Neonatal Resuscitation

14

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I. Anticipating resuscitation. Most newborns make the fetal-to-neonatal transition without intervention. When any risk factor from a candidate list of potential moderate and high risk factors was present, 20 % of newborns required positive-pressure ventilation (PPV) to aerate their lungs. Given the large number of births each year, this represents a relatively frequent emergency. With appropriate attention to identifiable risk factors, most neonatal resuscitations can be anticipated before birth, however; even in the complete absence of risk factors a small proportion (0.2–7 %) will require PPV. Achieving the best outcome requires an organized and efficient response from a highly reliable team. Because the need for resuscitation cannot always be predicted, every birth should be attended by at least one qualified individual with neonatal resuscitation skills, including basic airway management and positive-pressure ventilation, whose only responsibility is providing care for the newly born infant. If risk factors are identified, additional personnel should be present at the time of birth. A team with advanced airway and vascular access skills should be identified and immediately available for resuscitation. Risk factors include:
   A. Preterm delivery
   B. Category 2 or 3 fetal heart rate pattern
   C. Chorioamnionitis
   D. Maternal hypertension
   E. Vaginal breech delivery
   F. Obstetrical emergencies (shoulder dystocia, cord prolapse)
   G. Maternal opiate administration in labor
   H. Meconium-stained amniotic fluid
   I. Oligohydramnios
   J. Fetal anomalies
II. Normal postnatal transition.
   A. The first breath generates a large negative pressure that inflates the lungs and clears liquid.

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B. Subsequent short, deep inspirations followed by exhalation against a closed or partially closed glottis results in a larger volume of air inspired than expired and rapidly establishes functional residual capacity (FRC).
C. Carbon dioxide is exhaled.
D. Pulmonary vascular resistance decreases allowing pulmonary blood flow to increase. Pulmonary venous return fills the left atrium and ventricle.
E. Flow through the ductus arteriosus changes from right-to-left to left-to-right.

III. Neonatal resuscitation equipment
A. Preheated radiant warmer and warm towels/blankets in a warm, well lit area
B. Stethoscope
C. Bulb syringe
D. Positive-pressure ventilation device (self-inflating bag, flow-inflating bag, or T-piece resuscitator). All devices should be equipped with manometers and suitable pressure regulators. If using a flow-inflating bag or T-piece, a self-inflating bag must be available as a back-up if gas pressure is lost.
E. Compressed gas source (air and oxygen) with adjustable flowmeter and blender
F. Face masks for term and preterm newborns
G. Orogastric feeding tube (8 F) and syringe
H. Pulse oximeter with neonatal sensor
I. Electronic cardiac (ECG) monitor and leads (chest or limb)
J. Laryngoscopes (blade size-0 and size-1, size-00 optional) with backup bulbs and batteries
K. Endotracheal tubes (sizes 2.5, 3.0, 3.5) and (optional) stylet
L. Suction device with a range of catheter sizes (10–12 F)
M. Colorimetric carbon dioxide detector or capnometer
N. Measuring tape
O. Waterproof tape and scissors or endotracheal tube securing device
P. Emergency umbilical venous catheter supplies
Q. Epinephrine (1:10,000) and normal saline
R. Personal protective supplies (gloves, gowns, masks)
S. Special equipment for premature births
1. Polyethylene plastic bag/wrap, hat, and thermal mattress
2. Servo-controlled temperature sensor
3. Pre-warmed transport incubator
4. Surfactant
T. Special equipment for difficult airways and emergency vascular access
1. Laryngeal mask or other supraglottic device
2. Oral (Guedel) airway
3. Intraosseous needle

IV. Preparation
A. Complete a pre-resuscitation briefing (“time-out”).
1. Review the pregnancy/labor history and evaluate risk factors.
2. Establish the plan for timing of umbilical cord clamping with the obstetric provider.
3. Assign roles and responsibilities.
B. Check equipment and supplies using a standardized checklist.

V. Initial Steps (Fig. 14.1)
A. Rapidly evaluate gestational age, tone, and respiratory effort.
1. If no contraindication, delay cord clamping for 30–60 s.
2. Vigorous term newborns should be placed skin-to-skin on mother’s chest or abdomen to monitor transition.

