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European Resuscitation Council Guidelines for Resuscitation 2015 Section 7. Resuscitation and support of transition 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 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations (CoSTR, 2015).[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 and previously evaluated evidence.[4]

Summary of changes since 2010 guidelines

The following are the main changes that have been made to the guidelines for resuscitation at birth in 2015:

- **Support of transition**: Recognising the unique situation of the baby at birth, who rarely requires 'resuscitation' but sometimes needs medical help during the process of postnatal transition. The term 'support of transition' has been introduced to better distinguish between interventions that are needed to restore vital organ functions (resuscitation) or to support transition.
- **Cord clamping**: For uncompromised babies, a delay in cord clamping of at least 1 min from the complete delivery of the infant, is now recommended for term and preterm babies. As yet there is insufficient evidence to recommend an appropriate time for clamping the cord in babies who require resuscitation at birth.
- **Temperature**: The temperature of newly born non-asphyxiated infants should be maintained between 36.5 °C and 37.5 °C after birth. The importance of achieving this has been highlighted and reinforced because of the strong association with mortality and morbidity. The admission temperature should be recorded as a predictor of outcomes as well as a quality indicator.
- **Maintenance of temperature**: At <32 weeks gestation, a combination of interventions may be required to maintain the temperature between 36.5 °C and 37.5 °C after delivery through admission and stabilisation. These may include warmed humidified respiratory gases, increased room temperature plus plastic wrapping of body and head, plus thermal mattress or a thermal mattress alone, all of which have been effective in reducing hypothermia.
- **Optimal assessment of heart rate**: It is suggested in babies requiring resuscitation that the ECG can be used to provide a rapid and accurate estimation of heart rate.
- **Meconium**: Tracheal intubation should not be routine in the presence of meconium and should only be performed for suspected tracheal obstruction. The emphasis should be on initiating ventilation within the first minute of life in non-breathing or ineffectively breathing infants and this should not be delayed.
- **Air/Oxygen**: Ventilatory support of term infants should start with air. For preterm infants, either air or a low concentration of oxygen (up to 30%) should be used initially. If, despite effective ventilation, oxygenation (ideally guided by oximetry) remains unacceptable, use of a higher concentration of oxygen should be considered.
- **Continuous Positive Airways Pressure (CPAP)**: Initial respiratory support of spontaneously breathing preterm infants with respiratory distress may be provided by CPAP rather than intubation.

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).

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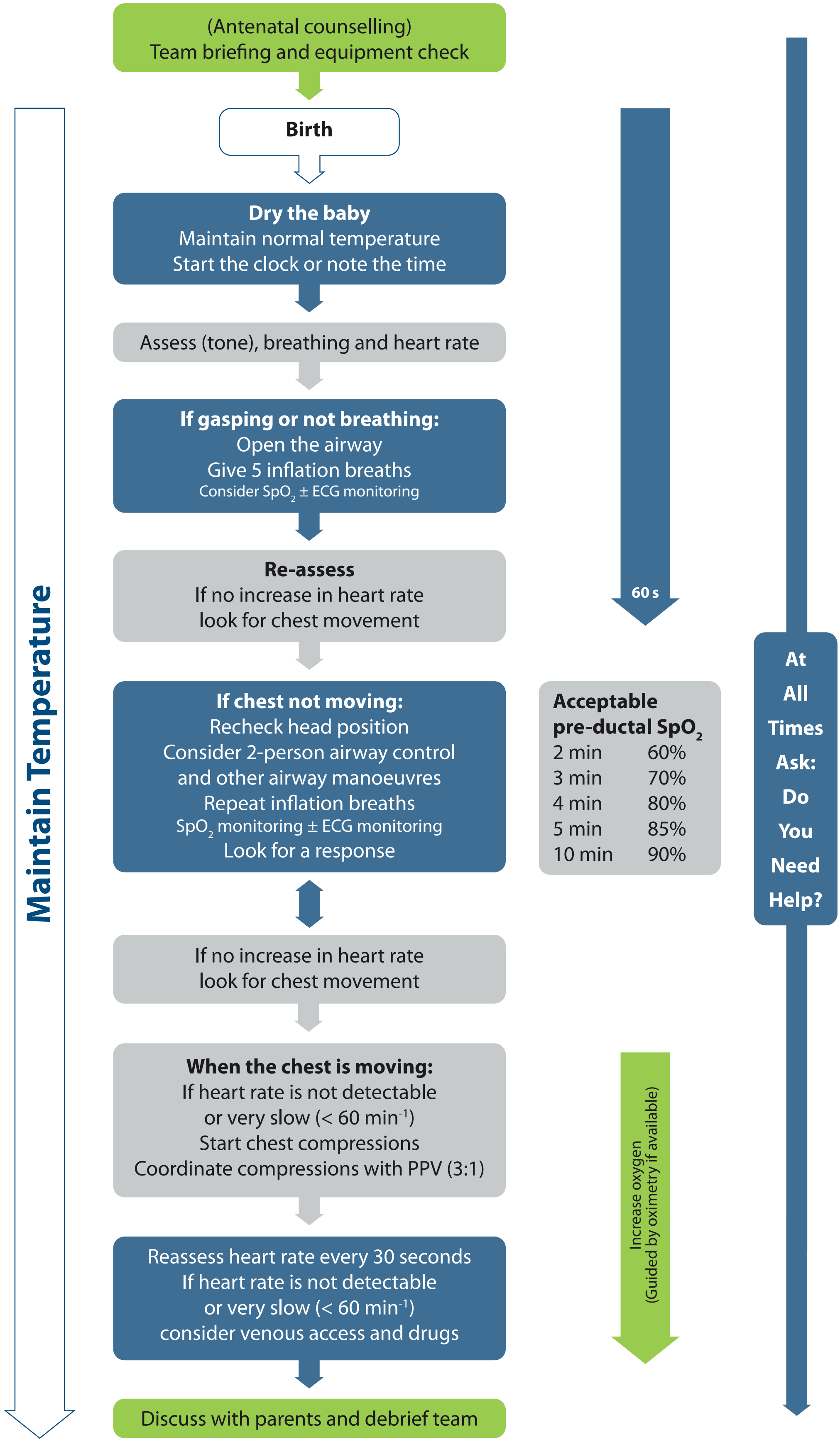

