PAEDIATRIC LIFE SUPPORT

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Paediatric Resuscitation is an essential cornerstone in the practice of paediatric anaesthesia. It is fundamental that all who treat infants and children are well versed in simple basic life support and that those who are required to perform the more complex skills are taught and regularly practise the advanced life support procedures.

Resuscitation of infants and children is different from adult resuscitation. Although there may be many similarities in the methodologies used in the resuscitation protocols with those used in adults, paediatric life support is governed by the fact that it begins from a different starting point. Adult sequences are based on the observation that the majority will be primarily cardiac in origin; they are therefore rapid and immediate in onset giving little or no warning of their occurrence and usually requiring a rapid defibrillation to achieve any measure of success. In infants and children the cause is usually a primary respiratory event which leads to the final cardiac event if not recognised and dealt with promptly[1-5]. Primary cardiac arrest in children is rare and ventricular fibrillation and ventricular tachycardia have been reported in less than 15% of the study population in the young[6-8]. The aetiology and pathogenesis of sudden death in this age group is therefore important. Many children have had a relatively long 'pre-arrest' phase, cardiac arrest signalling the end of a progressive physiological decline. It could be argued in such events early recognition and aggressive therapy could prevent many deaths in this 'pre-arrest' phase but, unfortunately, some will remain irreversible despite all the best efforts of the carers.

Trauma is the one cause of cardiac arrest where children and adults overlap. Trauma is the most common cause of death in the first four decades of life. Again, it could be argued that trauma is preventable and, even more importantly, cardiac arrest secondary to trauma can in some cases be prevented by careful correct management of the airway, breathing and circulation of the trauma victims before managing the secondary injuries.

The outcome of paediatric life support is poor. Survival rates are quoted at between 3 and 17%[1,2,5,8-16] and can be considered even more dismal when the majority are reported as showing significant neurological impairment after arrest. Outcome is related to the aetiology of the initial event. Better outcomes have been reported when the primary event was respiratory [10, 16, 17] rather than cardiac in nature.[10,11,18]

The audit and analysis of paediatric life support events is complex. Events are relatively uncommon and many studies have to collect data over many years and still have small sample numbers. In the BRESUS study in the United Kingdom only 2% of the victims were aged under 14 years[19]. In an American study surveying 15 years of prehospital events, only 7% of victims were below 30 years of age and only 3.7% were under 8 years old[6]. Furthermore the definitions used in evaluating events are inconsistent and often not comparable from study to study. In an effort to improve our knowledge of paediatric life support and its outcome a revised reporting template was formulated. This, the Paediatric Utstein Style Guidelines,[20] it is hoped, will help to standardise the reporting of outcomes of Paediatric Life Support and thereby provide an evidence based practice of comparable data sets to establish the true worth of these events.

One conclusion that is clear is that infants and children who progress to cardiac arrest have a very poor prognosis. Because of the aetiology of resuscitation in these age groups it is important that the pre-event symptoms are recognised early and treated effectively before there is respiratory collapse and the inevitable cardiac arrest. Therefore in paediatric life support prevention and recognition of the impending event is a major factor in the overall survival.

Paediatric Life Support

Guidelines for paediatric life support have been published by a number of national organisations[21-24]. In 1992 an International Liaison Group was established to examine the basic scientific data, analyse the national differences and to make recommendations formulated on science which would form the basis of international guidelines to be used in the future by individual national organisations. In 1997 the International Liaison Committee on Resuscitation (ILCOR), a multinational committee comprised of members representing most of the major national resuscitation organisations published a series of advisory statements including a paediatric statement[25].

In 1998 the European Resuscitation Council published its revised recommendations for resuscitation of infants and children, and for the resuscitation of babies at birth[26-28].

Age definitions

Paediatric life support deals with the resuscitation of infants and children. Because of the wide variation in anatomy, physiology and epidemiology throughout the paediatric age band it is therefore important to define various age ranges in an effort to rationalise treatment.

Anatomy

The size of a child is an obvious important consideration in determining the practical resuscitation protocol to be followed. Age will determine the finer details of the procedures to be performed especially in basic life support.

An infant is a child under the age of one year.

A child is aged between 1 and 8 years of age.

Children over the age of 8 years should still be treated as younger children but may require different techniques to attain adequate chest compressions.

The upper age limit of 8 years for children has been proposed as a watershed particularly in relation to the technique of chest compression. A small child under the age of eight will probably receive adequate chest compressions using a 'one-handed' technique. An older or larger child will probably require a 'two-handed' (adult) technique to achieve an adequate depth of compression. Nonetheless, because of the variability of size in children no definitive upper age limit can be stipulated and the rescuer must judge the effectiveness of the resuscitation and adapt his technique appropriately.

Adult resuscitation protocols have also been modified by the European Resuscitation Council to dovetail with the above definitions[29,30]. They require the rescuer to determine the cause of the arrest and where this is not primarily cardiac in origin, for example trauma or drowning, to use a protocol that more closely aligns to the paediatric recommendations.

Basic Life Support[26]-Figure 1.

