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Singapore Neonatal Resuscitation Guidelines 2016

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ABSTRACT We present the revised Neonatal Resuscitation Guidelines for Singapore. The 2015 International Liaison Committee on Resuscitation Neonatal Task Force's consensus on science and treatment recommendations (2015), and guidelines from the American Heart Association and European Resuscitation Council were debated and discussed. The final recommendations of the National Resuscitation Council, Singapore, were derived after the task force had carefully reviewed the current available evidence in the literature and addressed their relevance to local clinical practice.

Keywords: National Resuscitation Council guidelines for resuscitation 2016, neonatal resuscitation, newborn resuscitation

BACKGROUND AND INTRODUCTION

Ongoing research and evidence is a stimulus for change to the science and art of neonatal resuscitation. With the release of the 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations (CoSTR),[1-3] the National Resuscitation Council, Singapore, convened a workgroup to review and update the existing guidelines on neonatal resuscitation. The update is based on the international recommendations from the International Liaison Committee on Resuscitation (ILCOR), adjusted appropriately for relevance to local clinical practice and previously evaluated evidence.[4,5] The review updates and enhances the existing newborn and paediatric resuscitation guidelines, which were last reviewed and released in 2011.[6]

The guideline applies to newly born infants (infant at time of birth) transitioning from intrauterine to extrauterine life irrespective of place of birth, and newborn infants who have completed newborn transition and require resuscitation during the initial hospitalisation. The sequence of the discussion on treatment recommendations and practice guidelines is organised in alignment with the newborn resuscitation algorithm:

- Anticipate need and prepare equipment
- Umbilical cord management – delayed cord clamping (DCC) versus cord milking
- Temperature maintenance and initial steps
- Detection of heart rate (HR) – comparing electrocardiography (ECG) with oximetry or auscultation
- Oxygen administration and continuous positive airway pressure (CPAP)
- Positive pressure ventilation (PPV) and positive end-expiratory pressure (PEEP)
- Endotracheal intubation and laryngeal mask airway (LMA)
- Chest compression
- Medications
- Post-resuscitation care
- Withholding resuscitation and discontinuing resuscitative efforts
- Briefing and debriefing
- Training in neonatal resuscitation – provider and instructor training

In general, newly born term infants who are vigorous and have regular breathing effort and good tone do not require extra intervention at delivery, and may be left with the mother for routine care. Newly born preterm infants and term infants with poor tone, poor cry or breathing effort need support transitioning from fetal to extrauterine life. The newborn in need of support should be transferred to a radiant warmer to receive one or more of the sequential interventions, viz. initial steps, ventilation and oxygenation, initiation of chest compression and administration of adrenaline and/or volume expansion, if required. The first 60 seconds, also known as the 'golden minute', are allocated for provision of the initial steps, re-evaluation of HR and respiration, and to initiate ventilation. Based on the HR and respiration, the newborn may proceed to receive PPV. Once PPV is initiated, re-evaluation is assessed at intervals of 30 seconds using the HR, respiration and oxygen saturation by pulse oximetry, as illustrated in the newborn resuscitation algorithm (Fig. 1). Changes to the 2011 guidelines on resuscitation of newly born infants are summarised and tabulated (Table I).

ANTICIPATE NEED AND PREPARE EQUIPMENT

Transition from fetal to extrauterine life is a complex physiological process involving the conversion of placental gas exchange, with intrauterine lungs filled with fluid, to pulmonary respiration with aerated lungs. Approximately 85% of newborn infants born at term have been shown to initiate spontaneous respiration within 10–30 seconds of birth, with an additional 10% responding during drying and stimulation and about 3% initiating respiration after PPV; 2% of newborn infants need intubation to support

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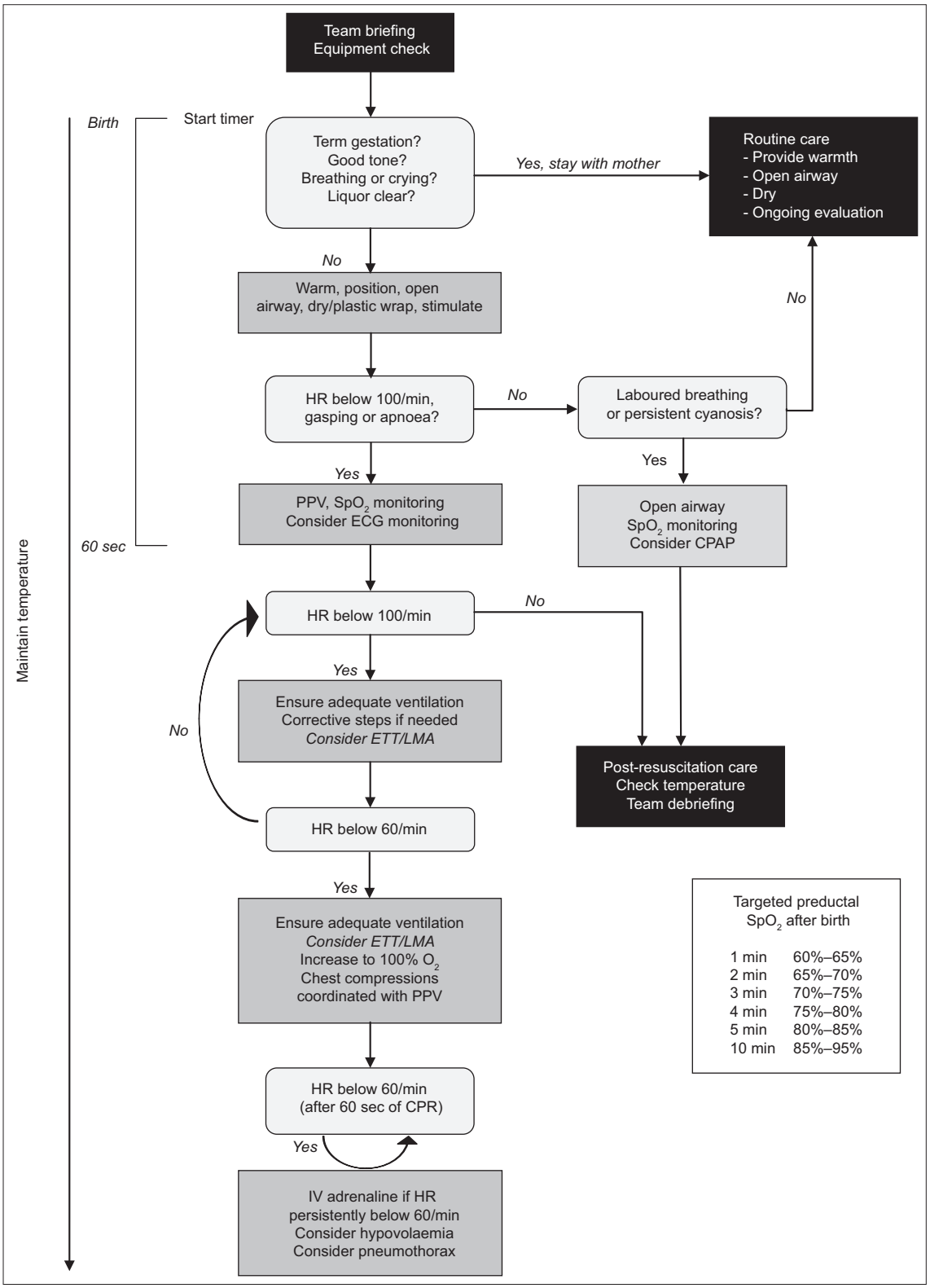