Fig. 7.1. Newborn life support algorithm. SpO_2: transcutaneous pulse oximetry, ECG: electrocardiograph, PPV: positive pressure ventilation.

Preparation

The fetal-to-neonatal transition, which occurs at the time of birth, requires anatomic and physiological adjustments to achieve the conversion from placental gas exchange with intra-uterine lungs filled with fluid, to pulmonary respiration with aerated lungs. The absorption of lung fluid, the aeration of the lungs, the initiation of air breathing, and cessation of the placental circulation bring about this transition.

A minority of infants require resuscitation at birth, but a few more have problems with this perinatal transition, which, if no support is given, might subsequently result in a need for resuscitation. Of those needing any help, the overwhelming majority will require only assisted lung aeration. A tiny minority may need a brief period of chest compressions in addition to lung aeration. In a retrospective study, approximately 85% of babies born at term initiated spontaneous respirations within 10 to 30 s of birth; an additional 10% responded during drying and stimulation, approximately 3% initiated respirations following positive pressure ventilation, 2% were intubated to support respiratory function and 0.1% received chest compressions and/or adrenaline.[5–7] However, of 97,648 babies born in Sweden in one year, only 10 per 1000 (1%) babies of 2.5 kg or more appeared to need any resuscitation at delivery.[8] Most of those, 8 per 1000, responded to mask inflation of the lungs 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 or help with transition at delivery. Of these, 90% responded to mask ventilation alone while the remaining 10% appeared not to respond to mask inflation and therefore were intubated at birth. There was almost no need for cardiac compressions.

Resuscitation or support of transition 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, maternal infection and multiple pregnancies.[9] Furthermore, caesarean delivery is associated with an increased risk of problems with respiratory transition at birth requiring medical interventions especially for deliveries before 39 weeks gestation.[10–13] However, elective caesarean delivery at term does not increase the risk of needing newborn resuscitation in the absence of other risk factors.[14–17]

Although it is sometimes possible to predict the need for resuscitation or stabilisation before a baby is born, this is not always the case. Any newborn may potentially develop problems during birth, therefore, personnel trained in newborn life support should be easily available for every delivery. In deliveries with a known increased risk of problems, specially trained personnel should be present with at least one person experienced in tracheal intubation. Should there be any need for intervention, the care of the baby should be their sole responsibility. Local guidelines indicating who should attend deliveries should be developed, based on current practice and clinical audit. Each institution should have a protocol in place for rapidly mobilising a team with competent resuscitation skills for any birth. Whenever there is sufficient time, the team attending the delivery should be briefed before delivery and clear role assignment should be defined. It is also important to prepare the family in cases where it is likely that resuscitation might be required.

A structured educational programme, teaching the standards and skills required for resuscitation of the newborn is therefore essential for any institution or clinical area in which deliveries may occur. Continued experiential learning and practice is necessary to maintain skills.

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 assessment, stabilisation or 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 cardiopulmonary resuscitation (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 take place in a warm, well-lit, draught free area with a flat resuscitation surface placed below a radiant heater (if in hospital), with other resuscitation equipment immediately available. All equipment must be regularly checked and tested.

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 and subsequent ventilation of an appropriate size for the newborn, warm dry towels and blankets, a sterile instrument for cutting and clamping the umbilical cord and clean gloves for the attendant and assistants. Unexpected deliveries outside hospital are most likely to involve emergency services that should plan for such events.

