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European Resuscitation Council Guidelines for Resuscitation 2010 Section 7. Resuscitation of babies at birth

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Introduction

The following guidelines for resuscitation at birth have been developed during the process that culminated in the 2010 International Consensus Conference on Emergency Cardiovascular Care (ECC) and Cardiopulmonary Resuscitation (CPR) Science with Treatment Recommendations.[1,2] They are an extension of the guidelines already published by the ERC[3] and take into account recommendations made by other national and international organisations.

Summary of changes since 2005 Guidelines

The following are the main changes that have been made to the guidelines for resuscitation at birth in 2010:

- For uncompromised babies, a delay in cord clamping of at least 1 min from the complete delivery of the infant, is now recommended. As yet there is insufficient evidence to recommend an appropriate time for clamping the cord in babies who are severely compromised at birth.
- For term infants, air should be used for resuscitation at birth. If, despite effective ventilation, oxygenation (ideally guided by oximetry) remains unacceptable, use of a higher concentration of oxygen should be considered.
- Preterm babies less than 32 weeks gestation may not reach the same arterial blood oxygen saturations in air as those achieved by term babies. Therefore blended oxygen and air should be given judiciously and its use guided by pulse oximetry. If a blend of oxygen and air is not available use what is available.
- Preterm babies of less than 28 weeks gestation should be completely covered in a food-grade plastic wrap or bag up to their necks, without drying, immediately after birth. They should then be nursed under a radiant heater and stabilised. They should remain wrapped until their temperature has been checked after admission. For these infants delivery room temperatures should be at least 26 °C.
- The recommended compression:ventilation ratio for CPR remains at 3:1 for newborn resuscitation.
- Attempts to aspirate meconium from the nose and mouth of the unborn baby, while the head is still on the perineum, are not recommended. If presented with a floppy, apnoeic baby born through meconium it is reasonable to rapidly inspect the oropharynx to remove potential obstructions. If appropriate expertise is available, tracheal intubation and suction may be useful. However, if attempted intubation is prolonged or unsuccessful, start mask ventilation, particularly if there is persistent bradycardia.
- If adrenaline (epinephrine) is given then the intravenous route is recommended using a dose of 10–30 $\mu g\,kg^{-1}$. If the tracheal route is used, it is likely that a dose of at least 50–100 $\mu g\,kg^{-1}$ will be needed to achieve a similar effect to 10 $\mu g\,kg^{-1}$ intravenously.
- Detection of exhaled carbon dioxide in addition to clinical assessment is recommended as the most reliable method to confirm placement of a tracheal tube in neonates with spontaneous circulation.
- Newly born infants born at term or near-term with evolving moderate to severe hypoxic–ischemic encephalopathy should, where possible, be offered therapeutic hypothermia. This does not affect immediate resuscitation but is important for post-resuscitation care.

The guidelines that follow do not define the only way that resuscitation at birth should be achieved; they merely represent a widely accepted view of how resuscitation at birth can be carried out both safely and effectively (Fig. 7.1).

Preparation

Relatively few babies need any resuscitation at birth. Of those that do need help, the overwhelming majority will require only assisted lung aeration. A small minority may need a brief period of chest compressions in addition to lung aeration. Of 100,000 babies born in Sweden in 1 year, only 10 per 1000 (1%) babies of 2.5 kg or more appeared to need resuscitation at delivery.[4] Of those babies

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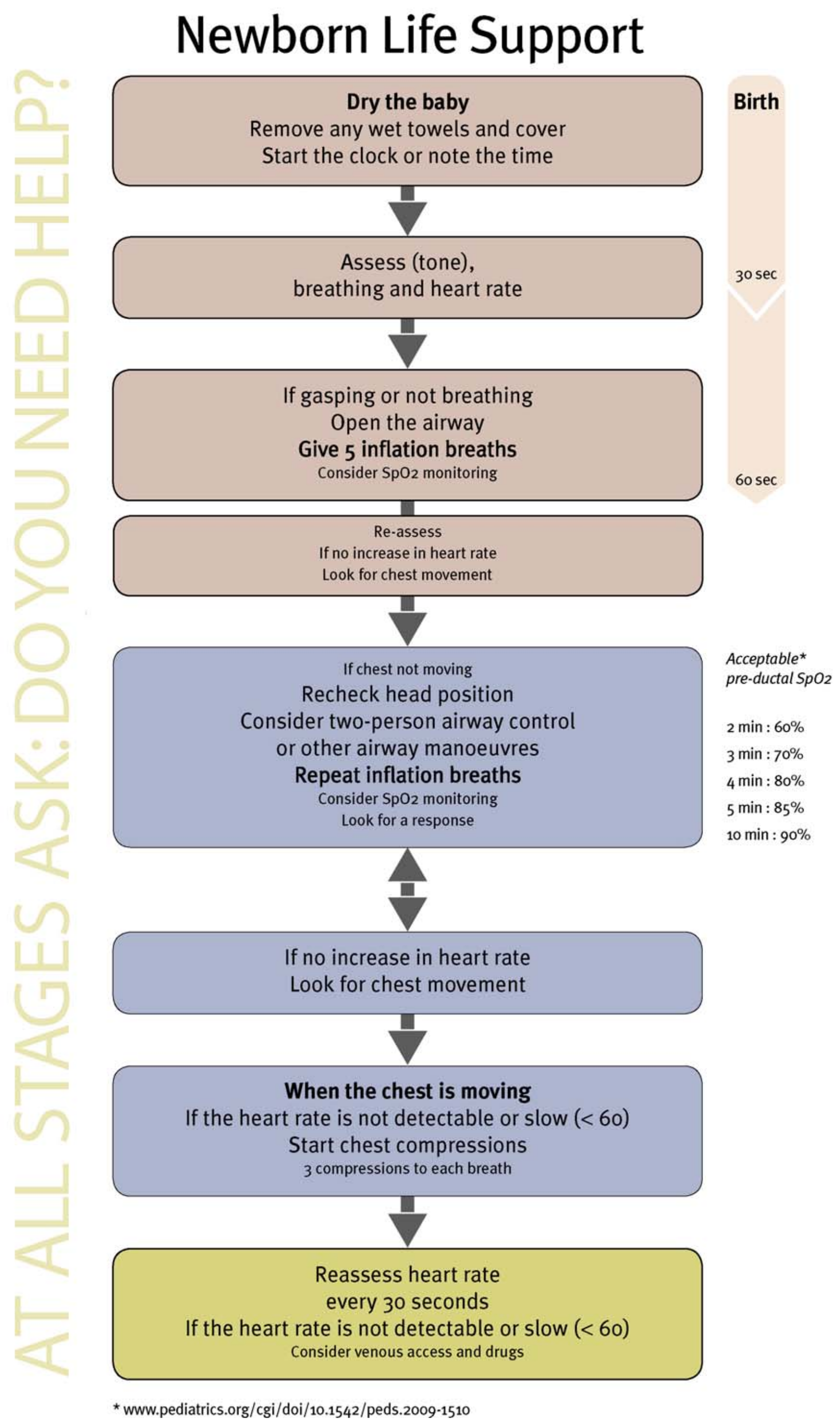

