Recent Recommendations and Emerging Science in Neonatal Resuscitation

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KEYWORDS

• Resuscitation • Newborn • Delivery room • Training • Laryngeal mask • Simulation

KEY POINTS

- The Neonatal Resuscitation Program (NRP) has evolved in the last several decades from expert opinion to evidence-based practice.
- Effective positive pressure ventilation continues to be the most important intervention during neonatal resuscitation.
- Major recent changes in NRP recommendations include delayed cord clamping, use of electrocardiographic monitoring, and rescinding the mandate on endotracheal suctioning of nonvigorous infants born through meconium-stained amniotic fluid.
- Emerging science in the use of oxygen, cord management, and the use of laryngeal masks will contribute to future recommendations.
- New technologies such as video laryngoscopy and telemedicine hold promise for improving education, training, and delivery of practice.

BACKGROUND

The Neonatal Resuscitation Program (NRP) was launched by the American Academy of Pediatrics (AAP) in 1987 with the publication of the first textbook, an innovative algorithmic approach to newborn resuscitation.[1] The program was initiated as an expert and consensus-based guideline because resuscitation science was nascent at the time. This new paradigm had an ambitious goal of having a trained individual at the birth of every infant in the United States. To accomplish this aim, the committee embarked on training a pyramid of instructors: national instructors would train regional instructors who would train hospital instructors, and these instructors would teach the

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bedside providers. The tenet of equality of team members, which included doctors, nurses, and respiratory therapists, was established. The NRP Steering Committee (NRPSC), made up of volunteers with an interest and expertise in neonatal resuscitation, supported by staff from the AAP and joined by liaisons from other professional groups, has provided robust leadership for the program's development. The textbook has been periodically revised and is now in its seventh edition.[2] Major developments in the NRP over the past three decades include:

1. Fostering resuscitation research
2. Establishing scientific evidence-based guidelines
3. Integrating cognitive, technical, and behavioral skills into individual and team performance

The NRPSC has supported resuscitation research through an annual grant competition for both early and established investigators. Other funding sources for resuscitation have been actively encouraged, with positive results.

Establishing a neonatal work group within the International Liaison Committee on Resuscitation (ILCOR) has advanced the scientific evidence base for guidelines. The ILCOR Neonatal Work Group, composed of international volunteer neonatologists, reviews the scientific evidence of the world's literature and produces a consensus summary, which is the basis for guidelines created by neonatal resuscitation councils globally. This work is available as Consensus on Science and Recommendations at eccguidelines.heart.org. If there are scientific gaps with low level or absent scientific support, a pragmatic approach is taken.[3] The program continues to be faced with the challenge of training providers for low-frequency events that have significant consequences. Developing delivery room technologies, such as telemedicine and videolaryngoscopy, provide the opportunity for improvements in performance and practice.

CURRENT NRP GUIDELINES

The seventh edition of the Textbook of Neonatal Resuscitation includes changes in the NRP training program, mandated at the beginning of 2017.[2] The current guidelines, as well as a summary of the emerging science in that area, are summarized herein.

Predelivery Anticipatory Preparation

During the birth of every newborn, the potential need for resuscitation must be anticipated. Thus, at least one clinician who is skilled in basic neonatal resuscitation should be present at every delivery, and this person must be available exclusively to assess the infant and provide intervention (for example, positive pressure ventilation [PPV]) if needed. Risk factors that increase the likelihood for the need for resuscitation should be ascertained before delivery, if possible, and provision of additional personnel trained in advanced resuscitation should be arranged. Rapid neonatal response teams should be immediately available for the unanticipated infant who requires resuscitation.[2,4]

When neonatal resuscitation is anticipated based on maternal or fetal factors, neonatal providers should meet with family before delivery, when feasible. All perinatal team members (obstetric and neonatal care providers, and the parents) should discuss resuscitation options and agree on a plan.

Timing of Umbilical Cord Clamping

Previously the procedure of umbilical cord clamping had been considered the obstetric team's domain and was routinely performed soon after delivery of infants born in the United States and many other areas of the world.[5] More recently, with new data about the benefits of delayed cord clamping, the NRP has provided recommendations about this procedure. The 2017 NRP guidelines recommend a 30- to 60-second delay in clamping in all term and preterm infants not requiring resuscitation. If the placental circulation is disrupted (eg, placental abruption), the cord should be clamped immediately.[6] Major evidence gaps remain regarding the timing of cord clamping in newborns requiring resuscitation because these patients were generally excluded from many of the studies on the timing of cord clamping.[3]

Emerging science

Since the 2015 ILCOR review and publication of the seventh edition of the NRP textbook, the American College of Obstetricians and Gynecologists has recommended delayed (30–60 seconds) cord clamping for both term and preterm infants.[7,8] A recent systematic review and meta-analysis by Fogarty and colleagues[9] examined this new practice of delayed clamping (comparing a delay of 30 seconds or more with early clamping that was <30 seconds). The investigators analyzed data from 18 randomized controlled trials of 2834 preterm and term infants and found that delayed clamping reduced mortality before discharge.