Timing of clamping the umbilical cord

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 the significantly increased pulmonary blood flow following the decrease in pulmonary vascular resistance upon lung aeration. The subsequent increase in size would, as a consequence, be caused by the blood returning to the heart from the lung.[18] Brady et al 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.[19] Experimental evidence from similarly treated lambs suggest the same holds true for premature newborn.[20]

Studies of delayed clamping have shown an improvement in iron status and a number of other haematological indices over the next 3–6 months and a reduced need for transfusion in preterm infants.[21,22] They have also suggested greater use of phototherapy for jaundice in the delayed group but this was not found in a randomised controlled trial.[21]

A systematic review on delayed cord clamping and cord milking in preterm infants found improved stability in the immediate postnatal period, including higher mean blood pressure and haemoglobin on admission, compared to controls.[23] There were also fewer blood transfusions in the ensuing weeks.[23] Some studies have suggested a reduced incidence of intraventricular haemorrhage and periventricular leukomalacia[22,24,25] as well as of late-onset sepsis.[24]

No human studies have yet addressed the effect of delaying cord clamping on babies apparently needing resuscitation at birth because such babies have been excluded from previous studies.

Delaying umbilical cord clamping for at least 1 min is recommended for newborn infants not requiring resuscitation. A similar delay should be applied to preterm babies not requiring immediate resuscitation after birth. Until more evidence is available, infants who are not breathing or crying may require the umbilical cord to be clamped, so that resuscitation measures can commence promptly. Umbilical cord milking may prove an alternative in these infants although there is currently not enough evidence available to recommended this as a routine measure.[1,2] Umbilical cord milking produces improved short term haematological outcomes, admission temperature and urine output when compared to delayed cord clamping (>30 s) in babies born by caesarean section, although these differences were not observed in infants born vaginally.[26]

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.[27] Exposure of the newborn to cold stress will lower arterial oxygen tension[28] and increase metabolic acidosis.[29] The association between hypothermia and mortality has been known for more than a century,[30] and the admission temperature of newborn non-asphyxiated infants is a strong predictor of mortality at all gestations and in all settings.[31–65] Preterm infants are especially vulnerable and hypothermia is also associated with serious morbidities such as intraventricular haemorrhage[35,42,55,66–69] need for respiratory support[31,35,37,66,70–74] hypoglycaemia[31,49,60,74–79] and in some studies late onset sepsis.[49]

The temperature of newly born non-asphyxiated infants should be maintained between 36.5 °C and 37.5 °C after birth. For each 1 °C decrease in admission temperature below this range there is an associated increase in mortality by 28%.[1,2,49] The admission temperature should be recorded as a predictor of outcomes as well as a quality indicator.

Prevent heat loss:

- Protect the baby from draughts.[80] Make certain windows closed and air-conditioning appropriately programmed.[52]
- Dry the term baby immediately after delivery. Cover the head and body of the baby, apart from the face, with a warm and dry towel to prevent further heat loss. Alternatively, place the baby skin to skin with mother and cover both with a towel.
- Keep the delivery room warm at 23–25 °C.[1,2,48,80] For babies less than 28 weeks gestation the delivery room temperature should be >25 °C.[27,48,79,81]
- If the baby needs support in transition or resuscitation then place the baby on a warm surface under a preheated radiant warmer.
- All babies less than 32 weeks gestation should have the head and body of the baby (apart from the face) covered with polyethylene wrapping, without drying the baby beforehand, and also placed under a radiant heater.[73,77,82,83]
- In addition, babies <32 weeks gestation, may require a combination of further interventions to maintain the temperature between 36.5 °C and 37.5 °C after delivery through admission and stabilisation. These may include warmed humidified respiratory gases,[84,85] increased room temperature plus cap plus thermal mattress [70,72,86,87] or thermal mattress alone,[88–92] which have all been effective in reducing hypothermia.
- Babies born unexpectedly outside a normal delivery environment may benefit from placement in a food grade plastic bag after drying and then swaddling.[93,94] Alternatively, well newborns >30 weeks gestation may be dried and nursed with skin to skin contact or kangaroo mother care to maintain their temperature whilst they are transferred.[95–101] They should be covered and protected from draughts.

Whilst maintenance of a baby's temperature is important, this should be monitored in order to avoid hyperthermia (>38.0 °C). Infants born to febrile mothers have a higher incidence of perinatal respiratory depression, neonatal seizures, early mortality and cerebral palsy.[102,103] Animal studies indicate that hyperthermia during or following ischaemia is associated with a progression of cerebral injury.[104,105]

Initial assessment

The Apgar score was not designed to be assembled and ascribed in order to then identify babies in need of resuscitation.[106,107] 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).[106] 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

Immediately after birth the heart rate is assessed to evaluate the condition of the baby and subsequently is the most sensitive indicator of a successful response to interventions. Heart rate is initially most rapidly and accurately assessed by listening to the apex beat with a stethoscope[108] or by using an electrocardiograph.[109–112] Feeling the pulse in the base of the umbilical cord is often effective but can be misleading because cord pulsation is only reliable if found to be more than 100 beats per minute (bpm)[108] and clinical assessment may underestimate the heart rate.[108,109,113] For babies requiring resuscitation and/or continued respiratory support, a modern pulse oximeter can give an accurate heart rate.[111] Several studies have demonstrated that ECG is faster than pulse oximetry and more reliable, especially in the first 2 min after birth;[110–115] however, the use of ECG does not replace the need to use pulse oximetry to assess the newborn baby's oxygenation.

