ILCOR ADVISORY STATEMENT: RESUSCITATION OF THE NEWLY BORN INFANT

An Advisory Statement From the Pediatric Working Group of the International Liaison Committee on Resuscitation

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ABSTRACT. The International Liaison Committee on Resuscitation (ILCOR), with representation from North America, Europe, Australia, New Zealand, Africa, and South America, was formed in 1992 to provide a forum for liaison between resuscitation organizations in the developed world. This consensus document on resuscitation extends previously published ILCOR advisory statements on resuscitation to address the unique and changing physiology of the newly born infant within the first few hours after birth and the techniques for providing advanced life support.

After careful review of the international resuscitation literature and after discussion of key and controversial issues, consensus was reached on almost all aspects of neonatal resuscitation, and areas of controversy and high priority for additional research were delineated. Consensus on resuscitation for the newly born infant included the following principles:

- **Personnel trained in the basic skills of resuscitation should be in attendance at every delivery. A minority (fewer than 10%) of newly born infants require active resuscitative interventions to establish a vigorous cry and regular respirations, maintain a heart rate >100 beats per minute (bpm), and maintain good color and tone.**
- **When meconium is present in the amniotic fluid, it should be suctioned from the hypopharynx on delivery of the head. If the meconium-stained newly born infant has absent or depressed respirations, heart rate, or muscle tone, residual meconium should be suctioned from the trachea.**
- **Attention to ventilation should be of primary concern. Assisted ventilation with attention to oxygen delivery, inspiratory time, and effectiveness judged by chest rise should be provided if stimulation does not achieve prompt onset of spontaneous respirations and/or the heart rate is <100 bpm.**
- **Chest compressions should be provided if the heart rate is absent or remains <60 bpm despite adequate assisted ventilation for 30 seconds. Chest compressions should be coordinated with ventilations at a ratio of 3:1 and a rate of 120 "events" per minute to achieve approximately 90 compressions and 30 rescue breaths per minute.**
- **Epinephrine should be administered intravenously or intratracheally if the heart rate remains <60 bpm despite 30 seconds of effective assisted ventilation and chest compression circulation.**

Common or controversial medications (epinephrine, volume expansion, naloxone, bicarbonate), special resuscitation circumstances affecting care of the newly born, continuing care of the newly born after resuscitation, and ethical considerations for initiation and discontinuation of resuscitation are discussed. There was agreement that insufficient data exist to recommend changes to current guidelines regarding the use of 21% versus 100% oxygen, neuroprotective interventions such as cerebral hypothermia, use of a laryngeal mask versus endotracheal tube, and use of high-dose epinephrine. Areas of controversy are identified, as is the need for additional research to improve the scientific justification of each component of current and future resuscitation guidelines. *Pediatrics* 1999;103(4). URL: http://www.pediatrics.org/cgi/content/full/103/4/e56; *resuscitation, newborn; birth, resuscitation; neonatal resuscitation.*

ABBREVIATIONS. ILCOR, International Liaison Committee on Resuscitation; AHA, American Heart Association; ERC, European Resuscitation Council; HSFC, Heart and Stroke Foundation of Canada; ARC, Australian Resuscitation Council; RCSA, Resuscitation Council of Southern Africa; CLAR, Council of Latin America for Resuscitation; BLS, basic life support; ALS, advanced life support; NRP, Neonatal Resuscitation Program; AAP, American Academy of Pediatrics; NZRC, New Zealand Resuscitation Council; WHO, World Health Organization; THAM, Tris buffer, trishydroxymethyl aminomethane; CO_2, carbon dioxide; bpm, beats per minute; IV, intravenous; CDH, congenital diaphragmatic hernia.

PURPOSE

The International Liaison Committee on Resuscitation (ILCOR) was formed in 1992 to provide a forum for liaison between the following principal resuscitation organizations in the developed world: the American Heart Association (AHA), European Resuscitation Council (ERC), Heart and Stroke Foundation of Canada (HSFC), Australian Resuscitation Council (ARC), Resuscitation Council of Southern Africa (RCSA), and Council of Latin America for Resuscitation (CLAR). Since 1992, international consensus conferences and publications have addressed many important resuscitation issues, in-

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cluding uniform Utstein-style reporting for out-of-hospital cardiac arrest, in-hospital cardiac arrest, pediatric arrest, and laboratory animal studies of cardiopulmonary arrest.[1–4] Ten meetings of the ILCOR group and ILCOR working groups in advanced life support, basic life support, and pediatric life support culminated in concurrent multinational publication of consensus international advisory statements on resuscitation in 1997.[5] The advisory statement on pediatric resuscitation[6] highlighted areas of consensus, conflict, or controversy and provided recommendations in the areas of pediatric basic life support (BLS), pediatric advanced life support (ALS), and BLS for the newly born. The great potential for worldwide improvement in BLS resuscitation for the newly born was acknowledged, but discussion of ALS for the newly born was beyond the scope of the previous document.

The ILCOR Pediatric Working Group, with the constituent councils named above, was joined by the Neonatal Resuscitation Program (NRP) Steering Committee of the American Academy of Pediatrics (AAP), New Zealand Resuscitation Council (NZRC), and the World Health Organization (WHO) to extend advisory recommendations beyond BLS to ALS for the newly born. Careful review of current constituent organization guidelines[7–13] and current international literature forms the basis for the present document. This advisory statement summarizes the current international consensus on ALS of the newly born, ie, within the first few hours after birth.

BACKGROUND

Need for BLS and ALS Guidelines for the Newly Born

Resuscitation of the newly born infant presents a different set of challenges than resuscitation of the adult or even the older infant or child. The transition from dependence on placental gas exchange in a liquid-filled intrauterine environment to spontaneous breathing of air presents dramatic physiologic challenges to the infant within the first minutes to hours after birth. Approximately 5% to 10% of the newly born population require some degree of active resuscitation at birth (eg, stimulation to breathe),[14] and approximately 1% to 10% born in the hospital are reported to require assisted ventilation.[15] More than 5 million neonatal deaths occur worldwide each year. It has been estimated that birth asphyxia accounts for 19% of these deaths, suggesting that the outcome might be improved for more than 1 million infants per year through implementation of simple resuscitative techniques.[16] Finally, the need for resuscitation of the newly born infant often can be predicted, thus allowing opportunities to select an optimal setting, prepare appropriate equipment, and mobilize trained personnel.

