

**Draft 2020 European Resuscitation Council Guidelines for Newborn resuscitation and support of transition of infants at birth**

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## **[h1] Abstract**

The European Resuscitation Council has produced these newborn life support guidelines, which are based on the International Liaison Committee on Resuscitation (ILCOR) 2020 Consensus on Science and Treatment Recommendations (CoSTR) for Neonatal Life Support. [NLS CoSTR 2020]. The guidelines cover the management of the term and preterm infant. The topics covered include

- An algorithm to aid a logical approach to resuscitation of the newborn
- Factors before delivery
- Training and education
- Thermal control
- Management of the umbilical cord after birth
- Initial assessment and categorisation of the newborn infant
- Airway and breathing support
- Airway adjuncts and assisted ventilation devices
- The delivery of PEEP and CPAP
- Supplemental oxygen
- Chest compressions
- Vascular access
- Drugs used during resuscitation
- Post resuscitation care
- Communication with parents
- Considerations when withholding and discontinuing support

## **[h1] Introduction and scope**

These guidelines are based on the International Liaison Committee on Resuscitation (ILCOR) 2020 Consensus on Science and Treatment Recommendations (CoSTR) for Neonatal Life Support .[NLS CoSTR 2020] For the purposes of the ERC Guidelines the ILCOR recommendations were supplemented by focused literature reviews undertaken by the ERC NLS guidelines Group for topics not reviewed by 2020 ILCOR CoSTR. When appropriate, the guidelines were informed by the expert consensus of the ERC guidelines group membership.

## **[h2] COVID 19 context**

The ERC has produced guidance on newborn life support in the context of coronavirus disease 2019 (SARS-COV-2) [Nolan 2020 153], this is based on an ILCOR CoSTR and systematic review. [Perkins 2020 145; Couper 2020 59] Our understanding of the risks to infants potentially exposed to SARS-COV-2 and the risk of virus transmission and infection to those providing care is evolving. Please check ERC and national guidelines for the latest guidance and local policies for both treatment and rescuer precautions.

These guidelines were drafted and agreed by the NLS guidelines group members before posting for public comment.

## **[h2] Summary of changes since the 2015 guidelines**

### **[h3] Management of the umbilical cord.**

Clamping for at least 60 seconds is recommended, ideally after the lungs are aerated. Where delayed cord clamping is not possible cord milking should be considered in infants >28 weeks gestation.

### **[h3] Initial inflations and assisted ventilation**

A starting pressure of 25 cm H<sub>2</sub>O is suggested for preterm infants < 32 weeks gestation.

### **[h3] Infants born through meconium-stained liquor**

In non-vigorous infants, recommendations are against immediate laryngoscopy with or without suction after delivery, because this may delay aeration and ventilation of the lungs.

### **[h3] Air/Oxygen for preterm resuscitation**

Recommendations are for starting in air at 32 weeks gestation or more, 21-30% inspired oxygen at 28 to  $\leq 32$  weeks gestation and 30% inspired oxygen at  $\leq 28$  weeks gestation. The concentration should be titrated to achieve saturations of  $>80\%$  at 5 minutes of age because there is evidence of poorer outcomes where this is not achieved.

### [h3] Initial inflations and assisted ventilation

If there is no response to initial inflations then an increase in the inflation pressure and, if other manoeuvres are not successful, securing the airway through the insertion of a laryngeal mask or tracheal tube are suggested.

### [h3] Laryngeal mask

If facemask ventilation is unsuccessful or if tracheal intubation is unsuccessful or not feasible a laryngeal mask may be considered as an alternative means of establishing an airway in infants of  $\geq 34$  weeks gestation (about 2000g, although some devices have been used successfully in infants down to 1500g).

### [h3] Chest compressions

If chest compressions are required, the inspired oxygen concentration should be increased to 100% and steps taken towards securing the airway with tracheal tube or laryngeal mask.

### [h3] Vascular access

The umbilical vein is still favoured as the optimal route of access but in the absence of other sites, intraosseous access is an alternative method of emergency access for drugs/fluids.

### [h3] Adrenaline

Where the heart rate has not increased after optimising ventilation and chest compressions an intravenous dose of adrenaline of 10-30 micrograms  $\text{kg}^{-1}$  is recommended, repeated every 3-5 minutes in the absence of a response.

### [h3] Glucose during resuscitation

An intravenous dose of 250 mg  $\text{kg}^{-1}$  (2.5 mL  $\text{kg}^{-1}$  of 10% glucose) is suggested in a prolonged resuscitation to reduce the likelihood of hypoglycaemia.

### [h3] Prognosis

165 Failure to respond despite 10-20 minutes of intensive resuscitation is associated with high risk  
166 of poor outcome. It is appropriate to consider discussions with the team and family about  
167 withdrawal of treatment if there has been no response despite the provision of all  
168 recommended steps of resuscitation and having excluded reversible causes.  
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## **[h1] Concise guideline for clinical practice**

### **[h2] Factors before delivery**

#### **[h3] Transition and the need for assistance after birth**

Most, but not all, infants adapt well to extra-uterine life but some require help with stabilisation, or resuscitation. Up to 85% breathe spontaneously without intervention; a further 10% respond after drying, stimulation and airway opening manoeuvres; approximately 5% receive positive pressure ventilation. Intubation rates vary between 0.4 and 2%. Fewer than 0.3% of infants receive chest compressions and only 0.05% receive adrenaline.

#### **[h3] Risk factors**

A number of risk factors have been identified as increasing the likelihood of requiring help with stabilisation, or resuscitation (figure 1).

Insert Figure 1 here

#### **[h3] Staff attending delivery**

Any infant may develop problems during birth. Local guidelines indicating who should attend deliveries should be developed, based on current understanding of best practice and clinical audit, and taking into account identified risk factors (figure 1). As a guide,

- Personnel competent in newborn life support should be available for every delivery.
- If intervention is required, there should be personnel available whose sole responsibility is to care for the infant.
- A process should be in place for rapidly mobilising a team with sufficient resuscitation skills for any birth.

#### **[h3] Equipment and environment**

- All equipment must be regularly checked and ready for use.
- Where possible, the environment and equipment should be prepared in advance of the delivery of the infant. Checklists facilitate these tasks.
- Resuscitation should take place in a warm, well-illuminated, draught-free area with a flat resuscitation surface and a radiant heater (if available).
- Equipment to monitor the condition of the infant and to support ventilation should be immediately available.



- Additional equipment, that might be required in case of more prolonged resuscitation should be easily accessible.

### **[h3] Planned home deliveries**

- Ideally, two trained professionals should be present at all home deliveries.
- At least one must be competent in providing mask ventilation and chest compressions to the newborn infant.
- Recommendations as to who should attend a planned home delivery vary from country to country, but the decision to undergo such a 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 the extent of the resuscitation of a newborn infant in the home, due to the distance from healthcare facilities and equipment available, and this must be made clear to the mother at the time plans for home delivery are made.
- When a birth takes place in a non-designated delivery area a minimum set of equipment of an appropriate size for the newborn infant should be available, including:
  - clean gloves for the attendant and assistants,
  - means of keeping the infant warm, such as heated dry towels and blankets,
  - a stethoscope to check the heart rate,
  - a device for safe assisted lung aeration and subsequent ventilation such as a self-inflating bag with appropriately sized facemask,
  - sterile instruments for clamping and then safely cutting the umbilical cord.
- Unexpected deliveries outside hospital are likely to involve emergency services that should be prepared and trained for such events and carry appropriate equipment.
- Caregivers undertaking home deliveries should have pre-defined plans for difficult situations.

### **[h3] Briefing**

- If there is sufficient time, brief the team to clarify responsibilities, check equipment and plan the stabilisation, or resuscitation.
- Roles and tasks should be assigned – checklists are helpful.
- Prepare the family if it is anticipated that resuscitation might be required.

## **[h2] Training/education**

## **[h2] Recommendations**

- Newborn resuscitation providers must have relevant current knowledge, technical and non-technical skills.
- Institutions or clinical areas where deliveries may occur should have structured educational programmes, teaching the knowledge and skills required for newborn resuscitation.
- The content and organisation of such training programmes may vary according to the needs of the providers and the organisation of the institutions.
- Recommended programmes include:
  - regular practice and drills,
  - team and leadership training,
  - multi-modal approaches,
  - simulation-based training,
  - feedback on practice from different sources (including feedback devices),
  - objective, performance focused debriefings.
- Ideally, training should be repeated more frequently than once per year.
  - Updates may include specific tasks, simulation and/or behavioural skills and reflection.

## **[h2] Thermal Control**

### **[h3] Recommendations**

### **[h3] Standards**

- The infant's temperature should be regularly monitored after birth and the admission temperature should be recorded as a prognostic and quality indicator.
- The temperature of newborn infants should be maintained between 36.5 °C and 37.5 °C.
- Hypothermia ( $\leq 36.0$  °C) and hyperthermia ( $> 38.0$  °C) should be avoided unless following resuscitation therapeutic hypothermia is being considered (see post resuscitation care)

### **[h3] Environment**

- Protect the infant from draughts. Ensure windows are closed and air-conditioning

appropriately programmed.

- Keep the environment in which the infant is looked after (e.g. delivery room or theatre) warm at 23–25 °C.
- For infants ≤28 weeks gestation the delivery room or theatre temperature should be >25 °C.

### **[h3] Term and near-term infants >32 weeks gestation**

- Dry the infant immediately after delivery. Cover the head and body of the infant, apart from the face, with a warm and dry towel to prevent further heat loss.
- If no resuscitation is required place the infant skin-to-skin with mother and cover both with a towel. Ongoing careful observation of mother and infant will be required especially in more preterm and growth restricted infants to ensure they both remain normothermic.
- If the infant needs support with transition or when resuscitation is required, place the infant on a warm surface using a preheated radiant warmer.

### **[h3] Preterm infants ≤32 weeks gestation**

- Completely cover with polyethylene wrapping (apart from face) without drying and use a radiant warmer.
- If umbilical cord clamping is delayed and a radiant warmer is not accessible at this point, other measures (such as those listed below) will be needed to ensure thermal stability while still attached to the placenta.
- A combination of further interventions may be required in infants ≤32 weeks including increased room temperature, warm blankets, head cap and thermal mattress.
- Skin-to-skin care is feasible in less mature infants however caution is required in the more preterm or growth restricted infant in order to avoid hypothermia.
- For infants receiving respiratory support, use of warmed humidified respiratory gases should be considered.
- A quality improvement program including the use of checklists and continuous feedback to the team has been shown to significantly reduce hypothermia at admission in very preterm infants.

### **[h3] Out of hospital management**

- Infants born unexpectedly outside a normal delivery environment are at higher risk of hypothermia and subsequent poorer outcomes.

- They may benefit from placement in a food grade plastic bag after drying and then swaddling. Alternatively, well newborns >30 weeks gestation may be dried and nursed skin-to-skin to maintain their temperature whilst they are transferred as long as mothers are normothermic. Infants should be covered and protected from draughts and watched carefully to avoid hypothermia and ensure airway and breathing are not compromised.

## [h2] Management of the umbilical cord after birth

- The options for managing cord clamping and the rationale should be discussed with parents before birth.
- Where immediate resuscitation or stabilisation is not required, aim to delay clamping the cord for at least 60 seconds. A longer period may be more beneficial.
- Clamping should ideally take place after the lungs are aerated.
- Where adequate thermal care and initial resuscitation interventions can be safely undertaken with the cord intact it may be possible to delay clamping whilst performing these interventions.
- Where delayed cord clamping is not possible consider cord milking in infants >28 weeks gestation.

## [h2] Initial assessment

May occur before the umbilical cord is clamped and cut (typically performed in this order) :

- Observe Tone (& Colour)
- Assess adequacy of **Breathing**
- Count the **Heart Rate**
- Take appropriate action to keep the baby warm during these initial steps.
- This rapid assessment serves to establish a baseline, identify the need for support and/or resuscitation and the appropriateness and duration of delaying umbilical cord clamping.
- Frequent re-assessment of heart rate and breathing indicates whether the infant is adequately transitioning or whether further interventions are needed.

## [h3] Tactile stimulation

Initial handling is an opportunity to stimulate the infant during assessment by

- Drying the infant,
- Gently stimulate the infant as you dry them, for example by rubbing the soles of the feet or the back of the chest. Avoid more aggressive methods of stimulation.

Insert Figure 2 here

### **[h3]Tone & Colour**

- A very floppy infant is likely to need ventilatory support.
- Colour is a poor means of judging oxygenation. Cyanosis can be difficult to recognise. Pallor might indicate shock or rarely hypovolaemia – consider blood loss and plan appropriate intervention.

### **[h3]Breathing**

- Is the infant breathing? - Note the rate, depth and symmetry, work/effort of breathing as
  - Adequate
  - Inadequate/abnormal pattern - such as gasping or grunting
  - Absent

### **[h3]Heart rate**

- Determine the heart rate with a stethoscope and a saturation monitor +/- ECG (electrocardiogram) for later continuous assessment.
  - Fast ( $\geq 100 \text{ min}^{-1}$ ) – satisfactory
  - Slow ( $60\text{-}100 \text{ min}^{-1}$ ) – intermediate, possible hypoxia
  - Very slow/absent ( $< 60 \text{ min}^{-1}$ ) – critical, hypoxia likely

If the infant fails to establish spontaneous and effective breathing following assessment and stimulation, and/or the heart rate does not increase (and/or decreases) if initially fast, respiratory support should be started.

### **[h3]Classification according to initial assessment**

On the basis of the initial assessment, the infant can usually be placed into one of three groups as the following examples illustrate.

1.

Insert Figure 3a here

**Good tone**

**Vigorous breathing or crying**

**Heart rate - fast ( $\geq 100 \text{ min}^{-1}$ )**

Assessment: *Satisfactory transition* - Breathing does not require support. Heart rate is acceptable.

Actions:

- Delay cord clamping.
- Dry, wrap in warm towel.
- Keep with mother or carer and ensure maintenance of temperature.
- Consider early skin-to-skin care if stable.

**2.**

Insert figure 3b here

**Reduced tone**

**Breathing inadequately (or apnoeic)**

**Heart rate - slow ( $< 100 \text{ min}^{-1}$ )**

Assessment: *Incomplete transition* - Breathing requires support, slow heart rate may indicate hypoxia.

Actions:

- Delay cord clamping only if you are able to appropriately support the infant.
- Dry, stimulate, wrap in a warm towel.
- Maintain the airway, lung inflation.
- Continuously assess changes in heart rate and breathing
- If no improvement in heart rate, continue ventilation.
- Help may be required.

**3.**

Insert figure 3c here

**Floppy +/- Pale**

**Breathing inadequately or apnoeic**

**Heart rate - very slow ( $<60 \text{ min}^{-1}$ ) or undetectable**

Assessment: *Poor/Failed transition* - Breathing requires support, heart rate suggestive of significant hypoxia

Actions:

- Clamp cord immediately and transfer to the resuscitation platform. Delay cord clamping only if you are able to appropriately support/resuscitate the infant.
- Dry, stimulate, wrap in warm towel.
- Maintain the airway – lung inflation and ventilation.
- Continuously assess heart rate, breathing, and effect of ventilation.
- Continue newborn life support according to response.
- Help is likely to be required.

### **[h3] Preterm infants**

- Same principles apply.
- Consider alternative/additional methods for thermal care e.g. polyethylene wrap.
- Gently support, initially with CPAP if breathing.
- Consider continuous rather than intermittent monitoring (pulse oximetry +/- ECG)

### **[h2] Newborn life support**

Following initial assessment and intervention, continue respiratory support if:

- The infant has not established adequate, regular breathing, or
- The heart rate is  $<100 \text{ min}^{-1}$ .

**Ensuring an open airway, aerating and ventilating the lungs** is usually all that is necessary. Without these, other interventions will be unsuccessful.

### **[h2] Airway**

Commence life support if initial assessment shows that the infant has not established adequate regular normal breathing, or has a heart rate  $<100 \text{ min}^{-1}$

Algorithm – inserts near this point?

Establishing and maintaining an open airway is essential to achieve postnatal transition and spontaneous breathing, or for further resuscitative actions to be effective.

### **[h3] Techniques to help open the airway**

- Place the infant on their back with the head supported in a neutral position (figure 4a).

Insert Figure 4a here

Insert Figure 4b here

- In floppy infants, pulling the jaw forwards (jaw lift) may be essential in opening and/or maintaining the airway and reducing mask leak (Figure 4b). When using a facemask, two person methods of airway support are superior and permit true jaw thrust to be applied.
- An oropharyngeal airway may be useful in term infants when having difficulty providing both jaw lift and ventilation, or where the upper airway is obstructed, for instance in those with micrognathia. However, oropharyngeal airways should be used with caution in infants  $\leq 34$  weeks gestation as they may increase airway obstruction.
- A nasopharyngeal airway may also be considered where there is difficulty maintaining an airway and mask support fails to achieve adequate aeration.

### **[h3] Airway obstruction**

- Airway obstruction can be due to inappropriate positioning, decreased airway tone and/or laryngeal adduction, especially in preterm infants at birth.
- Suction is only required if airway obstruction due to mucus, vernix, meconium, blood clots, etc. is confirmed through inspection of the pharynx after failure to achieve aeration.



- Any suctioning should be undertaken under direct vision, ideally using a laryngoscope and a wide bore catheter.

### [h3] Meconium

- Non-vigorous newborn infants delivered through meconium-stained amniotic fluid are at significant risk for requiring advanced resuscitation and a neonatal team competent in advanced resuscitation may be required.
- Routine suctioning of the airway of non-vigorous infants is likely to delay initiating ventilation and is not recommended. In the absence of evidence of benefit for suctioning, the emphasis must be on initiating ventilation as soon as possible in apnoeic or ineffectively breathing infants born through meconium-stained amniotic fluid.
- Should initial attempts at aeration and ventilation be unsuccessful then physical obstruction may be the cause. In this case inspection and suction under direct vision be considered. Rarely, an infant may require tracheal intubation and tracheal suctioning to relieve airway obstruction.

