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The Injured Child

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Introduction

There is often anxiety and uncertainty about the management of injured children in both the pre-hospital and hospital environments. The most important factors underpinning this anxiety are lack of training, lack of experience and lack of familiarity with paediatric vital signs and drug doses. The emotional responses evoked by injured children also play a part in causing distress and anxiety amongst rescuers. Seriously injured children are a rare event. Nonetheless, the immediate care practitioner must be able to assess and commence resuscitation in any age of child without making errors or becoming confused.

For most doctors, nurses and paramedics it is unusual to have to manage a seriously injured child. Clinical exposure to these cases is very limited and the confidence that comes with experience takes a long time to develop. To place this in context, emergency ambulance staff in the UK manage, on average, a total of 14 seriously injured patients (adults or children) a year (1). Only approximately 10% of emergency ambulance calls are for children and less than 5% of these children will require resuscitation (2). Thus, in the UK peacetime setting, ambulance personnel are unlikely to have to manage more than one seriously injured child a year (3,4). Of course, ambulance crews see many more children with minor injuries and illness and thus they develop a degree of confidence in handling children and their families. Resuscitation experience is however very limited. Hospital staff may be expected to have more experience of major paediatric injury. However, an analysis of major trauma at one of the largest UK acute hospitals identified only 7 children with major injuries (from 520 patients) over a one year period(5). The average A&E department will thus see less than one seriously injured child a month. With nurses and doctors on shift patterns, the individual exposure will often be even less. Combat medical technicians and other Army Medical Services personnel are likely to have even less experience of critically injured children. This lack of experience must be managed if injured children are to receive appropriate and timely pre-hospital and hospital care.

The fact that children of different ages have different anatomy and a wide range of physiological norms compared to adults is another cause of anxiety. Accurate selection of equipment and calculation of drug doses is fraught with difficulty and prone to error. This uncertainty surrounding weight estimations and the use of appropriate drugs and equipment in children has been well documented (6,7). Even the relatively simple action of administration of analgesia can be more complicated than it appears and major drug errors can occur (such as 10-fold overdoses of morphine or lidocaine).

A further factor is the relative paucity of dedicated training for paediatric emergencies in pre-hospital practice (2,5,8). A survey of UK ambulance services revealed that 40% provided paramedics with less than eight hours training in paediatric care and less than half provided an appropriate range of paediatric equipment on ambulances (8). The Joint Royal Colleges Ambulance Liaison Committee (JRCALC) has recognised this and have produced clear guidelines on paediatric care which have now been adopted by all UK ambulance services (9). These are also being incorporated into newer paramedic training syllabuses (2,9,10). Nonetheless, current levels of civilian pre-hospital paediatric training and experience vary widely from area to area.

This article aims to provide some guidance on preparing for and managing injured children in the pre-hospital setting. It does not replace practical experience, directed reading and attendance at an appropriate life support training course. It highlights some key issues for the pre-hospital practitioner. It is assumed that the reader is familiar with standard resuscitation guidelines (11-13) and texts that deal with paediatric emergency care (14-18). Personnel who are required to manage injured children should attend one of the Advanced Paediatric Life Support (APLS) (19-20), Pre-hospital Paediatric Life Support (PHPLS) (19,21,22) or Paediatric Advanced Life Support (PALS) (13) courses in order to further their understanding and increase their confidence.

Preparation

The only way to ensure that the management of the injured child will be efficient and timely is to make adequate preparations in terms of training and equipment. Training opportunities exist and regular re-training and practice is relatively simple to plan. It is perhaps much more difficult to achieve this in pre-hospital practice than in the hospital setting. Whether attendance at the above mentioned courses is possible or not, basic and continuation training for the pre-hospital

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Box 1. Minimum additional paediatric equipment (assuming that adult equipment and an aide memoire is available) (25,26).

Airway
Oro-pharyngeal airways (range of sizes)
Soft suction catheters (range of sizes)
Needle cricothyroidotomy kit (assembled for use)

Breathing
Non-rebreathing face mask with reservoir bag
Face masks (newborn, infant and child sizes)
Bag-valve-mask apparatus with pressure release valve (450-ml bag)

Circulation
Infant (6 – 8 cm) and child (9-10 cm) blood pressure cuffs
Intravenous cannula (22 gauge and 24 gauge)
Intraosseous needle (with three way tap and 20ml syringe)

provider should include the assessment of infants and children, the use of a length based aide memoire, airway management, monitoring, vascular and intraosseous access, fluid and drug administration, basic and advanced life support and the principles of extrication and triage (23). In terms of equipment, clear guidelines for facilities that receive injured children have been published (including lists of equipment) (24). Pre-hospital practitioners should be familiar with this range of equipment and should produce an appropriate equipment bag to reflect their scope of practice (Box 1) (25). The principles of equipment selection and packing for pre-hospital immediate care have been previously reviewed (26). The key aspects for paediatric care are that equipment should be appropriate for the range of ages and sizes likely to be encountered and that it should be packed in a way that allows all equipment within the same age or size range to be accessed immediately. There is evidence from hospital practice that if paediatric emergency equipment is stored according to weight ranges and used in conjunction with a length/weight based aide memoire then the resuscitation process is more efficient and less mistakes are made (6,27). It is perhaps even more important that equipment is organised in this way when working in the relatively uncontrolled pre-hospital environment. It is often argued that pre-hospital practitioners do not have the luxury of carrying a wide range of sizes of equipment or dedicated paediatric bags. However, if it is likely that injured children will be treated, then dedicated paediatric equipment bags, which are packed according to pre-determined weight ranges, are essential. Although commercially available colour coded bags which match the colours in the Broselow™ tape (see below) are available, an equivalent system can be created by using labels or coloured cards within the clear plastic pockets of standard bags.

Box 2. Vital signs in children (20,21).