Assess responsiveness

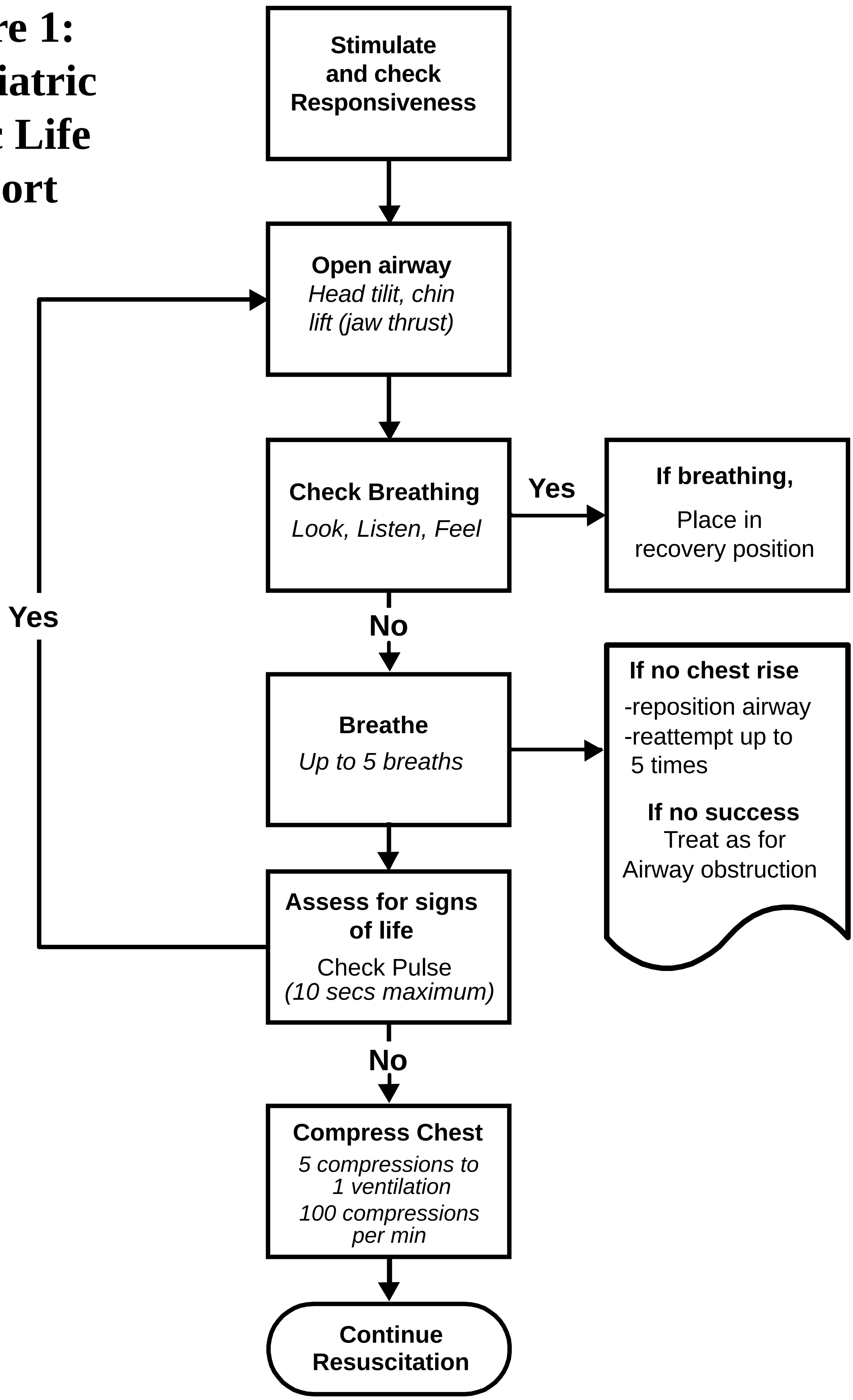
Before starting any resuscitation procedure it is vital to evaluate the situation for any danger or physical hazards. The first step in the sequence is to assess the level of responsiveness. Gentle but firm stimulation must be given and this alone may be sufficient to awaken the child or to stimulate respiration. Infants should not be vigorously shaken nor should children with a suspected spinal injury. If the child is unresponsive shout for help. Only move the child if he is in a dangerous location.

Airway

The tongue is the most common cause of airway obstruction in children. Simple head tilt - chin lift or jaw thrust manoeuvres will establish the paediatric airway, the jaw thrust procedure is particularly recommended when trauma is the cause of the collapse. A recent study has shown that there is no compromise of the airway by hyperextension of the neck[32]. None the less during trauma the cervical spine should be meticulously guarded by in-line cervical spine immobilisation.

If a foreign body is obstructing the airway then it should be removed carefully under direct vision. Blind probing

Figure 1: Paediatric Basic Life Support



of the child's airway is only likely to impact the object further or to directly cause tissue damage and must be discouraged. When complete upper airway obstruction has occurred as a result of inhalation of a foreign body, the object will probably be too far into the airway to either be seen or removed by simple means and will need advanced airway procedures.

Breathing

Assessing effective breathing is very difficult[33] and is subject to errors. Three methods are recommended in assessing respiration:

1. *Look for chest and abdominal movement.* This detects physical movement, but it may not be co-ordinated and effective in moving air in and out of the lungs.
2. *Feel at mouth and nose for air movement.* This answers the question as to the effectiveness of the chest movement.
3. *Listen over the airway for breath sounds.* An important manoeuvre which will indicate whether the child has large or small airway problems. An absence or lessening of airway noise could mean that the problem is improving; alternatively it could indicate that the child is moving less air past the obstruction and that the situation is getting worse.

If the infant or child is not breathing then it is essential to commence expired air resuscitation immediately. Using the mouth of the rescuer applied to the mouth and nose of the infant has been the conventional teaching but recently the effectiveness of mouth of the rescuer applied to the nose of the infant been described[34,35]. In the child, mouth to mouth expired air ventilation is recommended. Because of the probable hypoxic aetiology of the event, **five** expired air ventilations are considered the optimal number of breaths to oxygenate an infant or a child. The breaths should be slow, each lasting 1 to 1.5 seconds. These slow breaths minimise gastric distension from high pressure, high flow ventilation[36,37]. It is also important not to ventilate with excessive tidal volumes as this may lead to gastric distension and regurgitation of gastric contents[38]. A simple and effective guideline is to observe the child's chest and to stop ventilation when the child's chest looks as if he had taken a deep breath. If the chest does not move when attempting ventilation then reposition the airway or consider clearing the airway using the procedure described below for a choking child.

Circulation

Assessment of the circulation at this point in the resuscitation sequence has conventionally been by checking the pulse. Assessment of the brachial pulse is recommended[39] in infants and assessment of the carotid pulse in children.

