

Neonatal resuscitation

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Abstract

There have been important advances in the science of neonatal resuscitation and various international resuscitation committees have formulated evidence-based recommendations for the performance of resuscitation at birth. The new guidelines for resuscitation at birth were developed by International Liaison Committee on Resuscitation (ILCOR) and were presented at 2005 International Consensus Conference on Emergency Cardiovascular Care and Cardiopulmonary Resuscitation Science with treatment Recommendations. The European Resuscitation Council (ERC) and American Heart Association (AHA) further tailored the guidelines to meet their specific needs. In this article we have discussed the new resuscitation guidelines for newborns issued by ILCOR, American Heart Association and European Resuscitation Council.

Key words: Newborn, resuscitation, ventilation

Introduction

Majority of the newborns do not require any form of intervention at birth. However, approximately 10% need some assistance to begin breathing and 1% requires extensive resuscitation. The last International Liaison Committee on Resuscitation (ILCOR) document was published in the year 2000. Since then, several controversial neonatal resuscitation issues have been identified and a consensus has been reached on the role of supplementary oxygen, peripartum management of meconium, ventilation strategies, devices to confirm placement of an advanced airway, medications, maintenance of body temperature, post-resuscitation management and considerations for withholding and discontinuing resuscitation. The aim of this review is to discuss the new guidelines for resuscitation at birth taking into account the recommendations made by ILCOR, American Heart Association (AHA) and the European Resuscitation Council (ERC).^[1-3]

Pre-requisites

The presence of at least one adequately trained health worker to take care of the newborn at the time of delivery has been deemed necessary. For successful neonatal resuscitation, the health worker should anticipate, prepare adequately and promptly initiate supportive measures. The need for resuscitation in newborns can generally be predicted. Resuscitation should be carried out in a warm, well-lit, draught-free area on a flat resuscitation surface below a radiant heater. Resuscitation equipment should be easily available and should be checked daily. In the event of a preterm delivery (<37 weeks gestation) special preparations are required. The lungs of premature neonates are immature, hence more susceptible to injury by positive pressure ventilation. They have thin skin and large surface area, which cause rapid heat loss. They are more prone to acquiring infections and their small blood volume also increases the risk of hypovolemic shock.

Initial Assessment

At birth the following characteristics are rapidly assessed to identify the need for resuscitation:

- (a) Is the baby born after full term gestation?

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- (b) Is the amniotic fluid clear of meconium and evidence of infection?
- (c) Is the baby breathing or crying?
- (d) Does the baby have good muscle tone?

If the answer to all the questions is positive, the newborn does not require resuscitation. To prevent heat loss, the baby should be dried and covered in linen to maintain body warmth. In preterm babies, especially those with gestation age < 28 weeks, drying and wrapping may not be sufficient to conserve heat. They should be wrapped in a plastic wrapping without drying and placed under a radiant heater. The newborns' color, breathing and activity should be continuously assessed.

If the answer to any one of the above questions is negative, the neonate would require one or more of the following actions in sequence:

- A. Initial steps in stabilization (clearing the airway, positioning, stimulating)
- B. Ventilation
- C. Chest compressions
- D. Medication/s and volume expansion.

Progress to the next step in the sequence is based on simultaneous assessment of the three vital signs: respiration, heart rate and color. Approximately 30 sec have been allocated to complete one step successfully, re-evaluate and decide whether to progress to the next step.

Respiratory activity

The neonates' breathing should be checked. Rate, depth and symmetry of respiration should be evaluated. Any abnormal breathing patterns such as gasping or grunting should be noted.

Heart rate

Palpation of the pulse below the umbilical cord has been found to be reliable only if heart rate is more than 100 beats/minute.^[4] Heart rate is best evaluated by auscultation.

Colour

Although a healthy baby is born blue, the color becomes pink within 30 seconds of the start of effective breathing. A healthy neonate achieves and maintains pink mucous membranes without supplementary oxygen. Evaluation of central cyanosis is done by examining the face, trunk and mucous membranes. Peripheral cyanosis is often observed and does not by itself indicate hypoxemia. Pallor or mottling is seen in neonates having decreased cardiac output, hypovolemia, severe anemia, hypothermia or acidosis.

Tone

If the neonate is very floppy, it is most likely unconscious and would require respiratory support.

Classification According to Initial Assessment

The ERC has divided the neonates into four groups on the basis of the initial assessment [Table 1].