Colour

Colour is a poor means of judging oxygenation,[116] 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 hypoxaemia. 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 preductal 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}.**

There is no need for immediate clamping of the cord. 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. It remains important to ensure the baby's temperature is maintained.

(2)	**Breathing inadequately or apnoeic.** **Normal or reduced tone.** **Heart rate less than 100 min^{-1}.**

Dry and wrap. This baby will usually improve with mask inflation but if this does not increase the heart rate adequately, may rarely also require ventilations.

(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.

Preterm babies may be breathing and showing signs of respiratory distress in which case they should be supported initially with CPAP.

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

Newborn life support

Commence newborn life support if initial assessment shows that the baby has failed to establish adequate regular normal breathing, or has a heart rate of less than 100 min^{-1} (Fig. 7.1). 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 essential in opening the airway.

The supine position for airway management is traditional but side-lying has also been used for assessment and routine delivery room management of term newborns but not for resuscitation.[117]

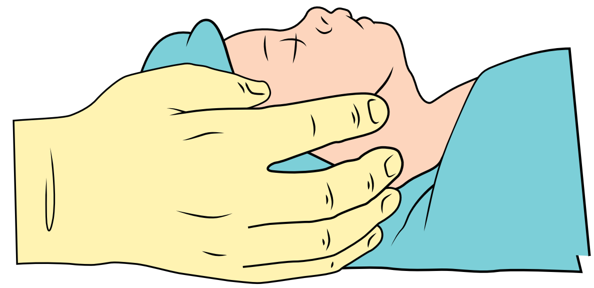

Fig. 7.2. Newborn with head in neutral position.

There is no need to remove lung fluid from the oropharynx routinely.[118] 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.[119–121]

Meconium

For over 30 years 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.[122,123] Furthermore other studies failed to find any evidence of benefit from this practice.[124,125]

Lightly meconium stained liquor is common and does not, in general, give rise to much difficulty with transition. The much less common finding of very thick meconium stained liquor at birth is an indicator of perinatal distress and should alert to the potential need for resuscitation. Two multi-centre randomised controlled trials showed that routine elective intubation and tracheal suctioning of these infants, if vigorous at birth, did not reduce MAS [126] and that suctioning the nose and mouth of such babies on the perineum and before delivery of the shoulders (intrapartum suctioning) was ineffective.[127] Hence intrapartum suctioning and routine intubation and suctioning of vigorous infants born through meconium stained liquor are not recommended. A small RCT has recently demonstrated no difference in the incidence of MAS between patients receiving tracheal intubation followed by suctioning and those not intubated.[128]

The presence of thick, viscous meconium in a non-vigorous baby is the only indication for initially considering visualising the oropharynx and suctioning material, which might obstruct the airway. Tracheal intubation should not be routine in the presence of meconium and should only be performed for suspected tracheal obstruction.[128–132] The emphasis should be on initiating ventilation within the first minute of life in non-breathing or ineffectively breathing infants and this should not be delayed. If suctioning is attempted use a 12–14 FG suction catheter, or a paediatric Yankauer sucker, connected to a suction source not exceeding −150 mmHg.[133] The routine administration of surfactant or bronchial lavage with either saline or surfactant is not recommended.[134,135]

Initial breaths and assisted ventilation

After initial steps at birth, if breathing efforts are absent or inadequate, lung aeration is the priority and must not be delayed (Fig. 7.3). In term babies, respiratory support should start with air.[136] The primary measure of adequate initial lung inflation is a

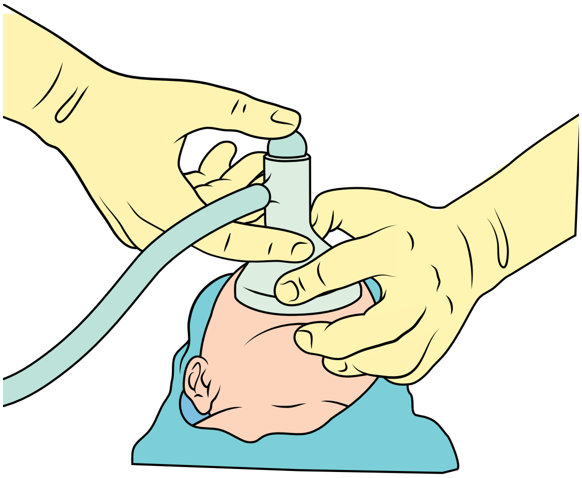

Fig. 7.3. Mask ventilation of newborn.