## [h2] Initial inflations and assisted ventilation

### [h3] Lung Inflation

Insert Figure 5a here

- If apnoeic, gasping or not breathing effectively, aim to start positive pressure ventilation as soon as possible – ideally within 60 seconds.
- Apply an appropriately fitting facemask connected to a means of providing positive pressure ventilation, ensuring a good seal.
- Give five “**inflations**” maintaining the inflation pressure for up to 2-3 seconds.
- Provide initial inflation pressures of 30 cm H<sub>2</sub>O for term infants commencing with air. Start with 25 cm H<sub>2</sub>O for preterm infants ≤32 weeks using 21-30% inspired oxygen (see ‘air/oxygen’).

### [h3] Assessment

- Check the **heart rate**

- An increase (within 30 seconds) in heart rate, or a stable heart rate if initially high, confirms adequate ventilation/oxygenation.
- A slow or very slow heart rate usually suggests continued hypoxia and almost always indicates inadequate ventilation.
- Check for **chest movement**
  - Visible passive chest movement with inflations indicates a patent airway and delivered volume.
  - Failure of the chest to move may indicate obstruction of the airway, or insufficient inflation pressure and delivered volume to aerate the lungs.

### [h3] Ventilation

If there is a heart rate response

- Continue uninterrupted ventilation until the infant begins to breathe adequately and the heart rate is above 100 min<sup>-1</sup>.
- Aim for about 30 breaths min<sup>-1</sup> with an inflation time of under one second.
- Reduce the inflation pressure if the chest is moving well.
- Reassess heart rate and breathing at least every 30 seconds.
- Consider a more secure airway (laryngeal mask/tracheal tube) if apnoea continues or if mask ventilation is not effective.

Insert Figure 5b here

### [h3] Failure to respond

If there is no heart rate response and the chest is not moving with inflations

- Check if the equipment is working properly.
- Recheck the head-position and jaw lift/thrust
- Recheck mask size, position and seal.
- Consider a gradual increase in inflation pressure.
- Consider other airway manoeuvres:
  - 2-person mask support if single handed initially.
  - Inspection of the pharynx and suction under direct vision to remove obstructing foreign matter if present.
  - Securing the airway via tracheal intubation or insertion of a laryngeal mask.
  - Insertion of an oropharyngeal/nasopharyngeal airway if unable to secure the airway with other means.

- If being used, check on a respiratory function monitor that expired tidal volume is not too low or too high (target about 5 to 8 mL kg<sup>-1</sup>).

Then:

- Repeat inflations.
- Continuously assess heart rate and chest movement.

If the insertion of a laryngeal mask or tracheal intubation is considered, it must be undertaken by personnel competent in the procedure with appropriate equipment. Otherwise continue with mask ventilation and call for help.

**Without adequate lung aeration, chest compressions will be ineffective; therefore, where the heart rate remains very slow, confirm effective ventilation through observed chest movement or other measures of respiratory function before progressing to chest compressions.**

## **[h2] Airway adjuncts, assisted ventilation devices, PEEP and CPAP**

### **[h3] Continuous positive airway pressure (CPAP) & Positive end expiratory pressure (PEEP)**

- In spontaneously breathing *preterm* infants consider CPAP as the initial method of breathing support after delivery - using either mask or nasal prongs.
- If equipment permits, apply PEEP at minimum of 5-6 cm H<sub>2</sub>O when providing positive pressure ventilation (PPV) to these infants.

### **[h3] Assisted ventilation devices**

- Ensure a facemask of appropriate size is used to provide a good seal between mask and face.
- Where possible use a T-piece resuscitator (TPR) capable of providing either CPAP or PPV with PEEP when providing ventilatory support, especially in the preterm infant.
- Nasal prongs of appropriate size may be a viable CPAP alternative to facemasks.
- If a self-inflating bag is used it should be of sufficient volume to deliver an adequate inflation. Care should be taken not to deliver an excessive volume. The self-inflating bag cannot deliver CPAP effectively.

### [h3] Laryngeal mask

- Consider using a laryngeal mask
  - In infants of  $\geq 34$  weeks gestation (about 2000g) - although some devices have been used successfully in infants down to 1500g.
  - If there are problems with establishing effective ventilation with a facemask.
  - Where intubation is not possible or deemed unsafe because of congenital abnormality, a lack of equipment, or a lack of skill.
  - Or as an alternative to tracheal intubation as a secondary airway.

### [h3] Tracheal tube

- Tracheal intubation may be considered at several points during neonatal resuscitation:
  - When ventilation is ineffective after correction of mask technique and/or the infant's head position, and/or increasing inspiratory pressure with TPR or bag-mask.
  - Where ventilation is prolonged, in order to establish a more secure airway.
  - When suctioning the lower airways to remove a presumed tracheal blockage.
  - When chest compressions are performed.
  - In special circumstances (e.g., congenital diaphragmatic hernia or to give surfactant).
- Exhaled CO<sub>2</sub> detection should be used when undertaking intubation to confirm tube placement in the airway.
- A range of differing sized tubes should be available to permit placement of the most appropriate size to ensure adequate ventilation with minimal leak and trauma to the airway.

Insert Table 1 here

- Respiratory function monitoring may also help confirm tracheal tube position and adequate ventilation through demonstrating adequate expired tidal volume (about 5 to 8 mL kg<sup>-1</sup>) and minimal leak.
- The use of a video laryngoscope may aid tube placement.
- If retained, the position of the tracheal tube should be confirmed by radiography.

## [h2] Air/Oxygen

- Pulse-oximetry and oxygen blenders should be used during resuscitation in the delivery room.
- Aim to achieve target oxygen saturation above the 25<sup>th</sup> percentile for healthy term infants in the first 5 minutes after birth (Table 2).

Insert Table 2 here

- If, despite effective ventilation, there is no increase in heart rate, or saturations remain low, increase the oxygen concentration to achieve an adequate preductal oxygen saturation.
- Check the delivered inspired oxygen concentration and saturations frequently (e.g. every 30 seconds) and titrate to avoid both hypoxia and hyperoxia.
- Wean the inspired oxygen if saturations exceed 95%.

### **[h3] Term and late preterm infants $\geq 35$ weeks.**

- In infants receiving respiratory support at birth, begin with air (21%).

### **[h3] Preterm infants $< 35$ weeks.**

- Resuscitation should be initiated in air or a low inspired oxygen concentration based on gestational age:
 

○ $\geq 32$ weeks	21%
○ 28 - $< 32$ weeks	21-30%
○ $< 28$ weeks	30%
- In infants  $< 32$  weeks gestation the target should be to avoid an oxygen saturation below 80% and/or bradycardia at 5 minutes of age. Both are associated with poor outcome.

## **[h2] Chest compressions**

### **[h3] Assessment of the need for chest compressions**

- If the heart rate remains very slow ( $< 60 \text{ min}^{-1}$ ) or absent after 30 seconds of good quality ventilation, start chest compressions.
- When starting compressions:

- Increase the delivered inspired oxygen to 100%.
- Call for experienced help if not already summoned.

Insert Figure 6a here

### **[h3] Delivery of chest compressions**

- Use a synchronous technique, providing three compressions to one ventilation at about 15 cycles every 30 seconds.
- Use a two-handed technique for compressions if possible.
- Re-evaluate the response every 30 seconds.
- If the heart rate remains very slow or absent, continue but ensure that the airway is secured (e.g. intubate the trachea if competent and not done already).

Insert Figure 6b here

- Titrate the delivered inspired oxygen against oxygen saturation if a reliable value is achieved on the pulse oximeter.

Consider

- Vascular access and drugs.

### **[h2] Vascular access**

During the resuscitation of a compromised infant at birth peripheral venous access is likely to be difficult and suboptimal for vasopressor administration.

### **[h3] Umbilical Venous Access**

- The umbilical vein offers rapid vascular access in newborn infants and should be considered the primary method during resuscitation.
- Ensure a closed system to prevent air embolism during insertion should the infant gasp and generate sufficient negative pressure.
- Confirm position in a blood vessel through aspiration prior to administering drugs/fluids.
- Clean, rather than sterile, access technique may be sufficient in an emergency.
- The umbilical route may still be achievable some days after birth and should be

considered in cases of postnatal collapse.

### [h3] Intraosseous Access

- Intraosseous (IO) access can be an alternative method of emergency access for drugs/fluids.

### [h3] Support of transition / post-resuscitation care

- If venous access is required following resuscitation, peripheral access may be adequate unless multiple infusions are required in which case central access may be preferred.
- IO access may be sufficient in the short term if no other site is available.

## [h2] Drugs

### [h3] During active resuscitation

Drugs are rarely required during newborn resuscitation and the evidence for the efficacy of any drug is limited. The following may be considered during resuscitation where, despite adequate control of the airway, effective ventilation and chest compressions for 30 seconds, there is an inadequate response and the HR remains below 60 min<sup>-1</sup>.

- Adrenaline
  - When effective ventilation and chest compressions have failed to increase the heart rate above 60 min<sup>-1</sup>
  - Intravenous or intraosseous is the preferred route:
    - At a dose of 10 – 30 micrograms kg<sup>-1</sup> (0.1 – 0.3 mL kg<sup>-1</sup> of 1:10,000 adrenaline [1000 micrograms in 10 mL]).
  - Intra-tracheally if intubated and no other access available.
    - At a dose of 50–100 micrograms kg<sup>-1</sup>.
  - Subsequent doses every 3-5 minutes if heart rate remains < 60 min<sup>-1</sup>.
- Glucose
  - In a prolonged resuscitation to reduce likelihood of hypoglycaemia.
  - Intravenous or intraosseous:
    - 250 mg kg<sup>-1</sup> bolus (2.5 mL kg<sup>-1</sup> of 10% glucose solution).
- Volume replacement

- With suspected blood loss or shock unresponsive to other resuscitative measures.
- Intravenous or intraosseous:
  - 10 mL kg<sup>-1</sup> of group O Rh-negative blood or isotonic crystalloid.
- Sodium bicarbonate
  - May be considered in a prolonged unresponsive resuscitation with adequate ventilation to reverse intracardiac acidosis.
  - Intravenous or intraosseous:
    - 1–2 mmol kg<sup>-1</sup> sodium bicarbonate (2–4 mL kg<sup>-1</sup> of 4.2% solution) by slow intravenous injection.

### **[h3]In situations of persistent apnoea**

- Naloxone
  - Intramuscular
    - An initial 200 microgram dose may help in the few infants who, despite resuscitation, remain apnoeic with good cardiac output when the mother is known to have received opioids. Effects may be transient so continued monitoring of respiration is important

## **[h2] Failure to respond**

Consider other factors which may be impacting on the response to resuscitation and which require addressing such as the presence of pneumothorax, hypovolaemia, congenital abnormalities, equipment failure etc.

## **[h2] Post-resuscitation care**

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

### **[h3] Glucose**

- Monitor glucose levels carefully after resuscitation.
- Have protocols/guidance on the management of unstable glucose levels.



- Avoid hyper- and hypoglycaemia.
- Avoid large swings in glucose concentration.
- Consider the use of a glucose infusion to avoid hypoglycaemia.

### **[h3] Thermal Care**

- Aim to keep the temperature between 36.5 °C and 37.5 °C.
- Rewarm if the temperature falls below this level and there are no indications to consider therapeutic hypothermia (see below).

### **[h3] Therapeutic Hypothermia**

- Once resuscitated, consider inducing hypothermia to 33-34 °C in situations where there is clinical and/or biochemical evidence of significant risk of moderate or severe HIE (hypoxic-ischaemic encephalopathy).
- Ensure the evidence to justify treatment is clearly documented; include cord blood gases, and neurological examination.
- Arrange safe transfer to a facility where monitoring and treatment can be continued.
- Inappropriate application of therapeutic hypothermia, without concern about a diagnosis of HIE is likely to be harmful (see temperature maintenance)

### **[h3] Prognosis (documentation).**

- Ensure clinical records allow accurate retrospective time based evaluation of the clinical state of the infant at birth, any interventions and the response during the resuscitation to facilitate any review and the subsequent application of any prognostic tool.

## **[h2] Communication with the parents**

### **[h3] Where intervention is anticipated**

- Whenever possible, the decision to attempt resuscitation of an extremely preterm or clinically complex infant should be taken in close consultation with the parents and senior paediatric, midwifery and obstetric staff.
- Discuss the options including the potential need and magnitude of resuscitation and the prognosis before delivery in order to develop an agreed plan for the birth.
- Record carefully all discussions and decisions in the mother's notes prior to delivery and in the infant's records after birth.

### **[h3] For every birth**

- Where intervention is required it is reasonable for mothers/fathers/partners to be present during the resuscitation where circumstances, facilities and parental inclination allow.
- The views of both the team leading the resuscitation and the parents must be taken into account in decisions on parental attendance.
- Irrespective of whether the parents are present at the resuscitation, ensure wherever possible, that they are informed of the progress of the care provided to their infant.
- Witnessing the resuscitation of their infant may be distressing for parents. If possible, identify a member of healthcare staff to support them to keep them informed as much as possible during the resuscitation.
- Allow parents to hold or even better to have skin-to-skin contact with their infant as soon as possible after delivery or resuscitation, even if unsuccessful.
- Provide an explanation of any procedures and why they were required as soon as possible after the delivery.
- Ensure a record is kept of events and any subsequent conversations with parents.
- Allow for further discussions at a later time to allow parents to reflect and to aid parental understanding of events.
- Consider what additional support is required for parents following delivery and any resuscitation.

### **[h2] Withholding and discontinuing resuscitation.**

- Any recommendations must be interpreted in the light of current national/regional outcomes.
- When discontinuing, withdrawing or withholding resuscitation, care should be focused on the comfort and dignity of the infant and family.
- Such decisions should ideally involve senior paediatric staff.

### **[h3] Discontinuing resuscitation**

- National committees may provide locally appropriate recommendations for stopping resuscitation.
- When the heart rate has been undetectable for longer than 10 minutes after delivery review clinical factors (for example gestation of the infant, or presence/absence of

dysmorphic features), effectiveness of resuscitation, and the views of other members of the clinical team about continuing resuscitation.

- If the heart rate of a newborn term infant remains undetectable for more than 20 minutes after birth despite the provision of all recommended steps of resuscitation and exclusion of reversible causes, consider stopping resuscitation
- Where there is partial or incomplete heart rate improvement despite apparently adequate resuscitative efforts, the choice is much less clear. It may be appropriate to take the infant to the intensive care unit and consider withdrawing life sustaining treatment if they do not improve.
- Where life sustaining treatment is withheld or withdrawn, infants should be provided with appropriate palliative (comfort focused) care.

### **[h3] Withholding resuscitation**

- Decisions about withholding life sustaining treatment should usually be made only after discussion with parents in the light of regional or national evidence on outcome if resuscitation and active (survival focused) treatment is attempted.
- In situations where there is extremely high (>90%) predicted neonatal mortality and unacceptably high morbidity in surviving infants, attempted resuscitation and active (survival focused) management is usually not appropriate.
- Resuscitation is nearly always indicated in conditions associated with a high (>50%) survival rate and what is deemed to be acceptable morbidity. This will include most infants with gestational age of 24 weeks or above (unless there is evidence of fetal compromise such as intrauterine infection or hypoxia-ischaemia) and most infants with congenital malformations. Resuscitation should also usually be commenced in situations where there is uncertainty about outcome and there has been no chance to have prior discussions with parents.
- In conditions where there is low survival (<50%) and a high rate of morbidity, and where the anticipated burden of medical treatment for the child is high, parental wishes regarding resuscitation should be sought and usually supported.

## **[h1] Evidence informing the guidelines**

### **[h2] Factors before delivery**

#### **[h3] Transition**

Survival at birth involves major physiological changes during transition from fetal to newborn life. First, lung liquid-clearance and aeration need to occur after which pulmonary gas exchange can be established. [te Pas 2008 607] This critical event initiates a sequence of inter-dependent cardiopulmonary adaptations which enable transition to independent life. [Hooper 2015 147] Spontaneous breathing effort (negative pressure) or less effective, artificial ventilation (positive pressure) are essential to generate the transpulmonary pressures required to aerate the liquid-filled lung to form and then maintain a functional residual capacity. [Hooper 2013 336; Dekker 2019 doi: 10.1038/s41390-019-0468-7]

Most, but not all, infants transition smoothly. Some infants have problems with transition, and without timely and adequate support, might subsequently need resuscitation. Recent, large-scale observational studies confirm that approximately 85% of infants born at term initiate respiration spontaneously; 10% will respond to drying, stimulation, opening the airway and/or applying CPAP or PEEP, approximately 5% will breathe following positive pressure ventilation. Estimates of intubation rates vary between 0.4% and 2%; <0.3% receive chest compressions and approximately 0.05% adrenaline. [Ersdal 2012 869; Niles 2017 102; Skåre 2018 140; Bjorland 2019 e000592; Perlman 1995 20; Barber 2006 1028; Halling 2017 232]

#### **[h3] Risk factors**

Several maternal and fetal pre- and intrapartum factors increase the risk for compromised birth or transition and the need for resuscitation. In a recent ILCOR evidence update most recent studies confirm previously identified risk factors for needing assistance after birth [Wykoff 2020 A156; Aziz 2008 444; Annibale 1995 862; Foo 2016 358; Berhan 2016 49; Berazategui 2017 F44; Yangthara 2018 570; Bajaj 2018 33; Londero 2019 261; Lee 2019 197; Liljestrom 2018 615] There is no universally applicable model to predict risk for resuscitation or need of support during transition, and the list of risk factors in the guidelines is not exhaustive.

Elective caesarean delivery at term, in the absence of other risk factors, does not increase the risk of needing newborn resuscitation. [Annibale 1995 862; Parsons 1998 241; Gordon 2005 599; Atherton 2006 332] Following the review of evidence, ILCOR recommendations are

unchanged: When an infant is delivered at term by caesarean delivery under regional anaesthesia a provider capable of performing assisted ventilation should be present at the delivery. It is not necessary for a provider skilled in neonatal intubation to be present at that delivery. [Wykoff 2020 A156]

### **[h3] Staff Attending Delivery**

It is not always possible to predict the need for stabilisation or resuscitation before an infant is born. Interventions may not be necessary but those in attendance at a delivery need to be able to undertake initial resuscitation steps effectively. It is essential that teams can respond rapidly if not present and needed to provide additional support. The experience of the team and their ability to respond in a timely manner can influence outcome. [Bensouda 2018 25] Units have different guidelines for when teams attend in advance, potentially leading to widely different outcomes. [Tu 2017 259] A prospective audit of 56 Canadian neonatal units found that, with the guidelines in force at that time, the need for resuscitation was unanticipated in 76% of cases. [Mitchell 2002 316] In a series of video recorded resuscitations in 2 Norwegian tertiary level units, the need for resuscitation was not anticipated in 32%. [Skåre 2016 25] Approximately 65% of all deliveries in a single Canadian unit were attended by the resuscitation team - only 22% of these infants required IPPV, as did another 4.6% where resuscitation was not anticipated. [Aziz 2008 444].

