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REVIEW ARTICLE

Recent Update on Neonatal Resuscitation

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Abstract

Every 5 y, the International Liaison Committee on Resuscitation publishes consensus on cardiopulmonary resuscitation, and emergency cardiovascular science and treatment recommendations. The latest update on neonatal resuscitation guidelines was published in 2020. Here, the authors review the important changes in the recent recommendations, including initial steps of resuscitation, umbilical cord management, management of nonvigorous infants born through meconium-stained amniotic fluid, sustained inflation in preterm infants, epinephrine, vascular access, timing of discontinuation of resuscitative effort, and team briefing and debriefing.

Keywords Delivery room · Heart rate · Infants · Neonate · Oxygen · Resuscitation · Ventilation

Introduction

Cessation of fetomaternal circulation at birth and the subsequent rapid physiologic changes involve both the cardiovascular and respiratory systems. Failure of this adaptation results in cardiopulmonary compromise and the need for resuscitation. Approximately, 85% of term infants will initiate breathing spontaneously within 30 s of birth and an additional 10% will respond to drying and tactile stimulation [1]. Around 5% to 10% of all newborns need some assistance to establish normal breathing at birth including positive pressure ventilation (PPV), 0.1% receive cardiac compressions, and 0.05% receive cardiac compressions with epinephrine [1–5]. However, among preterm infants, 10%–15% of extremely low-birth-weight (< 1000 g) and 6% of very-low-birth-weight (< 1500 g) infants receive extensive cardiopulmonary resuscitation including chest compression with or without epinephrine [6–8]. Delay in starting PPV in a nonbreathing newborn can increase risk of neonatal morbidity and mortality [1].

In 1987, American Academy of Pediatrics started the Neonatal Resuscitation Program (NRP) with the publication of its first textbook [9]. Every 5 y, the International Liaison Committee on Resuscitation (ILCOR) publishes consensus on cardiopulmonary resuscitation and emergency cardiovascular science and treatment recommendations since 2000 [10–14]. The 2020 recommendations for neonatal resuscitation include evidence from 7 systematic reviews, 3 scoping reviews, and 12 evidence updates [14]. These recommendations form the basis of the American Heart Association (AHA) and American Academy of Pediatrics NRP, 8th edition, which will be available by mid-2021. The objectives of this review are to update the readers with the changes in the latest edition of NRP, and discuss the ILCOR and AHA guidelines along with knowledge gaps in the current literature.

Recent Recommendations in Neonatal Resuscitation

The neonatal resuscitation algorithm remains unchanged from 2015. Table 1 summarizes the recent AHA recommendations.

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Table 1 Summary of American Heart Association/neonatal resuscitation recommendations