Fig. 7.1. Newborn life support algorithm.

receiving resuscitation, 8 per 1000 responded to mask inflation and only 2 per 1000 appeared to need intubation. The same study tried to assess the unexpected need for resuscitation at birth and found that for low risk babies, i.e. those born after 32 weeks gestation and following an apparently normal labour, about 2 per 1000 (0.2%) appeared to need resuscitation at delivery. Of these, 90% responded to mask inflation alone while the remaining 10% appeared not to respond to mask inflation and therefore were intubated at birth.

Resuscitation or specialist help at birth is more likely to be needed by babies with intrapartum evidence of significant fetal compromise, babies delivering before 35 weeks gestation, babies delivering vaginally by the breech, and multiple pregnancies. Although it is often possible to predict the need for resuscitation or stabilisation before a baby is born, this is not always the case. Therefore, personnel trained in newborn life support should be easily available at every delivery and, should there be any need for intervention, the care of the baby should be their sole responsibility. One person experienced in tracheal intubation of the newborn should ideally be in attendance for deliveries associated with a high risk of requiring neonatal resuscitation. Local guidelines indicating who should attend deliveries should be developed, based on current practice and clinical audit.

An organised educational programme in the standards and skills required for resuscitation of the newborn is therefore essential for any institution in which deliveries occur.

Planned home deliveries

Recommendations as to who should attend a planned home delivery vary from country to country, but the decision to undergo a planned home delivery, once agreed with medical and midwifery staff, should not compromise the standard of initial resuscitation at birth. There will inevitably be some limitations to resuscitation of a newborn baby in the home, because of the distance from further assistance, and this must be made clear to the mother at the time plans for home delivery are made. Ideally, two trained professionals should be present at all home deliveries; one of these must be fully trained and experienced in providing mask ventilation and chest compressions in the newborn.

Equipment and environment

Unlike adult CPR, resuscitation at birth is often a predictable event. It is therefore possible to prepare the environment and the equipment before delivery of the baby. Resuscitation should ideally take place in a warm, well-lit, draught free area with a flat resuscitation surface placed below a radiant heater, with other resuscitation equipment immediately available. All equipment must be checked frequently.

When a birth takes place in a non-designated delivery area, the recommended minimum set of equipment includes a device for safe assisted lung aeration of an appropriate size for the newborn, warm dry towels and blankets, a sterile instrument for cutting the umbilical cord and clean gloves for the attendant and assistants. It may also be helpful to have a suction device with a suitably sized suction catheter and a tongue depressor (or laryngoscope) to enable the oropharynx to be examined. Unexpected deliveries outside hospital are most likely to involve emergency services who should plan for such events.

Temperature control

Naked, wet, newborn babies cannot maintain their body temperature in a room that feels comfortably warm for adults. Compromised babies are particularly vulnerable.[5] Exposure of the newborn to cold stress will lower arterial oxygen tension[6] and increase metabolic acidosis.[7] Prevent heat loss:

- Protect the baby from draughts.
- Keep the delivery room warm. For babies less than 28 weeks gestation the delivery room temperature should be 26 °C.[8,9]
- Dry the term baby immediately after delivery. Cover the head and body of the baby, apart from the face, with a warm towel to prevent further heat loss. Alternatively, place the baby skin to skin with mother and cover both with a towel.
- If the baby needs resuscitation then place the baby on a warm surface under a preheated radiant warmer.
- In very preterm babies (especially below 28 weeks) drying and wrapping may not be sufficient. A more effective method of keeping these babies warm is to cover the head and body of the baby (apart from the face) with plastic wrapping, without drying the baby beforehand, and then to place the baby so covered under radiant heat.

Initial assessment

The Apgar score was proposed as a “simple, common, clear classification or grading of newborn infants” to be used “as a basis for discussion and comparison of the results of obstetric practices, types of maternal pain relief and the *effects* of resuscitation” (our emphasis).[10] It was not designed to be assembled and ascribed in order to then identify babies in need of resuscitation.[11] However, individual components of the score, namely respiratory rate, heart rate and tone, if assessed rapidly, can identify babies needing resuscitation (and Virginia Apgar herself found that heart rate was the most important predictor of immediate outcome).[10] Furthermore, repeated assessment particularly of heart rate and, to a lesser extent breathing, can indicate whether the baby is responding or whether further efforts are needed.

Breathing

Check whether the baby is breathing. If so, evaluate the rate, depth and symmetry of breathing together with any evidence of an abnormal breathing pattern such as gasping or grunting.

