Newborn and paediatric resuscitation 2011 guidelines

The Singapore National Resuscitation Council's Neonatal and Paediatric Resuscitation Workgroup, 2010–2011

ABSTRACT
We present the revised guidelines for newborn and paediatric resuscitation for Singapore. The 2010 International Liaison Committee on Resuscitation consensus on science as well as the main recommendations from the European Resuscitation Council and American Heart Association were debated and discussed. The final recommendations for the Singapore National Resuscitation Council were derived after carefully reviewing the current available evidence in the literature and balancing the local clinical climate of practice. In addition, much effort was spent on aligning the paediatric and neonatal recommendations with the adult (especially Basic Cardiac Life Support) recommendations.

Keywords: air ventilation, infant and paediatric resuscitation, newborn resuscitation

Singapore Med J 2011;52(8):560-572

INTRODUCTION
With ongoing research and reviews as well as the development of newer innovations in technology, the science (and art) of paediatric and neonatal resuscitation continues to be revamped and improved. The Singapore National Resuscitation Council (NRC)'s Paediatric Life Support Committee appointed a workgroup to review the international recommendations from the International Liaison Committee on Resuscitation (ILCOR) comprising inputs from the European Resuscitation Council (ERC) and American Heart Association (AHA), which were released at the end of 2010.[1-7] This review updates and enhances the existing National Paediatric and Neonatal guidelines that were last reviewed and released in 2005.[8,9] Paediatric resuscitation flow charts are listed in the Appendix (Boxes 1–6) at the end of the article.

NATURE OF REVIEW
The ILCOR task force identified 55 questions related to paediatric resuscitation. Evidence review was conducted by two or more independent reviewers for each topic. Draft consensus on the science and treatment recommendations was agreed upon, and these were re-circulated and refined until consensus was reached. Controversial and/or critical topics were subsequently addressed at the 2010 ILCOR conference.

The committee extensively reviewed the 2010 recommendations from the ERC and AHA. Important references made in the papers were accessed and reviewed. Other relevant documents and papers, where appropriate and indicated, were also reviewed. The workgroup comprised representations from the spectrum of paediatric speciality community – paediatric intensivists, paediatric anaesthetists, paediatric emergency physicians, neonatologists and paediatric nursing specialists.

The main recommendations from the ERC and AHA were debated and discussed. The final recommendations for the NRC were derived after carefully reviewing the current available evidence in the literature and balancing the local clinical climate of practice. Where appropriate, the existing Levels of Evidence and Classes of Recommendations are indicated against the respective proposals. In addition, much effort was spent on aligning the paediatric and neonatal recommendations with the adult (especially Basic Cardiac Life Support) recommendations.

For the final neonatal recommendations, the neonatologists met as another separate subgroup to arrive at the final 2011 recommendations. Where newborn resuscitation issues crossed into non-paediatric/neonatal areas of practice (e.g. perinatal care and the issue of delayed cord clamping), the relevant expert body(ies) (e.g. the Singapore Perinatal Society) was/were consulted before the final recommendations were agreed upon.

DEFINITIONS
A neonate is defined as a patient aged ≤ 28 days. An infant is a patient aged ≤ one year. A child is any patient aged one year to puberty. Unless otherwise stated, 'paediatrics' in our recommendations refers both to infants and children but excludes neonates.

KK Women's and Children's Hospital
National University Hospital
Singapore General Hospital
(Institutions listed in alphabetical order)

Correspondence to:
A/Prof Ng Kee Chong
Tel: (65) 6394 1170
Fax: (65) 6340 1172
Email: keech@kkh.com.sg

MAIN RECOMMENDATIONS

Basic paediatric life support

Recognition and assessment of cardiac arrest

- One should not take more than ten seconds to determine if there is cardiac arrest.
- The presence or absence of pulse is ***not*** a reliable determinant of cardiac arrest.
- Other determinants of cardiac arrest are unresponsiveness, gasping, not breathing normally and no signs of life.

Initial management of collapse

- One should always ensure the safety of the rescuer(s) and child at the onset.
- The initial assessment is to check for responsiveness of the child.
- If the child is noted to be unresponsive, one should proceed to open the airway (head tilt – chin lift).
- Check for breathing: look, listen and feel for ten seconds. Note that gasping is ***not*** breathing.
- Check for pulse within ten seconds (for the healthcare provider only): commence cardiopulmonary resuscitation (CPR) if there is cardiac arrest.
- Chest compression should be commenced before the initial two rescue breaths are given.
- If there is only a single rescuer, call for help after two minutes of resuscitation.
- If an automated external defibrillator (AED) is available, one should check for a shockable rhythm and then intervene.

Compression-ventilation ratio in basic paediatric life support

- Laypersons/healthcare providers: perform 30 compressions, followed by two ventilations (30:2) for a single rescuer.
- If a second rescuer is available, the first rescuer performs compressions and the second rescuer performs ventilations. Rotate the compressor role every two minutes. The switch should take less than five seconds.
- General rescuers who are unable or unwilling to provide mouth-to-mouth ventilation are encouraged to perform at least compression-only CPR.

Chest compression technique

- For infants, use the ‘two-finger’ technique for single rescuer and the ‘thumb-encircling’ technique for two or more healthcare provider rescuers.
- For children, use the ‘one- or two-hand’ technique.
- Achieve a compression of at least one-third of the antero-posterior chest diameter in all children over the lower half of the sternum.
- ***Push hard-push fast*** at a compression rate of at least 100 per minute.
- There must be complete chest recoil after each compression.
- There must be minimal interruptions (< five seconds) to minimise no-flow time.

Ventilatory rates

- Following return of spontaneous circulation (ROSC) and with cessation of CPR, continue ventilation, aiming to achieve 12 (for > eight years) to 20 (for 1–8 years) breaths per minute.

Automated external defibrillators

- AEDs can be used for children aged ≥ one year.
- AEDs are capable of accurately identifying arrhythmias in children; in particular, they are very unlikely to advise a shock inappropriately.
- Those aged 1–8 years should preferably be defibrillated with paediatric pads or the AEDs should have software that attenuates the output of the machine to 50–75 J (recommended for children 1–8 years old).
- If an attenuated shock or manually adjustable machine is not available, an unmodified adult AED may be used in children > one year old.
- For patients < one year old, the incidence of shockable rhythms is very low except when they suffer from cardiac disease. In these cases, the risk/benefit ratio may be favourable, and the use of an AED (preferably with dose attenuator) should be considered.

Foreign body airway obstruction (FBAO)

- There are no major changes to the management of paediatric FBAO treatment.
- Infants should have chest thrusts to help dislodge the FB. Infants should ***never*** be given abdominal thrusts (Heimlich manoeuvre) for FBAO care.
- Children aged ≥ one year may be given abdominal thrusts (Heimlich manoeuvre) for FBAO care. Those given abdominal thrusts should be examined subsequently by a doctor for possible abdominal injury.

Advanced paediatric resuscitation/management by healthcare workers

Initial management of collapse

- Pulse check (if done) should not take > ten seconds.
- Pulse should be assessed at the brachial (for infants), femoral (for infants and children) and carotid (for children).

Neonatal versus infant resuscitation

- Newborns who require CPR in the nursery or neonatal intensive care unit (NICU) should be managed as for a newborn in the delivery room (i.e. 3:1 chest compression to ventilation ratio).
- Newborns in other settings (e.g. pre-hospital, emergency department [ED], paediatric ICU should be resuscitated according to the infant guidelines (i.e. 30:2 if non-intubated).