### **[h3] Equipment and environment**

The detailed specification of the equipment required to support stabilisation and resuscitation of the newborn may vary and those using the equipment need to be aware of any limitations. Suggestions have been made on standardising an optimal layout of a resuscitation area, [Sawyer 2018 312] but no published evidence has demonstrated improvement in outcome as a result of specific arrangements. The guidelines are based on international expert opinion. [Wyllie 2015 249; Wykoff 2020 A156]

### **[h3] Planned home deliveries**

A systematic review of 8 studies involving 14 637 low risk planned home deliveries compared to 30 177 low risk planned hospital birth concluded that the risks of neonatal morbidity and mortality were similar. [Rossi 2018 102] Those attending deliveries at home need to recognise that despite risk stratification and measures to avoid the event, infants born at home may still require resuscitation and they must be prepared for this possibility. [Wyllie 2015 249]

### **[h3] Briefing & Checklists**

Briefing with role allocation to improve team functioning and dynamics is recommended [Halamek 2019 151178] although there is a lack of evidence of improved clinical outcomes. [Pflanzl-Knizacek 2019 ILCOR CoSTR SR EIT #645] Likewise, use of checklists during briefings (and debriefings) may help improve team communication and process, but again, there is little evidence of effect on clinical outcome. [Katheria 2013 1552; Bennett 2016 369] A recent ILCOR scoping review on the effect of briefing/debriefing on the outcome of neonatal resuscitation concluded that briefing or debriefing may improve short-term clinical and performance outcomes for infants and staff but the effects on long-term clinical and performance outcomes were uncertain. [Wykoff 2020 A156]

The opportunity to brief the family before delivery can significantly influence their expectation and understanding of events, decision making and interactions with health providers. Therefore, anticipatory liaison often forms part of national recommendations on practice [Sawyer 2018 312] (see section – parents & family).

### **[h2] Training/education**

Meta-analysis of adult resuscitations showed that attendance by one or more personnel on an advanced life support course improves outcome. [Lockey 2018 48] Research on educational methods in neonatal resuscitation is evolving, but due to study heterogeneity with non-standardised outcome measures, there is still little evidence on the effect of different training modalities on clinical outcome. [Rakshasbhuvankar 2014 1320; Patel 2017 e000183; Huang 2019 323]

For those taking resuscitation courses training or retraining distributed over time (spaced learning) may be an alternative to training provided at one single time point (massed learning) (weak recommendation, very low certainty of evidence). [Yeung 2020 ILCOR CoSTR SR EIT #1601] Intermittent, infrequent training without interval refreshment leads to skills decay in neonatal resuscitation. [Mosley 2013 582] whereas frequent and brief, onsite simulation-based training has been shown to improve patient 24 hour survival in a low-resource setting. (Mduma 2015 1) Two observational studies analysing video recordings of real time resuscitations against checklists of expected actions indicated frequent errors in the application of structured guidelines in newborn resuscitation. [Yamada 2015 109; Skåre 2018 140] This suggests that training should be repeated more frequently than once per year, however, the optimal interval

remains to be established. [Finn 2015 e203; Wyllie 2015 e169]

A structured educational programme in neonatal resuscitation was recommended in the 2015 ERC guidelines [Wyllie 2015 249] and supported by two systematic reviews and meta-analyses. A Cochrane review of 14 studies (187 080 deliveries) concluded that there was moderate quality evidence that such training decreased early neonatal mortality (typical RR 0.88 95% CI 0.78-1.00) [Dempsey 2015 Cd009106]. Findings of a meta-analysis of 20 trials comparing periods before and after neonatal resuscitation training and including 1 653 805 births [Patel 2017 e000183] showed an 18% reduction in perinatal mortality (RR 0.82 95% CI 0.74-0.91) but these findings had to be downgraded for risk of bias and indirectness. The optimal content or organisation of such training programmes will vary according to the needs of the providers and the organisation of the institutions.

A recent ILCOR systematic review included several studies on team training in neonatal resuscitation. [Thomas 2007 409; Thomas 2010 539; Nadler 2011 163; Rovamo 2015 671; Rosen 2018 433] Team performance and patient safety appeared to be enhanced by regular practice and drills that enabled those likely to be involved to rehearse and improve their abilities at an individual level and in teams. This suggested that specific team and leadership training be included as part of Advanced Life Support training for healthcare providers (weak recommendation, very low certainty of evidence). [Kuzovlev 2020 ILCOR CoSTR SR EIT #631]

Multi-modal approaches to teaching neonatal resuscitation are thought to be the most beneficial for learning, especially when simulation-based training with emphasis on feedback on practice is incorporated as a teaching method. [Soar 2010 1434; Mundell 2013 1174; Rakshasbhuvarkar 2014 1320; Levett-Jones 2014 e58; Garden 2015 300; Greif 2015 288; Dempsey 2015 Cd009106] Feedback may come from different sources such as the facilitator, the manikin itself or digital recordings (video, audio, respiratory function monitor etc.). [Greif 2015 288; O`Curraín 2019 F582; Mazza 2017 e0186731; Duff 2020 ILCOR CoSTR SR EIT #648] The role of modalities such as virtual reality, tele-education and board game simulation in resuscitation training remain to be established. A review of 12 such neonatal resuscitation-based games concluded that they had a potential to improve knowledge, skills and adherence to the resuscitation algorithm. [Ghoman 2020 98]

Feedback devices providing information on the quality of intervention may also be used in

real-life settings to improve performance and compliance with guidelines. [Van Vonderen 2016 38; Schmölzer 2019 151177; Pflanzl-Knizacek 2019 ILCOR CoSTR SR EIT #645; Brooks 2020 ILCOR CoSTR SR BLS #361] Debriefing on individual and team performance at resuscitations supported by objective data are recommended after cardiac arrest for both adult and children (weak recommendation, very low certainty of evidence). Pflanzl-Knizacek ILCOR CoSTR 2019 EIT #645; Edelson 2008 1063; Wolfe 2014 1688; Couper 2016 130; Blejenberg 2017 110] This approach to debrief also applies to neonatal resuscitation. [Nadler 2011 163; Morley 2018 387; Skåre 2018 394]

## **[h2] Thermal Control**

Exposed, wet, newborn infants cannot maintain their body temperature in a room that feels comfortably warm for adults. The mechanisms and effects of cold stress and how to avoid these have been reviewed. [Chitty 2013 362; Trevisanuto 2018 333] Heat loss can occur though convection, conduction, radiation and evaporation meaning unprotected infants will drop their body temperature quickly. Cold stress lowers the arterial oxygen tension and increases the risk of metabolic acidosis. Compromised infants are particularly vulnerable to cold stress. The admission temperature of newborn non-asphyxiated infants is a strong predictor of mortality and morbidity at all gestations and in all settings. [McCall 2018 1; Jauvaudin 2019 26] ILCOR recommendations are that it should be recorded as a predictor of outcomes as well as a quality indicator (strong recommendation, moderate-quality evidence) [Wyllie 2015 e169] Immediate drying and wrapping infants in a warm towel to avoid exposure to a cold environment will help them maintain their temperature

Preterm infants are especially vulnerable and hypothermia is also associated with serious morbidities such as intraventricular haemorrhage, need for respiratory support, hypoglycaemia, and in some studies late onset sepsis.[Wyllie 2015 e169] In a European cohort study of 5697 infants <32 weeks gestation admitted for neonatal care, an admission temperature <35.5 °C was associated with increased mortality in the first 28 days [Wilson 2016 61] For each 1°C decrease in admission temperature below the recommended range, an increase in mortality by 28% has been reported. [Laptook 2007 e643]

A Cochrane review involving 46 trials and 3850 dyads of infants >32 weeks gestation where resuscitation was not required concluded that skin-to-skin care may be effective in maintaining thermal stability (low quality evidence) and also improves maternal bonding and breast feeding



rates (low to moderate quality evidence). However, most trials were small and unblinded with heterogeneity between groups. [Moore 2016 CD003519] Skin-to-skin care is feasible in less mature infants however caution is required in the more preterm or growth restricted infant in order to avoid hypothermia. In one single centre observational study of 55 infants between 28<sup>+0</sup> and 32<sup>+6</sup> weeks gestation randomised to either skin-to-skin or conventional thermal care the mean body temperature of the skin-to-skin group was 0.3 °C lower 1 hour after birth (36.3 °C +/- 0.52, p = 0.03) [Linner 2020 697]: Further studies are ongoing. [Linner 2020 e038938]

Following a recent ILCOR evidence update including a Cochrane systematic review of 25 studies including 2433 preterm and low birth weight infants [McCall 2018 1], treatment recommendations are unchanged from 2015. It is recommended that newborn temperatures be kept between 36.5 °C and 37.5 °C in order to reduce the metabolic stress on the infant (strong recommendation, very low quality of evidence). [Wyllie 2015 e169; Wykoff 2020 A156] For newborn preterm infants of ≤32 weeks gestation under radiant warmers in the hospital delivery room, a combination of interventions is suggested which may include raising the environmental temperature to 23 °C – 25 °C, use of warmed blankets, plastic wrapping without drying, cap and thermal mattress to reduce hypothermia on admission to the neonatal intensive care unit (NICU) (weak recommendation, very-low quality of evidence). [Wykoff 2020 A156] For infants <28 weeks gestation the room temperature should ideally be above 25 °C. [Chitty 2013 362; Trevisanuto 2018 333; Manani 2013 8] In the absence of exothermic devices, food grade plastic wrap and swaddling can be effective in preterm infants. [Belsches 2013 e656; Chitty 2013 362; Trevisanuto 2018 333]

It is suggested that hyperthermia (greater than 38.0 °C) should be avoided because it introduces potential associated risks (weak recommendation, very-low quality of evidence). [Wyllie 2015 e169; Wykoff 2020 A156] Infants born to febrile mothers have a higher incidence of perinatal respiratory compromise, neonatal seizures, early mortality and cerebral palsy. [Lieberman 2000 983; Grether 1997 207; Kasdorf 2013 8] Animal studies indicate that hyperthermia during or following ischaemia is associated with a progression of cerebral injury. [Kasdorf 2013 8]

Temperature monitoring is key to avoiding cold stress. However, there is very little evidence to guide the optimal placement of temperature monitoring probes on the infant in the delivery room. In an observational study of 122 preterm infants between 28 and 36 weeks gestation randomised to different sites for temperature monitoring, dorsal, thoracic and axillary sited

probes measured comparable temperatures. [Bensouda 2018 27] There are to date no published studies comparing the use of rectal temperature probes.

Heated humidified gases reduced the incidence of moderate hypothermia in preterm infants. [te Pas 2010 e1427] A meta-analysis of two RCTs involving 476 infants <32 weeks gestation [Meyer 2018 319; McGrory 2018 47] indicated that heated, humidified inspired gases immediately following delivery reduced the likelihood of admission hypothermia in preterm infants by 36% (95% CI 17-50%) (high level of evidence). [Meyer 2018 319] There was no significant increase in the risk of hyperthermia nor a difference in mortality between humidified and non-humidified groups. It is unclear if other outcomes are improved.

Quality improvement programs including the use of checklists and continuous feed-back to the team have shown to significantly reduce hypothermia at admission in very preterm infants. [Manani 2013 8; DeMauro 2013 e1018]

### **[h3] Clamping the umbilical cord**

There is no universally accepted definition of 'delayed' or 'deferred' cord clamping' (DCC), only that it does not occur immediately after the infant is born. In recent systematic reviews and meta-analyses [Seidler 2020 Pediatrics; Gomersall 2020 Pediatrics] early or immediate cord clamping (ICC) has been defined as application of the clamp within 30 seconds of birth, Later or delayed cord clamping as application of a clamp to the cord greater than 30 seconds after birth or based on physiological parameters (such as when cord pulsation has ceased or breathing has been initiated), without cord milking

### **[h3] Physiology of cord clamping**

Observational data, physiological studies, animal models and some clinical studies suggest that ICC, currently widely practiced and introduced primarily to prevent maternal postpartum haemorrhage, is not as innocuous as was once thought. [Hooper 2016 4; Hooper 2015 608] ICC significantly reduces ventricular preload whilst simultaneously adding to left ventricular afterload. [Hooper 2015 147, Bhatt 2013 2113] Effects of this are seen in observational studies, with a decrease in cardiac size for 3 – 4 cardiac cycles [Peltonen 1981 14] and bradycardia [Brady 1962 1], and in experimental animal models. [Polglase 2015 e011750]

### **[h3] Differences with gestation**

In term infants, DCC results in the transfer of approximately 30 mL kg<sup>-1</sup> of blood from the

placenta. [Farrar 2011 70] This improves iron status and haematological indices over the next 3–6 months in all infants and reduces need for transfusion in preterm infants. [Strauss 2008 658; Rabe 2008 138] Concerns about polycythaemia and jaundice requiring intervention do not seem to be borne out in randomised trials. Concerns about the position of the infant in relation to the introitus also seem unfounded as the effects of uterine contraction and lung expansion seem to exert a greater impact on umbilical blood flow than gravity. [Vain 2014 235; Hooper 2017 F312]

In an ILCOR meta-analysis of 23 studies of 3514 eligible infants comparing ICC versus a delay of at least 30 seconds in preterm infants <34 weeks gestation [Seidler 2020 Pediatrics] the conclusion was that compared to ICC DCC may marginally improve survival (RR 1.02, 95% CI 0.993 to 1.04) (certainty of evidence moderate) Early cardiovascular stability was improved with less inotropic support (RR 0.36, 95% CI 0.17 to 0.75) and higher lowest mean blood pressure (MD 1.79 mmHg, 95% CI 0.53 to 3.05) in the first 12-24 hours. Infants had better haematological indices: The peak haematocrit appeared higher at 24 hrs (MD 2.63, 95% CI 1.85 to 3.42) and at 7 days (MD 2.70, 95% CI 1.88 to 3.52). Infants required fewer blood transfusions (MD -0.63, 95% CI -1.08 to -0.17). No effects were seen on any of the complications of prematurity such as severe IVH, NEC or chronic lung disease, nor was there any obvious adverse impact on other neonatal or maternal outcomes (moderate to high quality evidence). In sub-group analyses of DCC vs. ICC, there seemed to be an almost linear relationship between survival to discharge and duration of DCC; DCC for ≤1 minute, RR 1.00 (95% CI 0.97 – 1.04); DCC for 1 to 2 minutes, RR 1.03 (95% CI 1.00 – 1.05); DCC for > 2 minutes, RR 1.07 (95% CI 0.99 – 1.15). None of these results were statistically significant due to the relatively small numbers involved.

In term and late preterm infants an ILCOR meta-analysis of 33 trials (5236 infants) of DCC vs ICC [Gomersall 2020 Pediatrics] updated the findings of a previous 2013 Cochrane study [McDonald 2013 CD004074]. Analysis demonstrated no significant effect on mortality (RR 2.54, 95% CI 0.50 to 12.74; 4 trials, 537 infants) or need for resuscitation (RR 5.08, 95% CI 0.25 to 103.58; 3 trials, 329 infants) There were improved early haematological and circulatory parameters (haemoglobin ≤24 hours after birth (MD 1.17 g dL<sup>-1</sup> 95% CI 0.48 to 1.86, 9 trials, 1352 infants) and 7 days after birth (MD 1.11 g dL<sup>-1</sup> 95% CI 0.40 to 1.82, 3 trials, 695 infants) but no impact on longer term anaemia.. This updated review does not suggest clear differences in receipt of phototherapy (RR 1.28, 95% CI 0.90 to 1.82). (all findings low or very low certainty evidence). The analysis did not provide clear evidence on longer term

neurodevelopmental outcomes.

Further study is warranted; most studies used a temporal definition for the timing of cord clamping, there are insufficient data to recommend 'physiological' cord clamping (i.e. after the onset of respirations) [Hooper 2015 F355], although this may confer benefit. [Ersdal 2014 265] Physiological studies suggest that the hypoxic and bradycardic response observed after immediate clamping is not seen when clamping occurs after the first breaths. [Brady 1962 1; Polglase 2015 e0117504]

The question of resuscitating infants with the intact cord warrants further study; in most studies of delayed cord clamping infants who required resuscitation at birth were excluded as resuscitation could only be undertaken away from the mother. Equipment now exists that allows mother-side resuscitation and initial studies show that delayed cord clamping is feasible in such infants. [Duley 2018 F6; Katheria 2017 313.e1] However, it remains unclear which is the optimum strategy in these infants.

### **[h3] Cord milking**

Delayed umbilical cord clamping is contra-indicated when placental blood flow is compromised by placental abruption, cord prolapse, vasa praevia, cord avulsion or maternal haemorrhage. Umbilical cord milking with intact or cut cords has been considered an alternative in these situations. In 'intact cord milking' the cord is milked 3–5 times, resulting in a faster blood flow towards the baby than occurs with passive return due to uterine contraction. A term infant can receive up to 50 mL of 'placental' blood through this action. After milking the cord is clamped and cut, and the infant can be taken to the resuscitaire. [McAdams 2018 245]

'Cut cord milking' involves milking from a length of cord (~25 cm) after clamping and cutting. The volume of blood is less than from an intact cord, but still gives the term infant about 25 mL. The infant is taken to the resuscitaire immediately and milking occurs during resuscitation or stabilisation. [Upadhyay 2013 120.e1]

In preterm infants born before 34 weeks gestation, intact cord milking shows only transient benefits over ICC including less use of inotropic support, fewer infants needing blood transfusion, and higher haemoglobin and haematocrit on day 1 but not at 7 days, There were no differences in major neonatal morbidities (low to moderate quality evidence). There was no demonstrable benefit over DCC. [Seidler 2020 Pediatrics] In the meta-analyses, there was no

effect on mortality (RR 0.99; 95% CI 0.95 – 1.02), but of particular concern is that one large study of intact cord milking versus delayed cord clamping was terminated early when analysis demonstrated an excess of severe intraventricular haemorrhage (RD 16% 95% CI 6% to 26%; P = 0.002) in those infants born before 28 weeks allocated to the intact cord milking arm. [Katheria 2019 1877]

In term and late preterm infants there are insufficient data to allow meta-analysis of umbilical cord milking. [Gomersall 2020 Pediatrics]

## **[h2] Initial assessment**

### **[h3] Initial Assessment**

The Apgar score was not designed to identify infants in need of resuscitation. [Apgar 1953 260] However, individual components of the score, namely respiratory rate, heart rate (HR) and tone, if assessed rapidly, may help identify infants likely to need resuscitation.