Heart rate

This is best assessed by listening to the apex beat with a stethoscope. Feeling the pulse in the base of the umbilical cord is often effective but can be misleading, cord pulsation is only reliable if found to be more than 100 beats per minute (bpm).[12] For babies requiring resuscitation and/or continued respiratory support, a modern pulse oximeter can give an accurate heart rate.[13]

Colour

Colour is a poor means of judging oxygenation,[14] which is better assessed using pulse oximetry if possible. A healthy baby is born blue but starts to become pink within 30 s of the onset of effective breathing. Peripheral cyanosis is common and does not, by itself, indicate hypoxemia. Persistent pallor despite ventilation may indicate significant acidosis or rarely hypovolaemia. Although colour is a poor method of judging oxygenation, it should not be ignored: if a baby appears blue check oxygenation with a pulse oximeter.

Tone

A very floppy baby is likely to be unconscious and will need ventilatory support.

Tactile stimulation

Drying the baby usually produces enough stimulation to induce effective breathing. Avoid more vigorous methods of stimulation. If the baby fails to establish spontaneous and effective breaths following a brief period of stimulation, further support will be required.

Classification according to initial assessment

On the basis of the initial assessment, the baby can be placed into one of three groups:

1. **Vigorous breathing or crying**
   Good tone
   Heart rate higher than 100 min^{-1}
   This baby requires no intervention other than drying, wrapping in a warm towel and, where appropriate, handing to the

mother. The baby will remain warm through skin-to-skin contact with mother under a cover, and may be put to the breast at this stage.

2. **Breathing inadequately or apnoeic**
   Normal or reduced tone
   Heart rate less than 100 min^{-1}
   Dry and wrap. This baby may improve with mask inflation but if this does not increase the heart rate adequately, may also require chest compressions.
3. **Breathing inadequately or apnoeic**
   Floppy
   Low or undetectable heart rate
   Often pale suggesting poor perfusion
   Dry and wrap. This baby will then require immediate airway control, lung inflation and ventilation. Once this has been successfully accomplished the baby may also need chest compressions, and perhaps drugs.

There remains a very rare group of babies who, though breathing adequately and with a good heart rate, remain hypoxaemic. This group includes a range of possible diagnoses such as diaphragmatic hernia, surfactant deficiency, congenital pneumonia, pneumothorax, or cyanotic congenital heart disease.

Newborn life support

Commence newborn life support if assessment shows that the baby has failed to establish adequate regular normal breathing, or has a heart rate of less than 100 min^{-1}. Opening the airway and aerating the lungs is usually all that is necessary. Furthermore, more complex interventions will be futile unless these two first steps have been successfully completed.

Airway

Place the baby on his or her back with the head in a neutral position (Fig. 7.2). A 2 cm thickness of the blanket or towel placed under the baby's shoulder may be helpful in maintaining proper head position. In floppy babies application of jaw thrust or the use of an appropriately sized oropharyngeal airway may be helpful in opening the airway.

Suction is needed only if the airway is obstructed. Obstruction may be caused by particulate meconium but can also be caused by blood clots, thick tenacious mucus or vernix even in deliveries where meconium staining is not present. However, aggressive pharyngeal suction can delay the onset of spontaneous breathing and cause laryngeal spasm and vagal bradycardia.[15] The presence of thick meconium in a non-vigorous baby is the only indication for *considering* immediate suction of the oropharynx. If suction is

Fig. 7.2. Newborn with head in neutral position.

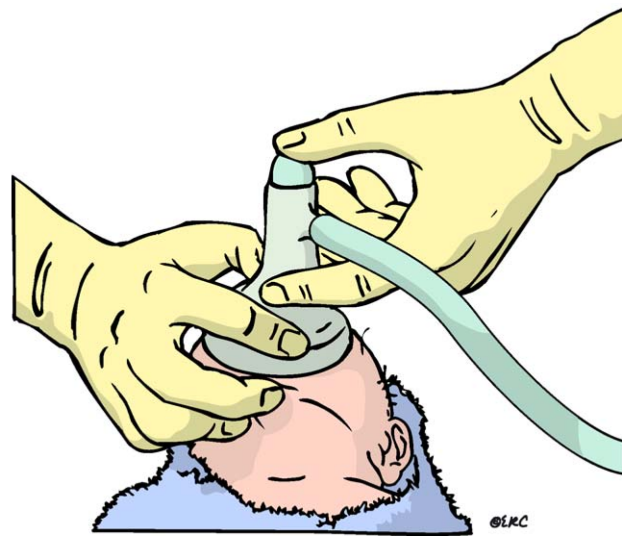

Fig. 7.3. Mask ventilation of newborn.

attempted this is best done under direct vision. Connect a 12–14 FG suction catheter, or a Yankauer sucker, to a suction source not exceeding minus 100 mm Hg.

Breathing

After initial steps at birth, if breathing efforts are absent or inadequate, lung aeration is the priority (Fig. 7.3). In term babies, begin resuscitation with air. The primary measure of adequate initial lung inflation is a prompt improvement in heart rate; assess chest wall movement if heart rate does not improve.

For the first five inflation breaths maintain the initial inflation pressure for 2–3 s. This will help lung expansion. Most babies needing resuscitation at birth will respond with a rapid increase in heart rate within 30 s of lung inflation. If the heart rate increases but the baby is not breathing adequately, ventilate at a rate of about 30 breaths min^{-1} allowing approximately 1 s for each inflation, until there is adequate spontaneous breathing.

Adequate passive ventilation is usually indicated by either a rapidly increasing heart rate or a heart rate that is maintained faster than 100 min^{-1}. If the baby does not respond in this way the most likely cause is inadequate airway control or inadequate ventilation. Look for passive chest movement in time with inflation efforts; if these are present then lung aeration has been achieved. If these are absent then airway control and lung aeration has not been confirmed. Without adequate lung aeration, chest compressions will be ineffective; therefore, confirm lung aeration before progressing to circulatory support.