Definition of Newly Born, Neonate, and Infant

The term newly born refers specifically to the infant in the first minutes to hours after birth. In contrast, the neonatal period is generally defined as the first 28 days of life. Infancy includes the neonatal period and extends through the age of 12 months. To avoid confusion and promote uniform definitions, the lay terms newborn and baby will be avoided here. This document is intended to apply specifically to newly born infants, although many of the principles are applicable throughout the neonatal period.

Unique Physiology of the Newly Born

The transition from fetal to extrauterine life is characterized by a series of unique physiologic events: the lungs change from fluid-filled to air-filled, pulmonary blood flow increases dramatically, and intracardiac and extracardiac shunts (foramen ovale and ductus arteriosus) initially reverse direction and subsequently close. Such physiologic considerations affect resuscitative interventions in the newly born. For initial lung expansion, fluid-filled alveoli may require higher ventilation pressures than commonly used in rescue breathing during infancy.[17,18] Physical expansion of the lungs, with establishment of functional residual capacity, and increase in alveolar oxygen tension both mediate the critical decrease in pulmonary vascular resistance and result in an increase in pulmonary blood flow after birth. Failure to normalize pulmonary vascular resistance may result in persistence of right-to-left intracardiac and extracardiac shunts (persistent pulmonary hypertension). Likewise, failure to adequately expand alveolar spaces may result in intrapulmonary shunting of blood with resultant hypoxemia. Disruption of the fetoplacental circulation also may render the newly born at risk for acute blood loss.

Developmental considerations at various gestational ages also influence pulmonary pathology and resuscitation physiology in the newly born. Surfactant deficiency in the premature infant alters lung compliance and resistance.[19] If meconium is passed into the amniotic fluid, this irritating substance may be aspirated, leading to airway obstruction. Complications of meconium aspiration are particularly likely in infants small for their gestational age or those born after term or with significant perinatal compromise.[20]

Although certain physiologic features are unique to the newly born, others pertain to infants throughout the neonatal period and into the first months of life. Severe illness resulting from a wide variety of conditions continues to manifest as disturbances in thermoregulation and respiratory function (cyanosis, apnea, gasping, respiratory failure). Persistent patency of the ductus arteriosus and intracardiac shunts may produce symptoms during the neonatal period or infancy. Thus, many of the considerations and interventions that apply to the newly born may remain important for days, weeks, or months after birth.

Choice of Action Depends on Evolving Status

In the newly born the significance of a vital-sign abnormality depends greatly on the time since birth and the time during which effective resuscitative measures have been administered. For example, a bradycardia encountered immediately after birth likely results from a failure of uteroplacental function, whereas the same degree of bradycardia en-

countered after the establishment of effective ventilation requires additional diagnostic considerations and potentially different interventions.

ANTICIPATION OF RESUSCITATION NEED

Personnel

Personnel trained in the basic skills of resuscitation at birth should be in attendance at every delivery. Ideally, at least one person should be responsible solely for the care of the infant. A person trained in ALS techniques for the newly born should be available for normal low-risk deliveries and in attendance for all deliveries considered at high risk for neonatal resuscitation. Appendix 1 lists the maternal, fetal, and intrapartum circumstances that place the newly born infant at risk. The list is designed to serve as a guideline for issues that local and regional resuscitation organizations are often called on to address. The personnel who attend the mother and infant at delivery (birth attendant, midwife, family physician, obstetrician, perinatologist, obstetrical nurse, neonatal nurse practitioner, pediatrician, neonatologist) will vary according to local circumstances. If it is anticipated that the infant is at high risk to require ALS resuscitative intervention, more than one experienced person should be mobilized.

Equipment

Although the need for resuscitation at birth can sometimes be predicted by consideration of risk factors, resuscitation cannot be anticipated for a significant number of infants.[21] Therefore, emergency preparedness requires that a complete inventory of resuscitation equipment and drugs be maintained at hand and in fully operational condition. Appendix 2 presents a consensus list of suggested equipment and drugs. Minor unresolved controversy was acknowledged over the advisability of inclusion of a 2.0-mm endotracheal tube for extremely premature infants. Proponents argued that the small tube might be lifesaving in the case of extreme prematurity. However, concerns for increased airway resistance (inversely proportional to the fourth power of the internal radius) were raised.[22–24] Additionally, the choice of buffer medications (bicarbonate versus THAM [Tris buffer, tris-hydroxymethyl aminomethane], 4.2% versus 8.4% bicarbonate as a stock solution) differed between councils. There was consensus that issues of adequacy of ventilation, potential for worsening respiratory acidosis with carbon dioxide (CO_2)-producing buffer administration, and concerns for hyperosmolarity of solution should enter the discussion of which buffer to select.

Communication

Appropriate preparation for an anticipated high-risk delivery requires communication between the person(s) caring for the mother and those responsible for the newly born. Communication among caregivers should include details of maternal medical condition and treatment that will affect the resuscitation and management of the newly born. For example, maternal sedatives and analgesics, tocolytics, and corticosteroids all can influence respiratory function at birth. Fetal heart rate monitoring may give information about fetal well-being. Findings of detailed antenatal ultrasonography can guide interventions such as thoracentesis for pleural effusions or immediate intubation for congenital diaphragmatic hernia.

When time permits, the team responsible for care of the newly born should introduce themselves to the mother and family before delivery. They should outline the proposed plan of care and solicit the family's questions. Especially in cases of potentially lethal fetal malformations or extreme prematurity, the family should be asked to articulate their beliefs and desires regarding the extent of resuscitation.

Environment

Temperature

Prevention of heat loss is important for the newly born. Cold stress can increase oxygen consumption and impede effective resuscitation; however, hyperthermia should be avoided.[25,26] Whenever possible, the infant should be delivered in a warm, draft-free area. Rapid drying of the skin, removing wet linen after delivery, placing the infant under a radiant warmer, and wrapping the infant in prewarmed blankets will reduce heat loss. Another strategy for reducing heat loss is placing the newly born skin-to-skin on the mother's chest or abdomen to use her body as a heat source. Several recent animal studies have suggested that selective (cerebral) hypothermia of the asphyxiated infant may protect against subsequent brain injury.[27–29] Although this was felt to be a promising area of research, there was consensus that no recommendation for routine implementation could be made until appropriate controlled studies in humans have been performed.