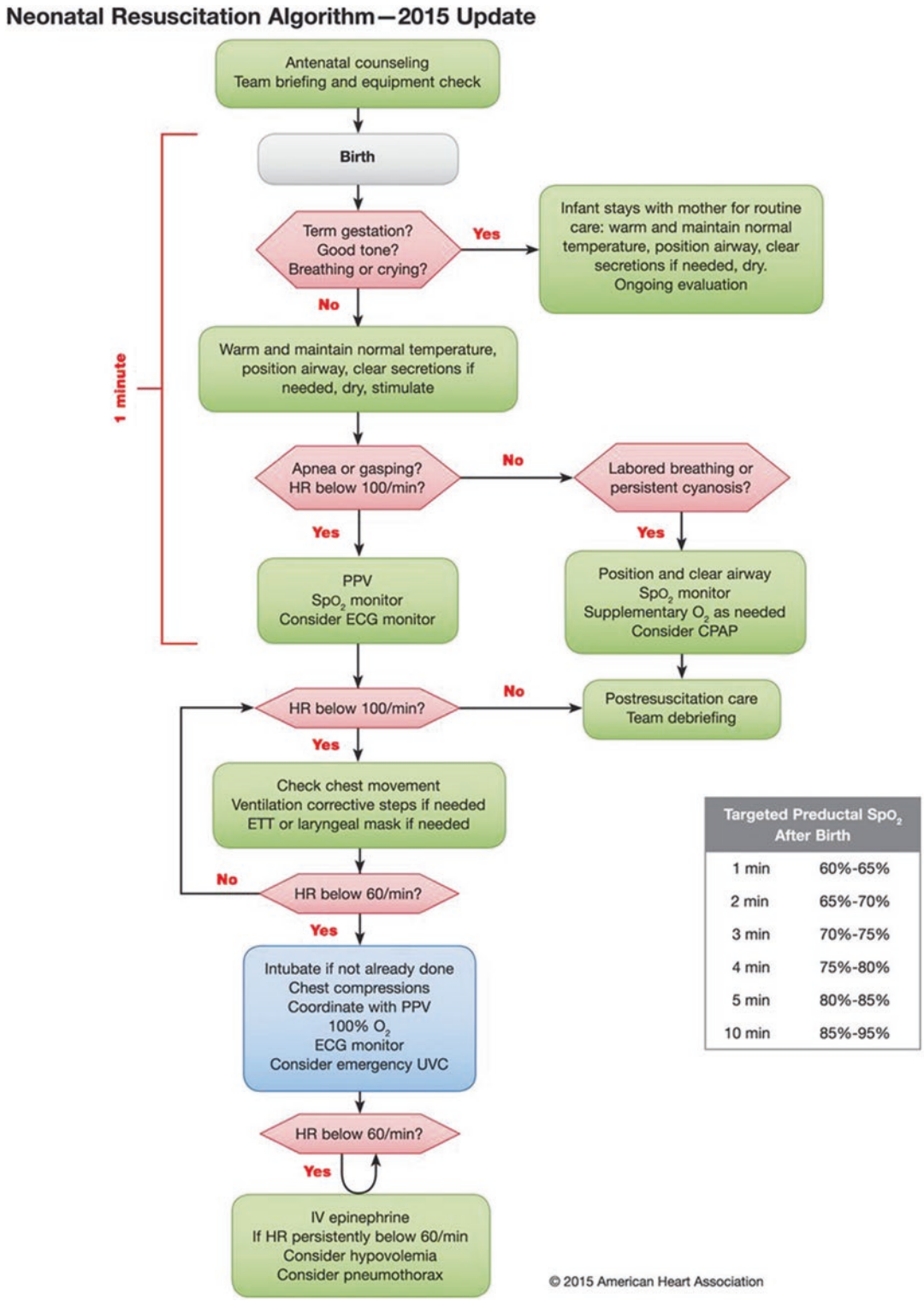

Fig. 14.1 Neonatal resuscitation algorithm. Wyckoff MH et al. Circulation. 2015;132:S543–S560