Some practitioners will ensure airway control by tracheal intubation, but this requires training and experience. If this skill is not available and the heart rate is decreasing, re-evaluate the airway position and deliver inflation breaths while summoning a colleague with intubation skills.

Continue ventilatory support until the baby has established normal regular breathing.

Circulatory support

Circulatory support with chest compressions is effective only if the lungs have first been successfully inflated. Give chest compressions if the heart rate is less than 60 min^{-1} despite adequate ventilation.

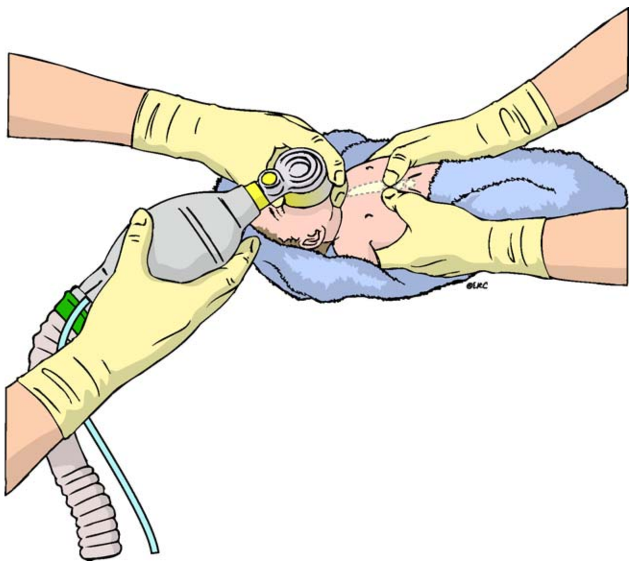

Fig. 7.4. Ventilation and chest compression of newborn.

The most effective technique for providing chest compressions is to place the two thumbs side by side over the lower third of the sternum just below an imaginary line joining the nipples, with the fingers encircling the torso and supporting the back (Fig. 7.4).[16–19] An alternative way to find the correct position of the thumbs is to identify the xiphisternum and then to place the thumbs on the sternum one finger's breadth above this point. The sternum is compressed to a depth of approximately one-third of the anterior–posterior diameter of the chest allowing the chest wall to return to its relaxed position between compressions.[20]

Use a ratio of three compressions to one ventilation, aiming to achieve approximately 120 events per minute, i.e. approximately 90 compressions and 30 ventilations. There are theoretical advantages to allowing a relaxation phase that is very slightly longer than the compression phase.[21] However, the quality of the compressions and breaths are probably more important than the rate.

Check the heart rate after about 30 s and every 30 s thereafter. Discontinue chest compressions when the spontaneous heart rate is faster than 60 min^{-1}.

Drugs

Drugs are rarely indicated in resuscitation of the newly born infant. Bradycardia in the newborn infant is usually caused by inadequate lung inflation or profound hypoxia, and establishing adequate ventilation is the most important step to correct it. However, if the heart rate remains less than 60 min^{-1} despite adequate ventilation and chest compressions, it is reasonable to consider the use of drugs. These are best given via an umbilical venous catheter (Fig. 7.5).

Adrenaline

Despite the lack of human data it is reasonable to use adrenaline when adequate ventilation and chest compressions have failed to increase the heart rate above 60 min^{-1}. If adrenaline is used, a dose of 10–30 $\mu g\,kg^{-1}$ should be administered *intravenously* as soon as possible.

The tracheal route is not recommended (see below) but if it is used, it is highly likely that doses of 50–100 $\mu g\,kg^{-1}$ will be required. Neither the safety nor the efficacy of these higher tracheal doses has been studied. Do *not* give these high doses intravenously.

Bicarbonate

If effective spontaneous cardiac output is not restored despite adequate ventilation and adequate chest compressions, reversing intracardiac acidosis may improve myocardial function and achieve a spontaneous circulation. There are insufficient data to recommend routine use of bicarbonate in resuscitation of the newly born. The hyperosmolarity and carbon dioxide-generating properties of sodium bicarbonate may impair myocardial and cerebral function. Use of sodium bicarbonate is discouraged during brief CPR. If it is used during prolonged arrests unresponsive to other therapy, it should be given only after adequate ventilation and circulation is established with CPR. A dose of 1–2 $mmol\,kg^{-1}$ may be given by slow intravenous injection after adequate ventilation and perfusion have been established.

Fluids

If there has been suspected blood loss or the infant appears to be in shock (pale, poor perfusion, weak pulse) and has not responded adequately to other resuscitative measures then consider giving fluid.[22] This is a rare event. In the absence of suitable blood (i.e. irradiated and leucocyte-depleted group O Rh-negative blood), isotonic crystalloid rather than albumin is the solution of choice for restoring intravascular volume. Give a bolus of 10 $ml\,kg^{-1}$ initially. If successful it may need to be repeated to maintain an improvement.

Stopping resuscitation

Local and national committees will determine the indications for stopping resuscitation. If the heart rate of a newly born baby is not detectable and remains undetectable for 10 min, it is then appropriate to consider stopping resuscitation. The decision to continue resuscitation efforts when the heart rate has been undetectable for longer than 10 min is often complex and may be influenced by issues such as the presumed aetiology, the gestation of the baby, the potential reversibility of the situation, and the parents' previous expressed feelings about acceptable risk of morbidity.

In cases where the heart rate is less than 60 min^{-1} at birth and does not improve after 10 or 15 min of continuous and apparently adequate resuscitative efforts, the choice is much less clear. In this situation there is insufficient evidence about outcome to enable firm guidance on whether to withhold or to continue resuscitation.