Age	Respiratory rate	Pulse rate	Blood pressure
< 1	30-40	110-160	70-90
1-2	25-35	100-150	80-95
2-5	25-30	95-140	80-100
5-12	20-25	80-120	90-110
>12	15-20	60-100	100-120

Aide memoire

A paediatric aide memoire should ideally incorporate vital signs, basic equipment requirements and relevant drug doses. Observations such as pulse rate, respiratory rate and blood pressure must always be related to the age of the child. Relatively subtle changes in respiratory or pulse rate can be important in the assessment of injured children so a list of the normal vital signs must be immediately available. The most widely used range of physiological norms are those produced by the Advanced Life Support Group (Box 2) (20,21). These divide children into five age groups which can generally be described as infants (below the age of 1 year), toddlers (aged 1 to 2 years), pre-school children (aged 2 to 5 years), school children (aged 5 to 12 years) and adolescents (12 years and over). There are different ranges of age specific norms published in different sources (14-18,28). Whichever is used, the practitioner must have a system that does not rely on memory alone.

The most widely used aide memoire for drug doses in hospital practice is the single page Oakley chart or an adaptation thereof. This was originally designed for use in cardiorespiratory arrests in children in the hospital setting (6). Following changes in resuscitation practice and publication of variations on the chart, updated versions have been produced (29,30). An alternative to the single page aide memoire is the colour coded tape (Figure 1). The best known version of this is the Broselow™ tape (31). It involves using a colour coded tape which relates height to weight (based on the fiftieth centile on growth charts). The tape itself provides detailed information on drug dosages and equipment requirements for children from birth (3 kg) to adolescence (34kg). The tape provides weight specific drug doses in kilogram increments and is also divided into seven colour coded zones which give equipment sizes for age/weight ranges. These colour codes can be related to colour coded bags or equipment drawers. The system is based on the fact that in the 1 to 10 year old child, length is essentially proportional to age and weight in the normal population. The concept of relating length to drug dose is the same as for the single page chart based systems but the clear advantage of a Broselow™ type system is the rapid allocation of children to colour coded weight

Fig 1. The Broselow Pediatric Emergency Tape. The tape is placed alongside the child and the closest weight section to the foot is used as an estimation of weight in kilograms. Each weight box contains a wide range of emergency drugs. In addition there are seven colour coded weight range bands which indicate the appropriate equipment for use in a child of that size (e.g. tracheal tube, laryngoscope blade, suction catheter, blood pressure cuff, intravenous cannula and nasogastric tube).

bands. The disadvantages of the tape are that it includes a very wide range of drugs and that it is inconsistent in terms of whether doses (in milligrams) or volumes (in millilitres) are given. Some ambulance services have developed similar but simpler colour coded aide memoire tapes that are specific to their practice. The Broselow ™ tape colour scheme has also been developed as a central colour theme for organisation of all paediatric equipment and drug doses (e.g. colour coded charts to simplify assessment of vital signs, colour coded mattresses in resuscitation rooms and pre-packed colour coded kits for critical interventions). Variations on this theme can easily and inexpensively be achieved.

In assessment of the use of an aide memoire, it has been shown that mistakes are made when doses are stated as milligrams rather than actual volumes for injection (millilitres) of prepared solution, when more than one concentration of drug is quoted and when more than one option is given (29,30). The point of the aide memoire is to make the immediate care of the injured child quicker and safer. It should therefore be simple to use and specific to the scope of practice of the individual practitioner or organisation. A combination of a single sheet aide memoire and a tape that relates length to colour coded weight ranges is probably the most effective system. An example of an aide memoire used regularly for the rapid treatment of seriously injured children in a UK setting is reproduced at Figure 2. Key elements of this aide memoire are that it includes vital signs and essential drug doses in volume of prepared solution. The original aide memoire was coloured to reflect the colour codes in the Broselow™ tape. It was designed to fit in the clear plastic thigh pocket of a flight suit and the BASICS specification overalls.

Having undergone training and prepared equipment and an easy to use aide memoire, it is essential to practice use of the aide memoire and immediate medical care with simulated paediatric resuscitations.

Do not rely on memory or perform calculations – use a length based aide memoire

Immediate medical care

In providing immediate medical care for injured children, the principles of the primary and secondary survey with assessment and resuscitation according to the conventional ABCDE approach should be followed (20,21,32). There are, however, some specific problems and caveats associated with injured children.

Airway management

Maintenance of adequate oxygenation in the injured child is of paramount importance. Hypoxia secondary to airway obstruction will rapidly result in bradycardia and hypoxic cardiac arrest. Pre-hospital practitioners

Box 3. Potential problems associated with differences between infant and pre-school paediatric airway and the adult airway (see text) (20,21).

Difference	Problem
Large tongue	Easy obstruction Impede laryngoscopy
High anterior position of larynx	Straight laryngoscope blade required
Short trachea	Risk of endobronchial intubation
Large epiglottis	Difficult laryngoscopy
Large tonsils and adenoids	Nasopharyngeal airway placement difficult Potential source of bleeding
Cricoid ring is narrowest part of airway	Uncuffed tracheal tubes required
Small cricothyroid membrane	Surgical cricothyroidotomy contraindicated
Large occiput	Tendency to flex neck and soft pharyngeal structures in supine position

Age	Resps	Pulse	SBP
< 1	30-40	110-160	70-90
1-2	25–35	100-150	90-95
2-5	25–30	95–140	80–100
5–12	20–25	80–120	90–110
>12	15-20	60-100	100–120