The pulse check should take no longer than ten seconds and if a pulse is not felt, or the pulse rate is below 60 beats per minute in an infant, then resuscitation should continue immediately with chest compressions. Despite the apparent simplicity of a pulse check, studies have shown that both the lay rescuer and the experienced health care professional have difficulty in making an accurate pulse check[40-43]. The inaccuracy of the procedure has led to the validity of a pulse check in paediatric life support being challenged[44]. The concept of not performing a pulse check at all before commencing chest compressions is considered difficult to accept by some as it may appear to be illogical not to formally establish cardiac arrest before commencing chest compressions. Therefore the guidelines now include the statement that starting chest compressions should be considered without delaying for a pulse check in an unresponsive child who does not show obvious signs of recovery after expired air ventilation.

Chest Compressions

Chest compressions (previously known as cardiac massage) are performed on the lower half of the sternum.[45] In the infant compression is performed using two fingers placed one fingers breadth below an imaginary line joining the nipples. In the child the heel of one hand is used and positioned one finger's breadth up from the xiphisternum. In the older child (over the age of 8) and in the larger young child, this one handed compression technique may be found to be inadequate and the two handed compression technique (as used in adult resuscitation) may be required to produce effective chest compression.

The depth of compression should be judged in relative rather than absolute terms. For infants and small children it is recommended to compress the chest to one third of its resting depth. The efficacy of chest compression can be judged by palpation of the femoral vessels but this may reflect venous and not arterial blood pulsation. More effective assessment can be made by analysis of the arterial waveform or evaluation of the expired carbon dioxide tracing.

The compression rate is 100 compressions per minute. A single expired air ventilation should be given after every five compressions. This provides adequate ventilation and oxygenation for the infant or child. In the older child, where two hands are required for effective chest compression, the adult ratio of 15 compressions to 2 ventilations can be used, compressing the chest at a rate of 100/min.

Activation of the Emergency Medical Services

Ideally the call for help given during the assessment of responsiveness should have activated the emergency medical services. In reality this is not always the case, and the priority in paediatric life support is to establish an airway, to commence effective breathing and to circulate the oxygenated blood. In paediatric life support therefore resuscitation is started and the Emergency Medical Services activated after approximately one minute of resuscitation. Thus the paediatric protocols have adopted the 'phone fast' rather than the 'phone first' philosophy based on the aetiological consideration of resuscitation event. This is considered a general recommendation but local emergency medical services circumstances or the availability of 'dispatcher- guided CPR' may override these recommendations.

Basic life support must continue without further interruption until experienced help arrives or until signs of life return.

Foreign Body Airway Obstruction

Airway obstruction due to aspiration of food or vomit or the inhalation of a foreign body will compromise the paediatric airway. Spontaneous coughing to clear the material should be encouraged but if this fails back blows and chest thrusts in infants and back blows together with alternate cycles of chest thrusts and abdominal thrusts in children may provide vibration to loosen the material and enough expiratory force to expel the obstruction. Abdominal thrusts are not recommended in infants under the age of one year as damage to the abdominal contents may occur. The importance of checking the mouth, formally opening the airway and attempting expired air ventilation after each cycle has been highlighted by the need to ensure that the airway is actually obstructed. These checks are also required to assess whether the clearing manoeuvres have dislodged the material enough to allow some air pass the obstruction. The precise sequence for the relief of airway obstruction has not been formally assessed.

Advanced Life Support[27] - Figure 2

The Basic Life Support sequence provides the fundamental primary treatment of an infant or child that collapses in cardiopulmonary arrest. Advanced life support is the definitive management of the condition using complex techniques, drugs and equipment. As in basic life support, advanced life support protocols emphasise the importance of establishing an airway, oxygenation and ventilation from the outset. Although it includes a pathway for the management of ventricular fibrillation (VF) and ventricular tachycardia (VT) the emphasis is on non-ventricular fibrillation and non-ventricular tachycardia (Asystole and Pulseless Electrical Activity – previously known as Electro-Mechanical Dissociation) as these are the rhythms found in the majority of paediatric events. Ventricular fibrillation has been documented in less than 10% of paediatric events[6,9,10,46-48].

Airway

The simple basic procedures of head-tilt, chin lift or jaw thrust remain the mainstay of airway management. The insertion of a Guedel airway, correctly sized from the centre of the mouth to the angle of jaw, may be of use to aid simple airway control in the short term. Alternatively a nasal airway can be inserted.