	AHA 2010/2015	AHA 2020	COR	LOE
Recommendation for anticipating resuscitation need	Every birth should be attended by at least 1 person who can perform initial steps and initiate PPV	Unchanged	1	B-NR
	Before every birth, assess for perinatal risk factor and assemble a qualified team	Unchanged	1	B-NR
	Use a standardized equipment checklist and check the function before birth	Unchanged	1	C-LD
	No Recommendation	When anticipating a high-risk birth, conduct a preresuscitation team briefing to identify potential interventions and assign roles and responsibilities.	1	C-LD
Umbilical cord management	Delayed cord clamping for longer than 30 s is reasonable for both term and preterm infants who do not require resuscitation at birth	For preterm infants who do not require resuscitation at birth, it is reasonable to delay cord clamping for longer than 30 s	2a	B-R
		For term infants who do not require resuscitation at birth, it may be reasonable to delay cord clamping for longer than 30 s	2b	C-LD
	There is insufficient evidence to recommend timing of cord clamping for infants who require resuscitation at birth	Unchanged	2b	C-EO
	Suggest against routine use of cord milking for infants <29 wk	For infants <28 wk., cord milking is not recommended.	3: No Benefit	B-R
Initial Steps				
Temperature at birth	Admission temperature should be routinely recorded	Unchanged	1	B-NR
	Temperature of newly born infants should be maintained between 36.5 °C and 37.5 °C after birth through admission and stabilization	Unchanged	1	C-EO
		Hypothermia (< 36 °C) should be prevented	1	B-NR
	Prevent hyperthermia (temperature>38 °C) due to potential associated risks	Unchanged	1	B-NR
Temperature management for newly born infants	It is reasonable to nurse newborns with skin-to-skin contact or kangaroo mother care	Placing healthy newborn infants who do not require resuscitation skin-to-skin after birth can be effective in improving breastfeeding, temperature control, and blood glucose stability	2a	B-R
		It is reasonable to perform all resuscitation procedures with temperature-controlling interventions in place.	2b	C-LD
	Radiant warmers, plastic bags and wraps (with a cap), increased room temperature, and warmed humidified inspired gases can be effective in preventing hypothermia in preterm babies in delivery room	Unchanged	2a	B-R
		Exothermic mattresses may be effective in preventing hypothermia in preterm babies	2b	B-R
	Use various combinations warming strategies to prevent hypothermia in infants born at < 32 wk. of gestation	Unchanged	2b	B-NR
	In resource-limited settings, it is reasonable to put newly born babies in a clean food-grade plastic bag up to neck and swaddle them to prevent hypothermia	Unchanged	2b	C-LD
Clearing of airway and tactile stimulation	Routine oral, nasal, oropharyngeal, or endotracheal suctioning is not recommended	Unchanged	3: No benefit	C-LD
		Tactile stimulation is reasonable in babies who appear to have ineffective respiratory effort after birth	2a	B-NR
	Consider suctioning if PPV is required and airway appears obstructed	Unchanged	2b	C-EO
Clearing the airway in infants delivered through meconium-stained amniotic fluid (MSAF)	Routine intubation with or without suctioning is not suggested for nonvigorous newborn delivered through MSAF	Routine laryngoscopy with or without suctioning is *not recommended* for nonvigorous newborn delivered through MSAF	3: No benefit	C-LD
		For nonvigorous newborns delivered through MSAF who have evidence of airway obstruction during PPV, intubation and tracheal suction can be beneficial	2a	C-EO

Table 1 (continued)

	AHA 2010/2015	AHA 2020	COR	LOE
Assessment of heart rate	Electrocardiography (ECG) may be reasonable for the rapid and accurate measurement heart rate during resuscitation of term and preterm newborns	Unchanged	2b	C-LD
	No recommendation	During chest compressions, ECG should be used for the rapid and accurate assessment of heart rate	1	C-EO
Positive pressure ventilation (PPV)	PPV should be provided immediately in newborn infants who are gasping or apneic or who are persistently bradycardic (< 100/min) despite appropriate initial actions	Unchanged	1	B-NR
Pressure		In newly born infants who require PPV, use peak inflation pressure of 20–25 cm water to inflate the lung and achieve heart-rate rise	2a	C-LD
PEEP	PEEP of 5 cm H_2O is suggested for preterm infants receiving PPV	It is reasonable to provide PEEP for infants receiving PPV	2b	C-LD
		Excessive peak inflation pressures are potentially harmful, and should be avoided	3: Harm	C-LD
Rate and inspiratory time during PPV	Rate 40–60/min	Unchanged	2a	C-LD
		In term and preterm infants, initiate PPV with an inspiratory time of 1 s or less	2a	C-LD
Sustained lung inflation	There is insufficient data to support routine application of sustained inflation of greater than 5 s to the transitioning newborn	**Sustained inflation to initiate resuscitation is potentially harmful and should not be performed in preterm infants**	**3: Harm**	**B-R**
CPAP	Spontaneously breathing preterm infants with respiratory distress may be supported with CPAP initially rather than routine intubation	It is reasonable to use CPAP (instead of intubation) for spontaneously breathing preterm infants, who require respiratory support immediately after delivery	2a	A
Oxygen administration	It is reasonable to initiate resuscitation with air (21% oxygen at sea level) for term and infants	Unchanged	2a	B-R
	Resuscitation of preterm newborns <35 wk. should be initiated with low oxygen (21% to 30%), and the oxygen concentration should be titrated with pulse oximetry	Unchanged	2b	C-LD
	Initiating resuscitation of preterm newborns with high oxygen (65% or greater) is not recommended	**100% oxygen should not be used in term and late preterm infant receiving respiratory support at birth because of excess mortality**	**3: Harm**	**B-R**
Chest compression	Initiate chest compression if heart rate remains below 60/min despite adequate ventilation for at least 30 s	Unchanged.	2a	C-EO
	Oxygen concentration should be increase to 100% whenever chest compressions are provided and wean supplementary oxygen concentration as soon as the heart rate recovers	Benefit of 100% oxygen compared with 21% oxygen or any other oxygen concentration for ventilation during chest compressions is uncertain. It may be reasonable to use higher oxygen concentrations during chest compressions	2b	C-EO
Compression to ventilation ratio and technique	3:1 compression-to-ventilation ratio for neonatal CPR	Unchanged	2b	C-EO
	Two thumb technique is the preferred option	Unchanged	2b	C-LD
Intravascular access		**For babies requiring vascular access at time of delivery, umbilical vein is the recommended route**	1	C-EO
		Reasonable to use intraosseous route, if intravenous (IV) access is not feasible	2b	C-EO
Medications	If the heart rate remains below 60/min after optimizing ventilation and chest compressions, reasonable to administer intravascular epinephrine (0.01 to 0.03 mg/kg)	Unchanged	2b	C-LD
		It is reasonable to administer endotracheal (ET) epinephrine at a larger dose (0.05 to 0.1 mg/kg), while vascular access is being obtained	2b	C-LD
		When ET epinephrine is given before vascular access is available and response is inadequate, give an intravascular dose as soon as access is obtained, regardless of the interval	2b	C-LD
		Administer further doses of epinephrine every 3 to 5 min, preferably intravascularly, if the heart rate remains less than 60/min	2b	C-LD