Compression-ventilation rates in paediatrics (healthcare workers)

- Not intubated
  - Laypersons/healthcare providers: perform 30 compressions, followed by two ventilations (30:2) for a single rescuer.
  - If a second rescuer is available, the first rescuer performs compressions and the second rescuer performs ventilations. Rotate the compressor role every two minutes. The switch should take < five seconds.
  - General rescuers who are unable or unwilling to provide mouth-to-mouth ventilation are encouraged to perform at least compression-only CPR.
- Intubated
  - After intubation, there should be at least 100–120 compressions per minute with 8–10 asynchronous ventilatory breaths.

Oxygen concentration in paediatric resuscitation

- Ventilate with 100% oxygen during active CPR.
- Once resuscitated (with ROSC), oxygen concentration should be judiciously titrated and lowered to the lowest minimum required by the child while maintaining SpO_2 at 94%–98%.

Use of cuffed versus uncuffed endotracheal tube (ETT)

- Except for newborns, infants and children may be intubated with cuffed ETTs.
- Indications for the use of cuffed ETTs in non-neonatal patients aged < eight years: when lung compliance is poor; airway resistance is high; or if there is a large air leak from the glottis.

Defibrillation

- Patients with ventricular fibrillation (VF) and pulseless ventricular tachycardia (VT) should be defibrillated.
- The defibrillation doses in paediatrics should be 4 J/kg for the first and every subsequent shock, followed each by 1–2 minutes of CPR.

Table I. Acceptable pre-ductal SpO_2

Time after delivery (min)	SpO_2 (%)
1	60–65
2	65–70
3	70–75
4	75–80
5	80–85
10	85–95

- Biphasic defibrillators are preferable, as they are associated with less post-shock myocardial dysfunction.
- Adrenaline should be given after the third shock and every alternate shock.
- Amiodarone should be given (after the third and fifth shock) along with adrenaline.
- The defibrillation pads can either be placed antero-laterally (one pad on the right and one on the left axilla) or antero-posteriorly (one pad on the left chest anteriorly and one posteriorly at the left scapula).
- Rule out and manage the correctable 'H's (hypoxia; hypovolaemia; hypo-/hyperkalaemia/metabolic; hypothermia; and hypoglycaemia) and 'T's (tension pneumothorax; toxins/therapeutic disturbances; tamponade [cardiac]; and thromboembolism [coronary or pulmonary]).

Intravascular/intraosseus (IO) access

- Bone marrow samples can be used for cross-match, chemical analysis and blood gas measurements.
- Samples can damage autoanalysers; thus, these samples should preferably be used in cartridge analysers instead.
- The benefits of semi-automated IO devices remain to be seen.

NEONATAL LIFE SUPPORT AND RESUSCITATION

Initial assessment and intervention

- Heart rate should remain the vital sign by which to judge the need for and efficacy for resuscitation. The most accurate way of assessing the heart rate is by auscultation of the praecordium. Palpation of the umbilical pulse can also be used to provide a rapid estimate of the pulse.
- Heart rate should be reassessed every 30 seconds in a neonate who requires resuscitation.
- If a neonate appears blue, it is recommended to check oxygenation with a pulse oximeter (Table I).

Air/oxygen for resuscitation

Term neonates

For term neonates receiving resuscitation at birth with positive pressure ventilation, it is recommended to begin with air as opposed to 100% oxygen. If despite effective ventilation, there is no increase in heart rate or oxygenation (preferably guided by oximetry), the use of higher oxygen concentration should be considered until the recovery of a normal heart rate.

Preterm

For neonates < 32 weeks old, it is recommended that blended oxygen be given judiciously, guided by oximetry. If blended oxygen is not available, resuscitation may be initiated using what is available.

Delay in cord clamping for those who do not require resuscitation

- For uncompromised neonates, there may be benefits in delaying the clamping of the umbilical cord for at least one minute from the complete delivery of the infant.
- There is insufficient evidence to recommend an appropriate time for clamping the cord in neonates who were severely compromised at birth.

Aspiration of meconium

- Intrapartum oropharyngeal suctioning of the neonate born through meconium-stained amniotic fluid is no longer recommended.
- For the non-vigorous neonate born through meconium, there is no change in the current practice of direct oropharyngeal and tracheal suctioning.

Temperature management for preterm neonates

- Immediately after birth, preterm neonates < 28 weeks old should be completely covered in a food-grade plastic wrap or bag up to their necks, without drying.
- They should then be nursed under a radiant warmer and stabilised. They should remain wrapped until their temperature has been checked.
- It is recommended that the temperature in the delivery room be maintained at minimally 26°C.

Ventilation

- There is no difference between longer or shorter inflation breaths.
- Positive end expiratory pressure (PEEP) may be considered in preterm neonates who present with respiratory distress.
- Spontaneously breathing preterm neonates who have respiratory distress may be supported with continuous positive airway pressure (CPAP) or intubation and ventilation. The most appropriate choice may be guided by local expertise and preferences.
- As for ventilation devices, there is yet no clinical evidence that compares T-piece with flow-inflating bags or self-inflating bags.

CPR for newborn

- CPR for newborns remains as 3:1 (compression to ventilation) ratio.

Confirmation of placement of ETT

- A prompt increase in heart rate is the best indicator that the tube is in the trachea and is providing effective ventilation.
- Detection of exhaled carbon dioxide, in addition to clinical assessment, can be used to confirm ETT placement.

Volume expansion

- Early volume replacement with crystalloid or red cells is indicated for neonates with blood loss who are not responding to resuscitation. Give a bolus of 10 mls/kg initially. This may be repeated if successful.
- There is insufficient evidence to support the routine use of volume administration in the neonate with no blood loss who is refractory to ventilation, chest compression and epinephrine.

Route and dose of adrenaline

- Adrenaline via the intravenous (IV) route is preferred. The dose of IV adrenaline used remains as 0.01–0.03 mg/kg.
- For the IV route, there is no evidence to suggest that a higher dose is better.
- A few case reports suggest that a higher dose of adrenaline should be used if administered through the ETT. If the IV route is not available, ETT adrenaline may be considered at a dose of 0.05–0.1 mg/kg.
- In neonates/newborns, the concentration of adrenaline for both IV and endotracheal routes should be 1:10,000.

Post-resuscitation care

Glucose control

- Hypoglycaemia is associated with poor neurological outcome.
- Glucose should be monitored after resuscitation.

Therapeutic hypothermia for moderate or severe hypoxic ischaemic encephalopathy (HIE)

- Term or near term neonates with moderate to severe HIE should be offered therapeutic hypothermia (33.5°C–34.5°C).

Withholding/non-initiation of resuscitation

- Where gestation, birth weight and/or congenital anomalies are associated with almost certain death and where unacceptably high morbidity are likely among the rare survivors, resuscitation is not indicated.
- This includes the following: extreme prematurity (gestational age < 23 weeks and/or birth weight < 400 g) and anomalies such as anencephaly or confirmed trisomy 13.

Discontinuation of resuscitation

- If there is no return of heart rate after ten minutes, evidence suggests that the newly born is likely to suffer from severe neurological impairment or death.
- Hence, it is suggested that if there is no return of heart rate after ten minutes of adequate resuscitation, it is acceptable to discontinue resuscitation.