Research is focused on determining the optimal timing of cord clamping in depressed infants. Many physiologic studies, both in animal models and in humans, of dynamic blood flow within and through the cord have deepened our understanding of the hemodynamic complexity of the placental transfusion at birth. In a preterm lamb model, Bhatt and coworkers[10] explored the hemodynamic differences between ventilation before and after cord clamping. They found that when the lung was not ventilated before cord clamping, the transitional circulation was characterized by bradycardia and cerebral blood pressure fluctuations. Katheria and colleagues[11] performed a clinical trial comparing delayed clamping with resuscitation performed on the delivery table versus early cord clamping with resuscitation performed on the warmer. They found no differences in outcomes such as hematocrit, need for phototherapy, or intraventricular hemorrhage. A large randomized controlled trial of resuscitation (VentFirst) of depressed preterm infants before cord clamping is under way.[12]

A possible alternative to delayed cord clamping for placental transfusion facilitation is the cord-milking technique. In this procedure the obstetric provider compresses the cord, moving the blood toward the newborn. This maneuver is accomplished by milking the intact unclamped cord 4 to 5 times. Another option is to clamp and cut a long segment of the cord immediately after birth and then milk the cord. The major advantage of either method of cord milking is that the newborn can be passed to the awaiting resuscitation team without delay while preserving the receipt of the placental transfusion. Katheria and colleagues[13] recently reviewed the evidence in term and preterm newborns supporting the practices of delayed cord clamping, intact umbilical cord milking, and cut-umbilical cord milking. However, Blank and colleagues[14] showed that umbilical cord–milking strategies compared with physiologically based cord clamping caused considerable hemodynamic disturbances in a preterm sheep model; thus, further study is warranted.

Initial Steps

Thermal defense of term and especially preterm infants remains a key factor in neonatal resuscitation. For small preterm infants, hypothermia is consistently associated with higher mortality and serious morbidities.[8] Delivery room temperatures should be at 23°C to 25°C (74°F–77°F).[15] A combination of techniques, including plastic wrapping, thermal mattresses, radiant warmers, caps, and warmed humidified gases for resuscitation are recommended for preterm infants born at <32 weeks' gestation. Nonasphyxiated newborns should have axillary temperatures of 36.5°C to 37.5°C (97.7°F–99.5° F). Hyperthermia should be avoided.[8]

Airway Management in the Event of Meconium-Stained Amniotic Fluid

Suctioning of newborns should be performed only if the airway is obstructed or if PPV is needed.[6,16] In nonvigorous infants born through meconium-stained amniotic fluid (MSAF), current recommendations include intubation and endotracheal suctioning only for those who need it for ventilation or airway obstruction.[3] Because MSAF remains an important risk factor for resuscitation need, a person skilled in intubation should still be immediately available for these births.[6]

Emerging science

The discontinuation of routine endotracheal suctioning in nonvigorous infants born through MSAF is supported by several small international studies. Singh and colleagues,[17] in a recent randomized controlled trial, found that although suctioned infants tend to have a lower incidence of meconium aspiration syndrome (MAS), the overall incidence of respiratory distress and mortality was similar in the suctioned and unsuctioned groups. Chettri and coworkers[18] and Nangia and colleagues[19] showed in two different randomized controlled trials, which included 297 infants, that there was no difference in the incidence of MAS severity or complications, mortality, or neurodevelopmental outcome measured by developmental assessment scales or incidence of hypoxic ischemic encephalopathy. A Cochrane review is in progress evaluating the efficacy of tracheal suctioning at birth in preventing MAS in this population.[20] Observational trials are beginning to provide evidence for the impact of this change in practice.[21]

Assessment of Heart Rate

Heart rate is the critical indicator for signaling the need for intervention in neonatal resuscitation and evaluating the patient's response to these interventions. Auscultation of the precordium has been the standard assessment method with the adjunctive use of pulse oximetry. However, studies comparing electrocardiogram (ECG) use with both auscultation and pulse oximetry show that ECG monitoring revealed the heart rate more rapidly and accurately.[3] Katheria and colleagues[22] found in a pilot trial that using ECG supported earlier and more accurate assessment, which in turn allowed earlier intervention. Current recommendations are to consider using a 3-lead ECG for rapid and accurate heart rate assessment when PPV is initiated. ECG is the preferred method of assessment once chest compressions begin.[6]