USE TAPE MEASURE FOR WEIGHT

Weight (kg) < 10 years = (age x 2) + 8

Weight (kg) > 10 years = 3 x age

Tube = (age/4) + 4 at (age/2) + 12 cm

Note down working weight here

Weight range (kg)	6–7 Pink	8–9 Red	10–11 Purple	12–14 Yellow	15–18 White	19–22 Blue	23–30 Orange	31–40 Green	ADULT
DRUG	VOLUME OF PREPARED SOLUTION (ML)								
Morphine *1mg/ml* (0.1 mg/kg)	0.6	0.8	1.0	1.3	1.6	2.0	2.7	3.6	5
	If naloxone required initial dose is 10 micrograms/kg repeated up to maximum 2g.								
Midazolam *1mg/ml* (0.2 mg/kg)	1.3	1.7	2.1	2.6	3.3	4.1	5.4	7.2	10
	For maintenance of anaesthesia use 1/3 initial dose of morphine and midazolam.								
Atropine *0.1mg/ml* (0.02mg/kg)	1.3	1.7	2.0	2.6	3.3	4.0	6.0	6.0	6.0
	Prepare atropine by diluting 600mcg in 6 ml saline or 1 mg in 10 ml saline.								
Ketamine IV *10mg/ml* (0.5 mg/kg)	0.3	0.4	0.5	0.7	0.8	1	1.3	1.8	4
	For IM use 4mg/kg of 100mg/ml solution. For induction IV use 2 mg/kg.								
Etomidate *2mg/ml* (0.3 mg/kg)	1	1.3	1.5	2	2.5	3	4	5.5	10
Suxamethonium *50 mg/ml* (2 mg/kg)	0.3	0.4	0.4	0.5	0.6	0.8	1	1.4	2
Pancuronium *2 mg/ml* (0.2 mg/kg)	0.3	0.4	0.5	0.6	0.8	1	1.3	1.8	4
	Use same doses for Vecuronium. Use 1/3 initial dose for maintenance.								
Adrenaline *0.1mg/ml* *1:10000* (0.01mg/kg)	0.6	0.8	1.0	1.3	1.6	2.0	2.7	3.6	10
	Use same volume for subsequent IV doses.								
Fluid bolus (20 ml/kg)	130	170	210	260	330	415	540	720	-
Sodium Bicarbonate *8.4%* (1mmol/kg)	6.5	8.5	10.5	13	16.5	21	27	36	50
	Dilute 8.4% to 4.2% in children under 1 (dilute with same volume water).								
Diazepam *5 mg/ml* (0.5 mg/kg)	0.6	0.8	1.0	1.3	1.6	2	2	2	2
	Lorazepam 0.1 mg/kg IV and rectal diazepam 2.5mg, 5mg and 10mg are alternatives.								
Glucose *10%* (5ml/kg)	32	42	52	65	82	105	135	180	400
	Take 4 ml 50% glucose and make up to 20ml with saline to give 20 ml bolus of 10%.								
Tracheal tube	3.5	3.5	4.0	4.5	5.0	5.5	6.0	6.5	-
Tube length	10.5	10.5	12	13.5	15	16.5	18	19.5	21/23

Fig 2. Example of a paediatric aide memoire used for pre-hospital care. It provides the normal range of vital signs for each age group together with drug doses in volumes according to weight ranges (and colour codes), tracheal tube sizes and other useful information. Although it is intended for use with a colour coded tape, a reminder of the weight calculations is also included. This aide memoire was also designed to fit in a clear plastic wallet within a thigh pocket such as those found in flight suits and BASICS overalls. An indelible pen is then used to highlight the working weight and column to avoid errors. The concentration of drug and the dose calculation on which the volume is based are stated in the drug column.

must be able to utilise a range of basic and advanced airway techniques in order to maintain the airway and ensure adequate ventilation. The relevant anatomical differences between adult and paediatric airways are emphasised on all the paediatric life support courses and are summarised in Box 3 (20,21,33). In essence, infants have a high anterior larynx (at the level of the C1 vertebra in infants compared to C3/4 at age 7 and C4/5 in adults) with a large tongue and epiglottis, short compressible trachea, potentially large adenoids and tonsils and a relatively large occiput. Infants below 6 months of age are also obligate nasal breathers. The paediatric airway is thus more easily compromised and traumatised following injury and during attempts to open and maintain the airway. The pre-hospital practitioner should be aware of these differences according to age and be able to modify the airway management technique.

Despite the anatomical differences most basic airway management techniques used in adults can be used in children. Opening of the airway, use of airway adjuncts, suctioning, removal of foreign bodies and use of a bag-valve-mask apparatus are all recommended. Manual jaw thrust and use of suction, oropharyngeal and nasopharyngeal airways are almost always sufficient to support the airway in the initial stages of resuscitation. As has already been repeatedly emphasised, the key to successful airway management is immediate availability of appropriately sized equipment and an awareness of the anatomical and physiological differences between adults and children. Paediatric oropharyngeal airways should be inserted 'the right way up' under direct vision with the assistance of a tongue depressor to avoid injuring the mouth and oropharynx. Paediatric nasopharyngeal airways are commercially available but tracheal tubes can be adapted for this purpose if necessary. The risk of bleeding following insertion of a nasopharyngeal airway in a child is greater than in adults. When performing suction in a child, soft flexible suction catheters are preferable to rigid catheters in infants and pre-school children. The risk of physical injury, hypoxia and reflex bradycardia should be anticipated whenever suctioning or other airway manoeuvre is being performed. Intravenous atropine may be required to counter reflex bradycardia associated with airway manipulation. In all cases, high flow oxygen via a non-rebreathing mask with a reservoir bag or bag-valve-mask apparatus should be applied as soon as the airway has been opened. If this causes agitation or distress in a child, it may be better to provide oxygen-enriched air by holding the oxygen supply close to the face or by using nasal cannulae.

Bag-valve-mask ventilation with or without airway adjuncts is the primary airway and ventilation intervention in pre-hospital paediatric care (34). Use of the bag-valve-mask technique has been associated with increased survival when compared to tracheal intubation in circumstances where transport times are short and pre-hospital practitioners are adequately trained in the use of the bag-valve-mask (35,36).

If basic airway manouvres fail and bag-valve-mask ventilation is ineffective, an appropriately sized laryngeal mask airway (LMA) can be used. Although LMAs are routinely used in the controlled environment of the operating theatre, and a full range of multiple use paediatric LMAs are available, single use devices have yet to be produced for pre-hospital use. Nonetheless, LMAs may be ideal for the difficult airway and high anterior larynx of infants and pre-school children (35,37).