DISCUSSION

Paediatric resuscitation

Recognition of cardiac arrest and role of pulse check

The validity and usefulness of pulse check to determine cardiac arrest has been found to be questionable.[10-17] Studies have reported that it is not easy to perform a pulse check quickly in both adults and infants. Laypersons and healthcare workers were found to be unable to perform an adequate pulse check within ten seconds in patients who were evaluated in an ICU setting without ongoing CPR. Two such studies conducted in children found that blinded healthcare workers inaccurately assessed the pulse in patients with non-pulsatile circulation and that they took more than ten seconds to do so.[16,17] A pulse was falsely detected 14%–24% of the time. Conversely, 21%–36% of patients who had a pulse did not have their pulse detected. The average time for detection of a pulse was 15 seconds and that for an absence of a pulse was 30 seconds.

It is therefore recommended that if the child is unresponsive or not breathing normally, or where there are no signs of life, the layperson should immediately commence CPR. Healthcare workers may do a pulse check within ten seconds, but this should not delay the commencement of CPR. In addition, breathing of a gasping nature is equivalent to poor respiratory effort and impending collapse.

Chest compression and ABCs

Cardiac arrest can be asphyxial or cardiac (i.e. VF) in origin. In cardiac arrest in infants and children, asphyxial cardiac arrest is more common.[1-4,18] While ventilations are very important in the acute resuscitation of these patients, a combination of ventilations and chest compressions results in better resuscitation outcomes, as evidenced by a recent large paediatric study by Kitamura et al.[19] This prospective observational study showed that for children with noncardiac cause of cardiac arrest (i.e. asphyxial), those who had standard bystander CPR (with chest compression and rescue breathing) had a higher 30-day survival and better neurological outcomes compared with those who had compression-only CPR. While there is some evidence that compression-only CPR may be more useful in adult cardiac arrests, there is no evidence to apply it to the paediatric population.

In adults who require CPR, the majority have VF cardiac arrest, and better outcomes are achieved when chest compressions are started early. Beginning CPR with 30 compressions rather than two ventilations leads to a shorter delay to first compression in adult studies. Other studies have shown that positioning the airway and establishing ventilation takes time and will delay the commencement of chest compressions.[18-21] Furthermore, it is unknown whether it makes a difference to begin CPR with chest compressions first, followed by ventilation (the so-called CAB) or the established ventilation and then chest compression (ABC). Starting with chest compression has been estimated to delay ventilation by about 18 seconds for a lone rescuer but the delay will be even shorter for a two-man rescue technique.[1-3] We therefore concur with the recommendations from other countries to standardise and simplify the sequence of CPR for both adults and children. This will simplify training across all age groups and establish consistency in teaching rescuers, regardless of whether the patients are infants, children or adults.

In children, the lower half of the sternum should be compressed. Compression depth remains at one-third of the anterior-posterior (A-P) chest diameter. Case reports have concluded that compression to one-third of the A-P diameter does not cause damage to intrathoracic organs. One should 'push hard and push fast', with complete release of pressure after each chest compression. For infant chests (including newborns), the two-finger or thumb-encircling technique (Fig. 1 & 2) should be used, and for child (> one year old) chests, one- or two-hand chest compression should be used (Fig. 3). There are no published studies indicating the effectiveness of one technique over the other. However, higher chest compression pressures may be generated by healthcare workers using the two-hand technique (using randomised cross-over manikin studies). Additionally, no studies have reported an increase in rescuer fatigue when either of the techniques was used in manikins.

Fig. 1 Two-finger chest compression.

Fig. 2 Thumb-encircling technique.

Compression to ventilation rates

In order to simplify and standardise CPR for both adults and paediatrics, the workgroup retained the current recommendations of 30 chest compressions to two ventilations for non-intubated patients and kept to an unsynchronised chest compression rate of 100 chest compressions and 8–10 ventilations per minute.(1-4)

Oxygen vs. room air for infant and paediatric resuscitation

While there is evidence for use of room air for newborn resuscitation (see below), there have not been any corresponding studies in infants and children. Several animal studies(22-25) have suggested that resuscitation with room air or an $FiO_2 < 1.0$ during cardiac arrest may be associated with less neurological deficit, whereas another animal study showed no difference.(26) Five animal studies(22-25, 27) have shown that resuscitation with 100% oxygen contributed to free radical-mediated reperfusion injury to the brain. As such, there is no strong clinical evidence as it presently stands for the use of less than 100% oxygen for acute resuscitation of the infant or child. However, once resuscitated (with ROSC), oxygen concentration should be judiciously titrated and lowered to the lowest minimum required by the child while maintaining a SpO_2 of 94%–98%.

Use of cuffed ETT in younger children

While the standard role of using uncuffed ETT in children < eight years old still applies, cuffed ETT may also be used in this group.(28,29) At ILCOR 2005, the indications for the use of cuffed ETT (provided the correct size is selected) in children aged < 8 years were poor lung compliance, high airway resistance and large glottic air leak.(1-4) The use of low-pressure, high-volume cuffed ETT has not been associated with increased incidence of post-extubation stridor in children. However, no studies have adequately assessed the potential long-term consequences, such as subglottic stenosis. Hence, if high airway pressures are anticipated during intensive care stay, cuffed ETT may be used so as to avoid the need for reintubation due to air leak around the ETT.(28-33)

Fig. 3 One-/two-hand chest compression technique.

Three studies in the paediatric anaesthesia setting (two randomised controlled studies and one cohort-controlled study) showed that the use of cuffed ETTs was associated with a higher likelihood of correct ETT size selection, and hence, associated with a lower reintubation rate.(28,34,35) Excessive cuff pressure may lead to pressure, subsequent ischaemia to surrounding laryngeal tissue and stenosis. Cuff pressure should be monitored and maintained below 25 cm H_2O. The recommended sizes of ETTs are shown in Table II.

Defibrillation for shockable rhythms

Studies have not reported a relationship between defibrillation dose and survival-to-hospital discharge or neurologic outcome from VF/pulseless VT. An initial dose of 2 J/kg seems to be effective in terminating VF in 18%–50% of children in out-of-hospital and in-hospital collapses.(1-4,36-40) Others have reported that children often received more than 2 J/kg during out-of-hospital

Table II. Recommended ETT sizes for neonates, infants and children.

	Uncuffed (mm)	Cuffed (mm)
Neonates (premature)	Gestational age (wk) /10	Not used
Neonates (full term)	3.5	Not used
Infants	3.5–4.0	3.0–3.5
Child (1–2 years)	4.0–4.5	3.5–4.0
Child (> 2 years)	Age (yr)/4 + 4	Age (yr)/4 + 3.5

cardiac arrest, with two-thirds (69%) requiring three or more shocks at escalating doses. Tiballs et al[37] and Rossano et al[38] did not find any improvement in survival for paediatric patients with short or long duration VF between energy doses of 2–10 J/kg. In animal studies, 0%–8% of long-duration VF episodes were terminated by 2 J/kg monophasic shock compared to 32% terminated by biphasic shock.[41,42] Most required two or more shocks to terminate the arrhythmia. One animal study found that the defibrillation threshold for short duration VF was 2.4 J/kg,[43] while another animal study found the threshold to be 3.3 J/kg.[44]