Fig. 1 Newborn resuscitation algorithm. CPAP: continuous positive airway pressure; CPR: cardiopulmonary resuscitation; ECG: electrocardiography; ETT: endotracheal tube; HR: heart rate; IV: intravenous; LMA: laryngeal mask airway; PPV: positive pressure ventilation

respiratory function and 0.1% require chest compressions and/or adrenaline.[7-9] Out of 10,114 newly born infants delivered at a local tertiary neonatal centre over a six-year period (2002–2008), 5.9% required PPV, 0.9% required intubation with or without chest compression, and 0.1% required adrenaline and/or volume infusion at delivery. Prematurity was strongly associated with the need for at least PPV at delivery, with the following odds ratio (OR) and 95% confidence interval (CI): newborns < 28 weeks: OR 123.6, 95% CI 68.8–222.1; newborns at 28–33 weeks: OR 12.5, 95% CI 9.7–16.1; and newborns at 34–36 weeks: OR 2.4, 95% CI 1.9–3.1.[10] Besides prematurity, the same study also showed that resuscitation or support of transition is more likely to be needed by newborns with intrapartum evidence of fetal compromise, newborns requiring instrumentation at delivery

Table I. Summary of changes to the 2011 Newborn and Paediatric Resuscitation Guidelines.[6]

Resuscitative intervention	Changes to 2011 guidelines
Resuscitation algorithm	• The time taken for initial steps, re-evaluation and initiation of ventilation if apnoea persists is changed from 30 s to 60 s. • Given the known evidence of hypothermia on mortality, the revised algorithm includes a running line to remind providers of the need to maintain thermoregulation throughout the immediate newborn period.
Cord clamping	• For stable term and preterm newly born infants, delay in cord clamping of 30–60 s from complete delivery is recommended. • For newly born infants requiring resuscitative interventions, focus should be directed at stabilising and establishing ventilation and oxygenation.
Temperature	• Temperature of non-asphyxiated newly born infants should be maintained at 36.5°C–37.5°C. • It is recommended that the admission temperature be recorded as a predictor of outcomes and quality indicator.
Temperature maintenance	• To ensure optimal temperature of 36.5°C–37.5°C in newly born preterm infants ≤ 32 weeks' gestation at delivery, a combination of strategies, including increasing room temperature to 25°C plus polyethylene wraps, caps and thermal mattresses, may be used in addition to the regular radiant warmer.
Heart rate (HR) measurement	• It is suggested that electrocardiography (ECG) provides more accurate and reliable measurement of HR; ECG monitoring may be considered for newly born infants requiring resuscitation. However, its use does not preclude the use of pulse oximetry, as the latter provides reliable measurement of oxygen saturation.
Meconium	• Tracheal suctioning should not be performed routinely in the presence of meconium, but carried out only if there is suspicion of airway obstruction. • Goal at resuscitation should be directed at initiating ventilation within the first minute of life in non-breathing or ineffectively breathing newly born infants.
Blending of gas	• Term newly born infants should be resuscitated using room air. • For preterm infants ≤ 32 weeks' gestation needing positive pressure ventilation, it is recommended that air or low-oxygen supplement of up to 40% be considered.
Continuous positive airway pressure (CPAP)	• It is recommended that respiratory support in the form of CPAP may be provided to newly born preterm infants ≤ 32 weeks' gestation who are spontaneously breathing but show evidence of respiratory distress.
Chest compression	• It is recommended that the two-thumb technique be used instead of the two-finger technique. • Given that access to the umbilicus can be optimised using the two-thumb approach, the two-finger technique is no longer necessary.
Briefing and debriefing	• It is recommended that briefings and debriefings used at simulation training be included for clinical activities.