There continues to be debate regarding whether pre-hospital tracheal intubation is associated with increased or decreased survival in the context of critical illness and cardiac arrest (34-36,38,39). There are clearly some children (such as those with facial burns) who may benefit from pre-hospital anaesthesia and rapid sequence intubation to protect the airway and optimise ventilation. In others, simple airway manoeuvres with bag-valve-mask ventilation may suffice. Pre-hospital anaesthesia has been reviewed in detail (40). When applying the principles to children, it is important to realise that safety margins are considerably smaller and that additional equipment will be required (33). All of the principles of pre-hospital anaesthesia should be followed. Variations specific to children are that uncuffed tracheal tubes are used in children under 8 years old, suxamethonium is used in higher doses than in adults (2 mg/kg) and all children under 1 year old should be pre-treated with atropine (0.02 mg/kg) before muscle relaxation. In addition, infants and pre-school children may be very sensitive to opioids such as fentanyl. Paediatric anaesthesia has been recognised as a sub-specialist field within anaesthesia and it should not be attempted by the inexperienced or where safer and effective alternatives exist.

Needle cricothyroidotomy can be life saving if all other attempts at securing an airway have failed. In injured children this usually arises in the context of maxillofacial injury associated with head injury or burns. The cricothyroid membrane in infants and small children is very small and therefore difficult to identify with confidence (33). Despite this, an attempt to cannulate either the cricothyroid membrane or the trachea is justified when there is immediate threat to life. It is good practice to have pre-assembled cricothyroidotomy equipment available (26). This should comprise a 14-gauge cannula and a means of connecting the cannula to a bag-valve-mask apparatus (e.g. via a tracheal tube connector) or an independent oxygen supply (e.g. via a three-way tap or an improvised syringe barrel and oxygen bubble tubing). There is considerable resistance when using bag-valve-mask apparatus and a cannula. Pre-hospital practitioners should be familiar with the 'feel' of this before having to attempt it for real. Inexperience may lead to the assumption that the cannula has been incorrectly positioned or that a pneumothorax has developed. Adequate oxygenation can be obtained using this bag-valve-cannula technique in children up to 10 years old. Surgical cricothyroidotomy or cricothyroidotomy with commercially available kits has not been shown to be successful or safe in children under 10 and is not recommended (33-34).

In all aspects of pre-hospital airway management, the desire to secure the best possible airway should be tempered by an awareness of the risks of delayed transportation and further injury to the child. How far to proceed will depend on the urgency of the intervention, the time to further medical help, the experience of the practitioner, the number and training of other personnel present, the equipment and drugs available and the environment. It is the ability to work through this decision process to the benefit of individual patients that defines the specialty of pre-hospital immediate care.

Assessment of breathing and ventilatory support

Respiratory compromise leading to respiratory failure and hypoxic cardiac arrest is a common sequence of events in fatal injuries in children. Once an airway has been achieved, it is essential to assess the adequacy of breathing and the need for ventilatory support. Again, the practitioner needs to have access to the normal respiratory rate range for any particular age of child (Box 2). The thoracic cage of children is pliable and there may be little external evidence of injury. Systematic assessment of the effort of breathing, the effectiveness of breathing and any evidence of inadequate ventilation may reveal significant underlying pulmonary injury. An increased respiratory rate, intercostal recession, accessory muscle use, flaring of the nostrils on inspiration, inspiratory or expiratory noises and grunting in infants and pre-school children are all signs that the child is having to increase the effort of breathing in order to maintain adequate ventilation and oxygenation (20,21). On further examination the chest movement may be asymmetric and breath sounds may be reduced or absent. As the child becomes tired with the increased effort of breathing, breath sounds may actually diminish. Other signs of inadequate ventilation are tachycardia, cyanosis and agitation or reduced level of consciousness. Pre-terminal signs in children with severe chest injury are bradycardia, cyanosis and a silent chest (20,21).

Immediate airway management and bag-valve-mask assisted ventilation with supplemental oxygen is considered the primary method of pre-hospital ventilatory support in children. Pressure release valves should be present on bag-valve-mask apparatus designed for children to prevent barotrauma (usually set at 40 cm H_20). Relatively subtle changes in the positioning of the child's airway may have a profound influence on the effectiveness of bag-valve-mask ventilation. If difficulty in ventilation is experienced, the most practical advice is to insert an oropharyngeal airway (if not already done) and try small degrees of neck extension (from the neutral position) while avoiding pressing on the soft tissues under the chin (33). The tidal volumes in children also vary according to age and the degree of compression of a 450-ml self-inflating bag will need to be modified to meet the ventilatory needs of the child. The degree of chest wall rise should be carefully assessed and ventilation adjusted accordingly. This is particularly important for mechanically ventilated children where the tidal volume of the ventilator may have been set according to an aide memoire card or length based algorithm and may not be right for the child. A typical starting tidal volume is 10ml/kg. The initial period of rescue breathing or bag-valve-mask ventilation will almost always lead to gastric insufflation in children. This will splint the diaphragm, reduce tidal volume and greatly increase the risk of vomiting and aspiration. The stomach should be decompressed as soon as practicable using an orogastric or nasogastric tube.

A further important physiological difference in children is that basal oxygen consumption is higher than in adults. Children also have a proportionately smaller functional residual capacity than adults do. The combination of increased oxygen demand and reduced reserve means that children will desaturate more quickly than adults. After respiratory arrest or pre-hospital anaesthesia, the period of adequate oxygenation after apnoea is less than half that of an adult (33,40). Lung injury or pre-existing disease may shorten this further. This further highlights the importance of early aggressive airway management and ventilatory support.

Assessment of circulation

Circulatory compromise leading to circulatory collapse and cardiac arrest is another common consequence of fatal paediatric injury. Bradycardia precedes asystole or pulseless electrical activity. Current resuscitation guidelines recommend that chest compressions should be started in the absence of a pulse, the absence of signs of circulation (movement, respiratory effort, vocal sounds) or if the pulse is less than 60 beats per minute in association with poor perfusion (13). It seems counter-intuitive to recommend commencement of chest compressions when a pulse is present but a pulse rate of 60 or less in a child with collapse or injury and evidence of shock is a pre-terminal sign. Chest compressions are very unlikely to cause harm to an infant or child in these circumstances. For the over eight year old the compression/ventilation ratio is 15:2 in all circumstances. For the under eight year old, the compression/ventilation ratio is 5:1. All pre-hospital practitioners should be familiar with current basic and advanced life support guidelines for children (13). Of particular importance is recognition of hypoxia, metabolic acidosis and hypovolaemia as the principle causes of cardiac arrest in children and thus the greater emphasis on intravenous fluid and alkalising agent (sodium bicarbonate) administration in advanced life support algorithms (13,20,21).