Communication with the parents

It is important that the team caring for the newborn baby informs the parents of the baby's progress. At delivery, adhere to

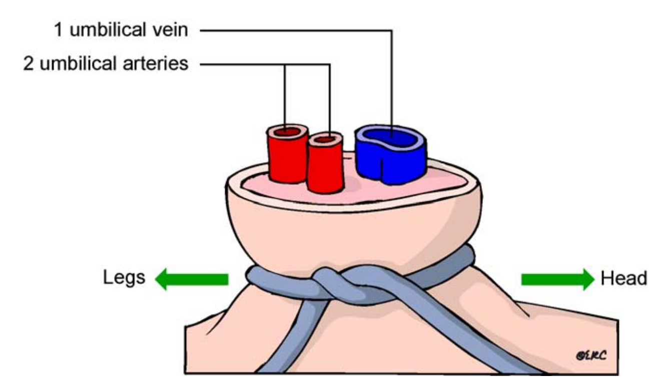

Fig. 7.5. Newborn umbilical cord showing the arteries and veins.

the routine local plan and, if possible, hand the baby to the mother at the earliest opportunity. If resuscitation is required inform the parents of the procedures undertaken and why they were required.

Decisions to discontinue resuscitation should ideally involve senior paediatric staff. Whenever possible, the decision to attempt resuscitation of an extremely preterm baby should be taken in close consultation with the parents and senior paediatric and obstetric staff. Where a difficulty has been foreseen, for example in the case of severe congenital malformation, discuss the options and prognosis with the parents, midwives, obstetricians and birth attendants before delivery.[23] Record carefully all discussions and decisions in the mother's notes prior to delivery and in the baby's records after birth.

Specific questions addressed at the 2010 Consensus Conference on CPR Science

Maintaining normal temperature in preterm infants

Significantly preterm babies are likely to become hypothermic despite careful application of the traditional techniques for keeping them warm (drying, wrapping and placing under radiant heat).[24] Several randomised controlled trials and observational studies have shown that placing the preterm baby under radiant heat and then covering the baby with food-grade plastic wrapping without drying them, significantly improves temperature on admission to intensive care compared with traditional techniques.[25–27] The baby's temperature must be monitored closely because of the small but described risk of inducing hyperthermia with this technique.[28] All resuscitation procedures including intubation, chest compression and insertion of lines, can be achieved with the plastic cover in place. Significantly preterm babies maintain their temperature better when the ambient temperature of the delivery room is 26 °C or higher.[8,9]

Infants born to febrile mothers have a higher incidence of perinatal respiratory depression, neonatal seizures, early mortality, and cerebral palsy.[28–30] Animal studies indicate that hyperthermia during or following ischaemia is associated with a progression of cerebral injury.[31,32] Hyperthermia should be avoided.

Meconium

In the past it was hoped that clearing meconium from the airway of babies at birth would reduce the incidence and severity of meconium aspiration syndrome (MAS). However, studies supporting this view were based on a comparison of suctioning on the outcome of a group of babies with the outcome of historical controls.[33,34] Furthermore other studies failed to find any evidence of benefit from this practice.[35,36] More recently, a multi-centre randomised controlled trial reported in 2000[37] showed that routine elective intubation and suctioning of these infants, if vigorous at birth, did not reduce MAS and a further randomised study published in 2004 showed that suctioning the nose and mouth of such babies on the perineum and before delivery of the shoulders (intrapartum suctioning) was also ineffective.[38] Intrapartum suctioning and routine intubation and suctioning of vigorous infants born through meconium-stained liquor are not recommended. There remains the question of what to do with non-vigorous infants in this situation. Observational studies have confirmed that these babies are at increased risk of meconium aspiration syndrome but there have been no randomised studies of the effect of intubation followed by suctioning versus no intubation in this group.

Recommendation: In the absence of randomised, controlled trials, there is insufficient evidence to recommend a change in the current practice of performing direct oropharyngeal and tracheal suctioning of *non-vigorous babies* with meconium-stained amniotic fluid, if feasible. However, if attempted intubation is prolonged or unsuccessful, mask ventilation should be implemented, particularly if there is persistent bradycardia.

Air or 100% oxygen

For the newly born infant in need of resuscitation at birth, the rapid establishment of pulmonary gas exchange to replace the failure of placental respiration is the key to success. In the past it has seemed reasonable that delivery of a high concentration of oxygen to the tissues at risk of hypoxia might help to reduce the number of cells which were damaged by the anaerobic process. However, in the last 30 years the 'oxygen paradox' – the fact that cell and tissue injury is increased if hypoxic tissue is then exposed to high concentrations of oxygen – has been recognized, the role of free radicals, antioxidants and their link with apoptosis and reperfusion injury has been explored, and the idea of oxidative stress established. In the light of this knowledge it has become increasingly difficult to sustain the idea that exposure to high concentrations of oxygen, however brief, is without risk. Furthermore, randomised studies in asphyxiated newborn babies strongly suggest that air is certainly as effective as 100% oxygen, if not more effective, at least in the short term.[39]

There is also abundant evidence from animal and human studies that hyperoxaemia alone is damaging to the brain and other organs at the cellular level, particularly after asphyxia. Animal studies suggest that the risk is greatest to the immature brain during the brain growth spurt (mid-pregnancy to 3 years).[40] These risks include deleterious effects on glial progenitor cells and myelination.[41]

Other issues include concerns that pulmonary vascular resistance may take longer to resolve if air is used rather than oxygen for lung inflation at birth. However, though two studies have shown that it may be reduced a little further and a little faster by use of oxygen rather than air, there is a price to pay. Exposure to high concentrations of oxygen at birth results in the creation of increased reactive oxygen species which, in turn, reduces the potential for pulmonary artery vaso-relaxation later in the neonatal course.