Table 1 (continued)

	AHA 2010/2015	AHA 2020	COR	LOE
Volume replacement	Volume expansion may be considered when blood loss is known or suspected and the infant's heart rate has not responded to other resuscitative measures	Administer volume expander to those with suspected hypovolemia, who remain bradycardic (< 60/min) despite ventilation, chest compressions, and epinephrine	2b	C-EO
	The recommended dose of saline or blood is 10 mL/kg, which may need to be repeated	**Volume expansion done with normal salineor blood at 10 to 20 mL/kg**	2b	C-EO
Postresuscitation care		For babies ≥36 wk. with evolving moderate-to-severe HIE, therapeutic hypothermia should be offered under clearly defined protocols	1	A
		Infant who received prolonged PPV or advance resuscitation should be transferred to an environment where close monitoring can be provided	1	C-LD
		Blood glucose should be check as soon as practical after advanced resuscitation, and treatment as indicated	1	C-LD
		Infants who are unintentionally hypothermic (< 36 °C) after resuscitation, it is reasonable to rewarm either rapidly (0.5 °C/h) or slowly (less than 0.5 °C/h)	2b	C-LD
Withholding and discontinuing resuscitation		Noninitiation of resuscitation and discontinuation of life-sustaining treatment during or after resuscitation are considered ethically equivalent.	1	C-EO
	In babies with the heart rate remains undetectable after 10 min of resuscitation, it may be reasonable to stop resuscitation; however, this decision must be individualized	If there is no heart rate despite all steps of resuscitation, cessation of resuscitation efforts should be discussed with the team and the family. A reasonable time frame for this change in goals of care is around 20 min after birth	1	C-LD
		For births at lower limit of viability or for conditions likely to result early death or severe morbidity, noninitiation or limitation of neonatal resuscitation is reasonable after expert consultation and parental involvement in decision-making	2a	C-EO
Training frequency	Training should be recurrent and considered more frequently than once per year	Individual or team booster training should occur more frequently than every 2 y to support retention of knowledge, skills, and behaviors	1	C-LD
		It may be reasonable to brief before delivery and debrief after neonatal resuscitation	2b	C-LD