Asystole is the most common cardiac rhythm detected in children in cardiac arrest (12). Only 15% of children will have ventricular fibrillation or pulseless ventricular tachycardia (41,42). This reflects the fact that respiratory failure and/or circulatory failure leads to cellular hypoxia and cardiac arrest. Few children survive once they become apnoeic and pulseless out of hospital and there is some evidence that outcome can only be improved if transfer times are very short or if on-scene restoration of spontaneous pulses can be achieved (36,43). This reflects the central dilemma surrounding the benefit of on scene intervention in all aspects of pre-hospital care - whether to attempt to improve the situation at the scene or whether to undertake minimal intervention and get to the nearest receiving facility as quickly as possible. If the arresting rhythm is ventricular fibrillation or pulseless ventricular tachycardia, defibrillation should always be attempted at the scene. Energy levels of 2 J/kg rising to 4 J/kg are currently recommended (12,13,20,21). It is however essential that the correct equipment is available. Automatic or semi-automatic external defibrillators (AEDs) may be used in children over the age of 8 years (i.e. 25 kgs or over). Below this age AEDs may not reliably detect arrhythmias and the defibrillation energies are too high (13). Manual defibrillators with paediatric paddles are required in environments where paediatric resuscitation is likely.

Cardiac arrest can be avoided if signs of circulatory collapse are correctly identified early in the assessment of the child. Children can compensate for loss of up to 25% of their circulating volume and may not become hypotensive until almost 40% volume loss. Compensated shock may be difficult to detect but must be actively sought in the injured child. Systematic evaluation of heart rate, strength of peripheral pulses and the adequacy of end organ perfusion (skin temperature, capillary refill time and mental state) should be repeated at regular intervals (20,21). By itself, capillary refill time is neither a sensitive or specific diagnostic test for intravascular volume status. In an ambient temperature, a delayed capillary refill time has been detected in 4% of healthy child volunteers (28). It is, however, a useful sign in combination with full assessment (especially if it is normal). In order to minimise the effects of low ambient temperature, it should be performed on the forehead or mid-sternum. Control of external haemorrhage, particularly from the scalp in infants, is also important in the initial assessment and the prevention of shock. Large dressings may simply act as sumps for continued bleeding from the scalp and direct pressure or early placement of a suture may be required to control bleeding. The circulating blood volume in a child is between 80 and 100 ml/kg depending on age but the absolute volume is small. What appears to be modest blood loss in a child who is compensating may in fact represent life threatening haemorrhage in a child on the brink of circulatory collapse. Rapid intravenous administration of a 20 ml/kg fluid bolus is indicated in all children with signs of shock.

Intra-osseous cannulation provides rapid access to the non-collapsible marrow venous plexus and is a safe and reliable route for administration of fluids and drugs in the shocked child. While some guidelines recommend cut-off ages of 6 years or less for immediate intraosseous access, there are numerous reports of successful intraosseous access in adults and very small children so age should not be seen as a barrier (12,44). Intraosseous access should be the first point of access in children and infants who are shocked or in cardiac arrest.

The initial management of acute burns has recently been reviewed (45). Burn shock should be anticipated and treated in children in the same way as for adults. The rule of nines cannot be used to estimate the total body surface area burned because of the changing surface area to weight ratio in growing children. A Lund and Browder chart should be used to quantify the percentage burn and thus the fluid requirements (20,45). Additional maintenance fluid requirements in children can be calculated on the basis of 100ml/kg for the first 10kg plus 50 ml/kg for the second 10 kg plus 20ml/kg for each additional kg (Box 4). In all cases, urine output and clinical assessment should guide fluid administration in any child whose pre-hospital time is likely to be prolonged.

Box 4. Maintenance fluid requirements in children. (20).

Weight	Daily fluid requirement	Hourly fluid requirement
First 10 kg	100 ml/kg	4 ml/kg
Second 10 kg	50 ml/kg	2 ml/kg
Subsequent kg	20 ml/kg	1 ml/kg
12 kg child requires	1000 ml for first 10kg plus 100ml for remaining 2kg = 1100ml per day (or 44 ml per hour)	
32 kg child requires	1000 ml for first 10kg plus 500 ml for second 10kg plus 40 ml for remaining 2 kg = 1540 ml per day (or 62 ml per hour)	

Hypoglycaemia in children can mimic shock. Inexpensive portable capillary blood glucose measuring devices are readily available and should be included in the pre-hospital equipment bag. This is particularly important for the child with a reduced conscious level. Almost all hypoglycaemia in children occurs during periods of reduced oral intake and increased metabolic demand such as during illness or following serious injury (17,18,20). Small children are particularly prone to hypoglycaemia because they have little in the way of glycogen stores. In addition, fluid replacement in shock or burns and maintenance fluid administration over time may lead to the development of hypoglycaemia if fluid with no dextrose is used. If hypoglycaemia is detected, fluid boluses of 10% glucose should be administered. Higher concentrations of glucose such as those used in adults may lead to cerebral oedema.

Spinal immobilisation and assessment of neurological disability

The assessment of the level of consciousness of a small child with a head injury can be difficult. In the rapid primary survey it is appropriate to use the **A**lert, responds to **V**oice, responds to **P**ain and **U**nresponsive (AVPU) categorisation while the airway is secured and ventilation and circulation are assessed. In subsequent assessment of neurological disability, pupil signs and paediatric variations of the motor and verbal components of the Glasgow Coma Score should be used in children under the age of 4 (Box 5) (20). As with adults, the aim of treatment in major head injury is to prevent further (secondary) neurological damage by preventing hypoxia, hypovolaemia and hypoglycaemia.