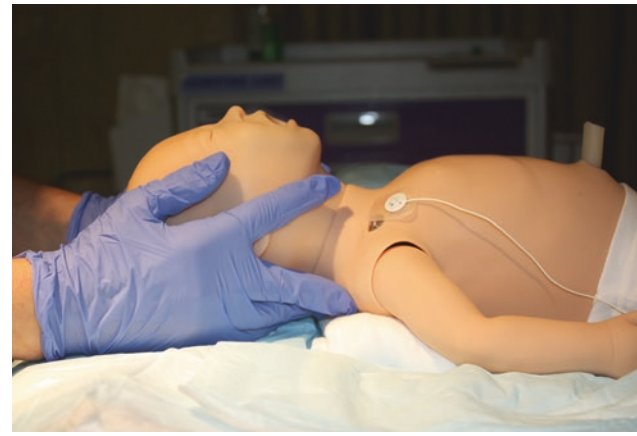

Fig. 14.2 Sniffing position

3. Preterm and non-vigorous newborns should be carried to a radiant warmerbed.

B. Remove wet towels and dry with warm towels/blanket.

C. Establish an open airway. Position the neck neutral or slightly extended in the "sniffing the morning air" position (Fig. 14.2).

D. Gently suction the mouth and nose with a bulb syringe if meconium stained fluid is present, the baby is not breathing, or the baby is having difficulty breathing. Routine suctioning and aggressive pharyngeal suctioning are not recommended.

E. Rub the back or extremities, as necessary, to stimulate breathing.

F. Evaluate response to the initial steps. Is the newborn breathing or crying? Is the heart rate (HR) at least 100 bpm?

1. If the baby is not breathing or the HR is <100 bpm by 1 min of age, proceed to positive-pressure ventilation
2. If the baby is breathing and the HR is at least 100 bpm, but central cyanosis persists, use pre-ductal pulse oximetry (right hand) to assess the need for supplemental oxygen.
3. Heart rate is most accurately assessed by auscultation at the cardiac apex or by using an ECG monitor. Palpation of the umbilical pulse is unreliable and often inaccurate.

VI. Positive-pressure ventilation.

Most newborns requiring resuscitation will improve when their lungs are effectively aerated and ventilated.

A. Place the baby supine. Consider placing a small, rolled towel or blanket under the baby's shoulders to prevent the prominent occiput from flexing the neck.

B. Standing at the head of the bed, hold the baby's head and neck in the sniffing position, and apply an appropriate size mask to the baby's face. The mask should not cover the eyes or extend beyond the chin. Use a one-hand (Fig. 14.3) or two-hand hold to ensure an airtight seal.

C. Begin PPV.

1. Inflate the lungs with 20–25 cm H_2O pressure. The first breaths may require higher pressure (30–40 cm H_2O). PEEP (5 cm H_2O) helps to establish and maintain FRC.
2. The ventilation rate is 40–60 breaths per minute.
3. Initiate ventilation with 21 % oxygen (room air) for term babies and 21–30 % oxygen for babies less than 35 weeks' gestation.
4. Use pre-ductal pulse oximetry (right hand) during PPV to evaluate oxygenation and adjust the oxygen concentration (F_iO_2). Use a target oxygen saturation table to guide supplemental oxygen.

