will almost always result in a leak around the tube. In fact, if there is not a leak at pressures of approximately 20 cmH₂O, it is likely that that tube is too large. Although uncuffed endotracheal tubes have been used preferentially in children, there is increasing evidence that cuffed endotracheal tubes may be advantageous in many settings. However, the use of a cuffed tube requires meticulous attention to size, to cuff pressure and to exact placement of the endotracheal tube in the correct position.

The trachea is short and soft. Overextension of the neck as well as flexion may therefore cause tracheal compression. The short trachea and the symmetry of the carinal angles mean that not only is tube displacement more likely, but a tube or a foreign body is also just as likely to be displaced into the left as the right main-stem bronchus.

**Breathing**

The lungs are relatively immature at birth. The air–tissue interface has a relatively small total surface area in the infant (less than 3 m²). In addition, there is a 10-fold increase in the number of small airways from birth to adulthood. Both the upper and lower airways are relatively small, and are consequently more easily obstructed. As resistance to flow is inversely proportional to the fourth power of the airway radius (halving the radius increases the resistance 16-fold), seemingly small obstructions can have significant effects on air entry in children. This may partially explain why so much respiratory disease in children is characterised by airway obstruction.

Infants rely mainly on diaphragmatic breathing. Their muscles are more likely to fatigue as they have fewer type I (slow-twitch, highly oxidative, fatigue-resistant) fibres compared with adults. Pre-term infants’ muscles have even less type I fibres. These children are consequently more prone to respiratory failure.

The ribs lie more horizontally in infants, and therefore contribute less to chest expansion. In the injured child, the compliant chest wall may allow serious parenchymal injuries to occur without necessarily incurring rib fractures. For multiple rib fractures to occur the force must be very large; the parenchymal injury that results is consequently very severe and flail chest is tolerated badly.

**Circulation**

At birth the two cardiac ventricles are of similar weight; by 2 months of age the RV : LV weight ratio is 0.5. These changes are reflected in the infant’s electrocardiogram (ECG). During the first months of life the right ventricle (RV) dominance is apparent, but by 4–6 months of age the left ventricle (LV) is dominant. As the heart develops during childhood, the sizes of the P wave and QRS complex increase, and the P-R interval and QRS duration become longer.
The child’s circulating blood volume per kilogram of body weight (70–80 ml/kg) is higher than that of an adult, but the actual volume is small. This means that in infants and small children, relatively small absolute amounts of blood loss can be critically important.

**Body surface area**

The body surface area (BSA) to weight ratio decreases with increasing age (Figure 1.5). Small children, with a high ratio, lose heat more rapidly and consequently are relatively more prone to hypothermia. At birth the head accounts for 19% of BSA; this falls to 9% by the age of 15 years.

**Physiological**

**Respiratory**

The infant has a relatively greater metabolic rate and oxygen consumption. This is one reason for an increased respiratory rate. However, the tidal volume remains relatively constant in relation to body weight (5–7 ml/kg) through to adulthood. The work of breathing is also relatively unchanged at about 1% of the metabolic rate, although it is increased in the pre-term infant.

In the adult, the lung and chest wall contribute equally to the total compliance. In the newborn, most of the impedance to expansion is due to the lung, and is critically dependent on the presence of surfactant. The lung compliance increases over the first week of life as fluid is removed from the lung. The infant’s compliant chest wall leads to prominent sternal recession when the airways are obstructed or lung compliance decreases. It also allows the intrathoracic pressure to be less ‘negative’. This reduces small-airway patency. As a result, the lung volume at the end of expiration is similar to the closing volume (the volume at which small-airway closure starts to take place).
The combination of high metabolic rate and oxygen consumption with low lung volumes and limited respiratory reserve means that infants in particular will desaturate much more rapidly than adults. This is an important consideration during procedures such as endotracheal intubation.

At birth, the oxygen dissociation curve is shifted to the left and P_{50} (PO_{2} at 50% oxygen saturation) is greatly reduced. This is due to the fact that 70% of the haemoglobin (Hb) is in the form of HbF; this gradually declines to negligible amounts by the age of 6 months.