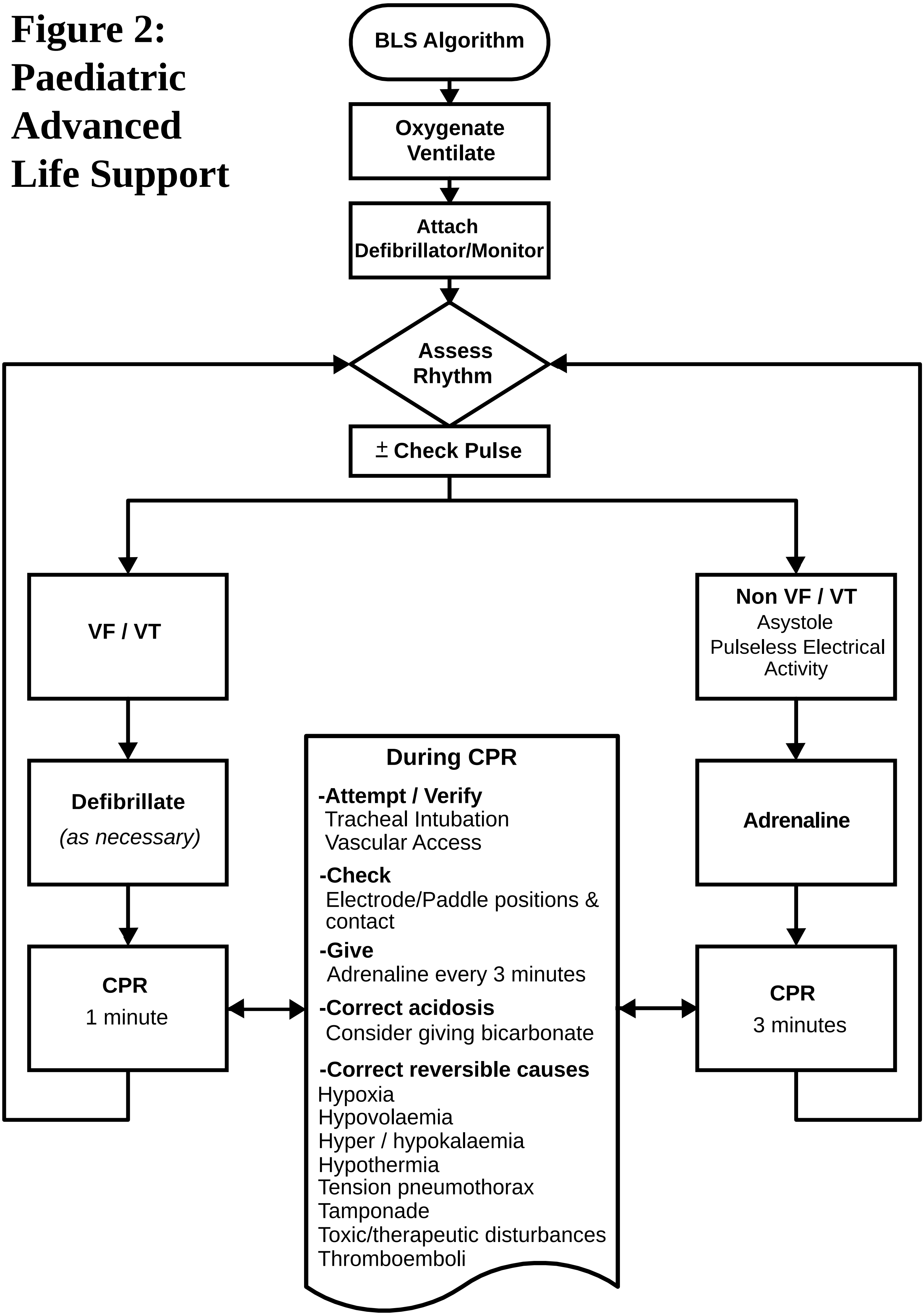
The laryngeal mask airway has been assessed as an effective airway adjunct in adult resuscitation and is a technique that can easily be taught to doctors, nurses and paramedic staff[49-54]. Small sized laryngeal masks are available for infants and children but their effectiveness in paediatric resuscitation has yet to be established. They will probably have their most significant effect where intubation is difficult or where the health care provider is not proficient in paediatric tracheal intubation skills.

Tracheal intubation is the most effective method of securing the paediatric airway. Using a straight bladed laryngoscope and a plain plastic tracheal tube of the appropriate size (*internal diameter (mm) = (age in years /4) + 4)* is a technique which requires a skill only developed by formal training and regular practice. Intubation must be achieved quickly and accurately without a prolonged delay to basic life support. Any attempt lasting longer than 30 seconds should be abandoned and the child reoxygenated before a further attempt at intubation is made. Having achieved tracheal intubation the tracheal tube needs to be carefully fixed in place to prevent its accidental removal or displacement.

Oxygenation

Although expired air resuscitation will provide some oxygenation the sooner ventilation with high-inspired oxygen levels can be established the better. Ventilation using a self-inflating bag-valve-mask with supplemented oxygen will provide higher levels of inspired oxygen.

Figure 2: Paediatric Advanced Life Support



Concentrations up to 90% can be achieved if the self-inflating bag is fitted with an oxygen reservoir system. Face masks for use with a self inflating bag should be of clear plastic so that the airway can be observed through the mask and the circular design mask with a soft seal rim have been found to be most efficient, especially in the hands of an inexperienced operator. Although many anaesthetists are experienced in the use of the Ayre's T-piece with the Jackson-Reece modification for paediatric ventilation, this circuit is not recommended for the less experienced and should not be part of the routine resuscitation equipment. Furthermore this system requires a constant flow of oxygen which may not always be immediately available. The self-inflating resuscitation bag can function independently and has the advantage of being capable of being operated safely and effectively by a much wider range of operators.

Circulation

There are few procedures more fraught with difficulty in resuscitation than establishing venous access in an infant or small child during resuscitation. Yet circulatory access is of prime importance to effective advanced life support[55,56]. The intravenous or intraosseous routes of drug delivery are the preferred options. The site of venous access has to be balanced against the resuscitation skills and relative difficulty and risks of the technique. Experimental data has demonstrated that vascular access via the superior vena cava by either peripheral or central routes is preferable during resuscitation[57-59]. Drugs given via the inferior vena cava take longer to reach the heart[58,59]. Similarly drugs administered centrally do act more rapidly than those administered via the peripheral route[58,60-62]. Central access above the diaphragm is difficult and fraught with potential problems. Peripheral access, especially via veins in the lower limbs is usually easier especially during resuscitation. Drugs administered via the peripheral route should be followed by a fluid flush to move more rapidly into the actual circulation. Therefore when judging the advantages of the different access points and deciding which to select it must be remembered that achieving access accurately safely and rapidly is the first priority.

Intraosseous access has gained popularity in the last few years – see Update in Anaesthesia 1995;5:15-17. It is relatively easy and generally safe. Resuscitation drugs and fluids administered by this route reach the heart in a time comparable to direct peripheral venous access[64-67]. Although originally recommended for children under the age of six the intraosseous route has been used in older age groups and in adults during cardiac resuscitation[67,68].

When establishing intraosseous access it is important to recognise the criteria for successful entry into the bone marrow. There should be a loss of resistance as the marrow cavity is entered, the needle should remain upright without support, bone marrow can be aspirated with a syringe and there is free flow of drugs and fluid without subcutaneous infiltration around the entry point[69,70]. Marrow aspirates can be used for estimation of haemoglobin, sodium, potassium, chloride and glucose[71]. Complications of intraosseous access include osteomyelitis, long bone fractures[72], subcutaneous drug extravasation and compartment syndrome[75-77].

The tracheal route of administration of drugs comes third to the intravenous and the intraosseous routes. It is best regarded as a route to be used where there has been, or is likely to be, a significant delay in establishing venous access and thus the administration of drugs. Therefore during resuscitation of the small infant or child it could be argued that the first important dose of adrenaline should be given by the tracheal route whilst venous access is being established[78,79]. There has been little research as to the efficacy of drugs administered via the tracheal route in children. The optimal dose of drug, its volume and its concentration has yet to be formally established[80-83]. Tracheal administration, despite its apparent simplicity, does have some disadvantages especially in the post resuscitation period. Hypertension and tachycardia, neither of which are optimal in the post arrest myocardium, have been reported and attributed to the depot storage effect of adrenaline that occurs in the lungs[84-88]. Severe hypertension may also be an underlying cause for a poor cerebral outcome[89].