(inclusive of emergency and elective lower-segment Caesarean section), newborns with meconium-stained liquor, and in cases of antepartum haemorrhage and multiple pregnancies.[10]

As the need for resuscitation at birth is often a predictable event, it is possible to prepare the environment and equipment before delivery. Resuscitation should take place in a warm, well-lit area with a flat resuscitation surface, preferably under a radiant warmer (if in a hospital). Equipment used at delivery should be regularly checked and tested following institutional policy. It is recommended that centres that cater to newborn infants have a written policy on maintenance of resuscitative equipment. In unexpected deliveries occurring in non-designated areas, warm, dry towels may be used to maintain normothermia. Although it is possible to predict the need for resuscitation or stabilisation before a newborn is delivered, this is not always so. Hence, it is recommended that neonatal centres caring for newly born infants have in place policies and procedures to activate and mobilise a team with complete resuscitation skills to meet the unanticipated need for resuscitation of newborns with no apparent risk factors.

Recommendations on equipping and preparing staff in resuscitation

1. All healthcare workers involved in the care of newborns are encouraged to be trained in neonatal basic life support.
2. Every birth should be attended to by at least one person whose primary responsibility is to care for the newly born infant. This person should be capable of performing the initial steps of newborn resuscitation and PPV.
3. In the presence of significant perinatal risk factors, a team with skills in chest compression, intubation and umbilical catheterisation should be mobilised and the team leader identified.
4. The team should arrive ahead of delivery and, using standardised checklists, ensure that specific equipment and supplies (depending on perinatal risk factors) are present and functioning.
5. Whenever time permits, the team leader should conduct a preresuscitation briefing, identify interventions that may be required, and assign roles and responsibilities to team members.[4,5]

UMBILICAL CORD MANAGEMENT – DELAYED CORD CLAMPING VERSUS CORD MILKING

Delayed cord clamping

Immediate cord clamping soon after birth is a common practice. However, evidence suggests that there are benefits in DCC at birth, especially for newborn infants who do not require resuscitation.[11] DCC is associated with lower incidence of all grades of intraventricular haemorrhage (IVH), higher systemic blood pressure and volume, lower need for blood transfusion, and lower incidence of necrotising enterocolitis. However, no difference has been demonstrated in severe IVH, mortality, temperature instability and long-term outcomes, although an increase in serum bilirubin associated with a greater need for phototherapy has been noted. This is regardless of gestational age.[1-3]

Recommendations on cord clamping

1. DCC for 30–60 seconds is recommended for both stable term and preterm newborns who do not require resuscitation at birth. The following should be noted:
    - Newly born infants who do not require resuscitation should be vigorous, have regular breathing effort and good tone, even if there is a history of meconium-stained amniotic fluid (MSAF).
    - Newly born infants may be placed at or below the level of the placenta till the umbilical cord is clamped.
    - Umbilical cord clamping timing should take precedence over cord blood collection for the purpose of cord blood banking.
2. DCC is contraindicated in deliveries involving monochorionic twins when placental circulation is compromised secondary to placental abruption, bleeding placenta praevia or cord avulsion, and in situations where immediate resuscitation is indicated (e.g. congenital diaphragmatic hernias).

Umbilical cord milking

Umbilical cord milking as an alternative to DCC for newborns with less than 29 weeks' gestation has generated some interest. Cord milking has been shown to improve blood pressure and haematologic indices, as well as reduce the risk of intracranial haemorrhage. However, no evidence of improved long-term outcomes has been demonstrated.[12-14] The safety profile of this practice is still unknown, particularly the safety of rapid changes in blood volume for extremely preterm newborns. Hence, cord milking cannot yet be recommended as a routine practice. Umbilical cord milking should be restricted to the confines of research.

TEMPERATURE MAINTENANCE AND INITIAL STEPS

Temperature maintenance

Reports have suggested that the admission temperature of newly born non-asphyxiated infants is a strong predictor of mortality for all gestational ages.[15-49] Preterm newborns are especially vulnerable to hypothermia. Serious morbidities associated with hypothermia include increased risk of IVH, respiratory issues, hypoglycaemia and late-onset sepsis. Because of this, ILCOR recommended in 2015 that admission temperature be recorded as a predictor of outcomes and a quality indicator.[3]

Recommendations on thermoregulation

1. The temperature of newly born non-asphyxiated infants should be maintained at a temperature of between 36.5°C and 37.5°C after birth, through admission and stabilisation. This can be done through the following steps:
    - Maintain the ambient environment of the delivery suite at 23°C–25°C, where feasible. For delivery of preterm newborns ≤ 32 weeks' gestation, an ambient temperature ≥ 25°C is preferred.
    - Dry stable term and preterm newborns ≥ 33 weeks' gestation immediately after birth. Whenever possible, provide skin-to-skin contact to help maintain body temperature. Cover both the newborn infant and mother with a towel. In situations where delivery occurs unexpectedly out of the delivery area, nursing the newborn skin-to-skin is especially effective in maintaining the newborn's body temperature.
    - Unstable term or preterm newborns ≥ 33 weeks' gestation who require resuscitation should be nursed under a radiant warmer to maintain normothermia.
    - Newly born infants ≤ 32 weeks' gestation should have their head and body covered using polyethylene wraps without drying the newborn beforehand, and the newborn should be placed under a radiant warmer. In addition, thermal mattress and caps may be used.
    - Check the temperature of the newborn – skin, axillary or rectal – before transfer and while maintaining skin-to-skin contact with the mother.
    - Admission temperature should be recorded soon after stabilisation or resuscitation.
    - Avoid hyperthermia (temperature > 38°C).
2. In newly born infants who are unintentionally hypothermic (temperature < 36°C) on admission, current evidence does not support either rapid (≥ 0.5°C/hour) or slow rewarming (< 0.5°C/hour).[50-53] These newborns' body temperature should be monitored during rewarming to avoid hyperthermia (> 38°C). Studies on newborns delivered to hyperthermic mothers showed increased risk of respiratory depression, neonatal seizures, early death and long-term adverse neurodevelopmental outcome.[54-60]

Initial steps

The initial steps of newborn resuscitation are best performed on a flat resuscitation table under a radiant warmer. The following four action steps should be performed in sequence:

1. Maintain normal temperature of the newly born infant.
2. Place the newly born infant flat with the neck in a neutral, 'sniffing' position to open the airway (Fig. 2).