In *Group 1* the neonate does not require any intervention. The infant should be dried, wrapped in warm linen and if appropriate handed to the mother. The baby can be breast-fed. In *Group 2* the neonate may respond to tactile stimulation and/or face oxygen. However, mask ventilation may also be required. In *Group 3* the neonate may improve with mask ventilation but might require chest compressions. In *Group 4* the neonate requires immediate ventilation and may also need chest compressions and drugs as well.

Initial Steps in Stabilization

At birth the newborn should be placed below a radiant heat source. The neonate should be placed on its back with the head in the neutral position. To maintain proper head position a 2 cm thick towel can be placed under the neonates' shoulder. If the infant is floppy, jaw thrust can be used or an appropriately sized oropharyngeal airway can be placed. If required the airway should be cleared with a bulb syringe or a suction catheter and breathing should be stimulated. Suction should be done under direct

Table 1: Classification of neonate according to initial assessment

	Breathing	Colour	Tone	Heart rate
Group 1	Vigorous or crying	Rapidly becoming pink	Good	Greater than 100 beats/min
Group 2	Inadequate or apnoeic	Remaining centrally blue	Normal or reduced	Less than 100 beats/min
Group 3	Inadequate or apnoeic	Blue or pale	Floppy	Less than 100 beats/min
Group 4	Inadequate or apnoeic	Pale	Floppy	Not detectable

vision and the vacuum pressure should not exceed -100 mmHg. The following aspects should be taken care of during the initial phase:

Temperature control

Studies have shown an association between hypothermia and increased mortality in premature neonates.^[1] Food grade, heat resistant plastic wrappings or plastic bags under radiant heat can be used in addition to the standard techniques to maintain temperature. All the guidelines recommend that the various resuscitation steps should be carried out with the temperature-controlling devices in place.

Management of meconium

Traditionally, intrapartum suctioning of meconium from the infants airway has been routinely carried out after delivery of the head but before delivery of the shoulders to prevent aspiration pneumonia. It has however been reported that intrapartum suctioning of meconium does not reduce the incidence of meconium aspiration syndrome.^[5] ILCOR no longer recommends routine intrapartum oropharyngeal or nasopharyngeal suctioning for infants born with meconium stained amniotic fluid. Furthermore, it recommends that tracheal suctioning is not necessary for infants born with meconium-stained fluid who are vigorous. A vigorous infant is described as one who has strong respiratory efforts; heart rate more than 100 beats per minute and a good muscle tone. However, in infants who are born with meconium-stained fluid and are depressed, tracheal suctioning should be done immediately after birth before any stimulation is carried out.

Periodic assessment

After carrying out the initial steps, assessment of the newborns' respiration, heart rate and color should be done before continuing with resuscitation. After the initial respiratory efforts, the newborn usually establishes regular respiration and has a heart rate more than 100 beats per minute. Moreover, its color also shows a marked improvement. Assisted ventilation is required if the neonate is gasping or apneic. Changes in heart rate also indicate an alteration in the neonate's condition.

Supplementary oxygen

There has always been considerable concern about the potential adverse effects of using 100% oxygen

during resuscitation of infants at birth. 100% oxygen is known to adversely affect breathing physiology and cerebral circulation and also cause tissue damage due to oxygen free radicals.^[3] Various studies have shown that air is as effective as supplementary 100% oxygen for resuscitation.^[6,7] A study by Ramji *et al.*, showed that room air was as good as 100% oxygen for resuscitation of asphyxic newborn babies at birth.^[8] Similarly, in the Resair 2 study, mortality was lower in infants resuscitated with room air as compared to those resuscitated with oxygen.^[9] However, both these studies were non-blinded and done in infants with birth weight <1000 gm and those without lethal abnormalities.

In contrast, a study in newborn hypoxic ischaemic piglets reported a significantly lower mean arterial pressure and a greater degree of cerebral hypoperfusion after reoxygenation with 21% oxygen as compared to 100% oxygen suggesting a less favorable outcome in newborns resuscitated with air.^[10] However, a more recent study in term neonates showed that room air causes less damage to heart and kidney than 100% oxygen.^[11] Lundstrom *et al.*, also reported that preterm infants exposed to 80% oxygen had lower cerebral blood flow when compared to those stabilized with 21% oxygen.^[12] Hence, so far the evidence is considered insufficient for specifying the concentration of oxygen to be used at initiation of resuscitation.