Standard Precautions

All fluids from patients should be treated as potentially infectious. Personnel should wear gloves and protective shields during procedures that are likely to expose them to droplets of blood or other body fluids. Local standards should be developed, with acknowledgment of individual circumstances and available resources.

Assessment

Concept of Integrated Assessment

Evaluation of the need to initiate and continue resuscitative efforts should begin immediately after birth and proceed throughout the resuscitation process until vital signs have normalized. The complex of signs (initial cry, respirations, heart rate, color, response to stimulation) should be evaluated simultaneously, with action dictated by the integrated findings (compound and ongoing action) rather than by evaluation of a single vital sign, action on the result, and then evaluation of the next sign (sequential action). The appropriate response to abnormal findings also depends on the time elapsed since birth and how the infant has responded to previous resuscitative interventions. It is recognized that evaluation

and intervention for the newly born are often simultaneous processes, especially when more than one trained provider is present. To enhance educational retention, this process is often taught as a sequence of distinct steps.

Response to Stimulation

Most newly born infants will respond to the stimulation of an extrauterine environment with movement of all extremities, strong inspiratory efforts, and a vigorous cry. If these responses are absent or weak, the infant should be stimulated. Appropriate stimulation includes drying the infant with a towel, flicking the bottoms of the feet, or gently rubbing the back. Such tactile stimulation may initiate spontaneous respirations in newly born infants who are experiencing "primary apnea." If these efforts do not result in prompt onset of effective ventilation, they should be discontinued because the infant is in "secondary" or "terminal apnea" and should be given assisted ventilation.[30] By consensus, slapping, shaking, spanking, or holding the newly born upside down is contraindicated and potentially dangerous.[6]

Respiration

After initial respiratory efforts, the newly born infant should be able to establish regular respirations sufficient to improve color and maintain a heart rate >100 beats per minute (bpm). Gasping is an ominous sign and requires intervention. The marked variability of respiratory rate that is characteristic of perinatal transition prevents designation of a specific respiratory rate requiring intervention.

Heart Rate

Heart rate is determined by listening to the precordium with a stethoscope, feeling for pulsations at the base of the umbilical cord, or feeling the brachial or femoral pulse. Palpation of the carotid artery is not recommended in the newly born because of the difficulty of reliably palpating the artery and the potential for causing iatrogenic airway obstruction and/or vagal stimulation of the newly born. Central and peripheral pulses are often difficult to feel in infants and should not be relied on independently if they are absent.[31,32] Heart rate should be consistently >100 bpm in an uncompromised newly born infant. An increasing or decreasing heart rate also can provide evidence of improvement or deterioration.

Color

An uncompromised newly born infant will be able to maintain a pink color without supplemental oxygen. Cyanosis is determined by examining central structures and mucous membranes. Acrocyanosis is usually a normal finding at birth but may indicate other conditions such as cold stress. Acrocyanosis is considered an unreliable indicator of oxygenation.

TECHNIQUES OF RESUSCITATION

The techniques of ALS resuscitation are discussed below and are outlined in Fig 1, which shows the universal template for ALS of the newly born.

Opening the Airway

The infant's airway is opened by positioning the infant and clearing secretions.

Positioning

The newly born infant should be placed on his or her back or side with the head in a neutral or slightly extended position. If respiratory efforts are present but not producing effective tidal ventilation, often the airway is obstructed; immediate efforts must be made to reposition the head or clear the airway.

Suctioning

Healthy, vigorous newly born infants generally do not require suctioning after delivery. If necessary, secretions should be cleared with a suction device (bulb syringe, suction catheter). Aggressive pharyngeal suction can cause laryngeal spasm and vagal bradycardia[33] and delay the onset of spontaneous breathing. In the absence of meconium or blood, mechanical suction with a catheter should be limited to a depth of 5 cm from the lips and a duration of 5 seconds. Negative pressure of the suction apparatus should not exceed 100 mm Hg (13.3 kPa).

Clearing the Airway of Meconium

When the amniotic fluid is contaminated with meconium, the mouth, pharynx, and nose should be suctioned as soon as the head is delivered (intrapartum suctioning).[34] If the fluid contains meconium and the infant has absent or depressed respirations or decreased muscle tone, direct laryngoscopy should be conducted immediately after birth for suctioning of residual meconium from the hypopharynx (under direct vision) and intubation/suction of the trachea.[35,36] Drying and stimulation generally should be delayed in such infants. Tracheal suctioning can be accomplished by applying suction directly to a tracheal tube as it is withdrawn from the airway. Intubation and suctioning during tracheal tube withdrawal can be repeated until meconium is no longer recovered, providing the infant's heart rate remains at >60 bpm. If the infant's respiration is severely depressed, tracheal reintubation for positive-pressure ventilation may be necessary even though some meconium remains in the airway. There is evidence that tracheal suctioning of the vigorous infant with meconium-stained fluid does not improve outcome and may cause complications.[37,38]

Tactile Stimulation

Drying and suctioning are both assessment and resuscitative interventions (see "*Response to Stimulation*"). If the infant fails to establish spontaneous and effective respirations after brief stimulation, BLS and/or ALS will be required.

Oxygenation and Ventilation

Free-Flow Oxygen

The traditional treatment for central cyanosis is administration of 100% oxygen, either by passive delivery via an oxygen mask or by positive pressure delivered via a resuscitation bag. Although there is