Fig. 2 Photograph shows the 'sniffing' position to maintain airway patency.

3. Clear secretions, if needed, with a bulb syringe or a 10F–12F suction catheter using a suction pressure of 80–100 mmHg.
4. Dry the newly born infant (replace with polyethylene wrap in preterm newborns ≤ 32 weeks' gestation) and stimulate the newborn to breathe. Avoid overstimulation.

Newly born infants who are vigorous and have regular breathing effort and good tone require only drying and wrapping in a warm towel. These newborns can continue to be kept warm through skin-to-skin contact with their mothers. Newborns may begin to breastfeed at this stage. It is important to monitor the body temperature of the newborns to ensure normothermia while maintaining their skin-to-skin contact with their mothers.

If a newly born infant is unable to establish spontaneous effective breathing or has a HR < 100 beats per minute (bpm) following stimulation, newborn life support is needed (Fig. 1). Ventilation is the most important step for the successful resuscitation of newborns who have not responded to the initial steps. The golden minute (60-second) mark for completing the initial steps, re-evaluating and beginning ventilation (if required) replaces the 30-second rule in the previous algorithm.[1-3] The recommendation to complete the initial steps in 30 seconds in the previous algorithm was not evidence-based, and it was felt that more time should be given to support newborns in transiting to extrauterine life. The golden minute emphasises the importance of avoiding unnecessary delay in the initiation of ventilation.

Clearing the airway

There is no need for routine suctioning of the oropharynx. Aggressive suctioning can cause laryngeal spasm and vagal bradycardia; hence, gentle suctioning is needed only if there is evidence of airway obstruction, or prior to endotracheal intubation.[61-63]

Management of newborns with meconium-stained liquor

Routine intrapartum oropharyngeal and nasopharyngeal suctioning of newly born infants who are born through MSAF before delivery of the shoulders does not prevent meconium aspiration syndrome. In healthy newborns, suctioning of the mouth and nose has been associated with cardiorespiratory complications. Thus, routine intrapartum oropharyngeal and nasopharyngeal suctioning of newly born infants who are born with clear amniotic fluid or MSAF is not recommended and strongly discouraged. Gentle clearing of the meconium from the mouth and nose should be reserved for newly born infants who have obvious obstruction to spontaneous breathing or require PPV.[3] For newborns with respiratory depression delivered through MSAF, routine intubation for tracheal suctioning is no longer recommended.[3] There is insufficient evidence to continue recommending this practice. The emphasis should be made on initiating ventilation within the first minute of life in non-breathing or ineffectively breathing newly born infants. Only when there is visible obstruction during PPV should intubation and suction be considered.

Recommendations on suctioning of airway

1. When amniotic fluid is clear, intrapartum oropharyngeal suctioning (including suctioning with a bulb syringe) is not recommended.
2. For vigorous newly born infants who are born through MSAF, intrapartum oropharyngeal suctioning is not recommended. Gentle clearing of the meconium from the mouth and nose with a bulb syringe may be done for those with obvious obstruction to spontaneous breathing.
3. For non-vigorous newly born infants born through MSAF, routine direct oropharyngeal and tracheal suctioning is no longer recommended. The initial steps of resuscitation performed under a radiant warmer should be performed in these newborns. Clear the oropharynx by suctioning with a 10F–12F catheter using a suction pressure of 80–100 mmHg. Initiate PPV if the newborn infant is not breathing or when HR is < 100 bpm after completion of the initial steps of resuscitation. If there is visible obstruction during PPV, consider tracheal suctioning.

DETECTION OF HEART RATE: COMPARING ECG WITH OXIMETRY OR AUSCULTATION

Immediately after birth, the HR is assessed to evaluate the condition of the newly born infant and determine the need for escalation of care. An increase in HR is an indicator of successful resuscitative intervention. Rapid and accurate assessment of HR is of critical importance. Umbilical cord palpation may not be accurate, particularly if the HR is < 100 bpm.[64] Auscultation of the precordium has been proposed as the preferred method, supplemented by the use of pulse oximetry, which provides continuous measure of the peripheral pulse. Emerging evidence has suggested that three-lead ECG displays HR faster than pulse oximetry, without difficulty in applying the leads.[65-68] The applicability of this tool needs further exploration in regular clinical practice.

Recommendations on assessment of heart rate

1. Auscultation is recommended for clinical assessment of HR. However, if a stethoscope is not available, umbilical cord palpation may be used.
2. It is suggested that three-lead ECG may be considered for continuous assessment of HR during chest compressions. However, the use of ECG does not replace the need for pulse oximetry to evaluate the newborn's oxygenation.[65-69]

OXYGEN ADMINISTRATION AND CONTINUOUS POSITIVE AIRWAY PRESSURE

Oxygen administration

Oxygen use in term and preterm newborns was last reviewed in 2010.[4,5] In term newborns receiving resuscitation with intermittent PPV, 100% oxygen was found to confer no advantage over air in the short term, and resulted in increased time to first breath, cry or both. Two meta-analyses of studies comparing term newborns receiving resuscitation with intermittent PPV initiated with room air vs. 100% oxygen showed a decrease in mortality for the former group.[70,71] Based on systematic reviews conducted by ILCOR in 2010, blended gas was recommended in resuscitation of preterm newborns, although the optimal oxygen concentration for these newborns was not clearly defined.