The guidelines recommend that if at birth respiratory efforts are absent or inadequate, lung inflation should be the priority and can be carried out with room air. Supplementary oxygen is recommended whenever positive pressure ventilation is indicated and in infants having persistent central cyanosis. If resuscitation is started with room air, supplementary oxygen should be used if there is no appreciable improvement within 90 seconds of birth. In premature infants excessive tissue oxygen may cause oxidant injury, hence high concentrations of oxygen should be avoided.

Ventilation

Initial breaths

Majority of the apneic newborn infants can be resuscitated with properly performed positive-pressure ventilation.^[13] In the bradycardic infant, heart rate promptly improves if the initial ventilation is adequate.^[14,15] Hence, the main objective in such infants is establishment of

effective ventilation. If the heart rate does not improve, chest wall movement should be assessed and if found inadequate, assisted ventilation should be delivered by a bag-valve-mask device.

As the initial peak inflating pressures necessary to achieve an increase in heart rate or movement of the chest wall are variable, ILCOR recommends that they should be individualized with each breath. The guidelines state that if the pressure is being monitored an initial inflation pressure of 20 cm of H₂O may be effective. In some infants a peak pressure \geq 30-40 cm of H₂O may be required. However, if the pressure is not being monitored, the minimal inflation required to achieve an increase in heart rate should be used. Assisted ventilation should be delivered at the rate of 40-60 breaths per minute. Vyas *et al.*, found that sustained inflation pressure of 30 cm H₂O for five sec for the first breath was effective in establishing lung volume in term infants requiring resuscitation.^[16] The ERC recommends that for the first few breaths the inflation should be maintained for two to three sec, as it helps lung expansion. However ILCOR has not recommended initial or subsequent inflation times. Most neonates show an improvement in heart rate within 30 sec of lung inflation. If the heart rate improves but the neonate still does not have adequate respiration, ventilation should be provided at 30 breaths per minute and inflation should be for one second.

Assisted ventilation devices

The ILCOR guidelines recommend that bag-valve-mask ventilation should be provided to a newborn by either a self-inflating bag or a flow inflating bag or a T-piece mechanical device designed to regulate pressure as per requirement. Bag-valve mask ventilation is contraindicated in newborns diagnosed to have congenital diaphragmatic hernia as it may distend the stomach and bowels. Positive pressure ventilation should be carried out carefully in newborns diagnosed to have tracheo-esophageal fistula, cystic adenoid malformation or pneumothorax. If bag-mask ventilation is unsuccessful and tracheal intubation is not feasible a laryngeal mask airway (LMA) may be used for ventilation. However, LMA is not recommended as a primary airway device during neonatal resuscitation.

Ventilation strategies for preterm infants

Animal studies have shown that immediately after birth

preterm lungs are more easily injured by inflations using large volumes.^[17] The ILCOR guidelines recommend that excessive chest wall movements should be avoided during ventilation immediately after birth. An initial inflation pressure of 20-25 cm of H₂O has been recommended if positive pressure ventilation is being applied. Furthermore, if the heart rate does not improve or there is no chest movement the inflating pressure can be increased.

Use of CPAP or PEEP

Spontaneously breathing newborns have been found to establish functional residual capacity more quickly than sick neonates.^[18] It has been shown that CPAP improves lung function, decreases requirement for intubation and reduces the number of days on assisted ventilation.^[19] However another study did not show any benefit on using CPAP.^[20] Excessive CPAP is known to over distend the lung, increase the work of breathing and decrease cardiac output.^[21,22] Since the data is still insufficient the ILCOR neither supports nor refutes the routine use of CPAP during resuscitation.

Endotracheal tube placement

Tracheal intubation may be required during resuscitation. Tracheal tube size and depth of insertion according to neonates gestational age and weight [Table 2]. The timing of intubation is more likely to be determined by the skill and experience of the resuscitator. However, it may be indicated during the following stages of resuscitation:

- If tracheal suctioning of meconium is required.
- If bag-mask ventilation is unsuccessful or prolonged.
- If chest compressions are to be performed simultaneously.
- For resuscitation of extremely low birth weight neonates or those born with congenital diaphragmatic hernia.