### **[h3] Tactile Stimulation**

Methods of tactile stimulation vary widely but the most optimal method remains unknown. [Dekker 2017 61; Baik-Schneditz 2018 952] In preterm infants, tactile stimulation is often omitted, [Dekker 2017 61; Gaertner 2018 132; van Henten 2019 F661; Pietravalle 2018 306] but in a single centre RCT of repetitive stimulation against standard stimulation only if deemed necessary in 51 infants between 28-32 weeks gestation, repetitive stimulation was shown to improve breathing effort and oxygen saturation ( $\text{SpO}_2$   $87.6 \pm 3.3\%$  vs  $81.7 \pm 8.7\%$ ,  $p = 0.007$ ). [Dekker 2018 37] Stimulation of more infants at birth (after introduction of a basic resuscitation training program) was associated with an increased 24-h survival in a multi-centre observational study in Tanzania, including 86,624 mainly term/near-term infants. [Msemo 2013 353]

### **[h3] Tone and Colour**

Healthy infants are cyanosed at birth but start to become pink within approximately 30 seconds of the onset of effective breathing. [van Vonderen 2014 230] Peripheral cyanosis is common and does not, by itself, indicate hypoxia. Persistent pallor despite ventilation may indicate significant acidosis, or, more rarely, hypovolaemia with intense cutaneous vascular vasoconstriction. A pink upper-part of the body and a blue lower part can be a sign of right-left shunting over an open duct.

Colour is an unreliable marker of oxygenation which is better assessed using pulse oximetry. There are few studies in the newborn. In an observational study involving 27 clinicians making a subjective assessment of oxygenation status using videos of preterm infants where saturations were known there was a lack of concordance with both under and over estimation of values. [O'Donnell 2007 F92]

### **[h3] Breathing**

Not crying may be due to apnoea but can function as a marker of inadequate breathing needing support. In an observational study of 19 977 infants just after birth in a rural hospital setting 11% were not crying, around half of whom were assessed as apnoeic. About 10% of those assessed as breathing at birth became apnoeic. Not crying but breathing was associated with a 12-fold increase in morbidity. [Ashish 2020 e20192719]

The presence or adequacy of breathing effort in preterm infants can be difficult to assess as breathing can be very subtle and is often missed. [Schilleman 2013 457; Van Vonderen 2014 230] Breathing perceived as inadequate will prompt an intervention. In a retrospective video based observational study of 62 preterm infants delivered at <28 weeks or with birth weight <1000g 80% were assessed as showing signs of breathing but all received respiratory support with CPAP or intubation. [O'Donnell 2010 846]

### **[h3] Heart rate**

Immediately after birth, the heart rate is assessed to evaluate the condition of the infant and subsequently, heart rate is the most sensitive indicator of a successful response to interventions. [Linde 2016 231; Linde 2017 80; Linde 2018 1] There is no published evidence unambiguously defining the thresholds for intervention during newborn resuscitation. The rates of 100 min<sup>-1</sup> and 60 min<sup>-1</sup> around which interventions are prompted are essentially pragmatic in nature. [Saugstad 2011 1058].

In uncompromised breathing term infants, where umbilical cord clamping was delayed, the heart rate is usually above 100 min<sup>-1</sup>. [Linde 2016 231]. In an observational study of term/near-term infants resuscitated in a rural setting the initial heart rates at birth were distributed in a bimodal peak around 60 and 165 min<sup>-1</sup>. Ventilation increased heart rate in most bradycardic newborns to a final median of 161 min<sup>-1</sup>. Lower initial and subsequent heart rates were associated with poorer outcomes. [Eilevstjonn 2020 69] In preterm infants <30 weeks gestation the heart rate does not stabilise until it reaches approximately 120 min<sup>-1</sup> and, in

some, stability was only achieved once the heart rate was  $>150 \text{ min}^{-1}$ . [Yam 2011 F102].

Auscultation by stethoscope is inexpensive, simple, and permits a reasonably accurate rapid assessment of heart rate. In delivery room studies of low risk infants heart rate determination was possible within 14(10-18) seconds (median(IQR)) [Murphy 2018 F490] and was found to underestimate ECG or Pulse oximetry (PO) values by between  $-9(+/-7)$  and  $-14(+/-21) \text{ min}^{-1}$  (mean difference (95% CI)) [Murphy 2018 F490; Kamlin 2006 319]

Palpation for a pulse at the base of the umbilical cord or (less reliably) the brachial or femoral arteries is also simple and rapid. Values may be considered valid if the heart rate is determined to be fast ( $>100 \text{ min}^{-1}$ ), however they are often inaccurate, intermittent and affected by movements with a tendency to significantly underestimate, [Kamlin 2006 319; Owen 2004 213] potentially prompting inappropriate interventions.

Continuous monitoring provides a more dynamic indication of heart rate change during resuscitation and is preferable to intermittent counting. A pulse oximeter (ideally connected to the right hand) can give an accurate heart rate as well as information on oxygenation. Initial values may underestimate the ECG a little; in a study of 53 infants pulse oximeter values were significantly lower than ECG over the first 2 minutes ( $81 (60-109)$  vs  $148 (83-170) \text{ min}^{-1}$  at 90 seconds ( $p < 0.001$ )). [van Vonderen 2015 49] Later differences of  $-2(26) \text{ min}^{-1}$  (mean(SD)) were observed when compared to ECG [Kamlin 2008 756], but the time to obtain reliable values may take longer than auscultation [Katheria 2012 e1177]. Findings differ as to whether advantage is gained from connecting the sensor to infant [O'Donnell 2005 F84] or oximeter [Deepak 2014 476] first, however, signal acquisition can be achieved within about 15 seconds once connected. Peripheral hypoperfusion, signal dropout, movement, arrhythmias, and ambient lighting can interfere with PO measurements. Pulse oximetry may significantly underestimate values when signal quality is poor. [Narayan 2015 e158]

ECG has been demonstrated to be a practical and rapid means of accurately determining the heart rate which may be a few seconds faster than pulse oximetry and more reliable, especially in the first two minutes after birth. [Anton 2019 199; Johnson 2019 196] Two RCT's reported faster times to HR assessment using ECG compared to PO with a mean(SD)  $66(20)$  vs  $114(39)$  seconds [Katheria 2017 e0187730] and a median(IQR)  $24(19-39)$  vs  $48(36-69)$  seconds [Murphy 2018 F490] both  $p = 0.001$ .

A recent ILCOR evidence update (Wykoff 2020 A156) concluded that the 7 new studies

identified since 2015 (2 systematic reviews, 2 RCT's and 3 observational studies) supported the previous recommendations that in infants requiring resuscitation. ECG can be used to provide a rapid and accurate estimation of heart rate (weak recommendation, low quality of evidence). [Perlman 2015 S204/S120; Wyllie 2015 e169]

It is important to be aware of the limitations of the methods. ECG does not replace oximetry as whilst ECG may indicate a heart rate in the absence of output (PEA), [Luong 2019 F572] pulse oximetry has advantages over ECG in providing a measure of perfusion and oxygenation. Newer technologies such as dry electrodes may improve signal; and methods such as plethysmography and Doppler may permit rapid reliable output-based determination of heart rate, but clinical validation is still needed before they can be recommended. [Johnson 2019 196; Anton 2019 199]

## **[h2] Airway**

### **[h3] Airway**

With flexion and extension, the airway can become occluded. [Chua 2012 411] The evidence on the mechanisms of airway occlusion in the newborn is limited. A retrospective analysis of images of the airway of 53 sedated infants between 0-4 months undergoing cranial MRI indicates how, in extension, obstruction might occur through anterior displacement of the posterior airway at the level of the tongue. [Bhalala 2016 1] Therefore, a neutral position is favoured to ensure optimal airway patency.

### **[h3] Jaw Lift**

There are no studies of jaw thrust/lift in the newborn. Studies in children [Ungern-Sternberg 2005 181] demonstrate that anterior displacement of the mandible enlarges the pharyngeal space through lifting the epiglottis away from the posterior pharyngeal wall, reversing the narrowing of the laryngeal inlet. Two person manual ventilation techniques are superior to single handed airway support. [Chua 2012 411]

### **[h3] Oropharyngeal/Nasopharyngeal airway**

Although the oropharyngeal airway (OPA) has been shown to be effective in children [Rechner 2007 790], there is no published evidence demonstrating effectiveness in helping maintain the patency of the airway at birth. In a randomised study of 137 preterm infants where gas flow through a mask was measured, obstructed inflations were more common in the OPA group (complete 81% vs. 64%;  $p = 0.03$ , partial 70% vs. 54%;  $p = 0.04$ ). [Kamlin 2019 106] However,



by helping lift the tongue and preventing it occluding the laryngeal opening, an OPA may facilitate airway support where difficulty is experienced and manoeuvres, like jaw lift, fail to improve ventilation. A nasopharyngeal airway (NPA) may help establish an airway where there is congenital upper airway abnormality [Abel 2012 331] and has been used successfully in preterm infants at birth [Kamlin 2013 e381]

### **[h3] Airway Obstruction**

The cause of airway obstruction is usually unknown. It may be due to inappropriate positioning of the head, laryngeal adduction, or pushing a facemask onto the mouth and nose too hard, especially in preterm infants at birth. In an animal model of premature birth Crawshaw used phase contrast X-ray to demonstrate that the larynx and epiglottis were predominantly closed (adducted) in those with unaerated lungs and unstable breathing patterns, making intermittent positive pressure ventilation (IPPV) ineffective unless there was an inspiratory breath, and only opening once the lungs were aerated [Crawshaw 2018 F112]. In an observational study of 56 preterm infants <32 weeks gestation significant mask leak (>75%) and/or obstruction to inspiratory flow (75%) were identified using respiratory function monitoring in 73% of interventions during the first 2 minutes of PPV [Schmölzer 2011 F254] There is no evidence that normal lung fluid and secretions cause obstruction, and thus no need to aspirate fluid from the oropharynx routinely.

### **[h3] Oropharyngeal and nasopharyngeal suction**

Oropharyngeal and nasopharyngeal suction has in newborn infants not been shown to improve respiratory function and may delay other necessary manoeuvres and the onset of spontaneous breathing. Consequences may include irritation to mucous membranes, laryngospasm, apnoea, vagal bradycardia, hypoxaemia, desaturation and impaired cerebral blood flow regulation. [Kelleher 2013 382, Cordero 1971 441, Gungor 2006 9, Bancalari 2019 271, Nejad 2014 400] A recent ILCOR scoping review of 10 studies (8 RCTs, 1 observational study and 1 case study) into the suctioning of clear fluid involving >1500 mainly term/near-term infants and found no evidence to challenge the current recommendations: Routine intrapartum oropharyngeal and nasopharyngeal suction for newborn infants with clear or meconium-stained amniotic fluid is not recommended (very low certainty evidence - downgraded for risk of bias, indirectness and imprecision). [Wykoff 2020 A156] If suctioning is attempted it should be undertaken under direct vision, ideally using a laryngoscope and a wide bore catheter.

There have been few studies investigating the effectiveness of suction devices for clearing the newborn airway. An in vitro study using simulated meconium demonstrated the superiority of the Yankauer sucker in clearing particulate matter when compared to large bore (12-14F) flexible catheters and bulb devices. Most devices could clear non-particulate matter but the only devices that cleared simulated particulate meconium were a Yankauer sucker or a bulb syringe device. Bulb suction devices are less effective but do not require a separate vacuum source. Smaller diameter suction catheters were much less effective. [Zareen 2013 F241] The paediatric Yankauer sucker has the advantage of single-handed use and effectiveness at lower vacuum pressures which may be less likely to damage mucosa. A meconium aspirator, attached to a tracheal tube functions in a similar manner and can be used to remove tenacious material from the trachea. These devices should be connected to a suction source not exceeding 150 mmHg (20kPa). [Bent 1992 1085]

### **[h3] Meconium**

Lightly meconium-stained liquor is common and does not, in general, give rise to much difficulty with transition. The less common finding of very thick meconium-stained liquor is an indicator of perinatal distress and should alert to the potential need for resuscitation.

There is no evidence to support intrapartum suctioning nor routine intubation and suctioning of vigorous infants born through meconium-stained liquor. [Foster 2017 CD010332, Wiswell 2000 1] Retrospective registry based studies do not demonstrate an increase in morbidity following a reduction in delivery room intubation for meconium. [Edwards 2019 E68, Kalra 2020 46]. An ILCOR systematic review of three RCT's involving 449 infants and one observational study of 231 infants demonstrated no benefit from the use of immediate laryngoscopy with or without tracheal suctioning compared with immediate resuscitation without laryngoscopy (RR 0.99; 95% CI 0.93-1.06 p=0.87) [Wykoff 2020 A156]. Parallel meta-analyses [Trevisanuto 2020 117; Phattraprayoon 2020 F1 ] including a further RCT with 132 infants [Kumar 2019 1825] derived similar conclusions. A post policy change impact analysis of the resuscitation of 1138 non-vigorous neonates born through meconium-stained amniotic fluid, found reduced NICU admissions and no increase in the incidence of Meconium Aspiration Syndrome (MAS) where suctioning was omitted in favour of immediate ventilation. [Oommen 2020 319771].

Routine suctioning of non-vigorous infants may result in delays in initiating ventilation although some newborn infants may still require laryngoscopy with or without tracheal intubation in order to clear a blocked airway or for subsequent ventilation. Therefore, in apnoeic or

ineffectively breathing infants born through meconium-stained amniotic fluid ILCOR treatment recommendations suggest against routine immediate direct laryngoscopy and/or suctioning after delivery with the emphasis on initiating ventilation in the first minute of life (weak recommendation, low certainty evidence). [Wykoff 2020 A156]

In infants with respiratory compromise due to meconium aspiration, the routine administration of surfactant or bronchial lavage with either saline or surfactant is not recommended. [Dargaville 2011 383, Dargaville 2013 e90]

## **[h2] Initial inflations and assisted ventilation**

After initial assessment at birth, if breathing efforts are absent or inadequate, lung aeration is the priority and must not be delayed. An observational study in low resource settings suggested those resuscitating took around 80 +/- 55 seconds to commence ventilation with a 16% (p=0.045) increase in morbidity/mortality in apnoeic infants for every 30 seconds delay in starting ventilation after birth. [Ersdal 2012 869] In term infants, respiratory support should start with air. [Welsford 2019 e20181825]

## **[h3] Inflation pressure & duration**

In newborn infants, spontaneous breathing or assisted initial inflations create the functional residual capacity (FRC). [Vyas 1981 635; Hooper 2013 336] When assisting ventilation, the optimum inflation pressure, inflation time and flow required to establish an effective FRC are subject to technical and biological variation and have not yet been conclusively determined. Debate continues about the validity of longer inflation breaths with recent discussion on the merits of sustained inflation (see below). [Kapadia 2020 ILCOR] Current ERC NLS recommendations on inflation breaths are for a longer duration although there is a lack of evidence demonstrating advantage or disadvantage over other recommended approaches. Once an airway is established, five initial breaths with inflation pressures maintained for up to 2-3 seconds are suggested [Wyllie 2015 e169] and may help lung expansion. [Vyas 1981 635; Harris 2016 7; Bhat 2017 906]

The evidence for the optimal initial pressure for lung aeration is limited The consensus is that inflation pressures of 30 cm H<sub>2</sub>O are usually sufficient to inflate the liquid filled lungs of apnoeic term infants. This value was originally derived from historical studies of limited numbers of infants. [Vyas 1981 635, Vyas 1986 189, Boon 1979 1031] A more recent

prospective study of 1237 term and near-term infants resuscitated in a rural setting using a bag-mask without PEEP suggests that higher initial pressures may sometimes be required, with median peak pressures of 37 cm H<sub>2</sub>O required for successful stabilisation. [Ersdal 2020 71] In preterm infants, critical review of the available evidence [Hird 1991 69; Bhat 2017 906; Lamberska 2016 e142; Murthy 2015 235] suggests that previously advocated initial inflation pressures of 20 cm H<sub>2</sub>O are probably to be too low to recruit the lungs effectively. Therefore, it is suggested that a starting pressure of 25cm H<sub>2</sub>O would be reasonable. Acknowledging that smaller airways have greater resistance than larger airways, some preterm infants may need higher pressures than 25 cm H<sub>2</sub>O for lung inflation.

The time to initiation of spontaneous breathing is reported to be inversely correlated with the peak inflation pressure and the inflation time. [Harris 2016 7] If the infant has any respiratory effort, ventilation is most effective when inflation coincides with the inspiratory efforts. [Murthy 2015 235] However, the tidal volume of positive pressure ventilations may then exceed that of spontaneous breaths. [Kaufman 2013 F405; Schilleman 2013 457] It is acknowledged that such synchronisation is difficult to achieve. [Foglia 2018 340].