A meta-analysis of seven randomised trials comparing initiating resuscitation of preterm newborns (< 35 weeks' gestation) with high oxygen (≥ 65%) and low oxygen (21%–30%) concentrations showed no improvement in survival to hospital discharge with the use of high oxygen concentrations.[2] In a subset of studies that evaluated these outcomes, no benefit was seen for the prevention of bronchopulmonary dysplasia, IVH or retinopathy of prematurity.[2] In all studies, irrespective of whether air or high oxygen concentration (including 100%) was used to initiate resuscitation, most newborns were breathing approximately 30% oxygen by the time of stabilisation.[2] Initiating resuscitation of preterm newborns with high oxygen concentrations is not recommended so as to avoid exposing preterm newborns to additional oxygen, as no current data has demonstrated any proven benefits for important outcomes. Therefore, resuscitation of preterm newborns should be initiated with low oxygen concentrations. In circumstances where blenders are not readily available, adaptations may be adopted to deliver supplemental oxygen of up to 40%.

Recommendations on the use of supplemental oxygen

1. For preterm newborns ≤ 32 weeks' gestation, resuscitation should be initiated at 21%–40% oxygen concentration. For newborns ≥ 33 weeks' gestation, resuscitation should be initiated at 21% oxygen. Supplemental oxygen should be titrated as per guidelines based on the preductal oxygen saturation (SpO_2) (Fig. 1).
2. If a newborn is breathing but SpO_2 is not within the target range, supplemental oxygen of 30%–40% at a flow rate of 10 L/minute may be delivered. Using the blender, adjust oxygen concentration to achieve preductal SpO_2 targets.
3. If a newborn has laboured breathing, or SpO_2 cannot be maintained despite 100% oxygen, a trial of CPAP may be considered.

Continuous positive airway pressure

Three randomised controlled trials (RCTs) involving 2,358 newly born infants delivered at < 30 weeks' gestation have demonstrated that CPAP, as compared with PPV, reduces the rate of intubation and duration of mechanical ventilation with no significant short-term disadvantage.[72-74] It was recommended that the initial respiratory support for spontaneously breathing preterm newborns may be provided by CPAP rather than intubation. CPAP may be delivered through a face mask or nasal prong interface. Data on the use of CPAP in term newborns is scanty, and appropriate use of this interface is driven by the clinical status and needs of individual term newborns.[75,76]

Recommendations on the use of CPAP

1. Spontaneously breathing premature newborns ≤ 32 weeks' gestation may be safely stabilised with CPAP at approximately 5 cmH_2O in the delivery room and during transfer, instead of with elective intubation. The need for intubation and surfactant administration should be determined based on institutional policies.
2. For newborn infants ≥ 33 weeks' gestation, CPAP at 5 cmH_2O may be considered if clinically indicated.

POSITIVE PRESSURE VENTILATION AND POSITIVE END-EXPIRATORY PRESSURE

Positive pressure ventilation

If breathing efforts are absent or inadequate, lung aeration must not be delayed. PPV can be effectively delivered with a flow-inflating bag, self-inflating bag or T-piece resuscitator. The benefits of sustained inflation of > 5 seconds' duration in reducing the need for mechanical ventilation were evident in three RCTs and two cohort studies.[77-81] No benefit was found for critical outcomes such as reduction of mortality, bronchopulmonary dysplasia or air leak.[2] One cohort study suggested that the need for intubation was less after sustained inflation.[1] However, there is insufficient data about the safety and method of application of sustained inflation for the transitioning newborn. Hence, the routine use of sustained inflation is not recommended.

The pressure required to aerate fluid-filled lung averages 20 cmH_2O (range 15–30 cmH_2O).[82,83] Efficacy of ventilation can be estimated by a prompt increase in HR and by observing for chest rise. If these are not achieved, then the airway and/or mask should be repositioned and the inflation pressure increased, if required. Most newborns would respond within 30 seconds of lung inflation.

If HR rises to > 100 bpm but the newborn is not breathing spontaneously, then ventilation should be continued at 40–60 breaths/minute until regular spontaneous breathing is established. In situations where HR fails to respond, possible causes include inadequate airway control or ventilation secondary to mask leak, inappropriate airway position and airway obstruction. Consider taking corrective steps (MR SOPA), which includes: **m**ask repositioning to correct for mask leak, **r**epositioning of the newborn's head to achieve 'sniffing' position, **s**uctioning to clear possible airway obstruction, **o**pening of the mouth, increasing of ventilatory **p**ressure to achieve chest rise, and **a**lternative airway such as endotracheal intubation or laryngeal mask.

Without adequate ventilation, chest compression will not be effective; hence, it is important to ensure adequate lung

Table II. Endotracheal tube (ETT) size and depth of tube placement (oral intubation).

Weight (g)	Gestational age (wk)	ETT size (mm, internal diameter)	Depth of insertion (cm, from upper lip)
< 1,000	< 28	2.5	6–7
1,000–2,000	28–34	3.0	7–8
2,000–3,000	34–38	3.5	8–9
3,000–4,000	> 38	3.5	9–10

aeration and ventilation before progressing to circulatory support. Continue ventilation until the newborn has established normal regular breathing.