COR Class of recommendation: 1: Strong (Benefit >>> Risk); 2a: Moderate (Benefit >> Risk); 2b: Weak (Benefit ≥ Risk); 3: No Benefit (Benefit = Risk); 3: Harm (Risk > Benefit); *HIE* Hypoxic-ischemic encephalopathy; *LOE* Level of evidence: A: High quality; B-R: Moderate from randomized trials; B-NR: Moderate from nonrandomized data; C-LD: Data with limitations of design or execution; C-EO: Consensus of expert opinion

Anticipation of Resuscitation Need

Anticipation and Preparation

The key to successful neonatal resuscitation includes an assessment of perinatal risk factors and rapid assembly of a team with members skilled in resuscitation. The recent update reaffirms that at least one personnel responsible for initiating resuscitation, who is trained to begin PPV, is present at each delivery and emphasizes the use of standardized equipment checklists and checking for function.

Umbilical Cord Management

Delayed umbilical cord clamping (DCC) is recommended for both term and preterm neonates in 2015. The 2020 AHA update affirms the previous recommendations (Table 1) [15]. A recent systematic review and meta-analysis showed that DCC reduced mortality before discharge. DCC is associated with a reduction in any grade intraventricular hemorrhage (IVH) but no difference in severe IVH or chronic lung disease [16–18].

However, there is insufficient evidence to recommend immediate/early cord clamping versus delayed cord clamping for infants, who require resuscitation at birth. Immediate cord clamping is considered for cases when placental transfusion is unlikely to occur, such as maternal hemorrhage or hemodynamic instability, placental abruption, or placenta previa [19]. Umbilical cord milking significantly increases the risk of severe IVH in preterm infants and recommended to avoid in babies <28 wk. gestational age [20, 21]. There is insufficient data to show what duration of delay is best, one or several minutes, and therefore, the optimal timing of umbilical cord clamping still remains unclear.

Initial Actions

Overall, the components of initial steps of resuscitation remain the same, but the order has been changed to facilitate common practice in the recent edition of NRP textbook (Table 2).

Airway Management in the Event of Meconium-Stained Amniotic Fluid

The 2015 ILCOR recommendation suggests against routine tracheal intubation for suctioning of meconium in nonvigorous infants born through meconium-stained amniotic fluid (MSAF) [13]. A recent systematic review and meta-analysis of four randomized trials involving nonvigorous newborns delivered through MSAF showed that immediate laryngoscopy with tracheal suctioning did not improve survival at discharge when compared with immediate resuscitation without laryngoscopy [22]. The rates of meconium aspiration syndrome and hypoxic-ischemic encephalopathy did not differ, thus emphasizing that routine laryngoscopy with or without tracheal suctioning is not recommended [14].

Assessment of Heart Rate

Heart rate (HR) is the most important clinical sign to evaluate compromised newborns and to guide resuscitation efforts in the delivery room. Auscultation remains the preferred clinical method for initial assessment of HR in the delivery room [15]. Studies have shown that clinical assessment of HR by auscultation or palpation may be unreliable and inaccurate [23–26]. Pulse oximetry and electrocardiography (ECG) remain important adjuncts to provide continuous HR assessment. In babies needing resuscitation, ECG provides the most rapid and accurate measurement of the newborn's HR at birth and during resuscitation. In contrast to ECG, pulse oximetry is slower in detecting the HR and can be inaccurate during the first few minutes after birth [27–29].

The 2020 recommendation of "ECG may be used for the rapid and accurate measurement of the newborn's HR during resuscitation" remains unchanged from the 2015 recommendation. However, if the infant needs chest compression, an ECG should be used for the rapid and accurate assessment of HR [15]. However, since the introduction of ECG for HR assessment in the delivery room, several animal studies and case series have reported pulseless electric activity during

Table 2 Overview of Neonatal Resuscitation Program 8th Edition Practice Changes (adapted from NRP 8th Edition Busy People Update - AAP)