There are now numerous reports of oximetry data following delivery. When using technology available from the early 2000 s, a reliable reading can be obtained from >90% of normal term births, approximately 80% of those born preterm, and 80–90% of those apparently requiring resuscitation, within 2 min of birth.[42] Uncompromised babies born at term at sea level have SaO_2 ~60% during labour,[43] which increases to >90% by 10 min.[44] The 25th percentile is approximately 40% at birth and increases to ~80% at 10 min.[45] Values are lower in those born by Caesarean section[46] and those born at altitude.[47] Those born preterm may take longer to reach >90%.[45] Those given supplemental oxygen had a higher incidence of SaO_2 >95%, even when a protocol to decrease the FiO_2 was implemented, although the extent of this was restricted by insufficient power and the particular protocols used in the studies.[48,49]

Recommendation: In term infants receiving resuscitation at birth with positive-pressure ventilation, it is best to begin with air as opposed to 100% oxygen. If, despite effective ventilation, there is no increase in heart rate or oxygenation (guided by oximetry wherever possible) remains unacceptable, use a higher concentration of oxygen.

As many preterm babies less than 32 weeks gestation will not achieve target values for transcutaneous oxygen saturation in air, blended oxygen and air may be given judiciously and ideally guided by pulse oximetry. Both hyperoxaemia and hypoxemia should be avoided. If a blend of oxygen and air is not available, resuscitation should be initiated with air.

Timing of cord clamping

Cine-radiographic studies of babies taking their first breath at delivery showed that those whose cords were clamped prior to this had an immediate decrease in the size of the heart during the subsequent three or four cardiac cycles. The heart then increased in size to almost the same size as the fetal heart. The initial decrease in size could be interpreted as being due to filling of the of the newly-opened pulmonary vascular system during aeration with the subsequent increase in size occurring as a consequence of blood returning to the heart from the lung.[50] Brady and James drew attention to the occurrence of a bradycardia apparently induced by clamping the cord before the first breath and noted that this did not occur in babies where clamping occurred after breathing was established.[51] Might such early clamping of the cord in a significantly preterm infant, whose ability to inflate his lungs by generating negative intrathoracic pressures is already compromised, either induce or prolong a bradycardia leading to a 'need' for resuscitation?

Studies in term infants clamped late have shown an improvement in iron status and a number of other haematological indices over the next 3–6 months. They have also shown greater use of phototherapy for jaundice in the delayed group but the use of phototherapy was neither controlled nor defined and many would regard this of little consequence.

Studies in preterm infants have consistently shown improved stability in the immediate postnatal period and reduced exposure to blood transfusion in the ensuing weeks. Some studies have suggested a reduced incidence of intraventricular haemorrhage and of late-onset sepsis.[52] Again some studies report increased jaundice and use of phototherapy but there have been no reports of increased use of exchange transfusion.

Studies have not addressed any effect of delaying cord clamping on babies apparently needing resuscitation at birth because such babies have been excluded.

Recommendation: Delay in umbilical cord clamping for at least 1 min is recommended for newborn infants not requiring resuscitation. A similar delay should be applied to premature babies being stabilised. For babies requiring resuscitation, resuscitative intervention remains the priority.

Initial breaths and assisted ventilation

In term infants, spontaneous or assisted initial inflations create a functional residual capacity (FRC).[53–59] The optimum pressure, inflation time and flow required to establish an effective FRC has not been determined. Average initial peak inflating pressures of 30–40 cm H_2O (inflation time undefined) usually ventilate unresponsive term infants successfully.[54,56,57,59] Assisted ventilation rates of 30–60 breaths min^{-1} are used commonly, but the relative efficacy of various rates has not been investigated.

Where pressure is being monitored, an initial inflation pressure of 20 cm H_2O may be effective, but 30–40 cm H_2O or higher may be required in some term babies. If pressure is not being monitored but merely limited by a non-adjustable 'blow-off' valve, use the minimum inflation required to achieve an increase in heart rate. There is insufficient evidence to recommend an optimum inflation time. In summary, try to provide artificial ventilation at 30–60 breaths min^{-1} to achieve or maintain a heart rate higher than 100 min^{-1} promptly.

Assisted ventilation of preterm infants

Animal studies show that preterm lungs are easily damaged by large-volume inflations immediately after birth[60] and that maintaining a positive end expiratory pressure (PEEP) immediately after birth protects against lung damage. Positive end expiratory pressure also improves lung compliance and gas exchange.[61,62]

Both over-inflation and repeated collapse of the alveoli have been shown to cause damage in animal studies. Inflation pressure is measured in an imperfect attempt to limit tidal volume. Ideally tidal volume would be measured, and after lung aeration, limited to between 4 and 8 ml kg^{-1} to avoid over-distension.[63]

When ventilating preterm infants, very obvious passive chest wall movement may indicate excessive tidal volumes and should be avoided. Monitoring of pressure may help to provide consistent inflations and avoid high pressures. If positive-pressure ventilation is required, an initial inflation pressure of 20–25 cm H_2O is adequate for most preterm infants.[64,65] If a prompt increase in heart rate or chest movement is not obtained, higher pressures may be needed. If continued positive-pressure ventilation is required, PEEP may be beneficial. Continuous positive airway pressure (CPAP) in spontaneously breathing preterm infants following resuscitation may also be beneficial.[65]

Devices

Effective ventilation can be achieved with a flow-inflating, a self-inflating bag or with a T-piece mechanical device designed to regulate pressure.[66–68] The blow-off valves of self-inflating bags are flow-dependent and pressures generated may exceed the value specified by the manufacturer if compressed vigoruously.[69] Target inflation pressures and long inspiratory times are achieved more consistently in mechanical models when using T-piece devices than when using bags,[70] although the clinical implications are not clear. More training is required to provide an appropriate pressure using flow-inflating bags compared with self-inflating bags.[71] A self-inflating bag, a flow-inflating bag, or a T-piece mechanical device, all designed to regulate pressure or limit pressure applied to the airway, can be used to ventilate a newborn.