A prompt increase in heart rate after intubation and ventilation indicates correct placement of tube and

Table 2: Tracheal tube size and depth of insertion according to neonates gestational age and weight

Gestation age (weeks)	Weight (kg)	Tube size (ID in mm)	Insertion depth (cm)
<28	<1	2.5	6.5-7.0
28-34	1-2	3.0	7.0-8.0
34-38	2-3	3.0/3.5	8.0-9.0
>38	>3	3.5/4.0	>9.0

effective ventilation.^[23]

Exhaled CO₂ detectors to confirm tracheal tube placement

Studies show that exhaled CO₂ detectors (capnometers) identify oesophageal intubations earlier than clinical assessments such as chest movement and assessment of condensed humidified gas during exhalation.^[24,25] A positive test confirms the placement of the tube in the trachea whereas a negative test strongly suggests esophageal intubation.^[24-26] However in critically ill neonates the result may be false negative due to poor cardiac output. Exhaled CO₂ detectors have been recommended to be useful for confirmation of tracheal intubation.

Chest Compressions

Chest compressions should be commenced when the heart rate fails to increase beyond 60 beats per minute in spite of adequate ventilation with supplementary oxygen for 30 sec. Chest compressions increase intrathoracic pressure and directly compress the heart hence generating blood flow. This blood flow delivers a small but crucial amount of oxygen and substrate to the brain and myocardium.

Chest compressions are known to interfere with effective ventilation and hence assisted ventilation should be properly delivered before starting chest compressions as most of the neonates can be revived with ventilation alone. For an effective chest compression, the sternum should be depressed at its lower third to a depth of approximately one third of the anterior-posterior diameter of the chest.^[27,28]

Two techniques have been described for performing chest compressions. The sternum can be compressed either with two thumbs with fingers encircling the chest and supporting the back or with two fingers while the second hand supports the back.^[29,30] The two thumbs-encircling hands technique has been recommended for providing chest compressions as it generates higher peak systolic and coronary perfusion than the two finger technique.^[31,32] However, if access to umbilicus is required for insertion of an umbilical catheter, the two-finger technique can then be used.

A compression ventilation ratio of 3:1 has been recommended. Approximately 90 compressions and 30

breaths should be delivered in one minute. Dean *et al.*, have reported that blood flow in a neonate is improved if the chest compression time is slightly shorter than relaxation time.^[33] The chest should recoil completely before the next compression is delivered. Contact should be maintained when the pressure is released. Compression and ventilation should be synchronized to avoid their simultaneous delivery. Moreover, ventilation should be delivered such that exhalation occurs during the subsequent compression. Heart rate, color and respiration should be reassessed every 30 seconds and chest compressions and ventilation should be continued till the spontaneous heart rate increases beyond 60 beats per minute.

Medications and Volume Expansion

Medications are rarely needed in neonatal resuscitation as bradycardia is usually due to inadequate lung inflation or profound hypoxemia and can be corrected by adequate ventilation.^[34] However, if the heart rate remains below 60 beats per minute despite adequate ventilation with 100% oxygen and chest compressions, adrenaline and even fluids may be required. Very rarely naloxone, sodium bicarbonate and vasopressors need to be used after resuscitation.

Adrenaline

Till date no placebo-controlled study has been carried out to evaluate tracheal or intravenous (IV) administration of adrenaline during cardiac arrest in human neonates. Studies carried out in newborn animals have shown no benefit after administration of IV or tracheal adrenaline during resuscitation.^[35,36] Animal and adult human studies have shown that the effective dose of adrenaline administered via the tracheal route is much higher than suggested by the current recommendations.^[37-39] The intravenous route is recommended as soon as an IV access is established and the IV dose is 0.01-0.03 mg/kg. The concentration of adrenaline for either route should be 1:10000 (0.1 mg/ml). For the tracheal route a higher dose of 0.1 mg/kg has been advised. The guidelines recommend that the higher dose of adrenaline should not be used intravenously during resuscitation as it can result in exaggerated hypertension, decreased cardiac output and poor neurological function.^[35,36,40]

Volume expansion

Volume expansion should be considered in shock,

failure to respond satisfactorily to resuscitative measures and in blood loss. Isotonic saline rather than albumin has been recommended for volume expansion. The recommended volume is 10 ml/kg and may be repeated. In premature neonates larger volumes should not be used as rapid volume expansion can lead to intraventricular hemorrhage.^[2]

Bicarbonate

The ERC recommends the use of bicarbonate if spontaneous cardiac output is not restored despite adequate ventilation and chest compressions. Intravenous bicarbonate in a dose of 1-2 mmol/kg may reverse intracardiac acidosis and improve myocardial function.