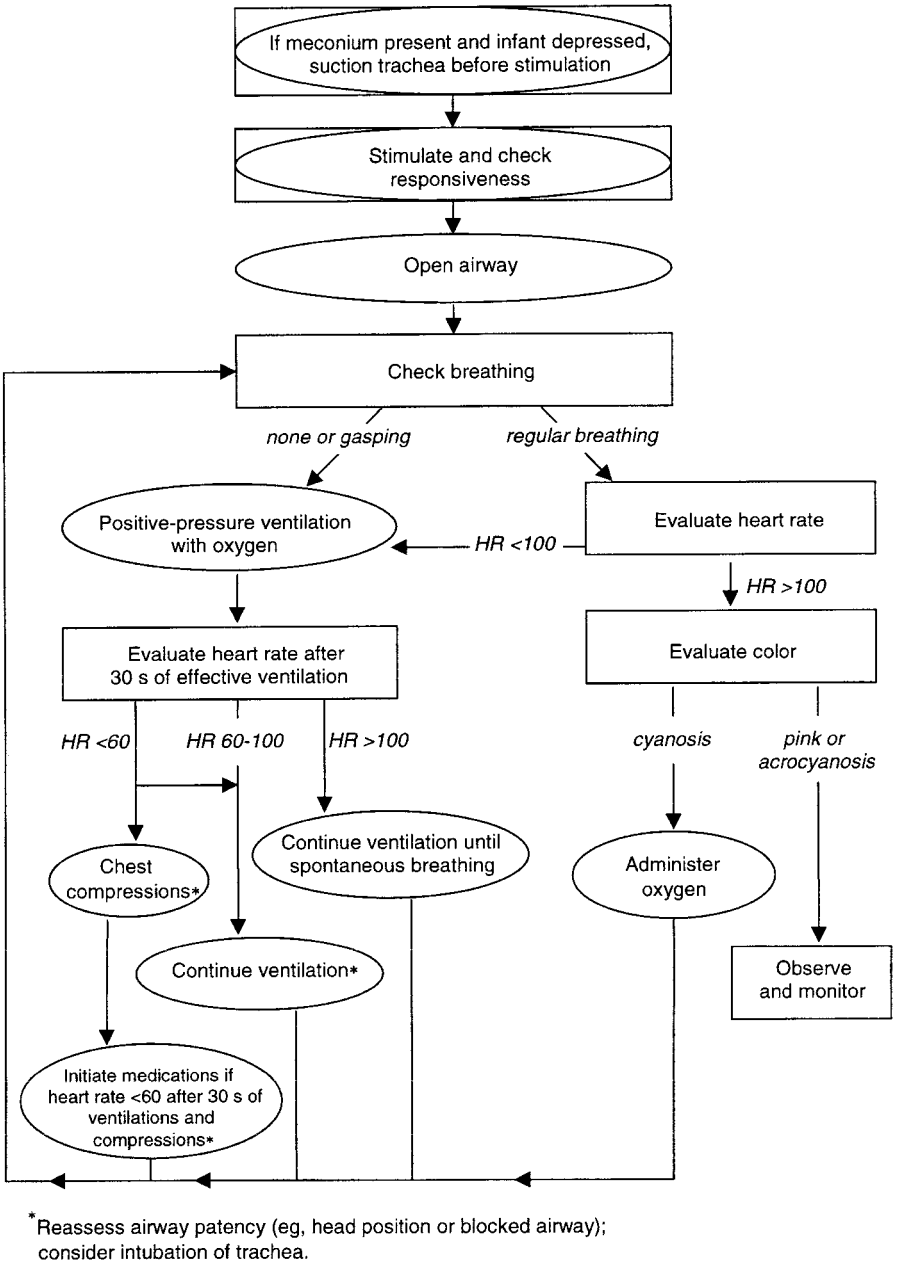


Fig 1. Universal template for advanced life support of the newly born infant. Rectangles indicate evaluation; ovals, action.

some in vitro evidence, a valid biochemical rationale, and preliminary clinical evidence[39] to support resuscitation with lower oxygen concentrations, current clinical data are insufficient to justify adopting this as a routine practice.[40,41] Conversely, in settings where availability of oxygen is limited (eg, the developing world), it is reasonable to consider resuscitation with room air. There is some evidence that infants born at high altitude (ie, low ambient Pao_2) have more difficulty establishing normal oxygenation and pulmonary blood flow than infants born at sea level.[42] However, the first priority should be to ensure adequate inflation of the fluid-filled lungs, followed by attention to the desired concentration of inspired oxygen.

Assisted Ventilation

Indications. Assisted ventilation should be initiated after stimulation if the infant remains apneic, is gasping, or the heart rate remains <100 bpm.

Technique. If assisted ventilation is given, higher inflation pressures and longer inflation times may be required for the first several breaths than for subsequent breaths. Some experts suggest very long inflation times (2 to 3 seconds) for initial inflations,[17] but this has not been accepted for universal recommendation. The assisted ventilation rate should be 30 to 60 inflations per minute. There is some controversy regarding advantages of lower versus higher rates. Lower rates allow longer inflation times and better coordination with chest compressions; higher rates permit higher minute ventilation. No controlled studies have demonstrated advantages of one versus the other.

Effectiveness of Ventilation

Effectiveness of ventilation is judged by watching adequacy of chest rise and improvement in vital signs. Critical adjustments to improve effectiveness

include improving the seal between mask and face, ensuring patency of the airway (clearing airway of material, adjusting head position, opening the mouth), increasing inflation pressure on the bag, and optimizing the position of the tracheal tube.

Mouth-to-Mouth/Nose and Mouth-to-Mask Ventilation

The best method for initially assisting ventilation is with a bag-valve–mask apparatus.[43–45] However, for BLS at birth, when equipment is not available, mouth-to-mouth/nose ventilation is effective. Consensus continues to support initial attempts at ventilation via both the infant's mouth and nose, with creation of a functional seal to ensure adequate chest rise and ventilation. To decrease the risk of infection to the rescuer, maternal blood and other body fluids should first be wiped from the face of the infant. New devices for delivery of mouth-to-mask or barrier resuscitation for the newly born are under development.[46,47]

Bag-Valve–Mask Ventilation

Types of Bags. Resuscitation bags should be no larger than 750 mL; they can either be self-inflating or require a compressed gas source to inflate (flow-inflating). The former require attachment of an oxygen reservoir to permit delivery of high oxygen concentrations. Those who advocate longer inflation times recommend a minimum bag volume of 500 mL so that inflation pressure can be maintained for at least 1 second. If the device contains a pressure-release valve, it should release at approximately 30 cm H_2O pressure and should have an override feature to permit delivery of higher pressures if necessary to achieve good chest expansion.

Mask Fit. Masks should be of appropriate size to seal around the mouth and nose but not cover the eyes or overlap the chin. Therefore, a range of sizes should be available. A round mask with a cushioned rim is preferable.[44]

Laryngeal Mask Airway Ventilation

Masks that fit over the laryngeal inlet have been developed and have been shown to be effective for ventilating newly born full-term infants.[48] However, these masks have not been evaluated in small, preterm infants, and relative effectiveness for the suctioning of meconium has not been reported.