Laryngeal mask airways

A number of studies have shown that laryngeal mask airways (LMAs) can be effectively used at birth to ventilate babies weighing over 2000 g, greater than 33 weeks gestation and apparently needing resuscitation. Case reports suggest that laryngeal masks have been successfully used when intubation has been tried and failed – and occasionally vice-versa. There are few data on smaller or less mature babies.

Recommendation: The laryngeal mask airway can be used in resuscitation of the newborn, particularly if facemask ventilation is unsuccessful or tracheal intubation is unsuccessful or not feasible. The laryngeal mask airway may be considered as an alternative to a facemask for positive-pressure ventilation among newborns weighing more than 2000 g or delivered ≥34 weeks gestation. There is limited evidence, however, to evaluate its use for newborns weighing <2000 g or delivered <34 weeks gestation. The laryngeal mask airway may be considered as an alternative to tracheal intubation as a secondary airway for resuscitation among newborns weighing more than 2000 g or delivered ≥34 weeks gestation.[72–74] The laryngeal mask airway has not been evaluated in the setting of meconium-stained fluid, during chest compressions, or for the administration of emergency intra-tracheal medications.

Carbon dioxide detection with face mask or LMA ventilation

Colorimetric exhaled CO_2 detectors have been used during mask ventilation of a few preterm infants in the intensive care unit[75] and

Table 7.1
Oral tracheal tube lengths by gestation.

Gestation (weeks)	Tracheal tube at lips (cm)
23–24	5.5
25–26	6.0
27–29	6.5
30–32	7.0
33–34	7.5
35–37	8.0
38–40	8.5
41–43	9.0

in the delivery room,[76] and may help to identify airway obstruction. Neither additional benefit above clinical assessment alone, nor risks attributed to their use have been identified. The use of exhaled CO_2 detectors with other interfaces (e.g. nasal airways, laryngeal masks) during PPV in the delivery room has not been reported.

Confirming tracheal tube placement

Tracheal intubation may be considered at several points during neonatal resuscitation:

- When suctioning to remove meconium or other tracheal blockage is required.
- If bag-mask ventilation is ineffective or prolonged.
- When chest compressions are performed.
- Special circumstances (e.g. congenital diaphragmatic hernia or birth weight below 1000 g).

The use and timing of tracheal intubation will depend on the skill and experience of the available resuscitators. Appropriate tube lengths based on gestation are shown in Table 7.1.[77]

Tracheal tube placement must be assessed visually during intubation, and positioning confirmed. Following tracheal intubation and intermittent positive-pressure, a prompt increase in heart rate is a good indication that the tube is in the tracheobronchial tree.[78] Exhaled CO_2 detection is effective for confirmation of tracheal tube placement in infants, including VLBW infants[79–82] and neonatal studies suggest that it confirms tracheal intubation in neonates with a cardiac output more rapidly and more accurately than clinical assessment alone.[81–83] Failure to detect exhaled CO_2 strongly suggests oesophageal intubation[79,81] but false negative readings have been reported during cardiac arrest[79] and in VLBW infants despite models suggesting efficacy.[84] However, neonatal studies have excluded infants in need of extensive resuscitation. There is no comparative information to recommend any one method for detection of exhaled carbon dioxide in the neonatal population. False positives may occur with colorimetric devices contaminated with adrenaline (epinephrine), surfactant and atropine.[75]

Poor or absent pulmonary blood flow or tracheal obstruction may prevent detection of exhaled CO_2 despite correct tracheal tube placement. Tracheal tube placement is identified correctly in nearly all patients who are not in cardiac arrest;[80] however, in critically ill infants with poor cardiac output, inability to detect exhaled CO_2 despite correct placement may lead to unnecessary extubation. Other clinical indicators of correct tracheal tube placement include evaluation of condensed humidified gas during exhalation and presence or absence of chest movement, but these have not been evaluated systematically in newborn babies.

Recommendation: Detection of exhaled carbon dioxide in addition to clinical assessment is recommended as the most reliable method to confirm tracheal placement in neonates with spontaneous circulation.

Route and dose of adrenaline (epinephrine)

Despite the widespread use of adrenaline during resuscitation, no placebo controlled clinical trials have evaluated its effectiveness, nor has the ideal dose or route of administration been defined.

Neonatal case series or case reports[85,86] indicate that adrenaline administered by the tracheal route using a wide range of doses (3–250 $\mu g\,kg^{-1}$) may be associated with return of spontaneous circulation (ROSC) or an increase in heart rate. These case series are limited by inconsistent standards for adrenaline administration and are subject to both selection and reporting bias.

One good quality case series indicates that tracheal adrenaline (10 $\mu g\,kg^{-1}$) is likely to be less effective than the same dose administered intravenously.[87] This is consistent with evidence extrapolated from neonatal animal models indicating that higher doses (50–100 $\mu g\,kg^{-1}$) of adrenaline may be required when given via the tracheal route to achieve the same blood adrenaline concentrations and haemodynamic response as achieved after intravenous administration.[88,89] Adult animal models demonstrate that blood concentrations of adrenaline are significantly lower following tracheal compared with intravenous administration[90,91] and that tracheal doses ranging from 50 to 100 $\mu g\,kg^{-1}$ may be required to achieve ROSC.[92]

Although it has been widely assumed that adrenaline can be given faster by the tracheal route than by the intravenous route, no clinical trials have evaluated this hypothesis. Two studies have reported cases of inappropriately early use of tracheal adrenaline before airway and breathing are established.[85,86] One case series describing in-hospital paediatric cardiac arrests suggested that survival was higher among infants who received their first dose of adrenaline by the tracheal route; however, the time required for first dose administration using the tracheal and intravenous routes were not provided.[93]

Paediatric[94,95] and newborn animal studies[96] showed no benefit and a trend toward reduced survival and worse neurological status after high-dose intravenous adrenaline (100 $mcg\,kg^{-1}$) during resuscitation. This is in contrast to a single paediatric case series using historic controls that indicated a marked improvement in ROSC using high-dose intravenous adrenaline (100 $mcg\,kg^{-1}$). However, a meta-analysis of five adult clinical trials indicates that whilst high-dose intravenous adrenaline may increase ROSC, it offers no benefit in survival to hospital discharge.[97]

Recommendation: If adrenaline is administered, give an intravenous dose 10–30 $\mu g\,kg^{-1}$ as soon as possible. Higher intravenous doses should not be given and may be harmful. If intravenous access is *not* available, then it may be reasonable to try tracheal adrenaline. If adrenaline is administered by the tracheal route, it is likely that a larger dose (50–100 $\mu g\,kg^{-1}$) will be required to achieve a similar effect to the 10 $\mu g\,kg^{-1}$ intravenous dose.