As for the type of defibrillation, some animal studies have shown that biphasic waveforms were more effective than monophasic waveforms for treatment of VF/pulseless VT.[41,42] However, there have not been any human studies that compared these two waveforms for paediatric defibrillation. Animal studies of AED shocks delivered using a paediatric attenuator of doses 2.5–4 J/kg were effective at terminating long duration VFs but required multiple shocks. Conversely, some animal studies have shown no difference in survival outcomes in short and long duration VF when 2–10 J/kg energy doses were used. Biphasic delivery was better than monophasic devices.[41,44-46]

The size, type and positioning of the paddles/pads used may affect the success of defibrillation.[47-57] One adult study[47] showed that shock success improved from 31% to 82% when the pad size was increased from 8 cm × 8 cm to 12 cm × 12 cm. Transthoracic impedence decreases with increasing pad/paddle size.[47-50] Decreased transthoracic impedence increases transthoracic current and thus, presumably, transmyocardial current. Several studies, both in children and adults, suggest that transthoracic impedence is not dependent on pad/paddle position.[51,52] There is, however, insufficient evidence to change the current recommendation to use the largest size paddles/pads that fit on the infant's or child's chest without them touching each other. The largest possible paddle/pad size that provides good contact with the chest wall should be used. There should be good separation between the two paddles/pads. The recommended size of paddle/pad for infants and children < 10 kg (< one year old) is 4.5 cm diameter, and that for children > 10 kg (> one year old) is 8–12 cm.[1-4]

The paddles/pads should be positioned antero-laterally, with one placed below the right clavicle and the other over the left axilla. If the paddles/pads are too large, one should be placed anteriorly to the left of the sternum and the other over the back, below the left scapula. If paddles are used, they should be applied firmly to decrease transthoracic impedence.[53, 54] There is no clear evidence that self-adhesive defibrillation pads or paddles are better; either may be used.[55-57]

Use and role of AEDs in infants/children

AEDs have been recommended for use in children 1–8 years old.[58,59] The AED should be one that recognises paediatric shockable rhythms. Ideally, the correct AED with a paediatric attenuator should be used.[9, 60-63] The dose attenuator will decrease the delivered energy to a lower dose that is more suitable for a child aged 1–8 years (i.e. 50–75 J). Myocardial damage, as assessed by haemodynamic or biochemical measurements, was lesser with a paediatric attenuator than without one when full energy adult AED doses were given.

AED in infants

For infants with VF/pulseless VT, the optimal defibrillation dose has not been established. Animal studies suggest that young myocardium may be able to tolerate high doses of energy.[46] Defibrillation for infants with a shockable rhythm should be by (in the following order) manual defibrillator; AED with dose attenuator; and AED without dose attenuator.

Infant vs. newborn resuscitation algorithm

It is clear that newborn resuscitation differs from infant resuscitation. Resuscitative management of the newborn in the delivery room and NICU differs from that in the ED, cardiac ICU and pre-hospital setting.[1-4] Intuitively, newborn physiology and resuscitative needs are also different from the resuscitative needs of a one-week-old child. A one-week-old newborn in the NICU needing CPR is usually resuscitated as per the newborn algorithm (i.e. 3:1 chest compression to ventilation). Conversely, a one-week-old neonate requiring CPR in the ED will be resuscitated as per the infant protocol, i.e. 30:2 if not intubated.

Currently, there is no definitive scientific evidence to help resolve this issue. While the type of CPR (i.e. newborn vs. infant CPR) is largely dependent on the location of care, it is reasonable to also take into consideration the underlying aetiology of the collapse. Where the newborn has a primary cardiac aetiology, more emphasis on chest compressions may be tailored in the acute resuscitation of the patient.

Newborn resuscitation

Initial assessment of newborn: use of O_2 saturation monitoring vs. colour to assess oxygenation in the initial assessment of the newborn

A prompt increase in heart rate remains the most sensitive indicator of effective resuscitation. Pulse oximetry and heart rate can be obtained accurately 90 seconds after birth with a pulse oximeter that is designed to reduce movement artefact and a neonatal probe. Targeted pre-ductal saturations have been recommended for both term and preterm newborns.

There is clear evidence that an increase in oxygenation and improvement in colour may take many minutes to achieve, even in uncompromised neonates. Foetal SpO_2 level is approximately 43%. Blood oxygen levels generally do not reach extrauterine values until approximately ten minutes after birth. Neonates will thus appear cyanosed soon after birth for several minutes. Skin colour is, hence, a poor indicator of oxyhaemoglobin saturation in the immediate period after birth, and has since been removed from the new resuscitation algorithm.

The pulse oximeter can be used to adjust the increase in oxygenation. A healthy neonate can be initially born blue but will usually 'pink' up quickly. Peripheral cyanosis does not necessarily mean hypoxia. Using colour as a gauge of oxygen saturation in assessment of the newborn is, therefore, not recommended. However, it should also not be completely ignored. Where colour might suggest a lack of oxygenation, one should check using a pulse oximeter.

The APGAR score was originally proposed as a basis for discussion and comparison of the results of obstetric practice, types of maternal pain relief and effects of resuscitation. It was not meant to be used as a trigger for initiating resuscitation. However, individual components of the score (viz respiratory rate, heart rate and tone) can be used to assess the effectiveness of resuscitation. The usefulness of heart rate as the most important predictor of outcome was propounded by Dr Virginia Apgar.(64)

Room air for newborn resuscitation

In term neonates receiving resuscitation with intermittent positive pressure ventilation, 100% oxygen conferred no advantage over air in the short term, and resulted in increased time to first breath and first cry, or both. Increased survival of newborns has occurred when resuscitation was initiated with room air rather than 100% oxygen, according to two meta-analyses of several randomised controlled trials.(65,66) There are currently no studies in term neonates that compare the outcomes when resuscitations are initiated with different oxygen concentrations. In preterm neonates < 32 weeks gestation, initial use of air or 100% oxygen is more likely to result in hypoxaemia or hyperoxia, respectively, than when blended oxygen and titration to oxygen saturation are used. Newborn animal models of asphyxia(67) have shown that exposure to high concentrations of oxygen at resuscitation is potentially harmful at the cellular level. The newborn antioxidant capacity is overwhelmed, leading to oxidative stress and increasing damage to cell structures, enzymes, RNA, DNA and eventually, organ damage. Also, in the preterm neonate, the use of high oxygen concentrations, even for brief periods, may contribute to bronchopulmonary dysplasia and retinopathy of prematurity. It is thus recommended that term neonates who require resuscitation at birth with positive pressure ventilation start with air rather than 100% oxygen. If there is no increase in heart rate despite effective ventilation (note that steps should be taken to ensure effective chest inflation and ventilation) or no improvement in oxygenation by pulse oximetry, the use of higher concentration of oxygen should be considered. For preterm neonates born at < 32 weeks gestation, blended oxygen and air should be given judiciously, preferably guided by pulse oximetry. If blended oxygen and air is not available, then resuscitation can be initiated using whatever is available.

Delayed clamping of cord

There has been recent interest in the timing of cord clamping. Umbilical cords clamped before the first breath may result in a decrease in the size of the heart during the subsequent third to fourth cardiac cycles. This initial decrease may be due to the filling of the newly opened vascular system during aeration, with subsequent increase in cardiac size due to blood returning to the heart from the lungs. Brady and James(68) noted bradycardia apparently caused by clamping before the first breath vs. no bradycardia in those whose clamping was done after the first breath. Early clamping in the significantly premature baby, whose ability to generate negative pressure to inflate the lungs is limited, may either induce or prolong bradycardia, leading to a 'need' for resuscitation. A Cochrane review of

Table III. Effects of delayed cord clamping.