Box 5. Modified Glasgow Coma Scale for children under 4 years old. (20).

Response	Score
Best eye opening response	
Spontaneously	4
To verbal stimulus	3
To painful stimulus	2
No response to pain	1
Best verbal response	
Alert, bables, coos, uses words to usual ability	5
Spontaneous irritable cry, less than usual words	4
Cries only to painful stimulus	3
Moans to pain	2
No response to pain	1
Best motor response	
Spontaneous or obeys verbal command	6
Withdraws to touch or localises pain	5
Withdraws from pain	4
Abnormal flexion to painful stimulus	3
Abnormal extension to painful stimulus	2
No response to pain	1

All patients with multiple injuries, significant head injuries or reduced conscious level should be assumed to have a cervical spine injury and be immobilised according to standard resuscitation practice (20,21). However, cervical spine injures occur in only 1 to 2% of children with multiple injuries (18) and in the alert child, studies have not identified any cervical spine injury in the absence of neck pain, neurologic symptoms, distracting injury, or altered mental status (46,47). In interpreting these findings, pre-hospital practitioners must be confident in their ability to communicate with the child and in the child's ability to identify symptoms. Injured children are frightened and the more frightened a child is, the younger they behave. It is not uncommon for a frightened child with obvious injuries to deny any symptoms at all. Attempts to immobilise a child with a cervical collar, long spine board and head blocks or tape may distress them or may simply not be possible in the circumstances. Infants, toddlers and pre-school children can be immobilised in adult long leg box or vacuum splints (Figure 3) or in child seats or cots with appropriate padding. At a road accident, the child in the car seat is best left in the car seat unless critical interventions are required. Cervical collars are often too big for very small children and serve only to hyper-extend or flex the neck. Some children may become agitated when attempts are made to secure them to a board or stretcher and these children are best left to find a position of comfort (with a cervical collar on if possible). In addition, the large occiput of small children will tend to flex the neck when placed on a long spine board. A folded blanket under the child's body or a dedicated paediatric immobilisation device will address this problem.

Fig 3. This four year old child was struck by a car, thrown into the air and then landed in front of the car. On scene the child had extensive scalp wounds and an angulated (closed) femoral shaft fracture. The femoral pulse was palpable at 150 beats per minute, the respiratory rate was 40 breaths per minute and the Glasgow Coma Score was 9/15 (E2,V3, M4). The child was anaesthetised and transported in a long leg vacuum splint with full spinal immobilisation and monitoring.

Exposure and extrication

The surface area to volume ratio in children when compared to adults makes them particularly vulnerable to heat loss – especially through the head in infants and small children. Efforts to reduce heat loss should be considered early and this is especially important when the child has been undressed in the pre-hospital environment.

The principles of management for trapped patients have previously been reviewed (47). The most common cause of paediatric entrapment in civilian practice is the child pedestrian or cyclist who has been dragged underneath a vehicle. With the exception of the age specific medical interventions already discussed there is little difference between the management of adults and children in this setting. It is common for relatives of the trapped child to arrive at the scene either before the emergency services or shortly after arrival. Dealing with distressed parents can be very distracting and difficult but they must not be ignored. An individual should be identified who will stay with the relatives, explain what is happening and provide support and, if necessary, restraint. If the parents or relatives can be engaged, they can be of considerable help in consoling an injured child and explaining the extrication plan or need for painful procedures such as intravenous cannulation. Analgesia is a fundamental element of pre-hospital care which may improve the clinical condition of the child and facilitate rapid extrication. Provided the appropriate drugs and expertise are available, there should be no hesitation in providing good early pain relief for children of all ages (48).

Multiple casualty incidents

Although major incidents involving large numbers of injured children do occur (49,50), pre-hospital practitioners are much more likely to be involved in incidents with three to five injured children. The commonest example is a road accident involving entire family groups. The practitioner may be faced with injured babies, pre-school children, school age children and adolescents as well as the accompanying adults. In this context, it is essential to follow multiple casualty triage procedures (51) and consider the need to activate a major incident response. A small number of critically injured children may completely overwhelm a receiving facility with limited paediatric equipment and personnel.

The triage sieve is widely used within the forces and in civilian practice (28,51). If adult physiological values are applied to children however, all of them will be triaged above injured adults at the scene. While this may initially seem appropriate, it will expose injured adults to unnecessary delays and may overwhelm the facilities at the receiving hospital with well patients. Despite this tendency to overtriage children, it is generally accepted that the standard triage sieve can be used if only a few children are involved. Children over ten years can be triaged as adults but if there are more than five children aged below ten, it is recommended that the triage sieve be modified to reflect the different vital signs in children (28,49,50,52).

The triage sieve begins with an assessment of ability to walk followed by airway patency, respiratory rate and circulatory compromise as measured by capillary refill time and pulse rate. Ability to walk is an unsuitable assessment for infants and toddlers. Assessment of whether the child is alert and moving all limbs is used instead. These children can be allocated a delayed (green) priority. Children who do not breathe on opening the airway are, in the context of multiple casualties, dead. It can be very difficult to withhold attempts at cardio-pulmonary resuscitation in this context – especially if relatives are present. Those who do breathe on opening the airway should be allocated an immediate (red) priority given the relative importance of hypoxia in children. Respiratory and pulse rates will almost always exceed adult normal values and result in overtriage. An appropriate vital signs aide memoire will assist in determining whether a child's respiratory and pulse rates are abnormal. A paediatric triage tape has been developed which relates the child's length to normal physiological values for three weight groups (28). The tape utilises the length/weight relationship to allocate children to one of three bands (3 – 10 kg, 11 – 18 kg and 19 – 32 kg). Each of these weight bands on the tape has a printed triage sieve with the relevant vital signs for that age/weight range. Capillary refill time is advocated as the first line assessment of circulation with the caveat that if it is prolonged, a pulse rate should be measured to ensure that the delayed capillary refuel is not due to low ambient temperature. While this physiological triage tool is useful in the initial assessment, it is important that all children are re-triaged at each stage in the management of the incident and that anatomical injury (e.g. burns) and mechanism of injury are taken into account (53).