Fig. 14.3 Face-mask with one-hand hold and CO_2 detector

D. The baby's HR should promptly increase with PPV.
   1. As soon as PPV is started, an assistant should monitor the HR response. Consider using an ECG monitor for accurate assessment of HR during PPV.
   2. If HR rapidly improves, continue PPV until the HR is at least 100 bpm and the baby is breathing effectively.
   3. If the HR does not increase within approximately 15 s, it is likely because effective ventilation has not been achieved. Ensure there is chest movement with PPV. If chest movement is absent or inconsistent, sequentially perform corrective steps until there is consistent chest movement.
   4. Corrective steps include repositioning the mask and neck, suctioning the airway, opening the mouth, and increasing the ventilating pressure. Consider placing a carbon dioxide (CO_2) detector between the PPV device and ventilation mask to monitor exhaled CO_2 as an additional indicator of effective ventilation.
   5. If the baby's HR is not improving and chest movement cannot be achieved with face-mask ventilation, insert an alternative airway (tracheal tube or laryngeal mask).
   6. If tracheal intubation is performed, select the correct tube size, confirm intubation with capnography, estimate the insertion depth using the nasal-tragus length (NTL), and confirm equal breath sounds with ventilation. The location of the vocal cord guide on the tracheal tube varies by manufacturer and is not a reliable indicator of correct insertion depth.
   7. If the HR remains <60 bpm after 30 s of effective ventilation through a properly placed endotracheal tube or laryngeal mask, increase the F_iO_2 to 100 % and proceed to chest compressions

VII. Chest compressions. Few newborns (approximately 1 in 1000) require chest compressions. The vast majority of babies requiring resuscitation will improve with effective ventilation alone.
   A. Chest compressions should be performed if the HR remains <60 bpm despite at least 30 s of ventilation that effectively aerates the lungs as indicated by consistent chest movement.
      1. Chest compressions should not be started until effective ventilation has been established.
      2. In most cases, a baby that requires compressions should be intubated.
   B. Encircle the chest with both hands, at the level of the lower third of the sternum, and compress the middle of the sternum with the thumbs (Fig. 14.4).
      1. Compress the chest by one third of the anteroposterior diameter.
      2. Compress at a rate of 90 compressions per minute.

Fig. 14.4 Hand placement for chest compressions. Hands encircle the chest with two thumbs placed on the sternum

Fig. 14.5 Chest compressions from the head of the bed

3. PPV must continue during compressions. At present, synchronous chest compressions and ventilations are recommended. Give one lung inflation after every third compression (a ratio of 3:1) resulting in 90 compressions and 30 ventilations per minute.
4. Once the alternative airway is secured, the compressor should stand at the head of the bed with the ventilator at the side (Fig. 14.5). This improves ergonomics and allows space for another provider to obtain emergency vascular access.

C. Check the HR response after 60 s of compressions using an ECG monitor to improve accuracy and limit the "thumbs-off-chest" time.
1. When compressions are stopped for a pulse check, the perfusion pressure within the coronary arteries decreases and may delay the return of circulation.
2. If the baby's HR remains less than 60 bpm despite compressions and effective ventilation, proceed to emergency medications.

VIII. Drugs. If chest compressions are required, it indicates that the myocardium is severely depressed and will likely require epinephrine, and possibly volume expansion, to achieve a sufficient coronary artery perfusion pressure to restore effective circulation. Once compressions start, another provider should rapidly secure central venous access with an umbilical venous catheter (UVC) or intraosseous needle (ION).

A. Epinephrine (adrenaline)
   1. Indication: HR <60 bpm despite 60 s of compressions and effective ventilation (preferably by endotracheal tube)
   2. Preparation: 1:10,000 (0.1 mg/mL)
   3. Route: UVC or ION, rapidly infused
   4. Dose: 0.1–0.3 mL/kg, repeated every 3–5 min, if needed
   5. Endotracheal absorption is less reliable and likely to be less effective. If the endotracheal route is used, while vascular access is being obtained, a higher dose (epinephrine 1:10,000; 0.3–0.5 mL/kg) is recommended. This larger dose should not be administered intravenously. Repeated endotracheal administration is not recommended.

B. Volume expansion. Routine volume expansion during and after resuscitation is not recommended.
   1. Indication: Insufficient response to the previous steps of resuscitation with signs of shock or a history of acute blood loss
   2. Preparation: Normal saline (0.9 % NaCl) or type-O, Rh-negative blood
   3. Route: UVC or ION
   4. Dose: 10 mL/kg

IX. Failure to Respond to Resuscitation.

A. If the baby does not respond to resuscitation measures, examine the baby, ensure effective ventilation and chest compressions, intubate if not already done, consider obtaining a chest X-ray, and evaluate each of the following:
   1. Is the endotracheal tube in the esophagus?
   2. Is there a leak in the ventilation system or has it become disconnected?
   3. Is the airway obstructed?
   4. Is there a tension pneumothorax?
   5. Is there a pleural or pericardial effusion?
   6. Is there evidence of pulmonary hypoplasia, a congenital diaphragmatic hernia, a pulmonary embolism, or septic/hemorrhagic shock?