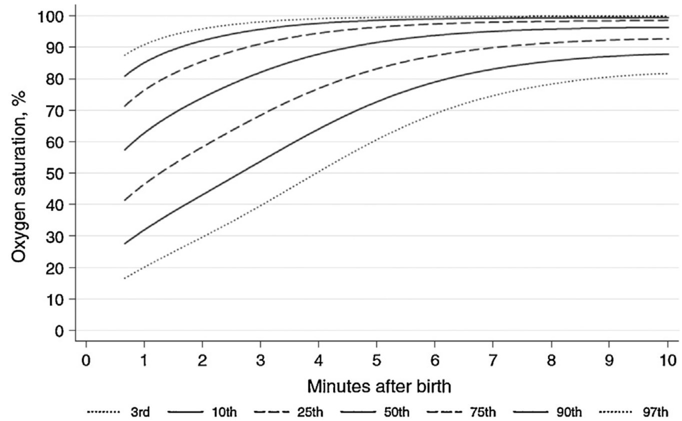

Fig. 7.4. Oxygen saturations (3rd, 10th, 25th, 50th, 75th, 90th, and 97th SpO_2 percentiles) in healthy infants at birth without medical intervention. Reproduced with permission from. [157]

prompt improvement in heart rate. If the heart rate is not improving assess the chest wall movement. In term infants, spontaneous or assisted initial inflations create a functional residual capacity (FRC).[137–141] The optimum pressure, inflation time and flow required to establish an effective FRC has not been determined.

For the first five positive pressure inflations maintain the initial inflation pressure for 2–3 s. This will usually help lung expansion.[137,142] The pressure required to aerate the fluid filled lungs of newborn babies requiring resuscitation is 15–30 cm H_2O (1.5–2.9 kPa) with a mean of 20 cm H_2O.[137,141,142] For term babies use an inflation pressure of 30 cm H_2O and 20–25 cm H_2O in preterm babies.[143,144]

Efficacy of the intervention can be estimated by a prompt increase in heart rate or observing the chest rise. If this is not obtained it is likely that repositioning of the airway or mask will be required and, rarely, higher inspiratory pressures may be needed. Most babies needing respiratory support 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 beats 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. Mask leak, inappropriate airway position and airway obstruction, are all possible reasons, which may need correction.[145–149] In this case, consider repositioning the mask to correct for leakage and/or reposition the baby's head to correct for airway obstruction.[145] Alternatively using a two person approach to mask ventilation reduces mask leak in term and preterm infants.[146,147] Without adequate lung aeration, chest compressions will be ineffective; therefore, confirm lung aeration and ventilation 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.

Sustained inflations (SI) > 5 s

Several animal studies have suggested that a longer SI may be beneficial for establishing functional residual capacity at birth during transition from a fluid-filled to air-filled lung.[150,151] Review of the literature in 2015 disclosed three RCTs[152–154] and two cohort studies,[144,155] which demonstrated that initial SI reduced the need for mechanical ventilation. However, no benefit was found for reduction of mortality, bronchopulmonary dysplasia, or air leak. One cohort study[144] suggested that the need for intubation was less following SI. It was the consensus of the COSTR reviewers that there was inadequate study of the safety, details of the most appropriate length and pressure of inflation, and long-term effects, to suggest routine application of SI of greater than 5 s duration to the transitioning newborn.[1,2] Sustained inflations >5 s should only be considered in individual clinical circumstances or in a research setting.

Air/Oxygen

Term babies. In term infants receiving respiratory support at birth with positive pressure ventilation (PPV), it is best to begin with air (21%) 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 to achieve an adequate preductal oxygen saturation.[156,157] High concentrations of oxygen are associated with an increased mortality and delay in time of onset of spontaneous breathing,[158] therefore, if increased oxygen concentrations are used they should be weaned as soon as possible.[136,159]

Preterm babies. Resuscitation of preterm infants less than 35 weeks gestation at birth should be initiated in air or low concentration oxygen (21–30%).[1,2,136,160] The administered oxygen concentration should be titrated to achieve acceptable pre-ductal oxygen saturations approximating to the 25th percentile in healthy term babies immediately after birth (Fig. 7.4).[156,157]

In a meta-analysis of seven randomized trials comparing initiation of resuscitation with high (>65%) or low (21–30%) oxygen concentrations, the high concentration was not associated with any improvement in survival,[159,161–166] bronchopulmonary dysplasia,[159,162,164–166] intraventricular haemorrhage[159,162,165,166] or retinopathy of prematurity.[159,162,166] There was an increase in markers of oxidative stress.[159]

Pulse oximetry. Modern pulse oximetery, using neonatal probes, provides reliable readings of heart rate and transcutaneous oxygen saturation within 1–2 min of birth (Fig. 7.4).[167,168] A reliable pre-ductal 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.[167] Uncompromised babies born at term at sea level have SpO_2 ~60% during labour,[169] which increases to >90% by 10 min.[156] The 25th percentile is approximately 40% at birth and increases to ~80% at 10 min.[157] Values are lower in those born by Caesarean delivery,[170] those born at altitude[171] and those managed with delayed cord clamping.[172] Those born preterm may take longer to reach >90%.[157]

Pulse oximetry should be used to avoid excessive use of oxygen as well as to direct its judicious use (Figs. 7.1 and 7.4). Transcutaneous oxygen saturations above the acceptable levels should prompt weaning of any supplemental oxygen.