Positive end-expiratory pressure

Two RCTs have suggested that the addition of PEEP during delivery room resuscitation of preterm newborns did not result in improvement in mortality, HR, need for cardiac drugs, chest compressions or intubation, pulmonary air leaks, chronic lung disease, and Apgar scores, although the studies were too underpowered to have sufficient confidence in a no-difference conclusion.[2] However, considering the evidence from animal studies and another trial that provided low-quality evidence that the maximum amount of supplementary oxygen required to achieve target SpO_2 may be slightly lower when using PEEP, it has been suggested that PEEP ventilation should be used in premature newborns during delivery room resuscitation.[4,5]

Recommendations for effective PPV

1. The decision for PPV is determined by simultaneous assessment of respiration (apneoa, gasping or laboured breathing) and HR (< 100 bpm).
2. For newly born infants requiring PPV, inspiratory pressure should be initiated at about 20–25 cmH_2O while assessing for adequate ventilation and response. The inflation pressure should be monitored and increased, when required.
3. The routine use of initial sustained inflation (> 5 seconds' duration) is not recommended.
4. For preterm newborns ≤ 32 weeks' gestation requiring PPV, PEEP of about 5 cmH_2O is suggested. For newborns ≥ 33 weeks requiring PPV, PEEP ventilation can be considered, if resources are available.
5. Assisted ventilation should be delivered at a rate of 40–60 breaths per minute till normal regular breathing is established.
6. Once PPV is started, the assessment of the newborn should consist of simultaneous evaluation of HR, respiration and SpO_2.

ENDOTRACHEAL INTUBATION AND LARYNGEAL MASK AIRWAY

Endotracheal intubation

Tracheal intubation may be considered at several time points during neonatal resuscitation. However, the procedure of intubation is a skill that is difficult to master and teach. Timing of tracheal intubation is dependent on the availability of a skilled resuscitator. Tube size to use and depth to insert is based on gestational age and/or estimated weight of the newborn at birth (Table II). Vocal cord guide on endotracheal tube (ETT) is only an approximation and may not reliably indicate the correct insertion depth. Tube position must be confirmed using chest radiography.

Exhaled carbon dioxide detection remains the most reliable method for confirmation of ETT placement.[84-87] The absence of detectable carbon dioxide suggests orogastric intubation, whereas cardiac arrest and tracheal obstruction may result in false negatives.[84,86] Additional clinical indicators of correct ETT placement include chest movement, equal breath sounds bilaterally and condensation of the ETT, and their routine use should be continued. Following endotracheal intubation and the delivery of effective ventilation, a prompt increase in HR is the best indicator that the tube is in the trachea.[88]

Recommendations for endotracheal intubation

1. Endotracheal intubation may be considered:
   - When bag-mask ventilation is ineffective or prolonged.
   - When suctioning the lower airway to remove presumed tracheal obstruction.
   - When chest compressions are performed.
   - In special circumstances such as congenital diaphragmatic hernia or to instil surfactant.
2. Select the appropriate tube size and determine the length of tube to insert (Table II).
3. Check position to confirm appropriate placement.

Laryngeal mask airway

The ability to secure an airway when face-mask ventilation fails is a critical determinant of successful resuscitation. The LMA has been proposed as an alternative, either as a primary device, replacing face-mask ventilation, or as a secondary device when intubation fails or is not feasible.

Three RCTs, which enrolled a total of 469 term newborns and compared the use of LMA to the face mask as a primary device, showed that LMA was more effective than face-mask ventilation in achieving vital signs and delivering adequate ventilation with no evidence of increased morbidities such as vomiting or gastric distension.[89-91]

For comparison of LMA to ETT as a secondary device (i.e. LMA or intubation when bag-mask ventilation has failed) for term newborns requiring PPV for resuscitation, one RCT involving 40 term newborns showed that LMA was as effective as endotracheal intubation in achieving vital signs or successful resuscitation.[92] The use of LMA resulted in lower risk of trauma to the soft tissue compared with endotracheal intubation.

While studies have proven the safety and feasibility of the LMA device as an alternative to endotracheal intubation in late-preterm and term newborns (≥ 34 weeks' gestation), more studies are needed on its use for newborns that are more premature.

Recommendations on the use of LMA

1. LMA may be used as an alternative to tracheal intubation during resuscitation of late-preterm and term newborns (≥ 34 weeks' gestation) if ventilation via face mask is unsuccessful.
2. Where intubation is not feasible or unsuccessful after failed PPV, LMA is recommended for resuscitation of late-preterm and term newborns (≥ 34 weeks' gestation).

CHEST COMPRESSION

Circulatory support with chest compression is effective only if the lungs are sufficiently inflated. Begin chest compression when HR is < 60 bpm after at least 30 seconds of effective ventilation, preferably via an ETT/LMA. The two-thumb technique, with both thumbs over the lower third of the sternum and fingers encircling the torso and supporting the newborn's back, is preferred (Fig. 3). The technique generates higher blood pressure, leading to improved perfusion and gas exchange during cardiopulmonary resuscitation (CPR), as well as less fatigue than the two-finger technique.[93-101] Once the ETT/LMA is secured, the two-thumb technique can be delivered effectively from the head of the bed, while the umbilicus is accessed for insertion of an umbilical catheter; hence, the two-finger technique is no longer recommended.