A recent observational study in preterm infants under 32 weeks suggested that the application of a mask to support breathing might induce apnoea in spontaneously breathing infants. [Kuypers 2019 178] However, the significance of this effect on outcome is currently unclear. [O'Donnell 2019 189]

### **[h3] Ventilation**

There is limited evidence on the optimal rate of ventilation for newborn resuscitation. In an observational study of 434 mask ventilated late preterm and term infants, ventilation at a rate of about 30 breaths min<sup>-1</sup> achieved adequate tidal volumes without hypocarbia and the frequency of 30 breaths min<sup>-1</sup> with V<sub>TE</sub> of 10-14 mLkg<sup>-1</sup> was associated with the highest CO<sub>2</sub> clearance [Holte 2019 e000544]. In an observational study of 215 near-term/term infants there was a non-linear relationship between delivered tidal volume and heart rate. The minimum volume necessary to produce an increase in heart rate was 6.0 (3.6-8.0) mLkg<sup>-1</sup>. A tidal volume of 9.3 mLkg<sup>-1</sup> produced the most rapid and largest increase in heart rate. [Linde 2017 80]

The delivered tidal volume required to form the FRC may exceed that of the exhaled TV: Foglia et al. describe this as being over 12 mLkg<sup>-1</sup> for a term infant. [Foglia 2018 340] Exhaled

tidal volumes increase during the first positive pressure ventilations as aeration takes place, compliance increases and the FRC is established. [Ersdal 2020 71] In most instances, it should be possible to reduce peak pressures once the lungs are aerated to prevent excessive tidal volumes. [Foglia 2018 340]

There are no published studies clearly determining the optimal inflation time when providing positive pressure ventilation. Longer inspiratory times may permit lower pressures. [Foglia 2018 340] Observational studies on spontaneously breathing newborn infants suggest that once lung inflation has been achieved they breathe at a rate between 30 and 40 breaths min<sup>-1</sup>, and regardless of which breathing pattern, an inspiratory time of 0.3-0.4 seconds is used. [te Pas 2009 352]

### **[h3] Assessment**

The primary response to adequate initial lung inflation is a prompt improvement in heart rate. [Linde J 2018 1; Linde J 2017 80] Most newborn infants needing respiratory support will respond with a rapid increase in heart rate within 30 seconds of lung inflation. [Thallinger 2017 66] Chest wall movement usually indicates aeration/inflation. This may not be so obvious in preterm infants. [Poulton 2011 175] Large chest excursions during positive pressure ventilation may be a marker of excessive tidal volumes, which should be avoided. Continued ventilation is required if the heart rate increases but the infant is not breathing adequately.

Failure of the heart rate to respond is most likely secondary to inadequate airway control or inadequate ventilation. Mask position or seal may be suboptimal. [Kaufman 2013 F405; Wood 2008 F235; Wood 2008 230] Head/Airway position may be in need of adjustment. [Chua 2014 411] Inflation pressures may need to be higher to achieve adequate inflation/tidal volumes. [Ersdal 2020 71] In preterm infants excessive mask pressure and glottal closure have been demonstrated to be factors. [Schmolzer 2011 F254; Martherus 2019 F102; Dekker 2019 Ped Res; Crawshaw 2018 F112]

Using a two-person approach to mask ventilation reduces mask leak in term and preterm infants and is superior to the single handed approach. [Tracy 2011 F195; Wood 2008 230] Published evidence on the incidence of physical matter as a cause of obstruction is lacking but it is recognised that meconium or other matter (e.g. blood, mucus, vernix) may cause airway obstruction. [Strand 2019 ILCOR NLS#865] The use of adjuncts to support the airway is discussed elsewhere (see airway & adjuncts).

### **[h3] Sustained inflations (SI) >5 s**

Animal studies have suggested that a longer SI may be beneficial for establishing functional residual capacity at birth during transition from a liquid-filled to air-filled lung. [Klingenberg 2013 F222; te Pas 2009 295] A Cochrane systematic review of initial inflation >1 second vs. standard inflations ≤1 second was updated in 2020. 8 RCT's enrolling 941 infants met inclusion criteria for the primary comparison of the use of SI without chest compressions. SIs were of 15-20 seconds at 20-30 cm H<sub>2</sub>O. No trial used SIs of ≤5 seconds. SI was not better than intermittent ventilation for reducing mortality in the delivery room (low quality evidence – limitations in study design and imprecision) and during hospitalisation (moderate quality evidence – limitations in study design). There was no benefit for SI vs. intermittent ventilation for the secondary outcomes of intubation, need for respiratory support or BPD (moderate quality evidence). [Bruschettini 2020 CD004953]

A large multicentre RCT which was not included in this analysis investigating effects of SI vs. IPPV among extremely preterm infants (23-26 weeks gestational age) concluded that a ventilation strategy involving 2 SIs of 15 seconds did not reduce the risk of BPD or death at 36 weeks postmenstrual age. The study enrolled 460 infants out of a planned 600 but was stopped early due to excess early mortality in the SI group possibly attributable to resuscitation. Death at less than 48 hours of age occurred in 16 infants (7.4%) in the SI group vs 3 infants (1.4%) in the standard resuscitation group (adjusted risk difference (aRD), 5.6% [95% CI, 2.1% to 9.1%]; p = 0.002). but this finding could not be attributed to the SI directly. [Kirpalani 2019 1165]

A recent ILCOR systematic review [Kapadia 2020 ILCOR NLS #809, Wykoff 2020 A156] identified 10 eligible RCTs including those above with 1509 newborn infants. For the primary outcome of death before discharge no significant benefit or harm was noted from the use of SI >1 second (actually >5 second) compared to PPV with inflations of ≤1 second (low certainty evidence downgraded for risk of bias and inconsistency). No studies were identified reporting on the secondary critical outcomes of long-term neurodevelopmental outcome or death at follow up. Subgroup analysis of different lengths of SI (6-15 seconds 9 RCTs 1300 infants, >15 seconds 2 RCTs 222 infants) and of different inspiratory pressures (>20 mmHg 6 RCTs 803 infants, ≤20 mmHg 699 infants) demonstrated no significant benefit or harm from SI compared to IPPV of ≤1 second (downgraded for risk of bias and variously for imprecision and inconsistency).

In subgroup analyses comparing SI >1 second to inflations of ≤1 second in infants at <28<sup>+0</sup> weeks there was low certainty evidence (downgraded for risk of bias and imprecision) from 5 RCTs enrolling 862 infants of potential harm (RR 1.38 95% CI 1.00 – 1.91). In infants 28<sup>+1</sup>–31<sup>+6</sup> weeks there was very low certainty evidence (downgraded for risk of bias and very serious imprecision) from 4 RCTs enrolling 175 preterm infants demonstrating no significant benefit or harm (RR 1.33 95% CI 0.22 – 8.20). No SIs were <5 seconds. There was no published data available for more mature infants.

Further sub-analyses excluding studies with a high risk of bias (9 RCTs 1390 infants RR 1.24 95%CI 0.92-1.68), studies with only a single breath (9 RCTs 1402 infants RR 1.17 95%CI 0.88-1.55) and those with sustained inflation with mask only (9 RCTs 1441 infants (RR 1.06 95%CI 0.61-1.39) demonstrated no difference in outcome between SI and normal inflations. (low certainty evidence, downgraded for risk of bias and imprecision).

ILCOR treatment recommendations suggest that the routine use of initial SI ≥5 seconds cannot be recommended for preterm newborn infants who receive positive pressure ventilation prompted by bradycardia or ineffective respirations at birth (weak recommendation, low-certainty evidence) but that a sustained inflation might be considered in research settings. There was insufficient evidence to make any specific recommendation on the duration of inflations in late preterm or term infants. It was recognised that the total number of infants studied were insufficient to have confidence in the estimate of effect; larger trials being needed to determine if there are benefits or harms from sustained inflation. [Wykoff 2020 A156].

There are no randomised trials comparing the use of initial breaths of ≤1 second with breaths of 2-3 seconds. A recent RCT in 60 preterm infants <34 weeks gestation of 2-3 second inflation breaths vs. a single 15 SI [Hunt 2019 17] demonstrated no difference in minute volume or end tidal CO<sub>2</sub>. Infants receiving the SI made a respiratory effort sooner (median 3.5 (range 0.2–59) versus median 12.8 (range 0.4–119) seconds, p = 0.001). SI was associated with a shorter duration of ventilation in the first 48 hours (median 17 (range 0–48) versus median 32.5 (range 0–48) hours, p = 0.025)

## **[h2] Airway Adjuncts/Assisted ventilation devices/PEEP&CPAP**

### **[h3] PEEP**

Animal studies have shown that immature lungs are easily damaged by large tidal volume inflations immediately after birth [Björklund 1997 348; Ingimarsson 2004 1446] and suggest that maintaining a PEEP immediately after birth may help reduce lung damage [Muscedere 1994 1327; Naik 2001 164] although one study suggests no benefit. [Polglase 2008 517] PEEP applied immediately after birth improves lung aeration, functional residual capacity, compliance and gas exchange, particularly oxygenation. [Probyn 2004 198; te pas 2009 537]

PEEP can more reliably be delivered by pressure limiting devices which use continuous gas flow, like TPR devices. A recent review of the evidence undertaken by ILCOR [Wykoff 2020 A156] identified two randomized trials and one quasi-randomized trial (very low quality evidence) comparing ventilation with TPR vs. SIB and reported similar rates of death and chronic lung disease. There was no difference in SpO<sub>2</sub> at 5 minutes after birth in 80 infants <29 weeks gestation (61% [13- 72%] versus 55% [42- 67%]; p = 0.27) [Dawson 2011 912]. No difference was identified in achieving HR >100 min<sup>-1</sup> in 1027 infants ≥26 weeks (1(0.5-1.6) vs 1(0.5-1.8) p=0.068 (min(IQR)) [Szyld 2014 234]. There were reductions in the magnitude of some interventions with TPR. 86(17%) vs. 134(26%) were intubated in the delivery room (OR 0.58(0.4-0.8) 95% CI p = 0.002). The maximum positive inspiratory pressure was 26(2) cm H<sub>2</sub>O TPR vs 28(5) cm H<sub>2</sub>O SIB (P < 0.001) mean(SD).

In a quasi-randomised study of 90 infants of 34 (3.7) (mean (SD)) weeks gestation the duration of PPV in delivery room was significantly less with TPR (median (IQR) 30 seconds (30-60) vs. 60 seconds (30-90) (p<0.001)) [Thakur 2015 21]. A higher proportion were intubated in the SIB group (34 vs 15% p=0.04). In one large multicentre observational study of 1962 infants between 23-33 weeks gestation improved survival and less BPD was seen when PEEP is used at birth (OR=1.38; 95% CI 1.06 to 1.80). [Guinsburg 2018 F49]

All term and preterm infants who remain apnoeic despite adequate initial steps must receive positive pressure ventilation. ILCOR treatment recommendations [Wykoff 2020 A156] are unchanged from 2015, suggesting PEEP should be used for the initial ventilation for premature newborn infants during delivery room resuscitation (weak recommendations, low-quality evidence). It is suggested that positive end expiratory pressure (PEEP) of approximately 5-6 cm H<sub>2</sub>O to begin with should be administered to preterm newborn infants receiving PPV. No clear recommendations on the level of PEEP can be made for term infants because of a lack of evidence. [Perlman 2015 S204/S120; Wyllie 2015 e169]



### **[h3] CPAP**

A Cochrane systematic review of CPAP applied within the first 15 minutes of life in preterm infants <32 weeks [Subramaniam 2016 CD001243] identified 7 RCT's involving 3123 infants concluded that CPAP reduced the need for additional breathing assistance but with insufficient evidence to evaluate prophylactic CPAP compared to oxygen therapy and other supportive care. (Evidence was downgraded to low quality because of considerable heterogeneity, imprecision and lack of blinding). In 3 of the studies involving 2354 infants comparing CPAP with assisted ventilation, prophylactic nasal CPAP in very preterm infants reduced the need for mechanical ventilation and surfactant and also reduced the incidence of BPD and death or BPD (evidence downgraded due to imprecision).

Another systematic review [Schmölzer 2013 Ff5980] included 4 RCT's 3 of which were included in the Cochrane analysis and one additional study. Pooled analysis showed a significant benefit for the combined outcome of death or bronchopulmonary dysplasia, or both, at 36 weeks corrected gestation for infants treated with nasal CPAP (RR 0.91, 95% CI 0.84 to 0.99, RD 0.04, 95% CI -0.07 to 0.00) NNT 25.

Following a review of the evidence [Wykoff 2020 A156] ILCOR recommendations are unchanged from 2015, that for spontaneously breathing preterm newborn infants with respiratory distress requiring respiratory support in the delivery room, it is suggested that CPAP should be used initially rather than intubation and IPPV (weak recommendation, moderate certainty of evidence). [Perlman 2015 S204/S120; Wyllie 2015 e169] There are few data to guide the appropriate use of CPAP in term infants at birth. [Poets 2015 F378; Classen 2019 e20191720] Retrospective cohort studies suggest that delivery-room CPAP may be associated with an increased incidence of pneumothorax in term/near term infants [Hishikawa 2015 F382; Clevenger 2017 157; [Smithart 2019 e20190756](#)].

### **[h3] Assisted ventilation devices**

Effective ventilation in the newborn can be achieved with a flow-inflating bag (FIB), a self-inflating bag (SIB) or with a pressure limited TPR. [Dawson 2011 912; Szyld 2014 e3234; Cole 1979 356; Allwood 2003 F375; Hoskyns 1987 376]. An attribute of a TPR device is its ability to deliver a consistent measure of PEEP or CPAP when compared to standard SIB's and this may be a factor contributing to any observed difference in outcomes between the devices (see section on PEEP).

Whilst the TPR appears to confer benefit it cannot be used in all circumstances. Unlike the TPR, the self-inflating bag can be used in the absence of a positive pressure gas supply. However, the blow-off valves of SIB are flow-dependent and pressures generated may exceed the value specified by the manufacturer, usually 30-40 cm H<sub>2</sub>O, if the bag is compressed vigorously [Oddie 2005 109; Ganga-Zandrou 1996 1270]. More training is required to provide an appropriate peak and end pressure using FIBs compared with self-inflating bags. In an observational manikin-based study of 50 clinicians, technical difficulties with the FIB impaired performance when compared to an SIB. [Kanter 1987 761]

A qualitative review identified 30 studies comparing TPR against other neonatal manual ventilation devices [Hawkes 2012 797] and noted that the majority of studies were manikin based with 2 infant based studies [Dawson 2011 912, Schmölzer 2010 F254]. Users of the TPR could provide PIPs closest to the target PIP, with least variation when compared to SIB and FIB [Bennett 2005 113; Kelm 2009 415; Dawson 2011 698; O'Donnell 2005 F392; Tracy 2011 F201]. Similarly TPR users provided a PEEP closer to the predetermined PEEP value with potentially less volutrauma with the TPR as tidal volumes are smaller and less variable in comparison to the SIB [O'Donnell 2005 F392; Kelm 2009 415; Tracy 2011 F201; Dawson 2011 698]. TPR provided a more consistent inspiratory time than SIB independent of experience. Prolonged inflation could be more reliably provided by the TPR [Klingenberg 2011 78 Neonatology]. Limitations of the TPR device were identified. Resuscitation is a dynamic process where the resuscitator needs to adapt to the response or non-response of the newborn. TPR users were not as good at detecting changes in compliance as users of the SIB and FIB [Kattwinkel 2009 123 e465]. PEEP valves could be inadvertently screwed down leading to excess PEEP [Finer 2011 717]. TPR users needed more time to change the inflating pressures during resuscitation compared to users of the SIB or FIB. Mask leak can be greater with the TPR than with SIB [O'Donnell 2005 F392; Tracy 2011 F195] and changes to TPR gas flow rate had significant effects on PIP, PEEP [te Pas 2011 266, Schmolzer 2010 F383, Schilleman 2011 920; Hinder 2019 F122 ] and mask leak [te Pas 2011 266]. The TPR can require more training to set up properly but once in use provided more consistent ventilation than the SIB even with inexperienced operators [Roehr 2010 753] .

The SIB cannot deliver CPAP and may not be able to achieve a consistent end expiratory pressure even with a PEEP valve. [Dawson 2011 698, Morley 2010 51, Bennett 2005 113, Kelm 2009 415, Hartung 2013 741, Hartung 2016 e0150225, Thio 2019 F83] The performance

of various TPRs [Hinder 2019 F122] and self-inflating bags [Tracy 2019 F403] may differ considerably. A newer upright design of SIB and revised mask confers advantages in use [Thallinger 2017 66, Rafferty 2018 F562, Narayanan 2017 1428] including improved delivery of PEEP. [Gomo 2020 1]

In addition to the 1107 infants in the two RCT's included in the 2015 analysis [Dawson 2011 912; Szyld 2014 234], an recent ILCOR scoping review of TPR vs. SIB for ventilation [Roehr 2020 10.1038/s41390-020-1005-4; Wykoff 2020 A156] reported a substantial number of additional patients in one further RCT (n=90) [Thakur 2015 21] and one large observational study (n=1962) [Guinsburg 2018 F49]. Studies differed regarding the investigated populations (two studies included term and preterm infants [Szyld 2014 234; Thakur 2015 21], two studies were in preterm infants only [Dawson 2011 912 e1; Guinsburg 2018 F49], The findings of these studies are outlined in the section on PEEP and suggest improved survival and less need for intubation and BPD with TPR use compared to SIB, particularly in preterm infants.

The ILCOR task force concluded that whilst the direction of evidence is shifting towards support for the use of TPR devices, until a further systematic review is conducted recommendations would remain unchanged [Wykoff 2020 A156]. The 2015 consensus on science [Wyllie 2015 e169] stated that the use of the TPR showed marginally but not statistically significant benefits for the clinical outcome of achieving spontaneous breathing.

### **[h3] Facemask versus nasal prong**

A problem when using a facemask for newborn ventilation is a potentially large and variable leak and loss of inflating gas volume arising from suboptimal selection of mask size and poor technique. In manikin studies using a T-piece and different masks, 50 volunteer operators had variable mask leak up to 80% with improvement after written instruction and demonstration of alternative mask hold techniques. [Wood 2008 F235; Wood 2008] Using flow monitoring recordings of the airway management of 56 newborn preterm infants Schmölzer demonstrated variable degrees of either obstruction ( $\geq 75\%$ ) and/or leak ( $> 75\%$ ) were noted during first 2 minutes of support in 73% of cases [Schmölzer 2010 254].