Positive end expiratory pressure

All term and preterm babies who remain apnoeic despite initial steps must receive positive pressure ventilation after initial lung inflation. It is suggested that positive end expiratory pressure (PEEP) of ~5 cm H_2O should be administered to preterm newborn babies receiving PPV.[173]

Animal studies show that preterm lungs are easily damaged by large-volume inflations immediately after birth[174] and suggest that maintaining a PEEP immediately after birth may protect against lung damage[175,176] although some evidence suggests no benefit.[177] PEEP also improves lung aeration, compliance and gas exchange.[178–180] Two human newborn RCTs demonstrated no improvement in mortality, need for resuscitation or bronchopulmonary dysplasia they were underpowered for these outcomes.[181,182] However, one of the trials suggested that PEEP reduced the amount of supplementary oxygen required.[182]

Assisted ventilation 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.[181–185] The blow-off valves of self-inflating bags are flow-dependent and pressures generated may exceed the value specified by the manufacturer if compressed vigorously.[186,187] Target inflation pressures, tidal volumes and long inspiratory times are achieved more consistently in mechanical models when using T-piece devices than when using bags,[187–190] 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.[191] 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. However, self-inflating bags are the only devices, which can be used in the absence of compressed gas but cannot deliver continuous positive airway pressure (CPAP) and may not be able to achieve PEEP even with a PEEP valve in place[189,192–195]

Respiratory function monitors measuring inspiratory pressures and tidal volumes [196] and exhaled carbon dioxide monitors to assess ventilation [197,198] have been used but there is no evidence that they affect outcomes. Neither additional benefit above clinical assessment alone, nor risks attributed to their use have so far been identified. The use of exhaled CO_2 detectors to assess ventilation with other interfaces (e.g., nasal airways, laryngeal masks) during PPV in the delivery room has not been reported.

Face mask versus nasal prong

A reported problem of using the facemask for newborn ventilation is mask leak caused by a failure of the seal between the mask and the face.[145–148] To avoid this some institutions are using nasopharyngeal prongs to deliver respiratory support. Two randomised trials in preterm infants have compared the efficacy and did not find any difference between the methods.[199,200]

Table 1
Oral tracheal tube lengths by gestation.

Gestation (weeks)	ETT 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

Laryngeal mask airway

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 LMA 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.[201] One recent unblinded RCT demonstrated that following training with one type of LMA, its use was associated with less tracheal intubation and neonatal unit admission in comparison to those receiving ventilation via a facemask.[201] There is limited evidence, however, to evaluate its use for newborns weighing <2000 gram 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.[201–206] The LMA is recommended during resuscitation of term and preterm newborns ≥34 weeks gestation when tracheal intubation is unsuccessful or not feasible. 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.

Tracheal tube placement

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

- When suctioning the lower airways to remove a presumed tracheal blockage.
- When, after correction of mask technique and/or the baby's head position, bag-mask ventilation is ineffective or prolonged.
- When chest compressions are performed.
- Special circumstances (e.g., congenital diaphragmatic hernia or to give tracheal surfactant).

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 1.[207] It should be recognised that vocal cord guides, as marked on tracheal tubes by different manufacturers to aid correct placement, vary considerably.[208]

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. [209] Exhaled CO_2 detection is effective for confirmation of tracheal tube placement in infants, including VLBW infants[210–213] and neonatal studies suggest that it confirms tracheal intubation in neonates with a cardiac output more rapidly and more accurately than clinical assessment alone.[212–214] Failure to detect exhaled CO_2 strongly suggests oesophageal intubation[210,212] but false negative readings have been reported during cardiac arrest [210] and in VLBW infants despite models suggesting efficacy.[215] However, neonatal studies have excluded infants in need of extensive resuscitation. False positives may occur with colorimetric devices contaminated with adrenaline (epinephrine), surfactant and atropine.[198]

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[211]; 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.

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.[3,4]

CPAP

Initial respiratory support of all spontaneously breathing preterm infants with respiratory distress may be provided by CPAP, rather than intubation. Three RCTs enrolling 2358 infants born at <30 weeks gestation demonstrated that CPAP is beneficial when compared to initial tracheal ventilation and PPV in reducing the rate of intubation and duration of mechanical ventilation without any short term disadvantages.[216–218] There are few data to guide the appropriate use of CPAP in term infants at birth and further clinical studies are required.[219,220]

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 beats min^{-1} despite adequate ventilation. As ventilation is the most effective and important intervention in newborn resuscitation, and may be compromised by compressions, it is vital to ensure that effective ventilation is occurring before commencing chest compressions.