The compression rate of 3:1 ventilation recommended for newborns with cardiovascular collapse results in a total of 120 events per minute (i.e. 90 compressions to 30 ventilations). Animal studies on higher compression-to-ventilation ratios compared to the current 3:1 ratio showed no improvement in short-term survival, gas exchange during CPR, time to recovery of spontaneous circulation (ROSC) and markers of tissue injury.[102-106] In addition, manikin studies have shown disadvantages in higher ratios for compressor fatigue and minute ventilation.[107] Quality of compressions and breaths are as important, if not more important, than the compression rates. The chest should be allowed to re-expand fully during relaxation, but the rescuer's thumb should not leave the chest. Effective coordination of compression and ventilation is recommended to avoid simultaneous delivery. Since hypoxia is the predominant cause of cardiovascular collapse in the newborn, effective resuscitation requires significant focus on ventilation. It is recommended that a 3:1 compression-to-ventilation ratio be retained for neonatal CPR.[1-3]

By the time the resuscitation of a newborn infant has reached the stage of chest compression, efforts to achieve ROSC using effective ventilation with low-concentration oxygen should have been attempted. Thus, it would appear sensible to increase the supplementary oxygen concentration to 100% at the initiation of chest compression. However, there are no human studies to support this, and animal studies have shown that 100% oxygen during CPR had no advantage.[108-114]

Coordinated chest compression and ventilation with oxygen at 100% for 60 seconds should be continued before HR, respiration and SpO_2 are rechecked. If HR is > 60 bpm, stop chest compression but continue PPV at a rate of 40–60 breaths per minute. If HR is > 100 bpm and the newborn is breathing spontaneously, slowly withdraw PPV. If the newborn is not responding and HR remains at < 60 bpm, review the adequacy of ventilation, supplementary oxygen, depth of chest compression, and coordination of compressions and ventilations.

Fig. 3 Photograph shows the two-thumb compression technique. Note the positioning of the thumbs and fingers in this technique.

Recommendations for synchronised CPR

1. Begin chest compressions when HR is < 60 bpm after at least 30 seconds of effective ventilation, preferably via an ETT/LMA.
2. Increase supplementary oxygen to 100%.
3. Apply the two-thumb technique by encircling the newborn's torso with both hands and placing both thumbs side by side, or over one another if the newborn is small. Compress the lower third of the sternum using the thumbs, with the fingers supporting the newborn's back.
4. Depress the sternum about one-third of the anteroposterior diameter of the chest and release to allow chest recoil and ventilation.
5. Ensure coordinated compressions and ventilation at a ratio of 3:1.
6. Continue chest compressions for 60 seconds before rechecking HR, respiration and SpO_2.

MEDICATIONS

Drugs are rarely indicated in resuscitation. Inadequate lung inflation and extreme hypoxaemia are common causes for bradycardia in newly born infants. The most effective intervention to correct bradycardia is adequate ventilation. If HR remains at < 60 bpm despite at least 30 seconds of adequate ventilation and another 60 seconds of adequate ventilation with 100% oxygen and coordinated chest compression, administration of adrenaline or volume, or both is indicated.

Recommendations on the use of adrenaline

1. Intravenous adrenaline is preferred. Tracheal route should be avoided, where possible. There is no safety or efficacy data on high tracheal doses.
2. Adrenaline (1:10,000) at 0.1–0.3 mL/kg (intravenous) should be administered rapidly followed by 0.5–1.0 mL of saline flush.[1,3-5] If the intravenous route is not

available, the endotracheal route at 0.5–1.0 mL/kg may be used.[4,5,9,115-120] If indicated, administration should be repeated via the intravenous route once umbilical venous or intraosseous access is established. There is no need to wait 3–5 minutes after the ETT dose.
3. Continue coordinated chest compression and ventilation following administration of adrenaline and assess its effect by measuring HR 60 seconds after the administration.
4. Intravenous adrenaline may be repeated at 3–5 minutes interval, if indicated.

Recommendations on the use of volume expansion

1. Consider volume expansion if blood loss is known or suspected, and HR has not responded to previous resuscitative intervention.[121]
2. Umbilical venous access is recommended.
3. Isotonic fluid such as 0.9% normal saline or type-O Rh-negative blood at 10 mL/kg may be administered intravenously.
4. Infuse predetermined volume over 10–15 minutes. Avoid rapid infusion in preterm newborns. Large volumes given rapidly to preterm newborns have been associated with IVH.
5. Repeat infusion may be given, if indicated.

Recommendations on the use of sodium bicarbonate and naloxone

1. There is currently no evidence to support the routine use of sodium bicarbonate infusion in newborns with metabolic acidosis.
2. The safety and efficacy of naloxone in newborns with respiratory depression born to mothers exposed to opiate remains uncertain. Animal studies and case reports highlighted complications such as pulmonary oedema, cardiac arrest and seizures with the use of naloxone.[122,123]

POST-RESUSCITATION CARE

Newly born infants may deteriorate following initial stabilisation after resuscitative intervention. These newborns should be monitored in an environment where anticipatory care is available.

Glucose control

Hypoglycaemia is associated with poor neurological outcome.[124] One clinical study demonstrated an association between hypoglycaemia and poor neurological outcome following perinatal asphyxia.[125] While hyperglycaemia in children following hypoxic ischaemia does not appear to result in harm, the range of blood glucose concentration that is associated with the least brain injury following asphyxia cannot be defined.

Recommendations for optimal glucose control

1. It is recommended that serum glucose should be monitored after resuscitation.[4,5]
2. Early parenteral nutrition should be provided to prevent hypoglycaemia, and hypoglycaemia should be corrected once it is detected.

Therapeutic hypothermia for moderate or severe hypoxic ischaemic encephalopathy

The 2010 ILCOR systematic review recommended that term or near-term newborns (> 36 weeks' gestation) with moderate to severe hypoxic ischaemic encephalopathy (HIE) should be offered therapeutic hypothermia (33.5°C–34.5°C) within six hours, if possible. In 2015, ILCOR suggested that the use of therapeutic hypothermia in resource-limited settings may be considered and offered to newborns of > 36 weeks' gestation with evolving moderate-to-severe HIE, but the procedure should be performed under clearly defined protocols similar to those used in published clinical trials and in facilities with capabilities for multidisciplinary care and longitudinal follow-up.[4,5]

Recommendation on management of moderate or severe HIE

Therapeutic hypothermia should be offered to eligible newborns, and the procedure must be performed in accordance with clearly defined protocols at centres with capabilities for multidisciplinary care and longitudinal follow-up.