Nasopharyngeal tubes have been suggested as an alternative. An observational study investigating respiratory function found that when using a single nasopharyngeal tube it took longer before PPV was given, leak was increased and obstruction occurred more frequently, inadequate tidal volumes were delivered more often and SpO<sub>2</sub> was lower in the first minutes

during PPV. [Van Vonderen 2015 81] However, two randomised trials in preterm infants of <31 weeks gestation involving 507 infants did not find any difference in intubation rates in the delivery room between facemask and single nasal prong. [McCarthy 2013 e389; Kamlin 2013 e381]

### **[h3] Laryngeal mask**

The laryngeal mask (LM) may be used in ventilation of the newborn, particularly if facemask ventilation or tracheal intubation is unsuccessful or not feasible. [Wyllie 2015 e169] A recent systematic review [Bansal 2018 152] of seven trials (794 infants) showed that the laryngeal mask was more effective than bag-mask in terms of shorter resuscitation and ventilation times, and less need for tracheal intubation (low- to moderate-quality evidence). Of note, bag-mask was effective in more than 80% of enrolled infants. Efficacy of the laryngeal mask was comparable to that offered by tracheal intubation (very low to low quality evidence), suggesting that it is a valid alternate airway device when attempts at tracheal intubation are unsuccessful during resuscitation or where those involved lack the skills or equipment to intubate safely.

As available studies included infants with birth weight >1500 g or 34 or more weeks gestation, evidence supporting laryngeal mask use in more premature infants is lacking. [Bansal 2018 152; Qureshi 2018 CD003314] The laryngeal mask has not been evaluated in the setting of meconium-stained fluid, during chest compressions, or for the administration of emergency intra-tracheal medications.

### **[h3] Tracheal tube placement**

The use and timing of tracheal intubation will depend on the skill and experience of the available resuscitators. Formulae may be unreliable in determining tracheal tube lengths. [Leung 2018 328; Uygur 2019 (DOI 10.1055/s-0039-3400982)] Appropriate tube lengths for oral intubation derived from observational data based on gestation are shown in Table 1. [Kempley 2008 369] Nasotracheal tube length was found to be approximately 1 cm more than the oral length. [Shukla 1997 561]. Uncuffed tubes are typically used. There is no published evidence to support the routine use of cuffed tubes during neonatal resuscitation. Efficacy has been demonstrated in infants <3kg during perioperative respiratory support. [Thomas 2018 204]

The diameter of the narrowest part of the airway and varies with gestational age and size of the infant whereas the external diameter of the tube (of the same internal diameter) may vary depending on manufacturer. [Fayoux 2006 954] A range of differing sized tubes should be

available to permit placement of that most appropriate to ensure adequate ventilation with only a small leak of gas around the tracheal tube and without trauma to the airway. A narrow diameter tube in a large airway may be confirmed in the correct position but fail to provide adequate ventilation because of low lung compliance and excessive leak. The tube diameter may be estimated as  $\leq 1/10$  of the gestational age. [Sherman 1989 183]

Tracheal tube placement must be assessed visually during intubation, and positioning confirmed clinically and, ideally, radiographically. Markings on the tips of tracheal tubes to aid tube placement distal to the vocal cords vary considerably between manufacturers. [Gill 2014 F344] Within institutions users will likely gain familiarity with specific types. Tube position may alter during the securing process. [Kempley 2008 369] A systematic review of published literature on methods of confirming correct tube placement concluded that objective assessments of tube position were better validated than subjective ones such as visual assessment of chest movement. [Schmölzer 2013 731] Following tracheal intubation and IPPV, a prompt increase in heart rate and observation of expired CO<sub>2</sub> are good indications that the tube is in the trachea. [Schmölzer 2013 731]

### **[h3] End tidal CO<sub>2</sub> and Respiratory function monitoring**

Detection of exhaled CO<sub>2</sub> in addition to clinical assessment is recommended to confirm correct placement of a tracheal tube in neonates with spontaneous circulation. [Wyllie 2015 e169] Even in VLBW infants [Aziz 1999 110; Repetto 2001 284] Detecting evidence of exhaled CO<sub>2</sub> confirms tracheal intubation in neonates with a cardiac output more rapidly and more accurately than clinical assessment alone. [Repetto 2001 284; Hosono 2009 79] However, studies have excluded infants in need of extensive resuscitation. Failure to detect exhaled CO<sub>2</sub> strongly suggests tube misplacement, most likely oesophageal intubation [Aziz 1999 110; Hosono 2009 79] or tube dislodgement. False negative end tidal carbon dioxide (ETCO<sub>2</sub>) readings have been reported during cardiac arrest [Aziz 1999 110] and in VLBW infants despite models suggesting effectiveness with low tidal volumes. [Garey 2008 e1524] Poor or absent pulmonary blood flow or tracheal obstruction may prevent detection of exhaled CO<sub>2</sub> despite correct tracheal tube placement. There is a lack of evidence in the neonate as to the effect of drugs on exhaled CO<sub>2</sub> monitoring, however studies in adults suggest drugs such as adrenaline and bicarbonate may affect end-tidal CO<sub>2</sub> determination. [Sandroni 2018 73] Insufficient inflating pressure to recruit an adequate FRC and generate sufficient expiratory flow might also be a factor. The inability to detect exhaled CO<sub>2</sub> despite correct placement may

lead to a decision to extubate. Where CO<sub>2</sub> detection is unreliable tube position should be confirmed by direct laryngoscopy.

Both qualitative (colorimetric) and quantitative (waveform) methods have been successfully used after delivery. [Hawkes 2017 74] Studies in adults suggest that waveform capnography may be more sensitive than colorimetry in detecting exhaled CO<sub>2</sub>, however, due to lack of data on the validity of waveform capnography in neonates, caution must be exercised when considering its use. [Sandroni 2018 73; Scrivens 2019 711; Mactier 2019 116]

Flow monitoring is useful for confirming tracheal tube position. In a randomised controlled trial a flow sensor confirmed appropriate tube placement faster and more reliably than capnography. [van Os 2016 370].

Respiratory flow/volume monitoring [Schmolzer 2012 e2377] and end tidal CO<sub>2</sub> [Leone 2006 e202, Kong 2013 104] may be used in non-intubated patients. The effectiveness of quantitative capnography in confirming mask ventilation has been demonstrated but may not provide reliable ET-CO<sub>2</sub> values. [Kong 2013 104] The use of exhaled CO<sub>2</sub> detectors to assess ventilation with other interfaces (e.g., nasal airways, laryngeal masks) during positive pressure ventilation in the delivery room has not been reported.

### **[h3] Video-laryngoscopy**

A systematic review of studies of video-laryngoscopy in newborn infants concluded by suggesting that video-laryngoscopy increases the success of intubation in the first attempt but does not decrease the time to intubation or the number of attempts for intubation (moderate to very low-certainty evidence). However, included studies were conducted with trainees performing the intubations and highlight the potential usefulness of video-laryngoscopy as a teaching tool. Well-designed, adequately powered RCTs are necessary to confirm efficacy and address safety and cost-effectiveness of video-laryngoscopy for neonatal endotracheal intubation by trainees and those proficient in direct laryngoscopy. [Lingappan 2018 CD009975] The effectiveness in the context of resuscitation at birth has not been fully evaluated.

## **[h2] Air/Oxygen**

### **[h3] Term infants and late preterm infants $\geq 35$ weeks.**

A recent ILCOR CoSTR [Wykoff 2020 A156] suggests that for term and late preterm newborns

(≥35 weeks gestation) receiving respiratory support at birth, support should start with 21% oxygen (weak recommendation, low certainty evidence). It recommends against starting with 100% inspired oxygen (strong recommendation, low certainty evidence). A systematic review and meta-analysis of 5 RCT's and 5 quasi RCTs included 2164 patients demonstrated a 27% relative reduction in short-term mortality when initial room air was used compared with 100% oxygen for neonates ≥35 weeks gestation receiving respiratory support at birth (RR = 0.73; 95% CI 0.57 to 0.94). [Welsford M 2019 e20181825]. No differences were noted in neurodevelopmental impairment or hypoxic-ischaemic encephalopathy (low to very low certainty evidence).

Use of low concentrations of inspired oxygen may result in suboptimal oxygenation where there is significant lung disease [Oei 2020 p101074] and in term infants a high inspired oxygen may be associated with a delay in onset of spontaneous breathing. [Davis 2004 1329] Therefore oxygen should be titrated to achieve adequate preductal saturations. If increased oxygen concentrations are used, they should be weaned as soon as possible [Wyllie 2010 e260; 136, Vento 2009 e439; Mariani 2007 418].

### **[h3] Preterm infants <35 weeks**

In an ILCOR systematic review and meta-analysis of 10 RCTs and 4 cohort studies including 5697 infants comparing initial low with high inspired oxygen for preterm infants <35 weeks gestation who received respiratory support at birth, there were no statistically significant benefits or harms from starting with lower compared to higher inspired oxygen in short or long term mortality (n = 968; RR = 0.83 (95% CI 0.50 to 1.37)), neurodevelopmental impairment or other key preterm morbidities. [Welsford M 2019 e20181828]. It is suggested that low (21-30%) rather than a higher initial concentration (60-100%) be used (weak recommendation, very low certainty evidence). The range selected reflects the low oxygen range used in clinical trials. Oxygen concentration should be titrated using pulse oximetry (weak recommendation, low certainty evidence). [Wykoff 2020 A156]

In contrast to term infants, in preterm infants the use of supplemental oxygen to reach adequate oxygenation increases breathing efforts. In an animal experimental study [Dekker 2019 427] and one RCT in 52 preterm infants <30 weeks gestation, [Dekker 2019 504] initiating stabilisation with higher oxygen concentrations (100% vs. 30%) led to increased breathing effort, improved oxygenation, and a shorter duration of mask ventilation. Minute volumes were significantly higher at 100% ( $146.34 \pm 112.68 \text{ mLkg}^{-1}\text{min}^{-1}$ ) compared to 30%

(74.43 ± 52.19 mLkg<sup>-1</sup>min<sup>-1</sup>), p = 0.014.

A recent European consensus statement recommended the use of an initial inspired oxygen concentration of 30% for newborns <28 weeks gestation, of 21-30% for 28-31 weeks gestation, and of 21% for >32 weeks gestation. [Sweet DG 2019 432]

### **[h3] Target oxygen saturation**

The target range recommended for both term and preterm infants are similar and based upon time based values for preductal saturations in normal term infants in air. [Dawson 2010 e1340] Consensus recommendations suggest aiming for values approximating to the interquartile range [Wykoff 2015 S543], or using the 25<sup>th</sup> centile as the lower threshold value. [Wyllie 2015 e169]

Insert figure 7 here

A systematic review of 8 RCTs with 768 preterm infants <32 weeks involving low (≤ 30%) vs higher (≥ 60%) initial oxygen concentrations, [Oei 2018 F446] concluded that failure to reach a minimum SpO<sub>2</sub> of 80% at 5 minutes was associated with a two-fold risk of death (OR 4.57, 95% CI 1.62 to 13.98, p <0.05), and had an association with lower heart rate (mean difference -8.37, 95% CI -15.73 to -1.01, p <0.05) and a higher risk of severe intraventricular haemorrhage (OR 2.04, 95% CI 1.01 to 4.11, p <0.05). It remained unclear whether this was because of the severity of illness, or the amount of oxygen administered during stabilisation.

Available data suggest nearly all preterm newborns <32 weeks gestation will receive oxygen supplementation in the first 5 minutes after delivery in order to achieve commonly recommended oxygen saturation targets. [Mariani 2007 418; Dawson 2010 e1340; Oei 2018 F446] However, it may be difficult to titrate the oxygen concentration in the first minutes [Goos, 2013 1108] and preterm infants <32 weeks gestation may spend a significant time outside the intended target range. [White, 2017 423] In an individual patient analysis of the 706 preterm infants enrolled in the RCTs only 12% reached the threshold SpO<sub>2</sub> of 80% at 5 min after birth. [Oei 2018 F446]

### **[h3] Titration of oxygen**

It is important to select the appropriate initial oxygen concentration, with careful and timely titration of inspired oxygen against time sensitive threshold saturation levels in order to avoid



extremes of hypoxia and hyperoxia and avoid bradycardia. A recent review suggested that oxygen delivery should be reviewed and titrated as necessary every 30 seconds in order to achieve this. [Kapadia 2020 101081]

An important technical aspect of the titration of supplemental oxygen when using a TPR device is that it takes a median 19 seconds (IQR 0-57) to achieve the desired oxygen concentration at the distal end of the TPR. [Dekker 2019 100] Although the cause of this delay is unclear, mask leak contributes significantly. A good mask seal can lead to a longer delay with a resulting lag between adjustment and response.

## **[h2] Circulatory support**

Circulatory support with chest compressions is effective only if the lungs have been successfully inflated and oxygen can be delivered to the heart. Ventilation may be compromised by compressions [Huynh 2015 F39] so it is vital to ensure that satisfactory ventilation is occurring before commencing chest compressions.

The most effective traditional technique for providing chest compressions is with two thumbs over the lower third of the sternum with the fingers encircling the chest and supporting the back. [Millin 2020 161; Houri 1997 65; David 1988 552; Menegazzi 1993 240] This technique generates higher blood pressures and coronary artery perfusion with less fatigue than the alternative two-finger technique. [Whitelaw 2000 213; Udassi 2010 712] In a manikin study, overlapping the thumbs on the sternum was more effective than adjacent positioning but more likely to cause fatigue. [Lim 2013 139]. 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. [Christman 2011 F99; Philips 1986 1024; Saini 2012 690; You 2009 1378; Meyer 2010 544] Delivering compressions from 'over the head' appears as effective as the lateral position. [Cheung 2019 559]

A recent ILCOR review of the evidence identified 19 studies published since 2015 including one systematic review [Douvanas 2018 805] and 18 RCT's all of which were manikin studies. No evidence was found to alter treatment recommendations from 2015 in suggesting that chest compressions in the newborn should be delivered by the two thumb, hand encircling the chest method as the preferred option (weak recommendation, very low certainty evidence). [Wykoff 2020 A156]. However newer techniques, one using two thumbs at an angle of 90° to

the chest and the other a 'knocking finger' technique, have been reported in manikins. Further studies are required to determine if they have any clear advantage over the standard two thumb technique [Wykoff 2020 A156; Rodriguez-Ruiz 2019 1529]

A recent evidence update was undertaken by ILCOR to identify the most effective compression to ventilation ratio for neonatal resuscitation [Wykoff 2020 A156]. 13 trials published since 2015 were found to be relevant. Four neonatal manikin studies comparing alternative compression to ventilation ratios or asynchronous ventilation strategies found no advantage over traditional synchronised 3:1 techniques. A number of animal trials compared the delivery of cardiac compressions during a sustained inflation with traditional 3:1 compression to ventilation. No consistently clear advantages were identified. Some trials are ongoing.

ILCOR found no evidence to change the 2015 recommendations for a 3:1 compression to ventilation ratio (weak recommendation, very low quality evidence), [Wyllie 2015 e169; Perlman 2015 S204/S120; Wykoff 2020 A156] aiming to achieve a total of approximately 90 compressions and 30 ventilations per minute. Compressions and ventilations should be coordinated to avoid simultaneous delivery. [Berkowitz 1989 558] There are theoretical advantages to allowing a relaxation phase that is slightly longer than the compression phase, [Dean 1991 896] however, the quality of the compressions and breaths are probably more important than the rate.

A 3:1 compression to ventilation ratio is used at all times for resuscitation at birth where compromise of gas exchange is nearly always the primary cause of cardiovascular collapse. Rescuers may consider using higher ratios (e.g. 15:2) if the arrest is believed to be of cardiac origin, more likely in a witnessed postnatal collapse than at birth.

When chest compressions are indicated by a persistent very slow/absent heart rate, it would appear reasonable to increase the supplementary inspired oxygen to 100%. However, there are no human studies to support this and animal studies demonstrate no advantage to 100% inspired oxygen during CPR. [Linner 2009 391; Lipinski 1999 221; Perez-de-Sa 2009 57; Solevag 2010 64; Temesvari 2001 812; Walson 2011 335; Yeh 2009 951]

Unless using continuous monitoring such as pulse oximetry or ECG, check the heart rate after no longer than 30 seconds and periodically thereafter. Whilst chest compressions may be

discontinued when the spontaneous heart rate is faster than 60 min<sup>-1</sup>, a continued increase in rate is necessary to truly demonstrate improvement. It is not until the heart rate exceeds 120 min<sup>-1</sup> that it becomes stable. [Yam 2011 F102, Eilevstjonn 2020 69]

Exhaled carbon dioxide monitoring and pulse oximetry have been reported to be useful in determining the return of spontaneous circulation; [Berg 1996 245; Bhende 1995 395; Bhende 1996 349; Chalak 2011 401] however, current evidence does not support the use of any single feedback device in a clinical setting and extrapolation of their use from adult and paediatric settings have, for a variety of reasons, been proven error prone in neonates. [Scrivens 2019 711, Wyllie 2015 e169; Perlman 2015 S204]

## **[h2] Vascular access**

### **[h3] Umbilical vein catheterisation (UVC) and intraosseous (IO) access**

In a systematic review [deAlmeida 2019 ILCOR CoSTR ] no evidence was identified comparing the umbilical venous route or use of intravenous (IV) cannulas against the IO route in the newborn for drug administration in any setting. No case series or case reports on IO administration in the delivery room setting were identified. Consensus suggests UVC as the primary method of vascular access. If umbilical venous access is not feasible, or delivery occurs in another setting, the IO route is suggested as a reasonable alternative (weak recommendation, very low certainty of evidence).

A systematic review on the use of IO in neonates in any situation identified one case series and 12 case reports of IO device insertion into 41 neonates delivering a number of drugs including adrenaline and volume. [Scrivens 2019 305] However, whilst the IO route has been demonstrated to be a practical alternative to the UVC significant adverse events include tibial fractures, osteomyelitis, and extravasation of fluid and medications resulting in compartment syndrome and amputation [Wykoff 2020 A156].