B. Discontinuing resuscitation.
   1. Absent heart rate (asystole): The decision to stop should be individualized, and variables to consider include uncertainty about the duration of asystole, whether the resuscitation interventions were optimal, the baby's gestational age, the etiology and timing of the perinatal events leading to cardiorespiratory arrest, the availability of advanced therapies (therapeutic hypothermia), and the family's desires and values. Although previous case series have indicated that confirmed absence of a HR after 10 min is a strong predictor of mortality or serious morbidity in late preterm and term newborns, recent reports from therapeutic hypothermia trials suggest that outcomes may not be as poor as previously reported. Given the limitations of the current evidence and the difficulty of assessing key variables during the time pressure of a complex resuscitation, in most circumstances it seems reasonable to continue resuscitative efforts for up to 20 min as more information is obtained.
   2. Prolonged bradycardia (HR <60 bpm) without improvement: Assuming that prolonged bradycardia reflects cardiorespiratory compromise (not congenital heart block) and resuscitative efforts have been optimized, there is currently insufficient evidence to make a specific recommendation when to discontinue resuscitative efforts.

X. Special considerations

A. Prematurity
   1. Careful attention to thermal management is particularly important and multiple methods may be required to avoid hypothermia. For preterm newborns <32 weeks' gestation,

increase the room temperature to 23–25 °C (74–77 °F); use a polyethylene plastic bag to wrap the newborn, without drying, from feet to neck; place a cap on the head; use an exothermic (warming) mattress; use a servo-controlled radiant warmer. The goal is to maintain an axillary temperature 36.5–37.5 °C.

2. PPV devices capable of providing PEEP or continuous positive airway pressure (CPAP) are preferred (T-piece or flow-inflating bag).
3. Resuscitation of newborns <35 weeks' gestation begins with 21–30 % oxygen.
4. Decisions regarding resuscitation at the edge of viability should involve shared decision-making with the parents and medical providers using all available prognostic information (Chap. 91).

B. Congenital diaphragmatic hernia
   1. Avoid prolonged face-mask ventilation.
   2. Promptly intubate the trachea and place a large double-lumen orogastric sump tube (Replogle) to prevent gaseous distention of herniated bowel.

XI. Controversies in resuscitation
   A. The role of delayed cord clamping or cord milking for babies requiring resuscitation
   B. The role of tracheal suction among non-vigorous newborns with meconium stained amniotic fluid
   C. The optimum pressure and inspiratory time for initial inflating breaths with PPV
   D. The optimal saturation targets and F_iO_2 for PPV in preterm newborns
   E. Tools and educational methods to improve intubation success
   F. Synchronous (coordinated) or asynchronous ventilations during chest compressions
   G. The role of pulmonary function monitoring during neonatal resuscitation
   H. When to discontinue resuscitation with unresponsive asystole and bradycardia
   I. Educational methods to address skill decay among resuscitation providers

Suggested Reading

Perlman JM, Wyllie J, Kattwinkel J, et al. 2015 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Part 7: Neonatal resuscitation. Circulation. 2015;132:S204–41.

Weiner G, editor. Textbook of neonatal resuscitation. 7th ed. Elk Grove Village, IL: American Academy of Pediatrics; 2016.

Wyckoff MH, Aziz K, Escobedo MB, Kapadia VS, Kattwinkel J, Perlman JM, Simon WM, Weiner GM, Zaichkin JG. Part 13: Neonatal resuscitation. 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2015;132:S543–60.

Wyllie J, Bruinenberg J, Roehr CC, Rudiger M, Trevisanuto D, Urlesberger B. European Resuscitation Council guidelines for resuscitation 2015. Section 7. Resuscitation and support of transition of babies at birth. Resuscitation. 2015;95:249–63.