Summary

Pre-hospital immediate care for seriously injured children is rarely required, but when it is, the response must be prompt and effective. The key to an effective and confident approach to injured children lies in understanding the age related anatomical and physiological differences between adults and children. These differences are most exaggerated in the first few years of life and excellent training courses and materials are available to help practitioners develop their confidence and skills in this age group. An easy to use length based aide memoire and a set of equipment packed according to size are essential to ensure safe management in the pre-hospital environment.

Care of the seriously ill child, emergency childbirth and neonatal resuscitation are beyond the scope of this article. Nonetheless, pre-hospital practitioners should develop an understanding of assessment of ill children and normal delivery and be prepared to assist with emergency childbirth and neonatal resuscitation. Excellent educational material, courses and web based resources are available to achieve this (54).

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References

1. Nicholl J, Hughes S, Dixon S, *et al.* The costs and benefits of paramedic skills in prehospital trauma care. *Health Technol Assess* 1998;**2:** 17.
2. Jewkes F. Prehospital emergency care for children. *Arch Dis Child* 2001;**84:**103-5.
3. Su E, Mann C, McCall M, Hedges JR. Use of resuscitation skills by paramedics caring for critically injured children in Oregon. *Prehosp Emerg Care* 1997;**1:**123-5.
4. Reisdorff E, Howell KA, Saul J *et al.* Prehospital interventions in children. *Prehosp Emerg Care* 1998;**2:**180-3.
5. Gaffney P, Johnson G. Paediatric prehospital trauma care. *Trauma* 1999;**1:**279-84.
6. Oakley PA. Inaccuracy and delay in decision making in paediatric resuscitation, and a proposed reference chart to reduce error. *BMJ* 1988;**297:**817-9.
7. Vilke GM, Marino A, Fisher R, Chan TC. Estimation of pediatric patient weight by EMT-PS. *J Emerg Med* 2001;**21:**125-8.
8. Gaffney P, Johnson G. Paediatric prehospital care: postal survey of paramedic training managers. *Arch Dis Child* 2001;**84:**82-3.
9. See www.asancep.org.uk/JRCALC
10. Institute of Health Care and Development. Ambulance Service Paramedic Training. 1999.
11. International Guidelines 2000 for CPR and ECC - a Consensus on Science. *Resuscitation* 2000;**46:** 301 –99.
12. Atkins DL, Chameeides L, Fallat ME *et al.* Resuscitation science of pediatrics. *Ann Emerg Med* 2001;**37:**S41-8.
13. See www.resus.org.uk
14. Glasgow JFT, Kerr Graham H. *Management of injuries in children*. London, BMJ Publishing Group, 1997.
15. Greaves I, Porter K. *Pre-hospital Medicine: The principles and practice of immediate care*. London, Arnold 1999.
16. Morton RJ, Phillips BM. *Accidents and emergencies in children (2nd ed)*. Oxford, Oxford University Press, 1996.
17. Beattie TF, Hendry GM, Duguid KP. *Pediatric emergencies*. London, Mosby International,1997.
18. Fleisher GR, Ludwig S (Eds). *Textbook of pediatric emergency medicine (4th ed)*. Philadelphia, Lippincott, Williams and Wilkins, 2000.
19. See www.alsg.org
20. Advanced Life Support Group. *Advanced paediatric life support: The practical approach (3rd ed)*. London, BMJ Books, 2001.
21. Advanced Life Support Group. *Prehospital paediatric life support*. London, BMJ Publishing Group, 1999.
22. Hodgetts TJ, Jewkes F, Lubas P, McCusker K. Pre-hospital paediatric life support. *Pre-hospital Immediate Care* 1998;**2:**74.
23. Pediatric Education Task Force. Education of out-of-hospital emergency medical personnel in pediatrics: Report of a national task force. *Ann Emerg Med* 1998;**31:**58-64.
24. American College of Emergency Physicians, American Academy of Pediatrics. Care of children in the emergency department: guidelines for preparedness. *Ann Emerg Med* 2001;**37:**423-7.
25. Luten R, Foltin G (eds). *Pediatric resources for pre-hospital care*. American Academy of Pediatrics 1989:42-5.
26. Mackenzie R, Greaves I, Sutcliffe RC. Equipment for Immediate Medical Care. *J R Army Med Corps* 2000;**146:**232-42.
27. Hughes G, Spoudeas H, Kovar IZ, Millington HT. Tape measure to aid prescription in paediatric resuscitation. *Arch Emerg Med* 1990;**7:**21-7.
28. Hodgetts TJ, Hall J, Maconochie I, Smart C.