Tracheal Intubation for Ventilation

Indications. Indications for tracheal intubation will vary depending on the presence or absence of meconium, gestational age of the infant, degree of respiratory depression, response to bag-valve–mask ventilation, and skill and experience of the resuscitator. Indications for intubation for meconium are described under "*Clearing the Airway of Meconium*," and indications for elective intubation of extremely low birth weight infants are described under "*Special Resuscitation Circumstances*." Tracheal intubation should be performed if bag-valve–mask assistance has been unsuccessful or prolonged.

TABLE 1. Guidelines for Tracheal Tube Sizes and Depth of Insertion

Tube Size, mm ID	Depth of Insertion From Upper Lip, cm	Weight, g	Gestation, wk
2.5	6.5–7	<1000	<28
3	7–8	1000–2000	28–34
3/3.5	8–9	2000–3000	34–38
3.5/4.0	≥9	>3000	>38

Equipment. Preferred tracheal tubes are of uniform diameter, without a shoulder, with a natural curve, radiopaque, and with a mark to indicate the appropriate depth of insertion. If an introducing stylet is used, care must be taken to prevent the stylet from protruding beyond the tip of the tube. Table 1 provides a guideline for tracheal tube sizes and their depth of insertion. Appropriate size and depth of insertion must always be verified clinically (see "*Verification*"). A laryngoscope with a straight blade (size 0 [7.5 cm] for premature infants, size 1 [10 cm] for term infants) is preferred.

Technique. Tracheal intubation by the oral route is recommended. The tip of the laryngoscope should be inserted into the vallecula or on top of the epiglottis and elevated gently to reveal the vocal cords. Cricoid pressure may be helpful. The tube should be inserted to an appropriate depth through the vocal cords, as indicated by a mark on the tube. The tube should be secured with the appropriate centimeter marking located at the upper lip. This depth of insertion should be recorded and maintained. Care providers should be aware that variation in head position alters the depth of insertion and may predispose to unintentional extubation or endobronchial intubation.[49,50]

Verification. In general, positive-pressure inflation sounds should be equal in both axillae and not audible over the stomach. In some special circumstances of resuscitation (eg, unilateral pneumonia, pneumothorax), one may expect asymmetrical breath sounds (see below). Lack of chest rise or symmetry of chest movement and lack of improvement in color and/or heart rate are the best signs of inappropriate tube placement. Some have advocated use of an end-tidal CO_2 monitor for verification of correct tube placement in the trachea.[51] These devices are associated with some false-negative but few false-positive results.[52]

Assisted Circulation

Indications for Chest Compressions

The heart rate, the change of heart rate, and the time elapsed after initiation of resuscitative measures should all be considered in deciding when chest compressions should be initiated. Establishment of adequate ventilation will restore vital signs in the vast majority of newly born infants. Because chest compressions may diminish the effectiveness of ventilation, they should not be initiated until effective ventilation has been established. Guidelines for initiation of chest compressions are

- Absent heart rate at any time

- Heart rate <60 bpm despite adequate assisted ventilation for 30 seconds

It is common practice to give compressions if the heart rate is 60 to 100 bpm and the heart rate is not rising. However, the ILCOR working group agrees that ventilation should be the priority in resuscitation of the newly born. Chest compressions are likely to compete with effective ventilation. Because no scientific data suggest an evidence-based resolution of these different council recommendations, the working group recommends a heart rate guideline of 60 bpm based on construct validity (ease of teaching and skill retention).

Compression Technique

Compressions should be delivered on the lower third of the sternum.[53,54] Consensus supports recommendation of a relative rather than absolute depth of compression (eg, compress to approximately one third of the anterior-posterior diameter of the chest rather than 2 to 3 cm) to generate a palpable pulse. Acceptable techniques are 1) two thumbs on the sternum, superimposed or adjacent to each other according to the size of the infant, with fingers surrounding the thorax, and 2) two fingers placed on the sternum at right angles to the chest.[55–57] Data suggest that the two-thumb technique may offer some advantages in generating peak systolic and coronary perfusion pressure and in provider preference over the two-finger technique without introducing additional complications.[55–60] The two-finger technique may be preferable for a single rescuer. Compressions and ventilations should be coordinated to avoid simultaneous delivery. There should be a 3:1 ratio of compressions to ventilations, with 90 compressions and 30 breaths to achieve approximately 120 "events" per minute. Thus, each event will be allotted approximately 0.5 seconds, with exhalation occurring during the first compression after each ventilation. Reassessment of the heart rate should continue approximately every 60 seconds, and chest compressions should continue until the spontaneous heart rate is >60 bpm.

Medications

Indications for Medication Administration

Drugs are rarely indicated in resuscitation of the newly born infant.[61] Administration of epinephrine is not recommended unless the heart rate remains <60 bpm after a minimum of 30 seconds of adequate ventilation and chest compression.[62] Volume expansion should be considered when there has been suspected blood loss and/or the infant appears to be in shock (pale, poor perfusion, weak pulse) and has not responded adequately to other resuscitative measures. If the mother has received a narcotic drug and the infant's respiratory drive is considered inadequate, naloxone may be indicated after vital signs have been established. However, support with artificial ventilation should be the priority. Naloxone should not be administered to newly born infants whose mothers are suspected of having recently abused narcotic drugs; naloxone may precipitate abrupt withdrawal signs in such infants. There are insufficient data to recommend routine use of bicarbonate in resuscitation of the newly born, as well as theoretical concerns that its hyperosmolarity and CO_2-generating properties may be detrimental to myocardial and/or cerebral function.[63–65] If used, it should be given only after adequate ventilation and circulation are ensured. Further use of bicarbonate in persistent metabolic acidosis should be directed by arterial blood gas levels, among other evaluations.

Routes of Medication Administration

Epinephrine and naloxone may be given via the endotracheal route, which is generally the most rapidly accessible site of administration. There are concerns that the endotracheal route may not result in as effective a level of epinephrine as does the intravenous (IV) route[66–69]; however, the data are insufficient to recommend a higher dose via the endotracheal route. The umbilical vein is the most rapidly accessible route for volume expanders and may also be used for epinephrine, naloxone, and/or bicarbonate. Naloxone may be given intramuscularly but only after adequate assisted ventilation has been delivered and the infant is judged to have adequate peripheral circulation. The umbilical artery is not generally recommended for administration of resuscitation drugs, because it is often not rapidly accessible and there are concerns that complications may result if vasoactive or hypertonic drugs (eg, epinephrine or bicarbonate) are given into an artery. Intraosseous lines are not commonly used in newly born infants because of the more readily accessible umbilical vein, the fragility of small bones, and the small intraosseous space in a premature infant.