Although direct intracardiac injection is still occasionally practiced, less than 70% of injections enter the heart and serious cardiac damage may occur. It is not recommended.

Drugs

Although many drugs have been tried in paediatric life support, few have retained their place in the resuscitation treatment protocols.

Adrenaline (Epinephrine)

Adrenaline is the mainstay of paediatric life support. It is used mainly for its alpha-adrenergic activity causing peripheral vasoconstriction, raising the peripheral vascular resistance, increasing the end diastolic filling pressure and thereby improving coronary blood flow[13,90]. Adrenaline's beta-adrenergic activity is also useful as it has a direct inotropic and chronotropic effect on the myocardium.

The recommended initial dose of adrenaline is 10mcg.kg^{-1} when administered via the intravenous or intraosseous routes. 10mcg.kg^{-1} is 0.01mg.kg^{-1} or 0.1ml.kg^{-1} of a 1 in 10,000 solution. Recent studies in and children have suggested the benefit of a higher dose of adrenaline for the unresponsive asystolic child[91]. Therefore, should the child not respond to the initial dose of adrenaline then a second dose of 100mcg.kg^{-1} (0.1ml.kg^{-1} of a 1 in 1000 solution) is recommended. If the child does not respond to this or additional 100mcg.kg^{-1} doses of adrenaline then the eventual outcome is likely to be poor; the results of studies show that no children have survived to discharge who have received more than two doses of adrenaline[5,9,15].

Atropine
Atropine is a parasympathetic blocking drug that will block the cardiac activity of the vagus nerve. It is used to treat bradycardia in a dose of 20mcg.kg^{-1}. Atropine should be considered in the peri-arrest scenario especially as it will prevent bradycardias of vagal origin (for example a vagal bradycardia during eye surgery) before they progress to cardiopulmonary collapse. Atropine is not recommended during resuscitation from cardiac arrest as the adrenergic effects of adrenaline are considered to over-ride the parasympathetic bradycardic effects on the heart.

Bicarbonate
Sodium bicarbonate is an alkalyzing agent used to correct the acidosis often associated with resuscitation. However, sodium bicarbonate is a solution with a high osmolarity containing a high level of sodium. The recommended dose is 1mmol.kg^{-1} (1ml.kg^{-1} of an 8.4% solution). Sodium bicarbonate should only be given if the child is being effectively ventilated as any carbon dioxide that is released by the process of acid neutralisation must be removed from the body via the lungs or paradoxical intracellular acidosis will result.

Treatment Algorithms
The administration of adrenaline plays a pivotal role in the advanced life support algorithms of paediatric life support. Establishing venous access and ventilating with oxygen are the first steps in advanced life support and form the basis for the advanced treatment protocol. The algorithm then divides into two pathways according to the presenting cardiac rhythm - Non Ventricular Fibrillation (or Tachycardia) or Ventricular Fibrillation (or Tachycardia).

Editors note: mcg.kg^{-1} is equivalent to mcg/kg and ml.kg^{-1} is the same as ml/kg

Non Ventricular Fibrillation or Tachycardia (Asystole or Pulseless Electrical Activity)
A profound bradycardia or asystole is the most common rhythm associated with cardiac arrest in infants and children. The profound bradycardia (usually described as being a pulse beat at less than one beat per second) may precede asystole but in itself the bradycardia does not produce an adequate cardiac output. A profound bradycardia should therefore be treated in the same way as an asystole. The treatment is an initial dose of adrenaline at 10mcg.kg^{-1} given by the intravenous or intraosseous route (or ten times this dose via the tracheal tube if venous access has not been established). Second and subsequent doses of adrenaline should be at 100mcg.kg^{-1}.

Where there is a cardiac rhythm but no cardiac output (Pulseless Electrical Activity) it is also necessary to treat any of the underlying reversible causes of cardiac arrest. These are the 4‘H’s and 4‘T’s of cardiac arrest.

Hypoxia	**T**ension Pneumothorax
Hypovolaemia	**T**amponade
Hyper/hypokalaemia	**T**oxic/Therapeutic disturbances
Hypothermia	**T**hromboemboli

Adrenaline should be administered every three minutes according to the schedule described previously and resuscitation should not be abandoned until a reasonable attempt has been made to correct these potentially reversible causes of cardiac arrest.

Ventricular Fibrillation and Tachycardia
These rhythms, though common in adults, are relatively rare in infants and children. Although one study [11] reported an incidence of 23% ventricular fibrillation in children, other studies report an incidence of between 0 and 10%[86,92,93]. Therefore the physician must always be aware of the occasional need to treat ventricular fibrillation in children by defibrillation.

The recommended sequence is to give two rapid defibrillatory shocks of 2 joules.kg^{-1}, followed by a single shock at 4 joules.kg^{-1}. All further defibrillation attempts should then be made at 4 joules.kg^{-1} in a rapid repeated series of 3 shocks. Following the first cycle of three defibrillation attempts adrenaline 10mcg.kg^{-1} should be given and, in accordance with previous explanations, a further dose of 100mcg.kg^{-1} should be given following the second cycle of three shocks and between all subsequent cycles. When ventricular fibrillation occurs in children there is often an underlying cause and the correction of hypothermia, drug overdose (tricyclic antidepressant overdose) and electrolyte imbalance (hyperkalaemia) should be considered.

Resuscitation of the Newborn[28]

Newborn resuscitation specifically refers to the resuscitation procedures at or immediately after the delivery of a newly born infant. There is a specific sequence of events centred on the respiratory and circulatory changes that occur in relation to the 'First Breath'. Therefore the recommended resuscitation procedures (Figure 3) emphasise the airway and breathing manoeuvres whilst the management of the circulation is left to the trained health care provider. Resuscitation of the newborn is unique in that it is, in most cases, predictable. It is only rarely an unexpected emergency procedure. Careful assessment of maternal and foetal factors, the mode of delivery and the obstetric care will predict the majority of newborns that will require resuscitation procedures.