Oxygenation Assessment and Administration

It is recommended that room air (21% O_2 at sea level) be used at the initiation of resuscitation in infants born at ≥35 weeks' gestation. In healthy term infants, supplemental oxygen should be used as needed to achieve saturation targets using pulse oximetry.[6,8] For preterm infants less than 35 weeks' gestation, the current recommendation is to begin resuscitation with 21% to 30% supplemental O_2 and titrate to saturation targets similar to term infants.[6,8] An optimal approach is not yet determined.

Emerging science

Preterm infants may benefit from target oxygen saturations that are based on gestational age. Oei and colleagues[23] recently analyzed individual patient data for 768 patients with birth gestational ages less than 32 weeks from 8 randomized controlled trials of lower versus higher initial FiO_2 (fraction of inspired oxygen) strategies targeted to specific predetermined oxygen saturation (SpO_2) before 10 min of age. They found that failing to reach Spo_2 of 80% at 5 minutes was associated with adverse outcomes including intraventricular hemorrhage, and risk of death was significantly increased with time to reach Spo_2 80%.

Ventilation

PPV is indicated for apneic or gasping infants and when heart rate is <100 beats/min. PPV may also be initiated in spontaneously breathing infants with heart rates greater than 100 beats/min who do not maintain oxygen saturations within the target range despite continuous positive airway pressure or free-flowing oxygen. During PPV, the continued recommendation is to start with a positive inspiratory pressure of 20 to 25 cm H_2O. A positive end-expiratory pressure (PEEP) of 5 cm H_2O is recommended; to attain this goal with self-inflating bags, a PEEP valve is necessary.[6,8]

A rising heart rate remains the cardinal indicator of successful ventilation. If the infant's heart rate does not increase after 15 seconds, ventilation-corrective steps should be taken. If the heart rate continues to fail to increase, tracheal obstruction should be considered and suctioning of the airway performed.[6]

Endotracheal Intubation and Laryngeal Mask Airway

Endotracheal intubation is indicated for ineffective or prolonged PPV or for special circumstances such as an abnormal airway anatomy. Intubation is strongly recommended when chest compressions are needed. A laryngeal mask airway may serve as an alternative airway interface when endotracheal intubation is not successful in term or larger preterm neonates. Laryngeal mask usage remains limited, owing to the lack of appropriately sized devices for the smaller infant and limited data to support their use.[3,6,8]

Emerging science

Laryngeal mask airways, with technological advances, are now available in many forms and configurations (**Fig. 1**). Although the original laryngeal mask airway was a multiuse device, cleaning requirements and high cost have steered providers toward less costly, single-use devices. Newer-generation devices provide higher seal pressures resulting from improved seal material or design, and some feature a gastric access port to vent or aspirate gastric contents.[24] Evidence for the broader use of the laryngeal mask for airway management and medication administration is developing. In 3 studies evaluating 158 infants, there were no clinically significant differences in insertion time or failure to correctly insert a laryngeal mask when compared with endotracheal intubation.[25] The use of a laryngeal mask is particularly valuable with diminishing exposure of trainees in neonatal tracheal intubation. Interhospital transfers, including air transport, of infants with congenital airway malformations have been managed with a size 1 (infants weighing <5 kg) laryngeal mask without administering sedatives or anesthetic drugs before device insertion.[26] Laryngeal mask airways used to administer anesthesia were associated with significantly fewer respiratory adverse events compared with endotracheal tubes in a randomized controlled trial of 181 infants undergoing minor elective procedures.[27]

Although there is limited evidence of the safety and efficacy of epinephrine via laryngeal mask in human neonates, recent studies demonstrate the effectiveness of laryngeal mask devices as conduits for surfactant administration.[28] Three trials (conducted by Pinheiro, Barbosa, and Roberts) successfully used laryngeal masks for surfactant administration.[29–31]

The laryngeal mask airway could become the preferred primary interface in neonatal resuscitation. Providing effective PPV is considered the single most important