Types and Doses of Medications

Epinephrine. The recommended IV or endotracheal dose is 0.1 to 0.3 mL/kg of a 1:10 000 solution (0.01 to 0.03 mg/kg), repeated every 3 to 5 minutes as indicated. The studies in newly born infants are inadequate to recommend routine use of higher doses of epinephrine. Higher doses have been associated with increased risk of intracranial hemorrhage and myocardial damage in animals.[61,70]

Volume Expanders. Volume expanders include crystalloid (normal saline, Ringer's lactate) and colloid (blood, 4% to 5% albumin, plasma substitute). The initial dose is 10 mL/kg given by slow IV push; the dose may be repeated after further clinical assessment and observation of response. Higher bolus volumes have been recommended for resuscitation of older infants. However, 10 mL/kg is recommended for newly born infants because they already have relatively high blood volumes at the time of birth[71] and because of concern about fragility of the germinal matrix in the brains of infants born prematurely.[72]

Naloxone. The recommended dose is 0.1 mg/kg of a 0.4-mg/mL or 1.0-mg/mL solution given intravenously, endotracheally, or intramuscularly. Concern was expressed that the 1.0-mg/mL concentration requires very small volumes of drug when used in small infants. Because the half-life of naloxone gen-

erally will be significantly shorter than that of the narcotic given to the mother, repeated doses may be necessary to prevent recurrent apnea.

Bicarbonate. A dose of 1 to 2 mEq/kg of 0.5-mEq/mL solution may be given by slow IV push after adequate ventilation and perfusion have been established. Higher concentrations have been associated with increased risk of intracranial hemorrhage.[73] The choice of buffer medications (4.2% bicarbonate, 8.4% bicarbonate, and THAM [Tris buffer]) differed between councils. There was consensus that issues of adequacy of ventilation, potential for worsening respiratory acidosis, and concerns for hyperosmolarity of solution should influence the selection of buffering agent.

SPECIAL RESUSCITATION CIRCUMSTANCES

Several circumstances have unique implications for resuscitation of the newly born infant. Birth attendants are sometimes aware of these special circumstances through prenatal diagnostic information. Although the implications of these circumstances for resuscitation are described below, full consideration and discussion of these entities are beyond the scope of this advisory statement.

Prematurity

Some experts recommend early elective intubation of extremely preterm infants (eg, <28 weeks of gestation) to help establish an air-fluid interface,[74] while others recommend that this be accomplished with a mask or nasal prongs.[75] Other experts recommend that infants younger than 30 to 31 weeks be electively intubated for surfactant administration after the initial stages of resuscitation have been successful.[76] Because premature infants have low body fat and a high ratio of surface area to body mass, they are also more difficult to keep warm. Their immature brains and the presence of a germinal matrix predispose them to development of intracranial hemorrhage during resuscitation.

Congenital Upper Airway Obstruction

An infant who is pink when crying but cyanotic when quiet should be evaluated for choanal or other upper airway obstruction. An oral airway initially may provide adequate relief of obstruction. Prone positioning and/or placement of a tube in the posterior pharynx may improve airway competence in an infant with a small hypopharynx. Infants with more compromising craniofacial malformations may require tracheal intubation.

Esophageal Atresia/Tracheoesophageal Fistula

Copious secretions and intermittent cyanosis and/or bradycardia may signal esophageal atresia, with or without tracheoesophageal fistula. The inability to pass an orogastric tube to the stomach can confirm this diagnosis; positioning of a sump tube in the proximal esophageal pouch and application of intermittent suction may decrease the aspiration of oral secretions. Elevation of the head may decrease aspiration of gastric contents via the fistula.

Congenital Diaphragmatic Hernia

Prenatal diagnosis of congenital diaphragmatic hernia (CDH) permits consideration of immediate tracheal intubation, rather than initial bag and mask ventilation, to minimize air entry into the gastrointestinal tract. Breath sounds after tracheal intubation may be expected to be asymmetrical, depending on the location of the CDH. In spontaneously breathing infants with CDH or in those receiving positive-pressure ventilation, a nasogastric tube should be placed to allow intermittent suction to decompress the small bowel and minimize lung compression.

Pneumothorax

Unilaterally decreased breath sounds, shift in the point of maximal cardiac impulse, and persistent cyanosis may indicate the presence of a pneumothorax. Needle thoracentesis can be both diagnostic and therapeutic.

Pleural Effusions/Ascites (Fetal Hydrops)

Pleural effusions and ascites present at birth may interfere with initial lung expansion. After an airway has been secured, thoracentesis and/or paracentesis may improve ventilation and oxygenation. Fluid shifts to the extravascular space may necessitate early consideration of intravascular volume expansion.

Pneumonia/Sepsis

Congenital pneumonia may be characterized by very poor lung compliance, necessitating high ventilation pressures/rates in the delivery room. Capillary leak may lead to a shock state, with early need for volume expansion.

Congenital Heart Disease

Infants who remain cyanotic despite adequate ventilation, oxygenation, and circulation may have cyanotic congenital heart disease or persistent pulmonary hypertension. Echocardiographic evaluation in such cases will be helpful.

Multiple Births

Multiple births are more frequently associated with a need for resuscitation because abnormalities of placentation, compromise of cord blood flow, and/or mechanical complications during delivery are more likely to be encountered. Monozygotic multiple fetuses may also have abnormalities of blood olume resulting from interfetal vascular anastomoses.

Maternofetal Hemorrhage

Vaginal bleeding before birth may be a sign of abruptio placenta or placenta previa. Although most of the blood loss in such conditions will be maternal, if even a small portion is fetal the fetus is likely to be hypovolemic because of the relatively smaller blood volume. In such cases, volume expanders may be required before the infant will respond to resuscitative measures.