The most effective technique for providing chest compressions is with two thumbs over the lower third of the sternum with the fingers encircling the torso and supporting the back (Fig. 7.5).[221–224] This technique generates higher blood pressures and coronary artery perfusion with less fatigue than the previously used two-finger technique.[222–234] In a manikin study overlapping the thumbs on the sternum was more effective than positioning them adjacent but more likely to cause fatigue.[235] 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.[225,236–240] Use a 3:1 compression to ventilation ratio, aiming to achieve approximately 120 events per minute, i.e. approximately 90 compressions and 30 ventilations.[241–246] There are theoretical advantages to allowing a relaxation phase that is very slightly longer than the compression phase.[247] However, the quality of the compressions and breaths are probably more important than the rate. Compressions and ventilations should be coordinated to avoid simultaneous delivery.[248] A 3:1 compression to ventilation ratio is used for resuscitation at birth where compromise of gas exchange is nearly always the primary cause of cardiovascular collapse, but rescuers may consider using higher ratios (e.g., 15:2) if the arrest is believed to be of cardiac origin.

When resuscitation of a newborn baby has reached the stage of chest compressions, the steps of trying to achieve return of spontaneous circulation using effective ventilation with low

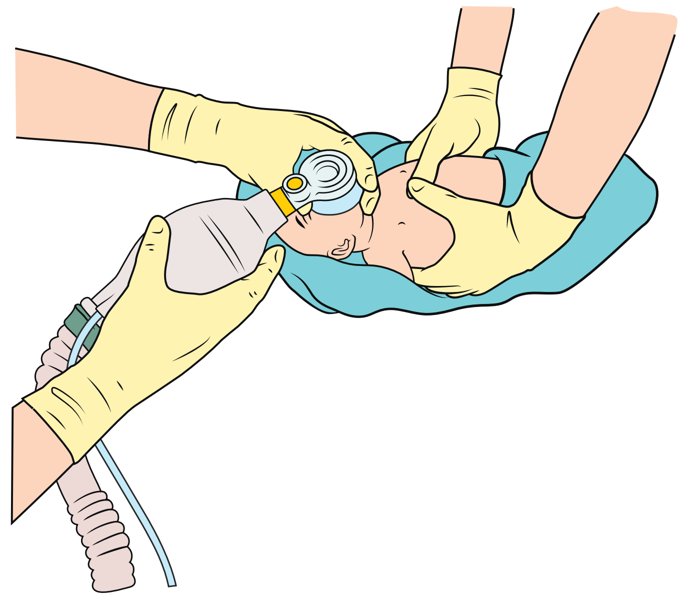

Fig. 7.5. Ventilation and chest compression of newborn.

concentration oxygen should have been attempted. Thus, it would appear sensible to try increasing the supplementary oxygen concentration towards 100%. There are no human studies to support this and animal studies demonstrate no advantage to 100% oxygen during CPR.[249–255]

Check the heart rate after about 30 s and periodically thereafter. Discontinue chest compressions when the spontaneous heart rate is faster than 60 beats min^{-1}. Exhaled carbon dioxide monitoring and pulse oximetry have been reported to be useful in determining the return of spontaneous circulation[256–260]; however, current evidence does not support the use of any single feedback device in a clinical setting.[1,2]

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 beats min^{-1} despite adequate ventilation and chest compressions, it is reasonable to consider the use of drugs. These are best given via a centrally positioned umbilical venous catheter (Fig. 7.6).

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 beats min^{-1}. If

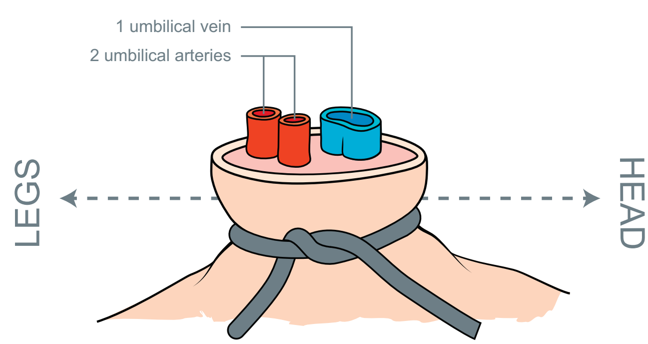

Fig. 7.6. Newborn umbilical cord showing the arteries and veins.

adrenaline is used, an initial dose 10 micrograms kg^{-1} (0.1 ml kg^{-1} of 1:10,000 adrenaline) should be administered intravenously as soon as possible[1,2,4] with subsequent intravenous doses of 10–30 micrograms kg^{-1} (0.1–0.3 ml kg^{-1} of 1:10,000 adrenaline) if required.