Post-resuscitation care

Babies who have required resuscitation may later deteriorate. Once adequate ventilation and circulation are established, the infant should be maintained in or transferred to an environment in which close monitoring and anticipatory care can be provided.

Glucose

Hypoglycaemia was associated with adverse neurological outcome in a neonatal animal model of asphyxia and resuscitation.[98] Newborn animals that were hypoglycaemic at the time of an anoxic or hypoxic–ischemic insult had larger areas of cerebral infarction and/or decreased survival compared to controls.[99,100] One clinical study demonstrated an association between hypoglycaemia and poor neurological outcome following perinatal asphyxia.[101] In adults, children and extremely low-birth-weight infants receiving intensive care, hyperglycaemia has been associated with a worse outcome.[102–104] However, in paediatric patients, hyperglycaemia *after hypoxia–ischaemia* does not appear to be harmful,[105] which confirms data from animal studies[106] some of which suggest it may be protective.[107] However, the range of blood glucose concentration that is associated with the least brain injury following asphyxia and resuscitation cannot be defined based on available evidence. Infants who require significant resuscitation should be monitored and treated to maintain glucose in the normal range.

Induced hypothermia

Several randomised, controlled, multi-centre trials of induced hypothermia (33.5–34.5 °C) of babies born at more than 36 weeks gestational age, with moderate to severe hypoxic–ischemic encephalopathy have shown that cooling significantly reduced death and neuro-developmental disability at 18 months.[108–111] Systemic and selective head cooling produced similar results.[109–113] Modest hypothermia may be associated with bradycardia and elevated blood pressure that do not usually require treatment, but a rapid increase in body temperature may cause hypotension.[114] Profound hypothermia (core temperature below 33 °C) may cause arrhythmia, bleeding, thrombosis, and sepsis, but studies so far have not reported these complications in infants treated with modest hypothermia.[109,115]

Newly born infants born at term or near-term with evolving moderate to severe hypoxic–ischemic encephalopathy should, where possible, be offered therapeutic hypothermia. Whole body cooling and selective head cooling are both appropriate strategies. Cooling should be initiated and conducted under clearly defined protocols with treatment in neonatal intensive care facilities and with the capabilities for multidisciplinary care. Treatment should be consistent with the protocols used in the randomised clinical trials (i.e. commence within 6 h of birth, continue for 72 h of birth and re-warm over at least 4 h). Animal data would strongly suggest that the effectiveness of cooling is related to early intervention. There is no evidence in human newborns that cooling is effective if started more than 6 h after birth. Carefully monitor for known adverse effects of cooling – thrombocytopenia and hypotension. All treated infants should be followed longitudinally.

Withholding or discontinuing resuscitation

Mortality and morbidity for newborns varies according to region and to availability of resources.[116] Social science studies indicate that parents desire a larger role in decisions to resuscitate and to continue life support in severely compromised babies.[117] Opinions vary amongst providers, parents and societies about the balance of benefits and disadvantages of using aggressive therapies in such babies.[118,119]

Withholding resuscitation

It is possible to identify conditions associated with high mortality and poor outcome, where withholding resuscitation may be considered reasonable, particularly when there has been the opportunity for discussion with parents.[24,120,121]

A consistent and coordinated approach to individual cases by the obstetric and neonatal teams and the parents is an important goal.[23] Withholding resuscitation and discontinuation of life-sustaining treatment during or following resuscitation are considered by many to be ethically equivalent and clinicians should not be hesitant to withdraw support when the possibility of functional survival is highly unlikely. The following guidelines must be interpreted according to current regional outcomes.

- Where gestation, birth weight, and/or congenital anomalies are associated with almost certain early death, and unacceptably high morbidity is likely among the rare survivors, resuscitation is not indicated.[122] Examples from the published literature include: extreme prematurity (gestational age less than 23 weeks and/or birthweight less than 400 g), and anomalies such as anencephaly and confirmed Trisomy 13 or 18.
- Resuscitation is nearly always indicated in conditions associated with a high survival rate and acceptable morbidity. This will generally include babies with gestational age of 25 weeks or above (unless there is evidence of fetal compromise such as intrauterine infection or hypoxia–ischaemia) and those with most congenital malformations.
- In conditions associated with uncertain prognosis, where there is borderline survival and a relatively high rate of morbidity, and where the anticipated burden to the child is high, parental desires regarding resuscitation should be supported.

Withdrawing resuscitation efforts

Data from infants without signs of life from birth, lasting at least 10 min or longer, show either high mortality or severe neurodevelopmental disability.[123,124] If faced with a newly born baby with no detectable heart rate which remains undetectable for 10 min, it is appropriate to then consider stopping resuscitation. The decision to continue resuscitation efforts when the infant has no detectable heart rate for longer than 10 min is often complex and may be influenced by issues such as the presumed aetiology of the arrest, the gestation of the baby, the potential reversibility of the situation, and the parents' previous expressed feelings about acceptable risk of morbidity.

If the heart rate is less than 60 min^{-1} at birth and persisting after 10 or 15 min the situation is even less clear and a firm recommendation cannot be made.

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