Naloxone

Naloxone has not been recommended as part of the initial resuscitation of newborns with respiratory depression. It may be considered in neonates with severe respiratory depression arising from ingestion of opioids by the mother. However, to date no study has evaluated the use of naloxone in neonates with severe respiratory depression from maternal opioids. One study in vigorous neonates (defined as a neonate with strong respiratory efforts, heart rate more than 100 beats per minute and a good muscle tone) of mothers who had ingested opioids reported a brief improvement in alveolar ventilation with naloxone.^[41]

In adults, high doses of naloxone are known to produce cardiac arrhythmias, hypertension and non-cardiogenic pulmonary edema.^[42] The heart rate and the color of the neonate should be restored by assisted ventilation before considering administration of naloxone at a dose of 0.1 mg/kg. The preferred route is intravenous or intramuscular and tracheal route is not recommended. Intravenous naloxone produces higher plasma concentrations but has a shorter half-life when compared to intramuscular route.^[43] Naloxone may have a shorter half-life than the maternal opioid, hence the neonate should be monitored for recurrent apnoea or hypoventilation.

Precautions During Resuscitation of Newborn Born to HIV Positive Mother

During resuscitation of a neonate born to a HIV positive mother, precautions should be taken to avoid transmission of the infection to the health worker. All babies should be handled with gloves. If suction is required during

resuscitation, mechanical suction or bulb suction unit should be used instead of mouth operated suction unit. Washing of hands, careful cleaning and disinfection of equipment and correct disposal of secretions are the other measures that should be adopted during resuscitation.

Post Resuscitation Management

Even after successful resuscitation, the neonates' condition can suddenly deteriorate.

Therefore the infant should be constantly monitored even after adequate respiration and circulation are present.

Glucose

Hypoglycaemia during resuscitation has been reported to be associated with poor neurological outcome following perinatal asphyxia.^[44] Though the optimal range of blood glucose concentration to minimize brain injury following asphyxia has not yet been defined, the guidelines recommend that glucose should be monitored and maintained in the normal range in neonates requiring resuscitation.

Temperature

Neonates born to febrile mothers are prone to respiratory depression, seizures, cerebral palsy and death.^[45,46] Therefore, such newborns should be kept normothermic and iatrogenic hyperthermia should be avoided if resuscitation is required.

Following a cerebral hypoxic event, reduction of body temperature by 2-3°C (modest hypothermia) has been shown to reduce cerebral metabolic and biochemical abnormalities as well as cerebral injury.^[47-49] However, infants with severe electroencephalographic suppression and seizures do not benefit from modest hypothermia.^[50] Modest hypothermia produces bradycardia and elevated blood pressure.^[51] Profound hypothermia (core temperature < 33°C) is known to cause arrhythmia, bleeding, thrombosis and sepsis.^[50,52-54] Thus, routine use of hypothermia after resuscitation of infants with suspected asphyxia has not been recommended due to lack of sufficient evidence.

Withholding or Discontinuing Resuscitative Efforts

Resuscitation is always indicated in conditions

associated with a high rate of survival and acceptable morbidity. It is not indicated when gestation, birth weight or congenital anomalies are associated with almost certain early death. Moreover conditions associated with unacceptable high morbidity among survivors are also an indication for withholding or discontinuing resuscitation. These include extreme prematurity (gestational age <23 weeks or birth weight <400 gm), anomalies such as anencephaly and confirmed trisomy 13 or 18. Parents' views on starting resuscitation should be supported when the prognosis is uncertain, survival chances are borderline, high rate of morbidity exists and the burden to the child is high. Studies report high mortality or severe neurodevelopment disability in neonates who show no signs of life for at least 10 minutes or longer after birth despite continuous and adequate resuscitation efforts.^[55,56] Hence it may be justifiable to stop resuscitation if there are no signs of life after 10 minutes of continuous resuscitation.

If resuscitation has been successful the chances of survival depend on the duration of the cardiac arrest and the time taken for resuscitation. This should be explained to the parents as the long term neurological and functional status of the newborn depends on these two factors in addition to proper post resuscitative monitoring and care.

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