Paediatric triage tape. *Pre-hospital Immediate Care* 1998;**2:**155-59.
29. Alexander R, El-Moalem HE. Comparison of two paediatric resuscitation charts for ease of use. *Resuscitation* 1998;**38:**151-5.
30. Burke DP, Bowden DF. Modified paediatric resuscitation chart. *BMJ* 1993;**306:**1096-8.
31. Lubitz DS, Seidel JS, Chameides L, Luten RC, Zaritsky AL, Campbell FW. A rapid method for estimating weight and resuscitation drug doses from length in the paediatric age group. *Ann Emerg Med* 1988;**17:**576-81.
32. Director General Army Medical Services. *Battle-field Advanced Trauma Life Support* (Army Code 63726). London, The Stationary Office, 1997.
33. Walls RM, Luten RC, Murphy MF, Schneider RE (eds). *Manual of emergency airway management.* Philadelphia: Lippincott, Willams and Wilkins, 2000.
34. Zideman D, Zaritsky A, Carlo W *et al.* Airways in pediatric and newborn resuscitation. *Ann Emerg Med* 2001;**37:**S126-S136.
35. Gausche M, Lewis RJ, Stratton SJ *et al.* Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome: a controlled clinical trial. *JAMA* 2000;**283:**783-90.
36. Sirbaugh PE, Pepe PE, Shook JE *et al*. A prospective,population based study of the demo-graphics, epidemiology, management and out-come of out-of-hospital pediatric cardiopulm-onary arrest. *Ann Emerg Med* 1999;**33:**174-84.
37. Tobias JD. Laryngeal mask airway: a review for the emergency physician. *Ped Emerg Care* 1996;**12:**370-7.
38. Perron AD, Sing RF, Branas CC, Huynh T. Predicting survival in pediatric trauma patients receiving cardiopulmonary resuscitation in the prehospital setting. *Prehosp Emerg Care* 2001;**5:**6-9.
39. Innes PA, Summers CA, Boyde IM, *et al*. Audit of paediatric cardiopulmonary resuscitation. *Arch Dis Child* 1993;**68:**487-91.
40. Mackenzie R, Lockey DJ. Pre-hospital anaesthesia. *J R Army Med Corps* 2000;**147:**322-34.
41. Walsh CK, Krongrad E. Terminal cardiac electrical activity in paediatric patients. *Am J Cardiol* 1983;**51:**557-61.
42. Innes PA, Summers CA, Boyde IM, *et al.* Audit of paediatric cardiopulmonary resuscitation. *Arch Dis Child* 1993;**68:**487-91.
43. Schindler MB, Bohn D, Cox P, *et al.* Outcome of out-of-hospital cardiac or respiratory arrest in children. *N Engl J Med* 1996;**335:**1473-9.
44. Greaves I, Evans GA, Boyle AA. Intraosseous infusions in the adult. *Trauma* 1999;**1:**291-9.
45. Treharne LJ, Kay A. The initial management of acute burns. *J R Army Med Corps* 2001;**147:**198-205.
46. Viccellio P, Simon H, Pressman BD, Shah MN, Mower WR, Hoffman JR. A prospective multicenter study of cervical spine injury in children. *Pediatrics* 2001;**108:**E20.
47. Mackenzie R, Sutcliffe R. Pre-hospital Care: The trapped patient. *J R Army Med Corps* 2000; **146:**39-46.
48. Mackenzie R. Analgesia and sedation. *J R Army Med Corps* 2000;**146:**117-127.
49. Carley SD, Mackway-Jones K, Donnan S. Delphi study into planning for care of children in major incidents. *Arch Dis Child* 1999;**80:**406-9.
50. Mackway-Jones K, Carley SD, Robson J. Planning for major incidents involving children by implementing a Delphi study. *Arch Dis Child* 1999;**80:**410-3.
51. Hodgetts TJ, Hanlan CG, Newey CG. Battlefield First Aid: a simple systematic approach for every soldier. *J R Army Med Corps* 1999;**145:**55-59.
52. Eichelberger MR, Gotschall CS, Sacco WJ, Bowman LM, Mangubat EA, Lowenstein AD. A comparison of the trauma score, the revised trauma score and the paediatric score. *Ann Emerg Med* 1989;**18:**1053-8.
53. Engum SA, Mitchell MK, Scherer LR et al. Prehospital triage in the injured pediatric patient. *J Ped Surg* 2000;**35:**82-7.
54. See www.med-help.net/Emergency-Child-Birth. htm

The Injured Child

Commentary

F Jewkes

This is an extremely comprehensive article about the emergency care of injured children with an emphasis on the pre hospital setting. The difficulties of this situation are clearly outlined - the rarity of these incidents, the difficulty of having adequate equipment and the lack of experience in the majority of those faced with such a situation.

"Ways to make life easy" are rightly stressed - this is important because those who are experienced in paediatric pre hospital injury management are few and rarely present. The only way of ensuring uniformly safe delivery of pre hospital care is to try to support those who are actually going to be faced with these problems. Charts and tables are discussed in detail and practical procedures that are easy to learn and have good skill retention are emphasised (e.g. intraosseous infusion). It is worth re-emphasising the now famous study by Gausche *et al* confirming suspicions that bag valve mask ventilation is at least as good as intubation in a semi urban setting - it is one of the only comprehensive studies in paediatric hospital care and is landark piece of work (1).

The Injured Child article is largely based on 'best practice' rather than clinical trials medicine. This is not surprising, because of the lack of prehospital paediatric research. The article does a sterling job of pointing out the physiological differences between adults and children and this is a good backdrop to remind us that it is not safe to extrapolate adult practices to children without very serious consideration. An example is the recent controversy over the management of uncontrollable haemorrhage before hospital. The practice of "controlled hypotention" in adults in this situation has been demonstrated to improve survical and current UK recommendations in adults are to titrate fluids to maintain the presence of a radial pulse (2). Children's blood pressure drops late and hypotension is a preterminal sign - no studies have been done to relate the peripheral pulses with blood pressure. Although the logic behind fluid restriction may well apply to children, there is much uncertainty and no evidence. So how should we manage them? The studies are not there, and it is becoming increasingly difficult to obtain ethical permission for research in children outside hospital. We continue to apply old, hospital based standards, although in this particular situation it has now been agreed that avoidance of overload is importance in children too.

Children also lag behind in other areas of care. The article suggests that children should receive adequate analgesia if the drugs and expertise are available. This pragmatic approach could be minsinterpreted as suggesting that an inferior standard of care is acceptable in children because of lack of equipment or expertise. Surely we should be seeking to improve the situation? Certainly in civilian life there is no excuse in not ensuring such resources are provided at the scene except in exceptional circumstances.

This very good synopsis of paediatric pre hospital trauma care should serve to remind us that children deserve an equally good standard of care to adults and they should not be excluded from pre hospital research. As long as the current situation continues, the care of children will continue to run the risk of being inferior to the rest of the population.

References.

1. Gausche M, Lewis RJ, Strattos SJ *et al*. Effects of out of hospital paediatric endotracheal intubation on survival and neurologic outcome. A controlled clinical trial. *JAMA* 2000;**283**:783-90.
2. Revell M, Porter K, Greaves I. Fluid resuscitation in prehospital trauma; a concensus view. *Trauma* 2002;**4**:21-26

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