The tracheal route is not recommended but if it is used, it is highly likely that doses of 50–100 micrograms kg^{-1} will be required.[3,7,136,261–265] 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 not recommended 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.[266] 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. When resuscitating preterm infants volume is rarely needed and has been associated with intraventricular and pulmonary haemorrhages when large volumes are infused rapidly.

Withholding or discontinuing resuscitation

Mortality and morbidity for newborns varies according to region and to availability of resources.[267] Social science studies indicate that parents desire a larger role in decisions to resuscitate and to continue life support in severely compromised babies.[268] Opinions vary amongst providers, parents and societies about the balance of benefits and disadvantages of using aggressive therapies in such babies.[269,270] Local survival and outcome data are important in appropriate counselling of parents. A recent study suggests that the institutional approach at the border of viability affects the subsequent results in surviving infants.[271]

Discontinuing resuscitation

Local and national committees will define recommendations for stopping resuscitation. If the heart rate of a newly born baby is not detectable and remains undetectable for 10 min, it may be 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, the availability of therapeutic hypothermia and the parents' previous expressed feelings about acceptable risk of morbidity.[267,272–276] The decision should be individualised. 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.

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.[38,272,277–282] There is no evidence to support the prospective use of any particular delivery room prognostic score presently described, over gestational age assessment alone, in preterm infants <25 weeks gestation.

A consistent and coordinated approach to individual cases by the obstetric and neonatal teams and the parents is an important goal.[283] 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.[38,277,284] Examples from the published literature include: extreme prematurity (gestational age less than 23 weeks and/or birth weight 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.[283]
- When withdrawing or withholding resuscitation, care should be focused on the comfort and dignity of the baby and family.

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 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.

European guidelines are supportive of family presence during cardiopulmonary resuscitation.[285] In recent years healthcare professionals are increasingly offering family members the opportunity to remain present during CPR and this is more likely if resuscitation takes place within the delivery room. Parents' wishes to be present during resuscitation should be supported where possible.[286]

The members of the resuscitation team and family members, without coercion or pressure, make the decision about who should be present during resuscitation jointly. It is recommended to provide a healthcare professional whose sole responsibility is to care for the family member. Whilst this may not always be possible it should not mean the exclusion of the family member from the resuscitation. Finally, there should be an opportunity for the immediate relative to reflect, ask questions about details of the resuscitation and be informed about the support services available.[286]

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.[283] Record carefully all discussions and decisions in the mother's notes prior to delivery and in the baby's records after birth.

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.[287] 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.[288,289] One clinical study demonstrated an association between hypoglycaemia and poor neurological outcome following perinatal asphyxia.[290] In adults, children and extremely low-birth-weight infants receiving intensive care, hyperglycaemia has been associated with a worse outcome.[288–292] However, in paediatric patients, hyperglycaemia after hypoxia-ischaemia does not appear to be harmful,[293] which confirms data from animal studies[294] some of which suggest it may be protective.[295] 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

Newly born infants born at term or near-term with evolving moderate to severe hypoxic - ischemic encephalopathy should, where possible, be offered therapeutic hypothermia.[296–301] 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 randomized 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. Commencing cooling treatment >6 h after birth is at the discretion of the treating team and should only be on an individualised basis. Carefully monitor for known adverse effects of cooling such as thrombocytopenia and hypotension. All treated infants should be followed longitudinally.

Prognostic tools

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).[106] Although widely used in clinical practice, for research purposes and as a prognostic tool,[302] its applicability has been questioned due to large inter- and intra-observer variations. These are partly explained by a lack of agreement on how to score infants receiving medical interventions or being born preterm. Therefore a development of the score was recommended as follows: all parameters are scored according to the conditions regardless of the interventions needed to achieve the condition and considering whether being appropriate for gestational age. In addition, the interventions needed to achieve the condition have to be scored as well. This Combined-Apgar has been shown to predict outcome in preterm and term infants better than the conventional score.[303,304]

Briefing/debriefing

Prior to resuscitation it is important to discuss the responsibilities of each member of the team. After the management in the delivery room a team debrief of the event using positive and constructive critique techniques should be conducted and personal bereavement counselling offered to those with a particular need. Studies of the effect of briefings or debriefings following resuscitation have generally shown improved subsequent performance.[305–310] However, many of these have been following simulation training. A method that seems to further improve the management in the delivery room is videotaping and subsequent analysis of the videos.[311] A structured analysis of perinatal management with feedback has been shown to improve outcomes, reducing the incidence of intraventricular haemorrhage in preterm infants.[312]

Regardless of the outcome, witnessing the resuscitation of their baby may be distressing for parents. Every opportunity should be taken to prepare parents for the possibility of a resuscitative effort when it is anticipated and to keep them informed as much as possible during and certainly after the resuscitation. Whenever possible, information should be given by a senior clinician. Early contact between parents and their baby is important.

Conflicts of interest

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