The actual route and method used may depend on local availability of equipment, training and experience [deAlmeida 2019 ILCOR CoSTR]. There is limited evidence on the effective use of IO devices immediately after birth, or the optimal site or type of device [Wagner 2018 332] although simulation studies undertaken in a delivery room setting suggest that the IO route can be faster to insert and use than UVC [Schwindt 2018 468].

### **[h3] Peripheral Access**

No studies were identified reviewing the use of peripheral IV cannulation in infants requiring resuscitation at birth. A retrospective analysis of 61/70 stable newborn preterm infants in a single centre showed that peripheral IV cannulation is feasible and successful in most cases at first attempt [Baik-Schneditz 2017 171].

### **[h2] Drugs**

Drugs are rarely indicated in resuscitation of the newborn infant. [Perlman 1995 149; Barber 2006 1028] Bradycardia is usually caused by profound hypoxia and the key to resuscitation is aerating the fluid filled lungs and establishing adequate ventilation. However, if the heart rate remains less than 60 beats min<sup>-1</sup> despite what are considered to be effective ventilation and chest compressions, it is reasonable to consider the use of drugs.

Knowledge of the use of drugs in newborn resuscitation is largely limited to retrospective studies, as well as extrapolation from animals and adult humans. [Antonucci 2018 417]

### **[h3] Adrenaline**

A recent systematic review identified 2 observational studies involving 97 newborn infants comparing doses and routes of administration of adrenaline [Isayama 2020 0586] . There were no differences between IV and endotracheal adrenaline for the primary outcome of death at hospital discharge (RR = 1.03 [95% CI 0.62 to 1.71]) or for failure to achieve return of spontaneous circulation, time to return of spontaneous circulation (1 study; 50 infants), or proportion receiving additional epinephrine (2 studies; 97 infants). There were no differences in outcomes between 2 endotracheal doses (1 study). No human infant studies were found addressing IV dose or dosing interval (very low certainty evidence). Despite the lack of newborn human data it is reasonable to use adrenaline when effective ventilation and chest compressions have failed to increase the heart rate above 60 beats min<sup>-1</sup>. ILCOR treatment recommendations suggest that if adrenaline is used, an initial dose of 10 - 30 micrograms kg<sup>-1</sup> (0.1 – 0.3 mL kg<sup>-1</sup> of 1:10,000 adrenaline [1mg in 10 mL]) should be administered intravenously (weak recommendation, very low certainty evidence). If intravascular access is not yet available, endotracheal adrenaline at a larger dose of 50 - 100 micrograms kg<sup>-1</sup> (0.5 – 1.0 mL kg<sup>-1</sup> of 1:10,000 adrenaline [1 mg in 10 mL]) is suggested (weak recommendation, very low certainty evidence) but should not delay attempts at establishing venous access (weak recommendation, very low certainty evidence). If the heart rate remains less than 60 min<sup>-1</sup>

further doses - preferably intravascularly - every 3-5 minutes are suggested (weak recommendation, very low certainty evidence). If the response to tracheal adrenaline is inadequate it is suggested an intravenous dose is given as soon as venous access is established regardless of the interval between doses (weak recommendation, very low certainty evidence). [Wykoff 2020 A156]

### **[h3] Glucose**

Hypoglycaemia is an important additional risk factor for perinatal brain injury. [Matterberger 2018 19] Endogenous glycogen stores are rapidly depleted during prolonged hypoxia. In one study infants with birth asphyxia had, prior to administration of glucose in the delivery room, significantly lower blood glucose ( $1.9 \pm 0.6$  mmol/L vs.  $3.2 \pm 0.3$  mmol/L), [Basu 2018 137] therefore in protracted resuscitation it is reasonable to use glucose by giving a  $250 \text{ mg kg}^{-1}$  bolus ( $2.5 \text{ mL kg}^{-1}$  of 10% glucose). After successful resuscitation formal steps to prevent both hypoglycaemia and hyperglycaemia should be instituted (see post-resuscitation care).

### **[h3] Volume replacement**

A recent ILCOR evidence update [Wykoff 2020 A156] identified no further human studies and a single animal RCT which supported the 2010 CoSTR recommendations. [Wyllie 2010 e260; Wyllie 2015 249] Early volume replacement is indicated for newborn infants with blood loss who are not responding to resuscitation. Therefore 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 volume replacement with crystalloid or red cells. Blood loss causing acute hypovolaemia in the newborn infant is a rare event. There is little to support the use of volume replacement in the absence of blood loss when the infant is unresponsive to ventilation, chest compressions and adrenaline. However, because blood loss may be occult and distinguishing normovolaemic infants with shock due to asphyxia from those who are hypovolaemic can be problematic, a trial of volume administration may be considered. [Wykoff 2020 A156]

In the absence of suitable blood (i.e. group O Rh-negative blood), isotonic crystalloid rather than albumin is the solution of choice for restoring intravascular volume. Give a bolus of  $10 \text{ mL kg}^{-1}$  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 [Finn 2017 163].

### **[h3] Sodium 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 newborn. The hyperosmolarity and carbon dioxide-generating properties of sodium bicarbonate may impair myocardial and cerebral function. [Katheria 2017 518]

A recent review of the evidence (Wykoff 2020 A156) concluded that there were no reasons to change the 2010 recommendations. [Wyllie 2010 e260; Wyllie 2015 249] Use of sodium bicarbonate is not recommended during brief cardiopulmonary resuscitation. Use, however, may be considered during prolonged cardiac arrest unresponsive to other therapy, when it should be given only after adequate ventilation is established and chest compressions are being delivered. A dose of 1–2 mmol kg<sup>-1</sup> sodium bicarbonate (2–4 mL kg<sup>-1</sup> of 4.2% solution) may be given by slow intravenous injection.

### **[h3] Naloxone**

There is no strong evidence that naloxone confers any clinically important benefits to newborn infants with respiratory depression due to hypoxia. [Moe-Byrne 2018 CD003483; Guinsburg 2006 121] Current recommendations do not support use of naloxone during resuscitation with the preference being to concentrate on providing effective respiratory support.

Use is best reserved for those infants whose cardiac output has been restored but who remain apnoeic despite resuscitation and where the mother has received opioid analgesia in labour. An initial intramuscular 200 microgram dose, irrespective of weight, provides a pragmatic delivery room approach suitable for most infants. An IM dose provides steady plasma concentrations for about 24 hours [Moreland 1980 609]. Infants whose breathing is suppressed by opioids may show a rebound tachypnoea after naloxone is given. [van Vonderen 2012 e309].

## **[h2] Post-resuscitation care**

### **[h3] Hypo and Hyperglycaemia**

Perinatal hypoxia interferes with metabolic adaptation and maintenance of cerebral energy supply in a number of ways. Significantly lower blood glucose levels in the delivery room promote ketogenesis. [Basu 2018 137] Hypoglycaemia is common; a quarter of infants with moderate to severe HIE reported to a national cooling registry had a blood glucose less than 2.6 mmol/L. [Azzopardi 2012 e38504]

Animal studies suggest hypoxic cerebral injury is worsened by both hypoglycaemia [Vannucci 1978 73; Vannucci 1980 276] and hyperglycaemia. [Park 2001 102] In human infants with hypoxic ischaemic encephalopathy an abnormal early postnatal glycaemic profile (i.e. hypoglycaemia, hyperglycaemia or labile blood glucose) is associated with distinct patterns of brain injury on MRI compared to normoglycaemia. [Basu 2018 137] Hyperglycaemia and a labile blood glucose were also associated with amplitude-integrated electroencephalography evidence of worse global brain function and seizures. [Pinchefskey 2019 23]

Both hypoglycaemia and hypoglycaemia were associated with poorer neurological outcomes in the CoolCap study [Basu 2016 F149] and there is a clear association between initial hypoglycaemia and poorer neurological outcome in infants with perinatal hypoxia. [Salhab 2004 361; Nadeem 2011 11]

A recent ILCOR review of the evidence on the post resuscitation management of glucose [Wykoff 2020 A156] identified no systematic reviews or RCT's specifically addressing the management of blood glucose in the first few hours after birth. 13 non randomised trials or observational studies were identified published since 2015 investigating whether the maintenance of normoglycaemia during or immediately after resuscitation improved outcome.

The update suggests that infants who require significant resuscitation should be monitored and treated to maintain glucose in the normal range. Protocols for blood glucose management should be used that avoid both hypo and hyperglycaemia and also avoid large swings in blood glucose level. The evidence update suggests that research to determine the optimal protocols for glycaemic management for preterm and term infants in the aftermath of resuscitation, and the optimal target range should be a high priority. Overall no change has been made to the previous recommendation that intravenous glucose infusion should be considered soon after resuscitation with the goal of avoiding hypoglycaemia (low certainty evidence). [Perlman 2010 Perlman 2010 e1319]

### **[h3] Rewarming**

If therapeutic hypothermia is not indicated, hypothermia after birth should be corrected because of evidence of poor outcomes. [Laptook 2007 e643; Wilson 2016 61] Infants should be maintained within the normal range of temperature.

A recent ILCOR evidence review [Wykoff 2020 A156] identified no systematic reviews or RCT's published since the previous guidelines. Two retrospective observational studies were identified which investigated whether in hypothermic infants ( $\leq 36^{\circ}\text{C}$  on admission) rapid or slow rewarming changed outcome. These involved 182 [Rech Morassutti 2015 557] and 98 [Feldman 2016 295] patients. The findings of both studies were that the rate of rewarming (after adjustment for confounders) did not affect the critical and important outcomes. However one study (Rech Morassutti 2015 557) suggested that rapid rewarming reduces risk for respiratory distress syndrome. The conclusion was that there was no new evidence to alter the 2015 ILCOR consensus [Perlman 2010 S516; Wyllie 2010 e260; Perlman 2010 e1319] that a recommendation for either rapid ( $0.5^{\circ}\text{C}/\text{hour}$  or greater) or slow rewarming ( $0.5^{\circ}\text{C}/\text{hour}$  or less) of unintentionally hypothermic newborn infants (temperature less than  $36^{\circ}\text{C}$ ) at hospital admission would be speculative.

### **[h3] Induced hypothermia**

This topic has not been reviewed as part of the most recent ILCOR process. A Cochrane review including 11 randomised controlled trials comprising 1505 term and late preterm infants calculated that therapeutic hypothermia resulted in a statistically significant and clinically important reduction in the combined outcome of mortality or major neurodevelopmental disability to 18 months of age (typical RR 0.75 (95% CI 0.68 to 0.83); typical RD -0.15, 95% CI -0.20 to -0.10) and concluded that newborn infants at term or near-term with evolving moderate to severe hypoxic-ischaemic encephalopathy should be offered therapeutic hypothermia. [Jacobs 2013 CD003311] Cooling should be initiated and conducted under clearly defined evidence-based protocols with treatment in neonatal intensive care facilities and with the capabilities for multidisciplinary care. Treatment should commence within 6 hours of birth, target a temperature between  $33.5^{\circ}\text{C}$  and  $34.5^{\circ}\text{C}$ , continue for 72 hours after birth and re-warm over at least four hours. A four way clinical trial of 364 infants randomised to receive longer (120 hours) or deeper ( $32^{\circ}\text{C}$ ) cooling found no evidence of benefit of longer cooling or lower temperatures. [Shankaran 2014 2629] Animal data strongly suggests that the effectiveness of cooling is related to early intervention. Hypothermia initiated at 6 to 24 hours



after birth may have benefit but there is uncertainty in its effectiveness. [Laptook 2017 1550]  
Such therapy is at the discretion of the treating team on an individualised basis. Current  
evidence is insufficient to recommend routine therapeutic hypothermia for infants with mild  
encephalopathy. [Kariholu 2020 225]

### **[h3] Prognostic tools**

This subject was not reviewed through the ILCOR process. No systematic or scoping reviews  
have been identified.

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). [Apgar 1953 260] Although widely used in clinical practice and for research  
purposes, the applicability has been questioned due to large inter- and intra-observer  
variations. In a retrospective study involving 42 infants between 23 and 40 weeks gestation  
O'Donnell found a significant discrepancy (average 2.4 points) between observers  
retrospectively scoring the APGAR from videos of the deliveries compared to the scores  
applied by those attending the delivery [O'Donnell 2006 486;].

A lack of correlation with outcome is partly explained by a lack of agreement on how to score  
infants receiving medical interventions or being born preterm. Variations in the APGAR score  
have been proposed attempting to correct for maturity and the interventions undertaken, such  
as the Specified, Expanded and Combined versions (which incorporates elements of both).  
These might have greater precision in predicting outcome in preterm and term infants when  
compared to the conventional score, but are not used widely. [Rudiger 2015 18; Dalili 2015  
e0122116]

### **[h2] Communication with the parents**

The principles governing the need for good communication with parents are derived from  
clinical consensus and enshrined in published European and UK guidance. [Bossaert 2015  
302; Nuffield Council on Bioethics. 2006]

Mortality and morbidity for newborns varies according to region, ethnicity and to availability of  
resources. [Harrington 2007 463; Ely 2020 1; Numerato 2015 e0131685] Social science

studies indicate that parents wish to be involved in decisions to resuscitate or to discontinue life support in severely compromised infants. [Lee 1991 110; Gillam 2011 594] Local survival and outcome data are important in appropriate counselling of parents. The institutional approach to management (for example at the border of viability) affects the subsequent results in surviving infants. [Rysavy 2015 1801]

European guidelines are supportive of family presence during cardiopulmonary resuscitation. [Mentzelopoulos 2021 in press] Healthcare professionals are increasingly offering family members the opportunity to remain present during resuscitation and this is more likely if this takes place within the delivery room. Parents' wishes to be present during resuscitation should be supported where possible. [Fulbrook 2007 255; [Wyllie CoSTR 2020](#)]

There is insufficient evidence to indicate an interventional effect on patient or family outcome. Being present during the resuscitation of their baby seems to be a positive experience for some parents but concerns about an effect upon performance exist in professionals and family members (weak recommendation very low certainty of evidence). [ILCOR CoSTR [2020](#)]

In a single centre review of management of birth at the bedside, parents who were interviewed were supportive but some found witnessing resuscitation difficult. [Sawyer 2015 e008495] Clinicians involved felt the close proximity improved communication but interviews suggested support and training in dealing with such situations might be required for staff. [Yoxall 2015 e008494] In a retrospective questionnaire based survey of clinicians' workload during resuscitation the presence of parents appeared to be beneficial in reducing perceived workload. [Zehnder 2020 318840]

Qualitative evidence emphasises the need for support during and after any resuscitation, without which the birth may be a negative experience with post traumatic consequences. [Harvey 2012 F439; Harvey 2013 002547] There should be an opportunity for the parents to reflect, ask questions about details of the resuscitation and be informed about the support services available. [Fulbrook 2007 255] It may be helpful to offer any parental witness of a resuscitation the opportunity to discuss what they have seen at a later date. [Harvey 2012 F439; Harvey 2013 002547]

Decisions to discontinue or withhold resuscitation should ideally involve senior paediatric staff.

## **[h2] Discontinuing or withholding treatment.**

### **[h3]Discontinuing resuscitation**

Failure to achieve return of spontaneous circulation in newborn infants after 10-20 minutes of intensive resuscitation is associated with a high risk of mortality and a high risk of severe neurodevelopmental impairment among survivors. There is no evidence that any specific duration of resuscitation universally predicts mortality or severe neurodevelopmental impairment.

When the heart rate has been undetectable for longer than 10 minutes outcomes are not universally poor. [Shah 2015 F492; Zhang 2020 933; Zhong 2019 143] For the composite outcome of survival without neurodevelopmental impairment a recent ILCOR systematic review identified low certainty evidence (downgraded for risk of bias and inconsistency) from 13 studies involving 277 infants reporting neurodevelopmental outcomes. Among all 277 infants 69% died before last follow up, 18% survived with moderate to severe neurodevelopmental impairment and 11% were judged to have survived without moderate or severe neurodevelopmental impairment (2% lost to follow up). [Wykoff 2020 A156] It can be helpful to consider clinical factors, effectiveness of resuscitation and the views of other members of the clinical team about continuing resuscitation. [Torke 2015 440]

If despite provision of all the recommended steps of resuscitation, and excluding reversible causes a newborn infant requires ongoing cardiopulmonary resuscitation for a prolonged period, it would be appropriate to discontinue resuscitative efforts. A reasonable time frame to consider this is around 20 minutes after birth (weak recommendation, very low certainty evidence). [Wykoff 2020 A156]

The decision to cease resuscitation is a clinical decision, but it is important, where possible, to give the family updates during the resuscitation and advance warning that there is a high chance the baby will not survive. In extremely preterm infants, prolonged resuscitation is associated with lower survival rates and higher morbidity, [Foglia 2020 e20201449; Haines 2016 1305] the decision should be individualised.

### **[h3]Withholding resuscitation**

In situations where there is extremely high predicted mortality and severe morbidity in surviving infants, withholding resuscitation may be reasonable, particularly when there has been the opportunity for prior discussion with parents. [Mactier 2020 232; Costeloe 2012 e7976; Marlow 2014 F181; Bottoms 1999 665; Ambalavanan 2005 1367; Manktelow 2013 e425; Medlock 2011 e23441; Tyson 2008 1672; Swamy 2010 F293] Examples from the published literature include: extreme prematurity (gestational age less than 22 weeks and/or birth weight less than 350 g), [Brumbaugh 2019 434] and anomalies such as anencephaly and bilateral renal agenesis.