It has been estimated that the use of simple airway measures could prevent newborn asphyxia occurring in 900,000 infants per year world-wide. Of the five million newborn deaths per year world-wide, 56% of which occur in 'out of hospital births', 19% have 'birth asphyxia' as a cause.[94] In the United Kingdom newborn mortality is much lower but with the increase in 'home deliveries' it has become increasingly important for the birth attendants and other health care professionals to be not only conversant with obstetric problems but also proficient in newborn resuscitation techniques.

The majority of newborn infants cry within a few minutes of birth and require little more than careful drying and then wrapping in a warm towel to prevent heat loss. If the baby does not cry, it should be gently stimulated by more vigorous drying with a towel or flicking the soles of the feet. More vigorous stimulation is contraindicated and can be potentially dangerous. Of those that do not cry most will only need clearing the airway and ventilation, very few will need full resuscitation including intubation, circulatory access and drug administration.

The newborn baby's initial cry and subsequent efforts at breathing must be carefully assessed to ensure that they result in adequate and sustained oxygenation of the lungs. Gasping without additional efforts at breathing are usually considered inadequate. Abnormal or absent ventilatory patterns will require immediate active intervention.

The initial assessment of the neonate is based on respiratory activity, colour and heart rate. These three parameters have been shown to be more accurate in the assessment of the newborn than the total Apgar scoring system[95,96].

The newborn can be classified into three groups.

1. **Fit and healthy baby,**
   Vigorous effective respiratory efforts
   Centrally pink
   Heart rate > 100/minute.

This baby requires no intervention other than drying, wrapping in a warm towel and, where appropriate, handing to the mother. The baby will usually remain warm by skin to skin contact with mother and may be put to the breast at this stage.

2. **Breathing inadequately or apnoeic**
   Central cyanosis
   Heart rate > 100/minute

This group of babies may respond to tactile stimulation and/ or facial oxygen but often need basic life support.

3. **Breathing inadequately or apnoeic**
   Pale or white due to poor cardiac output and peripheral vasoconstriction
   Heart rate <100/minutes or **No detectable heart rate (**although this was documented up to 15 - 20 minutes before delivery.)

These babies sometimes improve with initial basic life support but normally require immediate intubation and positive pressure ventilation progressing to chest compressions, and full advanced life support including resuscitation drugs if the baby fails to respond.

Newborn Basic Life Support (Figure 3)

Airway

Open the airway by tilting the head into the neutral position and lifting the jaw upward by gentle pressure on the mandible. The airway can be cleared of residual debris and fluid by gentle suction of the mouth and nares. Aggressive pharyngeal suction can delay the onset of spontaneous breathing and cause laryngeal spasm and vagal bradycardia[97]. It is not indicated unless the amniotic fluid is stained with thick meconium or blood. If suction is required, a 10FG (or if preterm, 8FG) suction catheter should be connected to a suction source not exceeding -100mmHg. This should not continue for longer than 5 seconds in the absence of meconium. The catheter should normally not be inserted further than about 5cm from the lips.

Breathing

Check for breathing by look, listen and feeling for respiratory effects. The inspired air can be supplemented with oxygen from a loose fitting facemask or funnel. Effective ventilation can only be carried out by using a well-fitting facemask that covers the mouth and nose but does not cover the eyes or overlap the chin[98].

Self-inflating resuscitation bags refill independently of adjuvant gas flow. They should incorporate a pressure limited pop-off valve pre-set at 20 - 30 cm H_2O. In a minority, this pressure may be inadequate to achieve lung expansion at birth and the facility to override this is useful for a few babies. The volume of the bag should be at least 500ml, so that the inflation pressure can be maintained for at least 0.5 seconds. Facemask T-piece resuscitation uses compressed air/oxygen fed to one arm of a T-piece attached to the facemask[99]. The baby's lungs are inflated by occluding the open arm of the T-piece. It is obviously essential to have a safety pressure release system (set at 20 - 30 cm H_2O) incorporated in the gas supply tubing. A method for monitoring the peak pressures will also be required. This system has the advantage that it requires only one hand for normal operation and the inflation pressures can be maintained for longer than with the self-inflating bags. It has been traditional to use 100% oxygen as the ventilating gas for resuscitation but there is data indicating that, in term babies, 100% inspired oxygen has little advantage and may increase oxygen free radical damage. Furthermore there is evidence that newborn resuscitation is as effective with air as with 100% inspired oxygen.[100-103] If gas-mixing facilities are available then a 40% inspired oxygen is recommended as the ventilating gas to expand the newborn lungs, but if cyanosis persists or the heart rate falls the inspired oxygen level should be raised.

The first five or six breaths require an inspiration held for 1 to 2 seconds. This prolonged inspiration will double the inspiratory volume and is more likely to establish the functional residual capacity needed by the baby to continue to breath spontaneously[104]. After these initial breaths a normal ventilatory pattern can be used, ventilating at a rate of approximately 30-40 breaths per minute until spontaneous respiration is established.

If the baby does not respond to these initial face mask resuscitation manoeuvres or the heart rate falls below 100 beats per minute, the health care professional must proceed to tracheal intubation and advanced life support procedures immediately.

Newborn Advanced Life Support (Figure 4)

Tracheal intubation is a skilled technique that requires training and practice. It is achieved, using a straight blade laryngoscope and an appropriate size of tracheal tube

Guideline for tracheal tube size

Tracheal Tube Size (mm. Internal Diameter)	**Weight** (g)	**Gestation** (weeks)
2.5	<1000	<28
3	1000 - 2500	28 - 36
3.5	>2500	>36

These are only guidelines and tubes 0.5mm larger and smaller should always be available.

Once the tracheal tube is passed through the vocal cords its position must be carefully checked to ensure that there is equal ventilation of both lungs. The tube should then be securely fixed in position. Ventilation is continued using the self-inflating bag or T-piece system.