Changes	NRP 7th Edition	NRP 8th Edition
Prebirth questions		
Umbilical cord management plan added to 4 prebirth questions, replacing "How many babies?"	The 4 prebirth questions: (1) Term gestation? (2) Amniotic fluid clear? (3) How many babies? (4) Additional risk factors?	The 4 prebirth questions: (1) Term gestation? (2) Amniotic fluid clear? (3) Umbilical cord management plans? (4) Additional risk factors?
Initial steps reordered to better reflect common practice	Initial steps: warm and maintain normal temperature; position airway, clear secretions if needed, dry stimulate	Initial steps: warm, dry, stimulate, position airway, suction, if needed
Heart rate assessment		
Electronic cardiac monitor is recommended earlier in the algorithm	Electronic cardiac monitor is preferred method for assessing heart rate during cardiac compressions	When alternative airway becomes necessary, cardiac monitor is recommended for most accurate assessment of heart rate
Medications		
Epinephrine (IV/IO) flush volume increased	Flush IV/IO epinephrine with 0.5–1 mL normal saline	Flush IV/IO epinephrine with 3 mL of normal saline (applies to all weights and gestational age)
Epinephrine IV/IO and endotracheal doses simplified for educational efficiency (dosage range is unchanged)	Range for IV or IO dose=0.01–0.03 mg/kg (equal to 0.1–0.3 mL/kg) Range for endotracheal dose=0.05–0.1 mg/kg (equal to 0.5–1 mL/kg)	The suggested initial IV or IO dose=0.02 mg/kg (equal to 0.2 mL/kg) The suggested endotracheal dose (while establishing vascular access)=0.1 mg/kg equal to 1 mL/kg)
Expanded timelines for cessation of resuscitative effort	If there is a confirmed absence of heart rate after 10 min of resuscitation efforts, it is reasonable to stop resuscitative effort; however, decision to continue or discontinue should be individualized.	If confirmed absence of HR after all appropriate steps performed, consider cessation of resuscitation efforts around 20 min after birth (decision should be individualized on patient and contextual factors).

ET Endotracheal; *HR* Heart rate; *IV* Intravenous; *IO* Intraosseous neonatal asphyxia [30–34]. Initiation of chest compressions can be delayed, if clinicians rely solely on the ECG display of HR. Therefore, ECG should be used in conjunction with other assessment methods including auscultation, palpation and pulse oximetry.

Ventilatory Support after Birth

Positive-Pressure Ventilation

Ventilation of the newborn's lung is the single most important and most effective step in neonatal resuscitation. The indications for PPV and rate of ventilation (40–60 breaths/min) remains unchanged. Use of positive end expiratory pressure (PEEP) with the initial breath may help achieve stable lung inflation more quickly, clear lung fluid, and prevent alveolar collapse during exhalation. Therefore, it is reasonable to provide PEEP in newborn infants receiving PPV, but the evidence from human studies is limited [15]. Excessive peak inflation pressure should be avoided, as it has been implicated in various complications such as pneumothorax.

Role of Sustained Inflation (SI) During Resuscitation Animal studies have demonstrated that a longer SI before initiating PPV can inflate the lungs and increase functional residual capacity [35, 36]. However, a meta-analysis of 10 trials involving 1502 infants showed no benefit of sustained inflation > 5 s during resuscitation [37]. SI was associated with increased death before discharge among preterm infants < 29 wk and currently, SI is *not* recommended [15]. There is insufficient evidence for or against the use of SI for term and late preterm infants.

T-Piece Resuscitator Versus Self-Inflating Bag for Ventilation

A recent scoping review included 4 clinical studies representing 2889 newborns [927 in three randomized, control trials (RCTs) and 1962 in one observational study] [14]. The large observational study in preterm infants from Brazil reported that the use of a T-piece resuscitator increased survival and decreased bronchopulmonary dysplasia and intubation in the delivery room [38]. Another clinical trial reported decreased intubation rates in the delivery room when T-piece resuscitators were used [39]. Currently, there is insufficient evidence regarding the use of T-piece resuscitator or self-inflating bag for initial PPV at birth, so no one device could be recommended over the other, as the confidence in the effect estimates is so low [14].

Oxygen Therapy

The recommendations for oxygen therapy in term and preterm infants remain largely unchanged [40].

Chest Compression

The indications and ratio of chest compression to ventilation remain unchanged. It is prudent to optimize ventilation before starting chest compression with endotracheal intubation, when possible. The current guidelines recommend using 100% oxygen while providing chest compressions; however, no studies have confirmed a benefit of this approach compared to any other oxygen concentration. It may be reasonable to increase inspired oxygen to 100% if there is no response to PPV with lower oxygen concentrations. Once the return of spontaneous circulation (ROSC) is achieved, the supplemental oxygen concentration needs to be titrated.