Effects of delayed cord clamping
Term neonates • Improved iron status and other haematological indices over the next 3–6 months • Greater need for phototherapy for jaundice (no well-controlled analysis available)
Preterm neonates • Reduced blood transfusion in immediate postnatal and ensuing weeks • Reduced incidence of intraventricular haemorrhage • Increased incidence of jaundice and use of phototherapy, but no reports of increased exchange transfusion

delayed cord clamping (> one minute after birth or when cord pulsations have ceased) in uncomplicated term births did not demonstrate any increase in the risk of maternal haemorrhage.[69] This placental transfusion of 80 ml of blood at one minute after birth provides the newborn with 40–50 mg/kg of extra iron, and this helps to improve the iron status of the child in the first six months of life. They were, however, more likely to receive phototherapy.

For uncomplicated preterm births, neonates with delayed cord clamping 30 seconds to three minutes after delivery have been shown to have higher blood pressures during stabilisation, lower incidence of intraventricular haemorrhage and received fewer blood transfusions. They were however, also more likely to need phototherapy. Thus, in uncomplicated term and preterm births, there may be benefits in delaying the clamping of the umbilical cord for at least one minute. There is currently insufficient evidence to support or refute a recommendation to delay cord clamping in neonates who require resuscitation. Table III summarises the effects of delayed cord clamping.

Temperature control for premature newborns

Very low birth weight neonates have poor temperature control and are at risk of hypothermia despite traditional methods of reducing heat loss (such as drying and placing under a radiant warmer). Several randomised studies and meta-analysis[70,71] have shown that placing the preterm neonate < 28 weeks gestation in food-grade wrap (polyethylene) at birth without drying significantly improves temperature on admission to the ICU. All resuscitation procedures can be done with the wrap in place. Maintaining a delivery room temperature of at least 26°C in combination with the polyethylene wraps is most effective. As there is a small risk of hyperthermia, the premature neonate's temperature must be closely monitored.

Theraupeutic hypothermia

Several randomised, multicentred trials[72-74] have shown that induced hypothermia (33.5°C–34.5°C) within six hours of birth in neonates born at > 36 weeks gestation with moderate to severe hypoxic-ischaemic encephalopathy significantly reduces death and neuro-disability at 18 months. Neonates > 36 weeks gestation with evolving moderate to severe hypoxic-ischaemic encephalopathy should be offered therapeutic hypothermia, where possible. Both whole body or selective head cooling are appropriate strategies.

Management of newborn with meconium-stained liquor

Routine intrapartum oropharyngeal and nasopharyngeal suctioning of term-gestation neonates born through meconium-stained amniotic fluid (MSAF) before delivery of the shoulders does not prevent meconium aspiration syndrome. In healthy neonates, suctioning of the nose and mouth is associated with cardiorespiratory complications. Thus, routine intrapartum oropharyngeal and nasopharyngeal suctioning for neonates born with clear or MSAF is no longer recommended. For the depressed neonate born through MSAF, there is currently no randomised trial comparing intubation and tracheal suctioning vs. no tracheal suctioning. Therefore, we do not recommend a change in the current practice of endotracheal suctioning of depressed neonates born through MSAF.

CONCLUSION

Resuscitation in the newborn, infant and child continues to evolve as new studies and observations throw light on how the science of resuscitation can better be applied on the ground. Much more research remains to be done to order to obtain a clearer understanding of how to enhance resuscitation in the neonatal and paediatric populations. In the past, much of the practice had been extrapolated from adult studies and observations. More direct clinical research needs to be done to better calibrate and fine-tune resuscitation to meet the acute resuscitative needs of the newborn, infant and child.

ACKNOWLEDGEMENTS

The Singapore NRC Neonatal and Paediatric Resuscitation Workgroup members: Ng K C, Quek B H, Wong C Y P, Chan, L Y I, Yeo C L, Chan Y H, Ng S B A, Kao P T, Puthucheary J, Buang S, Chong S L, Lin Y J D, Tan S K J, Ee T T K, Lee J, Ong L L, Tor S K, Lee S K.

The authors wish to thank the following for reviewing the neonatal recommendations: A/Prof Sam Rajadurai (Head and Senior Consultant, Department of Neonatology, KKH); Dr Selina Ho (Senior Consultant, Department of Neonatal & Developmental Medicine, SGH) and Dr Chinnadurai Amutha (Associate Consultant, Department of Neonatology, NUH).