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 treatment when it would not be in the best interests of the infant. [Wilkinson 2014 127]

A consistent and coordinated approach to individual cases by the obstetric and neonatal teams and the parents is an important goal. In conditions where there is low survival (<50%) and a relatively high rate of morbidity, and where the anticipated burden to the child is high, parental wishes regarding resuscitation should be sought and supported. [Nuffield Council on Bioethics,2006]

**Legends for Figures and tables.**

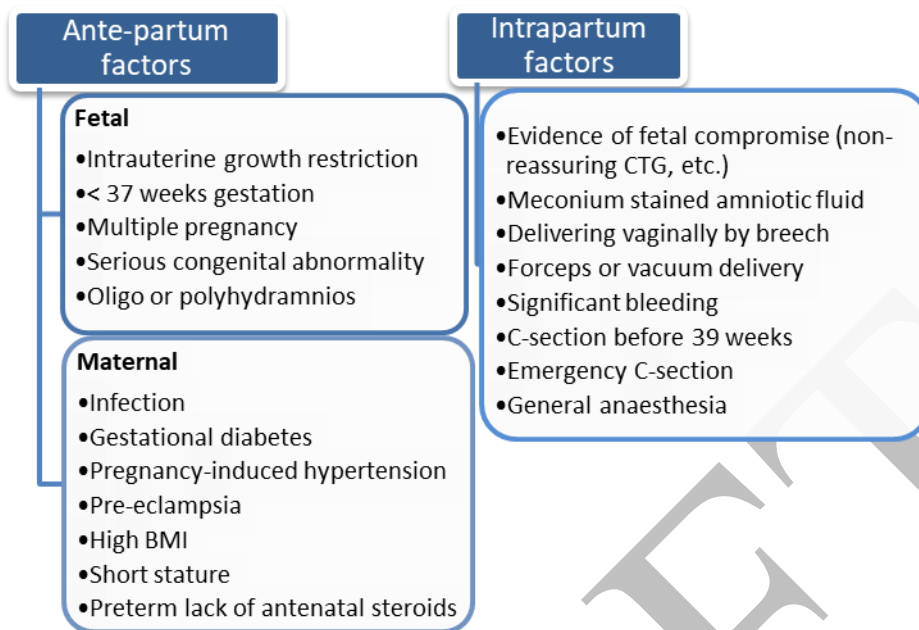


Figure 1:  
Common factors associated with an increased risk of a need for stabilisation, or resuscitation at birth

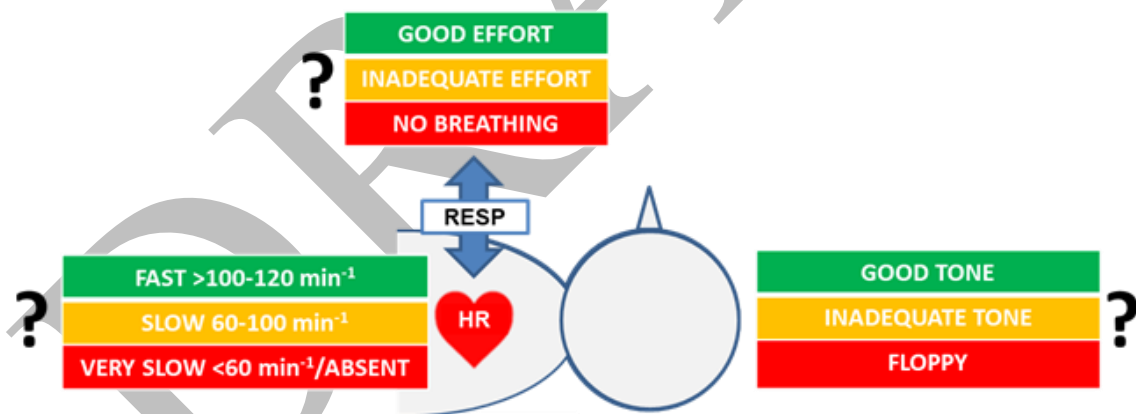


Figure 2:  
Assessment of tone, breathing and heart rate helps determine the need for intervention

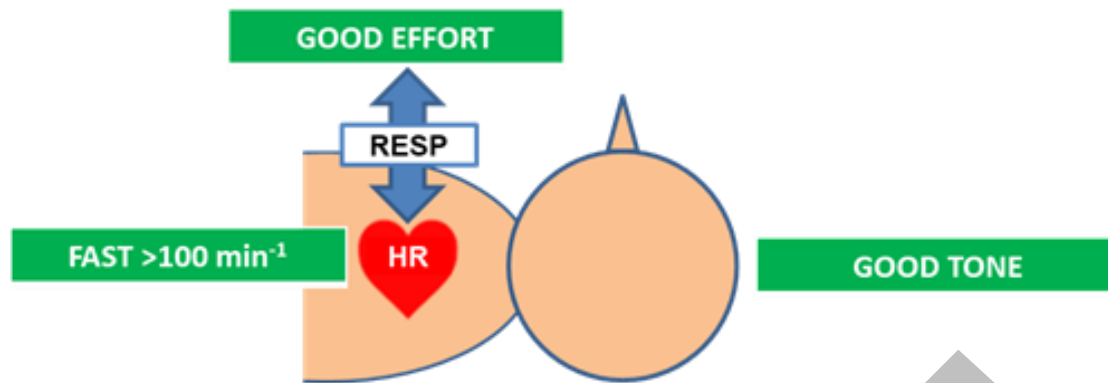


Figure 3a:  
Satisfactory Transition

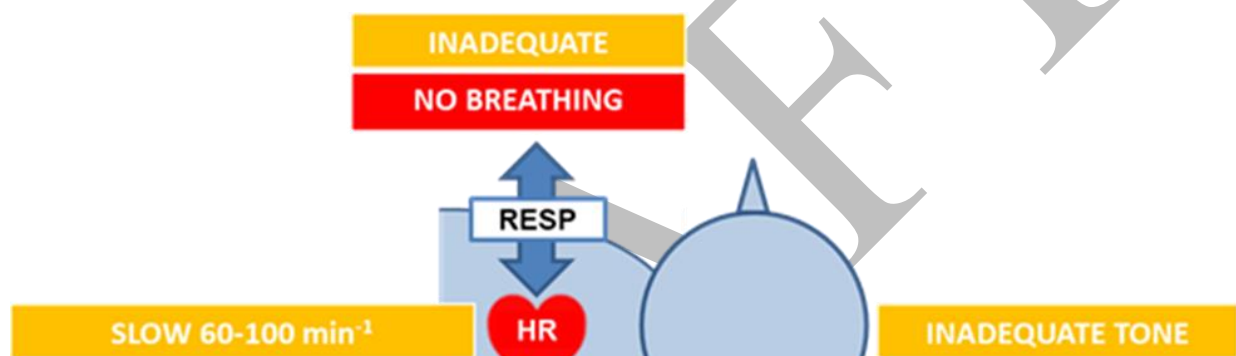


Figure 3b:  
Incomplete transition

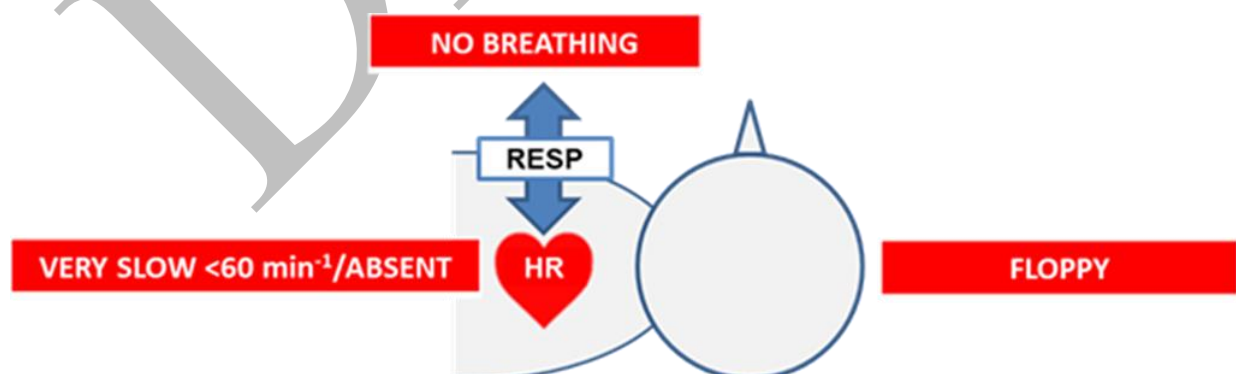
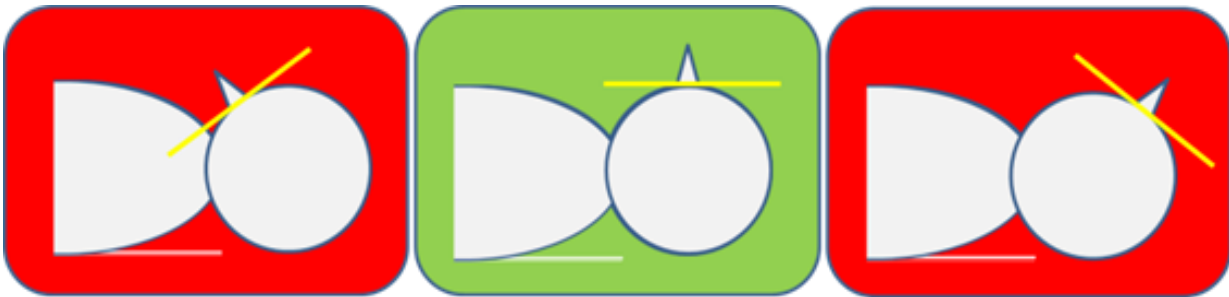


Figure 3c:  
Poor/failed transition

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2301 Figure 4a:

2302 Head in a neutral position. – Face is horizontal (middle picture), neither flexed (left) or  
2303 extended (right)

2304

2305

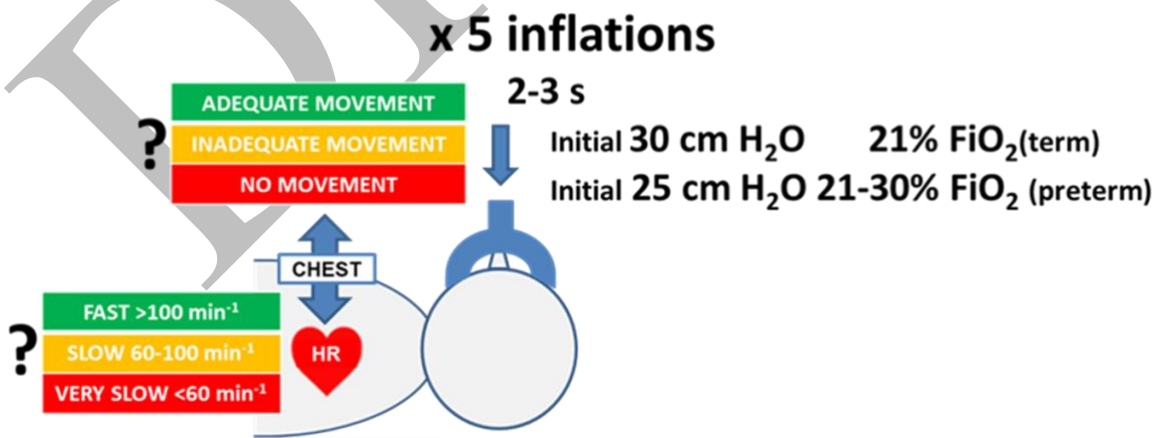


2306

2307 Figure 4b:

2308 Jaw Lift/Thrust - jaw lift/thrust enlarges the pharyngeal space

2309

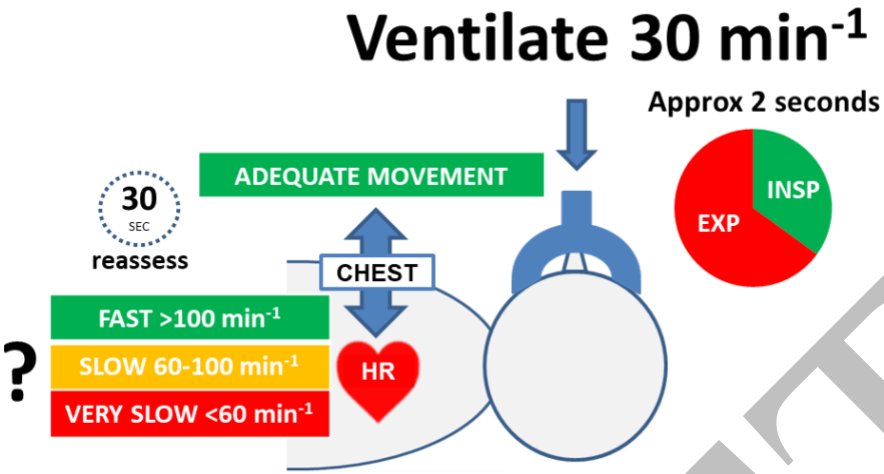


2310

2311 Figure 5a:

2312 Five 2-3 second inflations are given via facemask. Assess heart rate response and chest  
2313 movement

2314

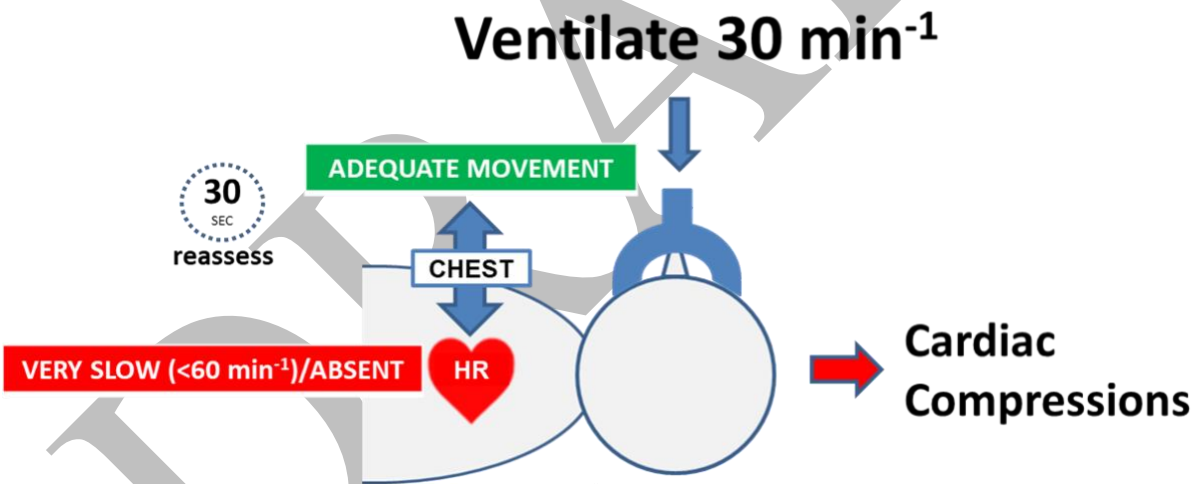


2315

2316 Figure 5b:

2317 Once inflations have been successfully delivered ventilate at about 30 breaths min<sup>-1</sup> Reassess  
2318 heart rate response frequently (or continuously).

2319



2320

2321 Figure 6a

2322 Deliver 30 seconds of good quality ventilation before reassessment of the heart rate

2323



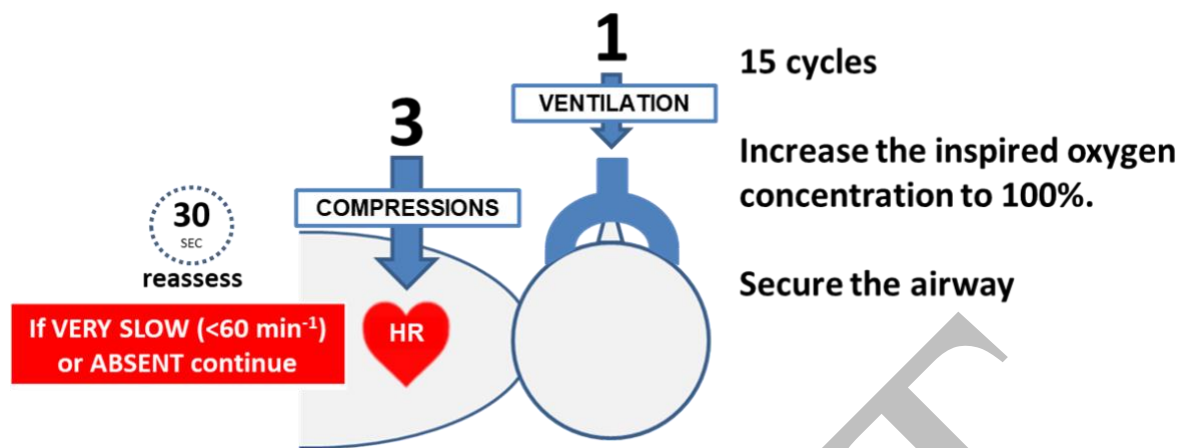


Figure 6b

If the heart rate remains very slow or absent start chest compressions with a ratio of 3:1 with ventilation for 30 seconds. Then reassess.

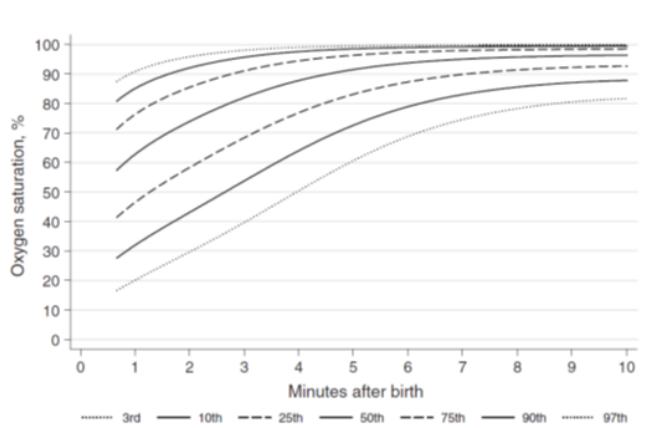


Figure 7

Oxygen saturations in healthy infants at birth without medical intervention (3<sup>rd</sup>, 10<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup>, 90<sup>th</sup>, 97<sup>th</sup> centiles. Reproduced with permission - from Dawson 2010 e1340

2336 Table 1  
 2337 Approximate oral tracheal tube size by gestation  
 2338 (For approximate nasotracheal tube length add 1 cm)  
 2339

Gestational Age (weeks)	Length at lips (cm)	External Diameter (mm)
23-24	5.5	2.5
25-26	6.0	2.5
27-29	6.5	2.5
30-32	7.0	3.0
33-34	7.5	3.0
35-37	8.0	3.5
38-40	8.5	3.5
41-43	9.0	4.0

2340  
 2341 Table 2  
 2342 Approximate target SpO<sub>2</sub> in the first 10 minutes for healthy term infants  
 2343 (Derived from Dawson 2010 e1340)  
 2344

Time after birth (min)	Lower SpO <sub>2</sub> target (%)
2	65
5	85
10	90

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