The immature infant lung is also more vulnerable to insult. Following prolonged respiratory support of a pre-term infant, chronic lung disease of the newborn may cause prolonged oxygen dependence. Many infants who have suffered from bronchiolitis remain ‘chesty’ for a year or more.

Table 1.1 shows respiratory rate by age at rest.

**Cardiovascular**

The infant has a relatively small stroke volume (1.5 ml/kg at birth) but has the highest cardiac index seen at any stage of life (300 ml/min/kg). Cardiac index decreases with age and is 100 ml/min/kg in adolescence and 70–80 ml/min/kg in the adult. At the same time the stroke volume increases, as the heart gets bigger and muscle mass relative to connective tissue increases. As cardiac output is the product of stroke volume and heart rate, these changes underlie the heart rate changes seen during childhood (see Table 1.1). In addition, the average infant is only able to increase heart rate by approximately 30% vs the adult who may be able to increase heart rate under stress by up to 300%.

Normal systolic pressures are shown in Table 1.1.

As the stroke volume is small and relatively fixed in infants, cardiac output is principally related to heart rate. The practical importance of this is that the response to volume therapy is blunted when normovolaemic because stroke volume cannot increase greatly to improve cardiac output. By the age of 2 years, myocardial function and response to fluid are similar to those of an adult.

Systemic vascular resistance rises after birth and continues to do so until adulthood is reached. This is reflected in the changes seen in blood pressure (see Table 1.1).

**Immune function**

At birth the immune system is immature and, consequently, babies are more susceptible than older children to many infections such as bronchiolitis, septicaemia, meningitis and urinary tract infections. Maternal antibodies acquired across the placenta provide some early protection but these progressively decline during the first 6 months. These are replaced slowly by the infant’s antibodies as he or she grows older. Infants may be particularly susceptible to infectious diseases in the period between waning of maternal antibodies and development of their own antibodies (sometimes in response to immunisation). Breastfeeding provides increased protection against respiratory and gastrointestinal infections.

**Psychological**

Children vary enormously in their intellectual ability and their emotional response. A knowledge of child development assists in understanding a child’s behaviour and formulating an appropriate management strategy. Particular challenges exist in communicating with children and as far as possible easing their fear of the circumstances they find themselves in.

**Communication**

Infants and young children either have no language ability or are still developing their speech. This causes difficulty when symptoms such as pain need to be described. Even children who are usually fluent may remain silent. Information has to be gleaned from the limited verbal communication and from the many non-verbal cues (such as facial expression and posture) that are available. Older children are more likely to understand aspects of their illness and treatment and so be reassured by adequate age-appropriate communication.
Fear

Many emergency situations, and many other situations that adults would not classify as emergencies, engender fear in children. This causes additional distress to the child and adds to parental anxiety. Physiological parameters, such as pulse rate and respiratory rate, are often raised because of it, and this in turn makes clinical assessment of pathological processes such as shock more difficult.

Fear is a particular problem in the pre-school child who often has a ‘magical’ concept of illness and injury. This means that the child may think that the problem has been caused by some bad wish or thought that he or she has had. School-age children and adolescents may have fearsome concepts of what might happen to them in hospital because of ideas they have picked up from adult conversation, films and television.

Knowledge allays fear and it is therefore important to explain things as clearly as possible to the child. Explanations must be phrased in a way that the child can understand. Play can be used to do this (e.g. applying a bandage to a teddy first), and also helps to maintain some semblance of normality in a strange and stressful situation. Finally, parents must be allowed to stay with the child at all times (including during resuscitation if at all possible); their absence from the child’s bedside will only add further fears, both to the child and to the parents themselves. But importantly, parents too must be supported and fully informed at all times.

1.4 Summary

The Advanced Paediatric Life Support course is focused on providing training for healthcare professionals in the recognition and management of life-threatening illness in children (in a way that is focused on the needs of the children); in recognition and initial management of important underlying conditions; and appropriate referral to teams that are able to provide definitive intervention. In this process it is also essential to remember the needs of the child’s family and to support the clinical team.

You should also be aware that there are some important differences in children:

- Absolute size and relative body proportions change with age
- Observations on children must be related to their age
- Therapy in children must be related to their age and weight
- The special psychological needs of children must be considered