WHEN THERE IS ANY DOUBT ABOUT THE POSITION OR PATENCY OF THE TUBE REMOVE THE TRACHEAL TUBE IMMEDIATELY AND REINTUBATE AFTER A BRIEF PERIOD OF OXYGENATION USING FACE MASK VENTILATION.

Circulation

The initial attempts at establishing a viable circulation are made using chest compressions. Chest compressions should be performed if:

1. The heart rate is less than 60 beats/minute.
2. The heart rate is less than 100 beats/minute and falls despite adequate ventilation.

The optimal technique is to place the 2 thumbs side by side over the lower one third of the sternum with the fingers encircling the torso and supporting the back.[105-107] The lower third of the sternum[45] is compressed 2 - 3cm in a term baby at a rate of approximately 120 compressions per minute. The compressions should be smooth and not jerky and each compression should last 50% of the compression/relaxation cycle. An alternative technique is

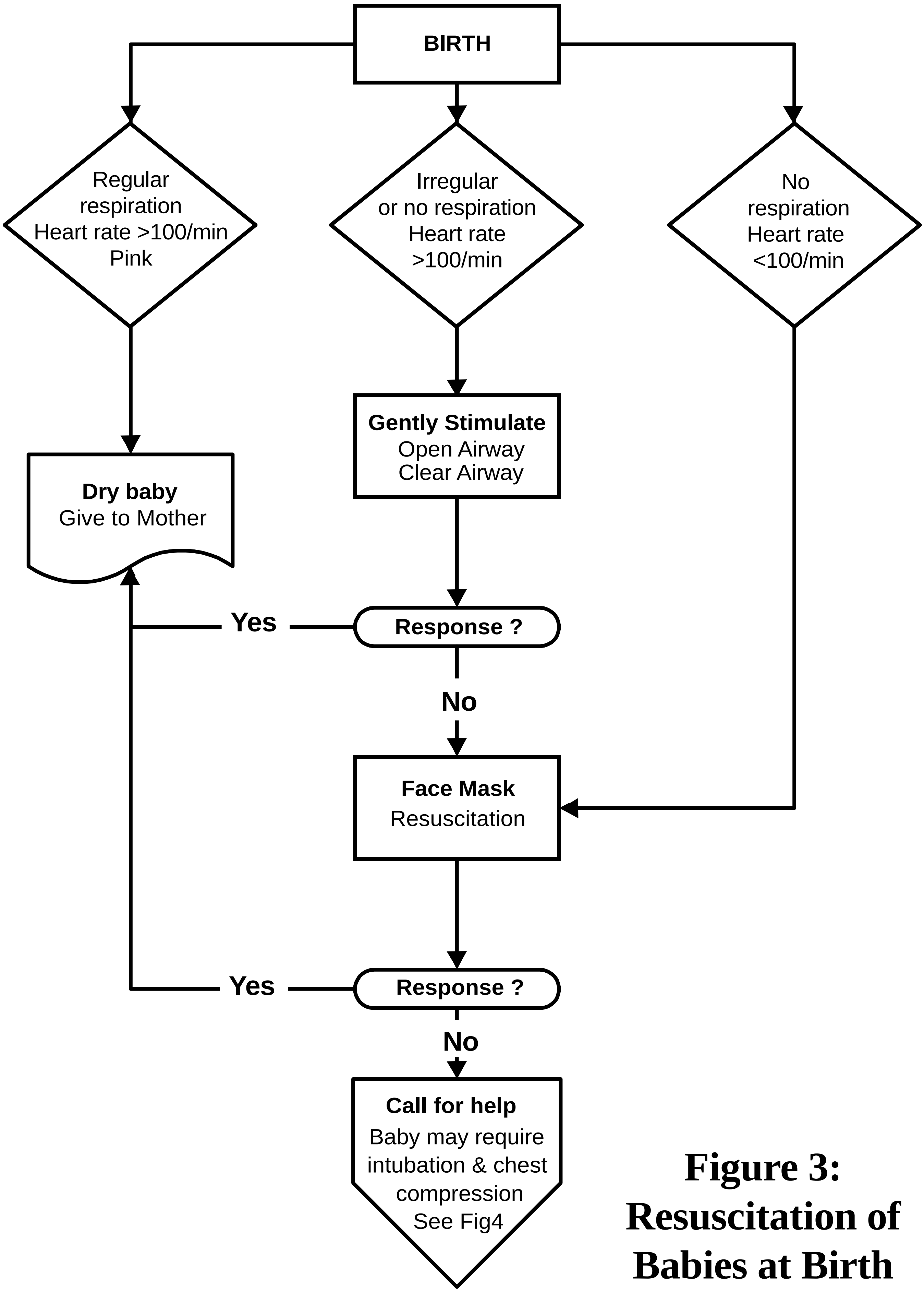
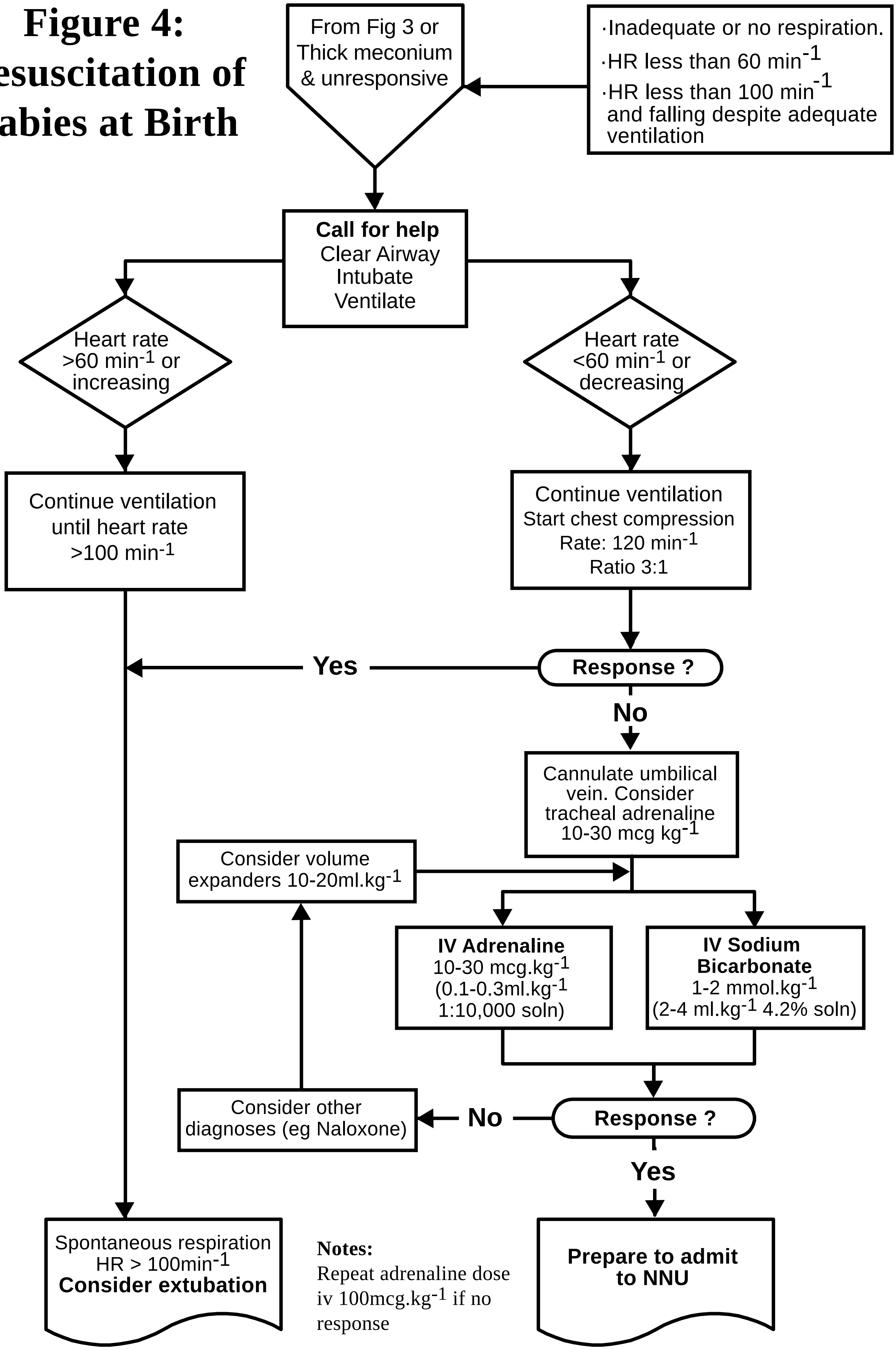