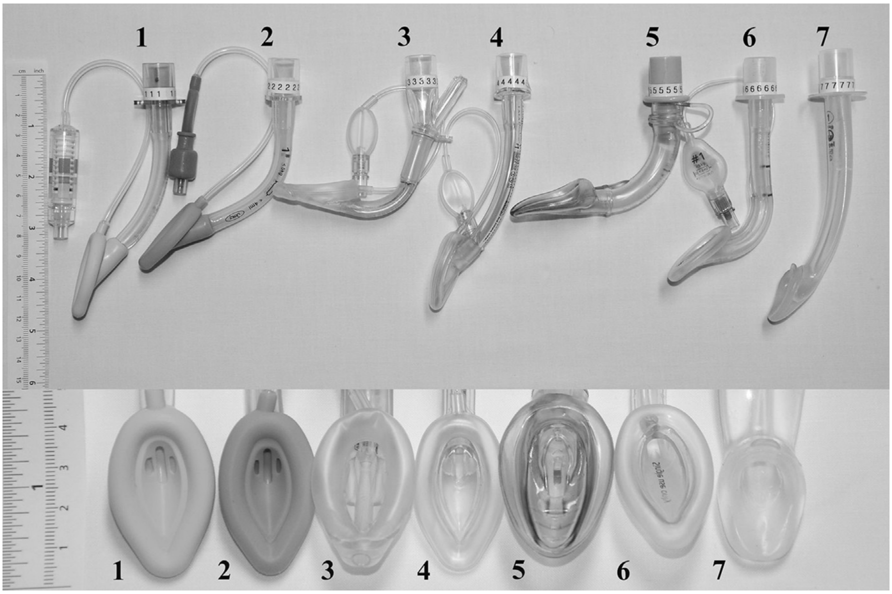

Fig. 1. Size 1 laryngeal masks. (1) Ultimate, (2) PRO-Breathe, (3) Supreme, (4) Unique, (5) air-Q, (6) AuroOnce, and (7) i-gel. (*From* Tracy MB, Priyadarshi A, Goel D, et al. How do different brands of size 1 laryngeal mask airway compare with face mask ventilation in a dedicated laryngeal mask airway teaching manikin? Arch Dis Child Fetal Neonatal Ed 2018;103(3):F273; with permission.)

component of successful neonatal resuscitation. Face mask ventilation may be difficult to perform successfully, resulting in prolonged resuscitation or neonatal asphyxia. A recent Cochrane review examining 5 trials with 661 infants showed superiority of laryngeal mask to face mask ventilation in achieving spontaneous breathing and decreasing the need for intubation.[25] This benefit is especially relevant for resources-limited environments including rural settings and/or developing countries. The pros and cons of using a laryngeal mask airway are summarized in **Table 1**.

Chest Compressions

Chest compressions are indicated when heart rate remains less than 60 beats/min after at least 30 seconds of PPV. When chest compressions begin, supplemental O_2

Table 1
Pros and cons of use of laryngeal mask airway

Pros	Cons
Quickly learnable by unskilled operators	Limited evidence for infants <34 wk gestation or birth weight <1500 g
Newer-generation devices with improved design and material	Potential for laryngospasm and soft-tissue injury (both are rare)
Faster placement as a result of easy insertion	Proper positioning needed for effectiveness
Better seal, negating the need for ventilation-corrective steps	Potential for gastric distention (gastric vent available)
Better outcomes[25]	

may be increased until the heart rate recovers and weaned rapidly afterward. In this scenario, ECG is preferred for assessing heart rate.[3,6,8]

Medications: Epinephrine

Epinephrine is indicated when the heart rate is <60 beats/min after 60 seconds of chest compressions coordinated with PPV using 100% O_2. Epinephrine can be administered by the intravenous (IV) or intraosseous (IO) route.[6,8] A higher dose may be given via the endotracheal route while IV or IO access is being obtained, although evidence for the efficacy of this practice remains lacking.[3,8]

Ethics and Care at End of Life

If the newborn is assessed to have no chance of survival by the responsible physician, initiating resuscitation is not an ethical option and should not be offered.[3,8] In conditions associated with a high risk of early death or significant burden of morbidity for the infant, decisions should be carefully discussed with parents.[3,6]

An Apgar score of 0 at 10 minutes of age remains highly correlated with mortality and serious morbidity. If a heartbeat remains undetectable after 10 minutes of resuscitative efforts, NRP states that it is reasonable to discontinue the efforts. This decision may be individualized depending on factors of the quality of the resuscitation efforts, the specific circumstances of the etiology of the event, and the availability/applicability of hypothermia treatment.[3,6,8]

EMERGING AREAS OF DEVELOPMENT IN RESUSCITATION TRAINING AND DELIVERY OF CARE

Education

The NRP instruction has progressively incorporated individual skills building and team function into the format of education since its inception. The most recent platform is Internet-based and uses both simulation and team performance.[32]