Vascular Access

Whenever vascular access is desired during resuscitation, the umbilical venous route is still preferred [14]. Outside the delivery room or when the intravenous access is not feasible, the intraosseous route may be an alternative route.

Medications: Epinephrine

The indications and dose of epinephrine remain unchanged. Administration of epinephrine via an umbilical venous catheter provides the most rapid and reliable medication delivery. There is a significant lack of evidence regarding the optimal dosage and efficacy of intravenous (IV) and endotracheal tube (ET) epinephrine in the newborn. In a recent randomized trial in term newborn lamb, epinephrine at 0.03 mg/kg followed by a 3 mL/kg normal saline flush for the first dose of epinephrine resulted in high rates of ROSC (100%) and quicker ROSC compared with use of 0.01 mg/kg of epinephrine with 1 mL or 3 mL/kg of normal saline flush [41].

Volume Expansion

Volume expansion is indicated when blood loss is known or suspected based on history and examination, and there has been no response to epinephrine. This remains unchanged.

Withholding and Discontinuing Resuscitation

Failure to achieve an ROSC in a newborn despite 10 to 20 min of intensive resuscitation is associated with a high risk of mortality and moderate-to-severe neurodevelopmental impairment among survivors. However, there is no evidence that any specific duration of resuscitation consistently predicts these dire outcomes. If there is no heart rate despite performing all the steps of resuscitation, it is reasonable to discuss with the team and family regarding a change in goals of care at around 20 min of age [14]. This process, however, needs to be individualized. Various factors that play a role include whether the resuscitation was optimal, availability of higher level of neonatal care (such as therapeutic hypothermia), circumstances before delivery, and the family's wishes.

If anticipated birth is at the extreme limit of viability or involves a lethal or severe morbidity, noninitiation or limitation of neonatal resuscitation would be reasonable after expert consultation and parental involvement in this crucial and sensitive shared decision-making process.

Postresuscitation Care

Neonates who receive prolonged PPV or more advanced resuscitation (e.g., intubation, chest compressions with or without epinephrine, etc) should be closely monitored after stabilization in a neonatal intensive care unit or in an area, where they can be closely scrutinized as they are at risk for further deterioration. Refer to the recommendations mentioned in Table 1.

Human and System Performance

Training Frequency

Neonatal resuscitation providers face various challenges with respect to the knowledge, skills, and behaviors needed to perform an effective and quality resuscitation. Historically, the NRP training is repeated every 2 y. Recent evidences suggest that without practice, there is knowledge and skill decay within 3 to 12 mo [42, 43]. Brief and frequent practice (also known as booster training) has been found to have an important role in improving neonatal resuscitation outcomes [44].

Briefing and Debriefing

Scoping reviews on briefing/debriefing following neonatal resuscitation, concluded that such practice might improve short-term clinical and performance outcomes for infants and staff [15]. This positively impacts on a variety of educational and clinical outcomes in neonatal, pediatric, and even adult simulation-based and clinical studies. However, the effects of briefing or debriefing on long-term clinical and performance outcomes are uncertain.

Knowledge Gaps

The most recent guidelines have not delved into the details of the most relevant devices during each step in resuscitation. The potential upcoming reviews will address the choice of devices and key equipment, including those required for ventilation (T-piece, self-inflating bag, flow-inflating bag), ventilation interface (face mask, laryngeal mask), suction (bulb syringe, meconium aspirator), monitoring (respiratory function monitors, heart-rate monitoring, near-infrared spectroscopy), and also focus on relevant contextual topics such as feedback and documentation [15].

Potential areas of future research could include optimal cord management for nonvigorous infants, the impact of routine use of ECG during resuscitation, optimal oxygen management during and after resuscitation, optimal timing and dosing of medication and volume expanders, role of briefing and debriefing on team performance and exploring the factors that could optimize postresuscitation care.

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Declarations

Conflict of Interest None.

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