Figure 3: Resuscitation of Babies at Birth

Figure 4: Resuscitation of Babies at Birth



Notes:
Repeat adrenaline dose iv 100mcg.kg^{-1} if no response

to use the index and middle finger of one hand to compress the lower half of the infant's sternum. This allows the operator's free hand to perform simple resuscitation procedures whilst maintaining external chest compressions. A single ventilation should be performed after every three chest compressions. The pulse should be checked periodically and chest compressions only discontinued when the spontaneous heart rate of greater than 100 beats per minute is established.

If the infant fails to respond to active ventilation following intubation and chest compressions then venous access must be established. A failure of the infant to respond is usually as a result of inadequate ventilation and it is therefore essential to check the seal of the facemask or the position of the tracheal tube. When satisfied that there is optimal airway control and in the continuing absence of improvement, the umbilical vein should be catheterised using a 4.5 – 5 FG umbilical catheter. This is achieved by transecting the cord 1 - 2cm away from the abdominal skin and inserting the umbilical catheter until there is a free flow of blood up the catheter.

An initial dose of intravenous adrenaline, 10-30mcg.kg^{-1} (0.1 - 0.3 ml.kg^{-1} of 1:10,000 solution), should be given via the umbilical venous catheter, flushing the adrenaline through the catheter with 2ml of saline. If venous access fails, an intra-osseous needle can be inserted into the proximal tibia and this route temporarily used instead of the venous umbilical catheter. If there is a delay in establishing umbilical vein catheterisation or intraosseous access then the same dose of adrenaline, 10 - 30mcg. kg^{-1}, can be given through the tracheal tube. Despite the tracheal administration of adrenaline being widely practiced there is little evidence that it is effective.[108-110] It may be least effective if given before the lungs are fully inflated.

If there is still no response the baby should be given 1 -2 mmol.kg^{-1} body weight of sodium bicarbonate slowly over 2-3 minutes. Use a 4.2% bicarbonate solution or mix a volume of 8.4% sodium bicarbonate solution with an equal volume of 5 or 10% dextrose or sterile water. This results in a concentration of 0.5mmol.ml^{-1} solution. Basic life support must be continued. Sodium bicarbonate is a hyperosmolar solution and should be administered by slow infusion in preterm babies below 32 weeks because of the risk of inducing intracerebral bleeding. Further doses of bicarbonate are best given in response to the results of arterial blood gas analysis data.

Repeat doses of adrenaline should be given if the newborn continues to fail to respond. Subsequent larger doses, up to 100mcg.kg^{-1}, may be considered but there is evidence that the need for adrenaline during resuscitation is associated with a poor prognosis[111].

Hypovolaemia in the newborn requires active volume replacement. Indications for intravenous fluid therapy are:

1. Evidence of acute fetal blood loss.
2. Pallor that persists after oxygenation.
3. Faint pulses with a good heart rate and poor response to resuscitation including adequate ventilation.
4. Fluid replacement, at 10-20mls.kg^{-1}, can be given as 4.5% albumin, whole blood or plasma.

Finally, intramuscular naloxone (100mcg.kg^{-1}) should be considered in the apnoeic newborn who rapidly becomes pink and who obviously has a satisfactory circulation on resuscitation. Naloxone is a narcotic antagonist and is specifically indicated where there is a history of recent therapeutic administration of opiates to the mother.

Conclusion

Paediatric life support is an essential part of the resuscitation cycle. To be effective, those practising paediatric resuscitation at basic or advanced levels need to be properly trained and practised in the skills of the procedure. Delay or hesitation in recognising the need for or performing resuscitation will have dire consequences.

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