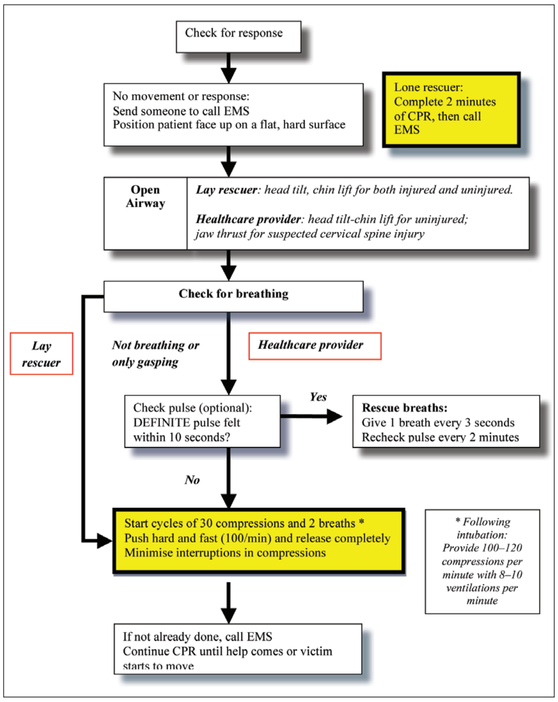
REFERENCES

1. Kleinman ME, Chameides L, Schexnayder SM, et al. Part 14: Pediatric Advanced Life Support: 2010 American Heart Association. Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation 2010; 122 Suppl 3: S876-S908.
2. Kleinman ME, de Caen AR, Chameides L, et al. Part 10: Pediatric Basic and Advanced Life Support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Circulation 2010;122 Suppl 2:S466-515.
3. Berg MD, Schexnayder SM, Chameides L, et al. Part 13: Pediatric Basic Life Support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation 2010; 122 Suppl 3: S862-875.
4. Biarent D, Bingham R, Eich C, et al. European Resuscitation Council Guidelines for Resuscitation 2010 Section 6. Paediatric life support. Resuscitation. 2010; 81:1364-88.
5. Perlman JM, Wyllie J, Kattwinkel J, et al. Part 11: Neonatal Resuscitation: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation 2010; 122 Suppl 2:S516-38.
6. Kattwinkel J, Perlman JM, Aziz K, et al. Part 15: Neonatal Resuscitation: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Circulation 2010; 122 Suppl 3: S909-19.
7. Richmond S, Wyllie J. European Resuscitation Council Guidelines for Resuscitation 2010 Section 7. Resuscitation of babies at birth. Resuscitation 2010; 81:1389-99.
8. Teo WS, Anantharaman V, Lim SH. Update on resuscitation 2006. Singapore Med J 2007; 48:100-5.
9. NHCS. Updates in Paediatric Resusciration [online]. Available at: www.nhcs.com.sg/educationandtraining/cprtrainingaccreditationguidelines/cprtraining/Documents/Updates in Paediatric Resuscitation NEW.pdf. Accessed August 19, 2011.
10. Mather C, O'Kelly S. The palpation of pulses. Anaesthesia 1996; 51:189-91.
11. Ochoa FJ, Ramalle-Gómara E, Carpintero JM, García A, Saralegui I. Competence of health professionals to check the carotid pulse. Resuscitation 1998; 37:173-5.
12. Bahr J, Klingler H, Panzer W, Rode H, Kettler D. Skills of lay people in checking the carotid pulse. Resuscitation 1997; 35:23-6.
13. Eberle B, Dick WF, Schneider T, et al. Checking the carotid pulse check: diagnostic accuracy of first responders in patients with and without a pulse. Resuscitation 1996; 33:107-16.
14. Lee CJ, Bullock LJ. Determining the pulse for infant CPR: time for a change? Mil Med 1991; 156:190-3.
15. Tanner M, Nagy S, Peat JK. Detection of infant's heart beat/pulse by caregivers: a comparison of 4 methods. J Pediatr 2000; 137:429-30.
16. Tibballs J, Russell P. Reliability of pulse palpation by healthcare personnel to diagnose paediatric cardiac arrest. Resuscitation 2009; 80:61-4.
17. Atkins DL, Everson-Stewart S, Sears GK, et al. Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry-cardiac arrest. Circulation 2009; 119:1484-91.
18. Kitamura T, Iwami T, Kawamura T, et al. Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. Lancet 2010; 375:1347-54.
19. Heidenreich JW, Higdon TA, Kern KB, et al. Single-rescuer cardiopulmonary resuscitation: 'two quick breaths'–an oxymoron. Resuscitation 2004; 62:283-9.
20. Berg RA, Hilwig RW, Kern KB, Ewy GA. "Bystander" chest compressions and assisted ventilation independently improve outcome from piglet asphyxial pulseless "cardiac arrest." Circulation 2000; 101:1743-8.
21. Iglesias JM, López-Herce J, Urbano J, et al. Chest compressions versus ventilation plus chest compressions in a pediatric asphyxial cardiac arrest animal model. Intensive Care Med 2010; 36:712-6.
22. Balan IS, Fiskum G, Hazelton J, Cotto-Cumba C, Rosenthal RE. Oximetry-guided reoxygenation improves neurological outcome after experimental cardiac arrest. Stroke 2006; 37:3008-13.
23. Liu Y, Rosenthal RE, Haywood Y, et al. Normoxic ventilation after cardiac arrest reduces oxidation of brain lipids and improves neurological outcome. Stroke 1998; 29:1679-86.
24. Zwemer CF, Whitesall SE, D'Alecy LG. Cardiopulmonary-cerebral resuscitation with 100% oxygen exacerbates neurological dysfunction following nine minutes of normothermic cardiac arrest in dogs. Resuscitation 1994; 27:159-70.
25. Feet BA, Yu XQ, Rootwelt T, Oyasaeter S, Saugstad OD. Effects of hypoxemia and reoxygenation with 21% or 100% oxygen in newborn piglets: extracellular hypoxanthine in cerebral cortex and femoral muscle. Crit Care Med 1997; 25:1384-91.
26. Rootwelt T, Loberg EM, Moen A, Oyasaeter S, Saugstad OD. Hypoxemia and reoxygenation with 21% or 100% oxygen in newborn pigs: Changes in blood pressure, base deficit, and hypoxanthine and brain morphology. Pediatr Res 1992;32:107-13
27. Lipinski CA, Hicks SD, Callaway CW. Normoxic ventilation during resuscitation and outcome from asphyxial cardiac arrest in rats. Resuscitation 1999; 42:221-9.
28. Motoyama EK. The shape of the pediatric larynx: cylindrical or funnel shaped? Anesth Analg 2009; 108:1379-81.
29. Fine GF, Borland LM. The future of the cuffed endotracheal tube. Paediatr Anaesth 2004; 14:38-42.
30. Mhanna MJ, Zamel YB, Tichy CM, Super DM. The "air leak" test around the endotracheal tube, as a predictor of postextubation stridor, is age dependent in children. Crit Care Med 2002; 30:2639-43.
31. Weiss M, Dullenkopf A, Fischer JE, Keller C, Gerber AC. Prospective randomized controlled multi-centre trial of cuffed or uncuffed endotracheal tubes in small children. Br J Anaesth 2009;103:867-73.
32. Parwani V HI-H, Hsu B, Hoffman RJ. Experienced emergency physicians cannot safely or accurately inflate endotracheal tube cuffs or estimate endotracheal tube cuff pressure using standard technique. Acad Emerg Med 2004; 11:490-1.
33. Ashtekar C S and Wardhaugh A. Do cuffed endotracheal tubes increase the risk of airway mucosal injury and post-extubation stridor in children? Best Bets 2005: #01088.
34. Khine HH, Corddry DH, Kettrick RG, et al. Comparison of cuffed and uncuffed endotracheal tubes in young children during general anesthesia. Anesthesiology 1997; 86:627-31; Discussion 627A.
35. Bordet F, Allaouchiche B, Lansiaux S, Combet S, Pouyau A, Taylor P, Bonnard C, Chassard D. Risk factors for airway complications during general anaesthesia in paediatric patients. Paediatr Anaesth 2002; 12:762-9.
36. Haskell SE, Atkins DL. Defibrillation in children. J Emerg Trauma Shock 2010; 3:261-6.
37. Tibballs J, Carter B, Kiraly NJ, Ragg P, Clifford M. External and internal biphasic direct current shock doses for pediatric ventricular fibrillation and pulseless ventricular tachycardia. Pediatr Crit Care Med 2011; 12:14-20.
38. Rossano JW, Quan L, Kenney MA, Rea TD, Atkins DL. Energy doses for treatment of out-of-hospital pediatric ventricular fibrillation. Resuscitation 2006; 70:80-9.
39. Atkins DL, Kerber RE. Pediatric defibrillation: current flow is improved by using "adult" electrode paddles. Pediatrics 1994; 94:90-3.