WITHHOLDING RESUSCITATION AND DISCONTINUING RESUSCITATIVE EFFORTS

Withholding resuscitation

The 2010 ILCOR guideline suggested that when gestation, birth weight or congenital anomalies are associated with an almost certain early death and when unacceptably high morbidity is likely among the rare survivors, resuscitation is not indicated. In conditions associated with uncertain prognosis, when there is borderline survival with a high rate of morbidity and high burden to the child, the parents' views on resuscitation should be supported.[4,5] Studies have indicated that parents desire a larger role in decisions to resuscitate and continue life support in severely compromised infants.[126,127]

Recommendations on withholding resuscitation

1. In deliveries at a confirmed gestational age of < 23 weeks' gestation or where known congenital anomalies are associated with an almost certain early death and unacceptably high morbidity among the rare survivors (e.g. anencephaly, Bart's hydrops, Trisomy 13, Trisomy 18), initiation of resuscitation is not an ethical treatment option and should not be offered.
2. When antenatally identified conditions are associated with high mortality and poor outcome, the physician responsible should discuss the risks and benefits of life-sustaining treatment and allow the parents to participate in the decision on whether attempting resuscitation is in their newborn's best interest. If it is jointly agreed that intensive care will not improve the chance of the newborn's survival or will pose an unacceptable burden for the newborn, it is ethical to provide compassionate palliative care and not initiate resuscitation.
3. In deliveries at borderline viability of 23–24 weeks' gestation, therapeutic options and prognosis must be discussed with the parents before delivery, when feasible, and a combined decision on the resuscitative approach arrived at prior to

delivery. In these situations, a consistent and coordinated approach to individual cases by the obstetric and neonatal teams is recommended.
4. Where the parents are uncertain or when a combined decision (between the parents and physician) has not been reached at the time of delivery, maximal resuscitation should still be provided.
5. Further critical care intervention and decision to withdraw should be based on response to resuscitation.

Discontinue resuscitative intervention

Apgar score of 0 at ten minutes is a strong predictor of mortality and morbidity in late-preterm and term newborns. It is suggested that when HR remains undetectable after ten minutes of effective resuscitation, cessation of resuscitation is considered reasonable.[1-5] However, the decision should be individualised.

Recommendations on resuscitative intervention

1. In newborns with an Apgar score of 0 after ten minutes of continuous, effective resuscitation, it may be reasonable to stop assisted ventilation if HR remains undetectable.
2. The decision to continue or discontinue resuscitative efforts must be individualised according to certain factors, including specific circumstances before delivery (e.g. known timing of insult), whether the resuscitation was considered optimal, and prior understanding of parental views on acceptable morbidities.[128,129]

BRIEFING AND DEBRIEFING

Studies on the effects of debriefs before and after resuscitation have shown improvement in subsequent performance in simulation settings.[130-135] A structured analysis of perinatal management with feedback showed reduction in the incidence of IVH in preterm newborns.[136] Debrief after resuscitation is performed for the purposes of reflective learning and practice improvement in some local neonatal centres.

Recommendations on briefing and debriefing

1. Whenever possible, the team should discuss and assign responsibilities to individual team members prior to the start of resuscitation.
2. The resuscitation team is encouraged to conduct a debrief to reflect on the steps of resuscitation and provide constructive feedback at the end of resuscitation.

TRAINING IN NEONATAL RESUSCITATION

Training of providers

The use of simulation in teaching neonatal resuscitation was recommended in the 2010 ILCOR guideline. Studies evaluating the frequency of training of healthcare providers in neonatal resuscitation showed no difference in patient outcomes but some advantages in psychomotor performance, knowledge and confidence when focused training occurred every six months or more frequently.[137-153] The 2015 ILCOR systematic review suggested that neonatal resuscitation task training occurs more frequently than the current two-year interval.[1,2]

Recommendation on retraining of providers

1. Considering the time, manpower constraints and cost of training, it is suggested that individual providers seek recurrent focused retraining on specific tasks and/or skills at two-yearly intervals or more depending on their needs.

Training of instructors

The best instructor training methodology remains unclear. Studies exploring the impact of preparation of instructors for training of healthcare providers showed no association between the preparation provided and instructor or learner performance.[154-160] The 2015 ILCOR systematic review suggested that training of resuscitation instructors incorporate timely, objective, structured, individually targeted verbal and/or written feedback.[1,2]

Recommendations on educating and retraining of instructors

1. Enhance instructors' skills through hands-on training opportunities, with a debrief on their teaching performance at the end of each training session.
2. To maintain instructorship, each instructor has to teach a minimum of three workshops over two years and refresh their knowledge through completion of e-lessons on neonatal resuscitation and online multiple choice questions once every two years.
3. It is suggested that instructors consider attending at least one educational course, conference or local instructor update session once every two years.

CONCLUSION

The science and practice of neonatal resuscitation will continue to improve through ongoing studies that evaluate the outcomes of resuscitative interventions, and research on the available feedback devices to guide and fine-tune resuscitation. The consensus on Singapore neonatal resuscitation has been achieved following repeated discussions and debate on the ILCOR neonatal guidelines and recommendations, as well as with better understanding of local practice and needs. The Singapore Neonatal Resuscitation Guidelines 2016 represents the widely accepted view of how resuscitation of newly born infants in need of support can be carried out safely and effectively.

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