POSTRESUSCITATION ISSUES

Continuing Care of the Newly Born Infant After Resuscitation

After resuscitation with ALS, ongoing supportive care, monitoring, and appropriate diagnostic evaluation must be provided. Once adequate ventilation and circulation have been established, the infant who has required resuscitation is still at risk and should be maintained in or transferred to an environment in which close monitoring and anticipatory care can be provided. This should include oxygen saturation and heart rate monitoring with blood gas measurement as indicated. Blood pressure should be documented and blood glucose level checked during stabilization after resuscitation. Glucose is consumed more rapidly during conditions of anaerobic metabolism and therefore infants who require resuscitation are more likely to have low glycogen stores; hypoglycemia is often encountered after resuscitation. An infant who has experienced perinatal compromise or with ongoing respiratory distress may have experienced an insult to the gastrointestinal tract. Special consideration should be given to parenteral versus enteral hydration and nutrition for several days.

Continuing Care of the Family

The mother continues to be a patient herself, with physical and emotional needs. Mothers with acute or chronic medical problems will need ongoing monitoring and treatment in the postpartum period.

The team caring for the newly born infant should inform the parents of the infant's condition at the earliest opportunity. If resuscitation has been necessary, the parents should be informed of the procedures undertaken and their indications; parental questions should be solicited and answered as frankly and honestly as possible. Every effort should be made to enable the parents to have contact with the newly born infant.

ETHICS

Initiation of Resuscitation

The delivery of extremely immature infants and those with severe congenital anomalies raises questions about initiation of resuscitation.[77–81] In such cases, initiation of resuscitation at delivery does not mandate continued support. Noninitiation of support and later withdrawal of support are generally considered to be ethically equivalent; however, the latter approach allows time to gather more complete clinical information and to provide counseling to the family. Possible exceptions include infants with anencephaly and extremely immature infants for whom there is no possibility of survival. In general, there is no advantage to delayed, graded, or partial support; if the infant survives, outcome may be worsened as a result of this approach.

Discontinuation of Resuscitation

It is reasonable to consider discontinuation of resuscitative efforts if the infant with cardiorespiratory arrest has not responded with a spontaneous circulation in 15 minutes. Both survival and quality of survival deteriorate precipitously at this point in term infants; other data in preterm infants of very low birth weight suggest that survival is negligible if there are no signs of life after 10 minutes of appropriate cardiopulmonary resuscitation.[82,83] Local discussions are recommended to formulate guidelines consistent with local resources and outcome data.

DOCUMENTATION OF RESUSCITATION

It is essential for good clinical care, for communication, and for medicolegal concerns that the findings at each assessment and the actions taken in resuscitation are fully documented. The Apgar scores quantify and summarize the response of the newly born infant to the extrauterine environment and to resuscitation.[84,85] An Apgar score is used to assess and record breathing, heart rate, muscle tone, reflex irritability, and color at 1 and 5 minutes after birth and then sequentially every 5 minutes until vital signs have stabilized. These scores should not be used to dictate appropriate resuscitative actions, nor should interventions for depressed infants be delayed until the 1-minute assessment. Complete documentation must also include a narrative description of interventions performed and their timing. An alternative is the use of a standard resuscitation record, which is suitable for use in both BLS and ALS settings. Such a standardized form offers the further advantage of uniform data collection to facilitate study and comparison of resuscitation techniques and outcomes.

AREAS OF CONTROVERSY AND NEED FOR ADDITIONAL RESEARCH

The ILCOR Pediatric Working Group recognizes the difficulty in creating advisory statements for universal application. After careful review of the rationale for current guideline recommendations from among the constituent resuscitation councils (Table 2), the working group identified the following areas of controversy regarding resuscitation of the newly born infant. The group believes that additional research is required in these areas before more specific, evidence-based universal ALS guidelines for newly born infants can be developed.

- Under what conditions should newly born infants with meconium staining receive tracheal suctioning?
- Is intraosseous infusion of fluids and medications effective for resuscitation of the newly born?
- What is the optimal concentration of oxygen to provide during resuscitation?
- What is the optimal, practical, and evidence-based indication for initiating chest compressions?
- What is the optimal frequency and depth for delivery of chest compressions?
- What is the optimal dose of epinephrine?
- What is the appropriate dose and what are the appropriate indications for volume expansion?
- What are the appropriate indications for bicarbonate administration in resuscitation of newly born infants?
- Is there a role for localized cerebral cooling and/or use of pharmacologic agents for neuroprotection

TABLE 2. Examples of Similarities and Minor Differences in Recommendations for Newly Born ALS Among the International Liaison Committee on Resuscitation (ILCOR), the American Heart Association and American Academy of Pediatrics (AHA/AAP), the Heart and Stroke Foundation of Canada (HSFC), the European Resuscitation Council (ERC), the Resuscitation Council of Southern Africa (RCSA), and the Australian Resuscitation Council (ARC)

	ILCOR	AHA/AAP	HSFC	ERC	RCSA	ARC
Suction meconium from trachea	Yes, in depressed newly born	Yes, if thick or in depressed newly born	Yes, in depressed newly born	Yes, if thick or in depressed newly born	Yes, if thick or in depressed newly born	Yes, if thick or in depressed newly born
Bag size, mL	<750	250–750	250–750	>500	250–750	250–750
Pressure release, cm H_2O	20–40	30–40	30–40	20–30	30–40	30–40
Assisted ventilation rate, breaths/min	30–60	30 if CC; 40–60 if no CC	30 if CC; 40–60 if no CC	30 if CC; 40–60 if no CC	30 if CC; 40–60 if no CC	30 if CC; 40–60 if no CC
Coordination of ventilation/compression	Yes	Yes	Yes	Yes	Yes	Yes
Heart rate at which CC is initiated, bpm	<60 despite adequate ventilation for 30 s	<60 or 60–80 and not rising	<60 or 60–80 and not rising	<60 or <100 and falling, despite adequate ventilation	<60 or 60–80 and not rising	<80 and falling
Heart rate at which CC is stopped, bpm	>60	>80 and rising	>80 and rising	>100	>80 and rising	>80 and rising
Compression and ventilation ratio	3:1 90 CC + 30 breaths/min = 120 events/min	3:1 90 CC + 30 breaths/min = 120 events/min	3:1 90 CC + 30 breaths/min = 120 events/min	3:1 Rate of 120 CC/min	3:1 90 CC + 30 breaths/min = 120 events/min	3:1 90 CC + 30 breaths/min = 120 events/min
Preferred compression method	Two-thumb technique	Two thumbs or two fingers	Two thumbs or two fingers	Two thumbs or two fingers	Two thumbs or two fingers	Two thumbs or two fingers
Compression location	Lower 1/3 of sternum	Lower 1/3 of sternum	Lower 1/3 of sternum	Lower 1/3 of sternum	Lower 1/3 of sternum	Lower 1/3 of sternum
Compression depth	Approx 1/3 AP diameter of chest	1/2–3/4 inch (1.3–1.9 cm)	2–3 cm	2–3 cm	1.5–2.5 cm (approx 1/3 to 1/2 AP diameter of chest)	2–3 cm
Epinephrine dose, 1:10 000	0.01–0.03 mg/kg	0.01–0.03 mg/kg	0.01–0.03 mg/kg	0.01–0.03 mg/kg	0.01–0.03 mg/kg	0.01–0.03 mg/kg
Buffer, 1–2 mEq/kg	$NaHCO_3$ (4.2%)	$NaHCO_3$ (4.2%)	$NaHCO_3$ (4.2%)	$NaHCO_3$ (4.2%) or THAM	$NaHCO_3$ (4.2%)	$NaHCO_3$ (4.2%)