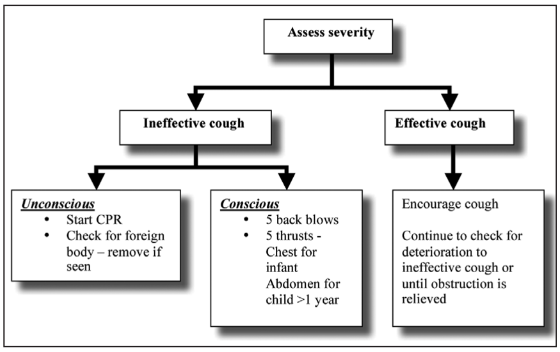
40. Rea TD, Helbock M, Perry S, et al. Increasing use of cardiopulmonary resuscitation during out-of hospital ventricular fibrillation arrest: survival implications of guideline changes. Circulation 2006; 114:2760-5.
41. Clark CB, Zhang Y, Davies LR, Karlsson G, Kerber RE. Pediatric transthoracic defibrillation: biphasic versus monophasic waveforms in an experimental model. Resuscitation 2001; 51:159-63.
42. Berg RA, Chapman FW, Berg MD, Hilwig RW, Banville I, Walker RG et al. Attenuated adult biphasic shocks compared with weight-based monophasic shocks in a swine model of prolonged pediatric ventricular fibrillation. Resuscitation 2004; 61:189-97.
43. Killingsworth CR, Melnick SB, Chapman FW, et al. Defibrillation threshold and cardiac responses using an external biphasic defibrillator with pediatric and adult adhesive patches in pediatric-sized piglets. Resuscitation 2002; 55:177-85.
44. Berg MD, Banville IL, Chapman FW, et al. Attenuating the defibrillation dosage decreases postresuscitation myocardial dysfunction in a swine model of pediatric ventricular fibrillation. Pediatr Crit Care Med 2008; 9:429-34.
45. Tang W, Weil MH, Jorgenson D, et al. Fixed-energy biphasic waveform defibrillation in a pediatric model of cardiac arrest and resuscitation. Crit Care Med 2002; 30:2736-41.
46. Walcott GP, Melnick SB, Killingsworth CR, Ideker RE. Comparison of low-energy versus high-energy biphasic defibrillation shocks following prolonged ventricular fibrillation. Prehosp Emerg Care 2010; 14:62-70.
47. Dalzell GW, Cunningham SR, Anderson J, Adgey AA. Electrode pad size, transthoracic impedance and success of external ventricular defibrillation. Am J Cardiol 1989; 64:741-4.
48. Atkins DL, Sirna S, Kieso R, Charbonnier F, Kerber RE. Pediatric defibrillation: importance of paddle size in determining transthoracic impedance. Pediatrics 1988; 82:914-8.
49. Pagan-Carlo LA, Birkett CL, Smith RA, Kerber RE. Is there an optimal electrode pad size to maximize intracardiac current in transthoracic defibrillation? Pacing Clin Electrophysiol 1997; 20:283-92.
50. Kerber RE, Grayzel J, Hoyt R, Marcus M, Kennedy J. Transthoracic resistance in human defibrillation. Influence of body weight, chest size, serial shocks, paddle size and paddle contact pressure. Circulation 1981; 63:676-82.
51. Pagan-Carlo LA, Spencer KT, Robertson CE, et al. Transthoracic defibrillation: importance of avoiding electrode placement directly on the female breast. J Am Coll Cardiol 1996; 27:449-52.
52. Garcia LA, Kerber RE. Transthoracic defibrillation: does electrode adhesive pad position alter transthoracic impedance? Resuscitation 1998; 37:139-43.
53. Bennetts SH, Deakin CD, Petley GW, Clewlow F. Is optimal paddle force applied during paediatric external defibrillation? Resuscitation 2004; 60:29-32.
54. Deakin CD, Sado DM, Petley GW, Clewlow F. Determining the optimal paddle force for external defibrillation. Am J Cardiol 2002; 90:812-3.
55. Stults KR, Brown DD, Cooley F, Kerber RE. Self-adhesive monitor/ defibrillation pads improve prehospital defibrillation success. Ann Emerg Med 1987; 16:872-7.
56. Cornwell L, Mukherjee R, Kelsall AW. Problems with the use of self-adhesive electrode pads in neonates. Resuscitation 2006; 68:425-8.
57. Bradbury N, Hyde D, Nolan J. Reliability of ECG monitoring with a gel pad/paddle combination after defibrillation. Resuscitation 2000; 44:203-6.
58. Samson R, Berg R, Bingham R, Pediatric Advanced Life Support Task Force ILCOR. Use of automated external defibrillators for children: an update. An advisory statement from the Pediatric Advanced Life Support Task Force, International Liaison Committee on Resuscitation. Resuscitation 2003; 57:237-43.
59. Samson RA, Berg RA, Bingham R, et al. Use of automated external defibrillators for children: an update: an advisory statement from the pediatric advanced life support task force, International Liaison Committee on Resuscitation. Circulation 2003; 107:3250-5.
60. Atkinson E, Mikysa B, Conway JA, et al. Specificity and sensitivity of automated external defibrillator rhythm analysis in infants and children. Ann Emerg Med 2003; 42:185-96.
61. Atkins DL, Hartley LL, York DK. Accurate recognition and effective treatment of ventricular fibrillation by automated external defibrillators in adolescents. Pediatrics 1998; 101:393-7.
62. Jorgenson D, Morgan C, Snyder D, et al. Energy attenuator for pediatric application of an automated external defibrillator. Crit Care Med 2002; 30 Suppl 4: S145-7.
63. Bar-Cohen Y, Walsh EP, Love BA, Cecchin F. First appropriate use of automated external defibrillator in an infant. Resuscitation 2005; 67:135-7.
64. Apgar V. A proposal of a new method of evaluation of the newborn infant. Curr Res Anesth Analg 1953; 32:261-7.
65. Rabi Y, Rabi D, Yee W. Room air resuscitation of the depressed newborn : A systematic review and meta-analysis. Resuscitation 2007; 72:353-63.
66. Davis PG, Tan A, O'Donnell CP, Schilze A. Resuscitation of newborn infants with 100% oxygen or air: a systematic review and meta-analysis. Lancet 2004; 364:1329-33.
67. Saugstad OD. Oxygen for newborns: How much is too much? J Perinatol 2005; 25:S45-9.
68. Brady JP, James LS. Heart rate changes in the fetus and newborn infant during labor, delivery, and the immediate neonatal period. Am J Obstet Gynecol 1962; 84:1-12.
69. McDonald SJ, Middleton P. Effect of timing of umbilical cord clamping of term infants on maternal and neonatal outcomes. Cochrane Database of Systematic Reviews 2008; Issue 2. Art. No: CD004074; DOI: 10.1002/14651858.CD004074.pub2. Accessed on August 2, 2011.
70. Cramer K, Wiebe N, Hartling L, Crumley E, Vohra S. Heat loss prevention: a systematic review of occlusive skin wrap for premature neonates. J Perinatol 2005; 25:763-9.
71. Vohra S, Roberts RS, Zhang B, Janes M, Schmidt B. Heat loss prevention (HeLP) in the delivery room: A randomized controlled trial of polyethylene occlusive skin wrapping in very preterm infants. J Paediatr 2004; 145:750-3.
72. Gluckman PD, Wyatt JS, Azzopardi D, et al. Selective head cooling with mild systemic hypothermia after neonatal encephalopathy: multicentre randomised trial. Lancet 2005; 365:663-70.
73. Shankaran S, Laptook AR, Ehrenkranz RA, Tyson JE, McDonald SA, Donovan EF, Fanaroff AA, Poole WK, Wright LL, Higgins RD, Finer NN, Carlo WA, Duara S, Oh W, Cotten CM, Stevenson DK, Stoll BJ, Lemons JA, Guillet R, Jobe AH. Whole-body hypothermia for neonates with hypoxic-ischemic encephalopathy. N Engl J Med 2005; 353:1574-84.
74. Azzopardi DV, Strohm B, Edwards AD, Dyet L, Halliday HL, Juszczak E, Kapellou O, Levene M, Marlow N, Porter E, Thoresen M, Whitelaw A, Brocklehurst P. Moderate hypothermia to treat perinatal asphyxial encephalopathy. N Engl J Med 2009; 361:1349-58.