Emerging science

A growing body of evidence shows that simulation is a standardized technique for teaching neonatal resuscitation.[33] Simulation may be the preferred teaching model for resuscitation because of the need for quick critical analysis, communication skills, team-building behaviors, and procedural expertise, such as neonatal endotracheal intubation.[34]

Having a provider skilled at endotracheal intubation is key to preventing not only complications from birth asphyxia but also soft-tissue and airway damage, pneumothorax, esophageal perforation, and death that can arise as a result of deficient laryngoscope handling and tube positioning.[35] Proficiency in neonatal intubation is a procedural requirement for all pediatric trainees by the Pediatric Residency Review Committee of the Accreditation Council for Graduate Medical Education.[36] However, even after NRP training, numerous reports conclude that many providers remain feeling unprepared to resuscitate a newborn, much less being able to proficiently perform neonatal intubation.[37,38] Finer and Rich videotaped actual neonatal resuscitative efforts and identified gaps in acquired and maintained skills.[39] Simulation-based training was identified as a new teaching strategy to address these translational gaps and to foster mastery learning.[40–42]

Videolaryngoscopy (VL) is emerging as a helpful educational tool for endotracheal intubation. A randomized controlled trial by Volz and colleagues[43] revealed higher success rates for neonatal intubation among trainees after practice with VL, in comparison with traditional training, confirming previous studies.[44–46]

Real-time media-enhanced feedback may augment the simulation-based training experience. The authors demonstrated that the addition of Google Glass, wearable eyeglasses allowing real-time video feedback, when teaching neonatal endotracheal intubation to novice learners, shortens successful intubation time and increases confidence scores in a simulation environment.[47]

Ongoing simulation-based training is a step toward mastery learning. The most recent seventh edition of NRP stresses the importance of simulation debriefing, which encourages reflection on learning experiences for better retention of both knowledge and skills.[48]

Telemedicine

As the sophistication of the science and the demands of complex medical conditions advance, the difficulties of providing a high level of care in health care systems escalate. Telemedicine is a relatively new tool that can be used to extend the provision of low-frequency/high-consequence resuscitations for newborns and support resuscitation education.

Emerging science

Telemedicine is rapidly becoming an important tool for enhancing skilled provision of neonatal resuscitation. The AAP recommends that infants born at less than 32 weeks' gestation should be delivered at level III neonatal intensive care units (NICUs) because mortality rates are lower among very low birth weight infants delivered and treated at appropriate facilities.[49–52] Yet in many states less than 80% of women of reproductive age live within 50 miles of a level III NICU.[53] One promising solution to address the rural-urban disparity in access to subspecialty care is the use of telemedicine.[54–57] In simulated settings, telemedicine has been shown to decrease the time needed to establish effective ventilation. Fang and colleagues[58] compared the outcomes of infants who received a teleneonatology consult during resuscitation with controls who did not. Neonates who received a teleneonatology consult had a higher median quality rating evaluated by a blinded expert panel compared with the control group.

Recent work has demonstrated the feasibility and safety of a newborn resuscitation telemedicine program (NRTP) to remotely assist local providers with resuscitation.[59] Appropriate equipment for telemedicine application is essential for the audiovisual connection between the consultant at the remote site and the local provider. Both wired and wireless devices have been used in emergency telemedicine clinical settings. Beck and colleagues[60] recently conducted a study to compare the two technologies. A highly reliable connection is key for NRTP, owing to the critical nature of consults as assessments and interventions occur at 30-s to 1-min intervals during newborn resuscitation. Therefore, a wired connection device is probably the more reliable option to provide consultation in highly emergent settings.

Implementation of NRTP presents challenges because it differs substantially from the conventional way of providing neonatal resuscitation.[61] Key to the successful implementation of telemedicine is the inclusion of local stakeholders in the planning and design of clinical workflows. Although most providers in community settings are NRP trained, the lack of continued exposure to newborn resuscitation leads to decay in both knowledge and skills. Continuing education, including NRP and mock codes using telemedicine, are helpful to prepare the team for smooth application of NRTP when the need arises.

SUMMARY

Current recommendations in the seventh edition of the NRP textbook, effective in 2017 and reflected in the training program, were updated on the basis of the ILCOR review and consensus on science. Emerging science in many areas, including management of umbilical cord clamping, oxygen use, ventilation, rapid and accurate patient assessments, and laryngeal mask airway use will undoubtedly inform future recommendations. Exciting new technologies, such as telemedicine, may extend the benefits of our knowledge and improve our delivery of care. The developing science of human factors in neonatal resuscitation continues to improve the training and performance of skilled providers for these patients at the critical time of birth.

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