CC indicates chest compression; AP, anterior-posterior; bpm, beats per minute.

of asphyxiated newly born infants?
- Is there a consistent marker of poor prognosis or duration of unsuccessful resuscitation that can be used to guide initiation and/or termination of newly born resuscitation?

SUMMARY

Scientific justification of each component of current resuscitation council guidelines is difficult because of the paucity of outcome data specifically addressing interventions in the newly born. Rapid transitions from intrauterine to extrauterine physiology further complicate the interpretation of findings and make education of trained birth attendants more complex. Assessment, stimulation, and provision of the first breaths of life are simultaneous critical steps in initial resuscitation of the newly born. The ILCOR advisory statement on pediatric resuscitation[6] highlighted areas of consensus, conflict, or controversy and provided recommendations of the working group after consideration and debate of the relevant international resuscitation literature in the areas of pediatric BLS, pediatric ALS, and BLS for the newly born. In the present document, the ILCOR Pediatric Working Group, joined by the Neonatal Resuscitation Program Steering Committee of the American Academy of Pediatrics, New Zealand Resuscitation Council, and World Health Organization, extends its advisory recommendations beyond BLS to ALS for the newly born. Careful review and comparison of current guidelines from constituent organizations and current international literature form the basis for initial evidence-based discussion of critical resuscitative interventions. A high degree of uniformity exists in current guidelines for resuscitation of newly born infants at birth, with controversies arising mostly from local and regional preferences, training networks, customs, and equipment/medication availability rather than scientific evidence. Areas of active research and evolving controversy (eg, induced cerebral hypothermia in birth asphyxia, if and when to suction meconium) are identified. Evidence-based evaluation of these advisory statements and the impact of their implementation on newly born, neonatal, and pediatric resuscitation training and resuscitation outcomes will be topics of discussion at future international resuscitation guideline conferences.

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APPENDIX 1

Examples of Risk Factors Associated With the Need for Resuscitation in the Newly Born Infant

Maternal

- Premature/prolonged rupture of membranes
- Bleeding in second or third trimester
- Severe pregnancy-induced hypertension
- Chronic hypertension
- Substance abuse
- Pharmacologic therapy (eg, lithium, magnesium, adrenergic blocking agents)
- Diabetes mellitus
- Chronic illness (eg, anemia, cyanotic congenital heart disease)
- Maternal infection
- Heavy sedation
- Previous fetal or neonatal death
- No prenatal care

Fetal

- Multiple gestation
- Preterm gestation (especially <35 weeks)
- Postterm gestation (≥42 weeks)
- Size-date discrepancy
- Growth restriction (retardation)
- Rhesus isoimmunization/hydrops fetalis
- Polyhydramnios and oligohydramnios
- Reduced fetal movement before onset of labor
- Congenital abnormalities
- Intrauterine infection

Intrapartum

- Fetal distress
- Abnormal presentation
- Prolapsed cord
- Prolonged rupture of the membranes
- Prolonged labor (or prolonged second stage of labor)
- Precipitous labor
- Antepartum hemorrhage (abruptio placenta, placenta previa)
- Thick meconium staining of amniotic fluid
- Nonreassuring fetal heart rate patterns
- Narcotic administration to mother within 4 hours of delivery
- Forceps delivery
- Vacuum-assisted (Ventouse) delivery
- Cesarean section

APPENDIX 2

Recommended Equipment and Drugs for Resuscitation of the Newly Born Infant

Equipment

- Firm, padded resuscitation surface
- Overhead warmer or other heat source
- Light source
- Clock (timer optional)
- Warmed linens (infant hat optional)
- Stethoscope
- Suction catheter (6F, 8F, 10F, 12F)
- Meconium suction device (to apply suction directly to endotracheal tube)

Feeding tube (8F) and 20-mL syringe for gastric decompression
Oxygen supply (flow rate of up to 10 L/min) with flowmeter and tubing
Portable oxygen cylinders
Face masks (various sizes)
Oropharyngeal airways (sizes 0 and 00)
Resuscitation system for positive-pressure ventilation (any one)
Face mask with T-piece
Face mask with self-inflating bag and oxygen reservoir
Face mask with flow-inflating bag, valve, and manometer
Laryngeal mask airway (optional)
Laryngoscopes with straight blade, spare bulbs, and batteries
Endotracheal tubes (sizes 2.5, 3, 3.5, and 4 mm ID)
Stylet
Supplies for fixation of endotracheal tubes and IVs (eg, scissors, tape, alcohol sponges)
Feeding tube or umbilical catheter (5F) shortened for surfactant administration
Umbilical vein catheterization tray
Syringes with needles (assorted sizes)
IV cannulas (assorted sizes)
Electrocardiograph with cardiotachometer (optional)
Pulse oximeter (optional)
End-tidal CO_2 indicator (optional confirmation for intubation)

Drugs

Epinephrine: 1:10 000 concentration (0.1 mg/mL)
Volume expanders: Normal saline, 4% to 5% albumin-saline, Ringer's lactate, blood
Naloxone hydrochloride: 1.0 mg/mL or 0.4 mg/mL solution
Sodium bicarbonate: 0.5 mEq/mL solution (4.2% concentration)
Dextrose: 5% and 10% solutions

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