APPENDIX

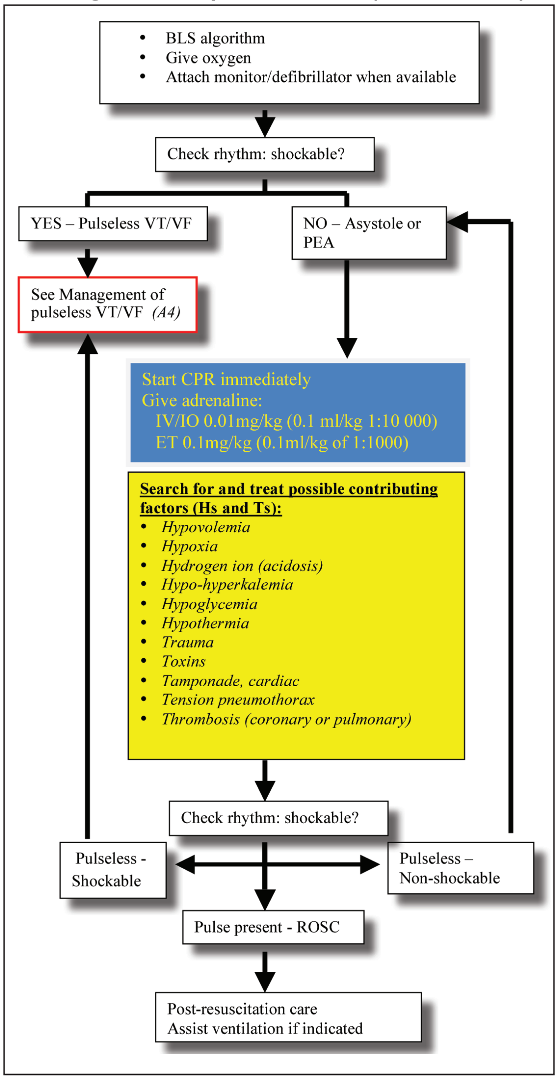
Box 1. Paediatric resuscitation



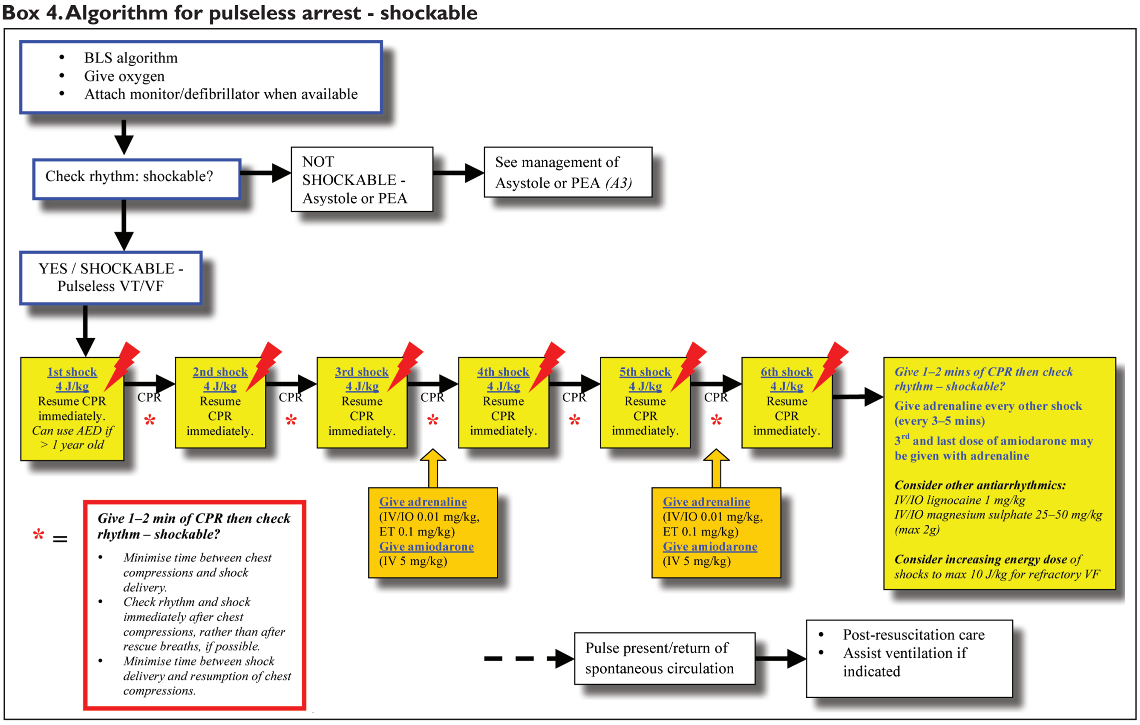
Box 2. Paediatric FBAO treatment



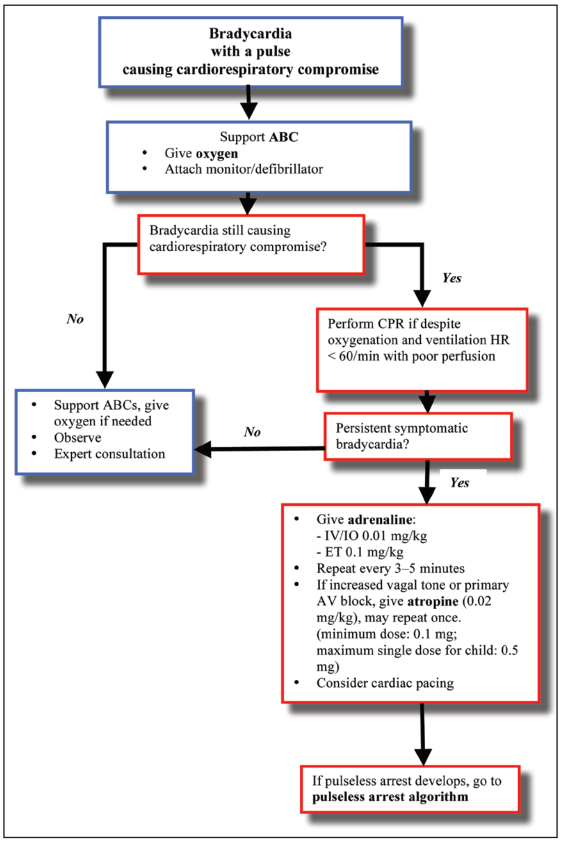
Box 3. Algorithm for pulseless arrest (non-shockable)



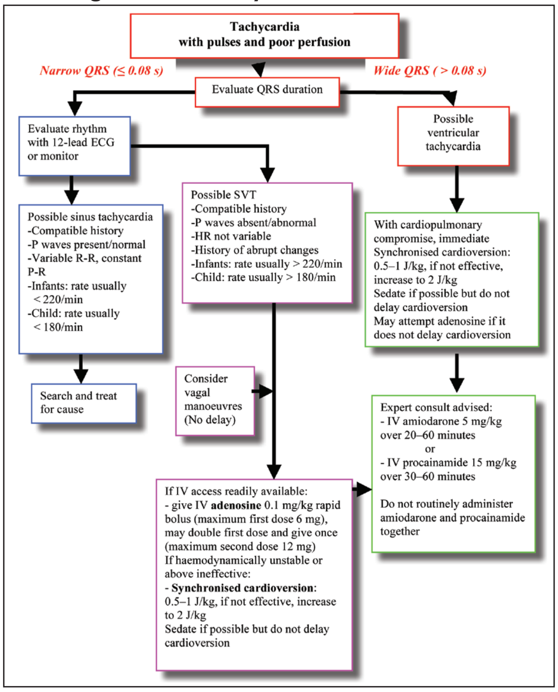
Box 4. Algorithm for pulseless arrest - shockable



Box 5. Algorithm for bradycardia



Box 6. Algorithm for tachycardia



Box 7. Algorithm for newborn resuscitation