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Does Neonatal Resuscitation Deserve a Special Chapter?

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PRESENTACION:

Es un honor para mi presentar esta conferencia en el marco del segundo Congreso Virtual de Cardiología.
A pesar de los importantes avances de la Pediatría en los últimos 20 años nuestro país presenta aún tasas de mortalidad infantil y neonatal elevadas en parte debido a que en muchos lugares los niños que nacen son recibidos en áreas y servicios donde no existen los recursos necesarios para brindar una atención adecuada y cuyo personal no ha recibido el entrenamiento necesario en reanimación neonatal.
No hace tantos años desde que la neonatología surgió como una subespecialidad de la pediatría al comprenderse que el recién nacido tenía características que lo hacían diferente del paciente pediátrico.
Hasta entonces la presencia de personal especialmente entrenado en reanimación neonatal en la sala de partos no había surgido como una necesidad. Aún hoy en muchos centros del interior de nuestro país y del resto de Latinoamérica la presencia del neonatólogo en todos los partos no es constante. Sin embargo, en los últimos años se han implementado en Argentina distintos programas de educación en reanimación neonatal auspiciados fundamentalmente por la Sociedad Argentina de Pediatría que junto con el desarrollo de la terapia intensiva neonatal han contribuido a la disminución de la mortalidad infantil en nuestro país.
En el año 2000 se publicaron las guías internacionales para la reanimación neonatal surgidas en el marco de la Conferencia Internacional en resucitación Cardiopulmonar. Estas guías actualizaron las últimas recomendaciones publicadas en el año 92.
Como resultado de este proceso de actualización basado en la evaluación de la evidencia actual surgieron las nuevas recomendaciones.
Destacada entonces la importancia de los programas de educación en reanimación neonatal y el gran impacto de los mismos en la salud infantil en nuestro país tengo el placer de presentar la conferencia de la Dra. Susan Niermeyer: Does Neonatal Resucitation Deserve a Special Chapter?
La Dra. Niermeyer es Profesora Asociada de Pediatría de la Universidad de Ciencias de la Salud y Neonatóloga de Staff de la sección de Neonatología del Children´s Hospital de Denver Colorado.
Actualmente se desempeña como Visiting Research Scientist en el Instituto Boliviano de Biología de altura.
Su mayor interés cient ífico se ha basado entre otros tópicos en la fisiología cardiopulmonar en la altura en lactantes y niños, la adaptación a la altura y la reanimación neonatal.
Es en la actualidad una de las autoridades más importantes en este tema y se encuentra entre los profesionales que más han contribuido con su educación y difusión.
La Dra. Niermeyer es miembro del programa de resucitación neonatal de la American Academy of Pediatrics y de la American Heart Association.
Además de haber disertado sobre el tema en importantes congresos nacionales e internacionales ha publicado numerosos artículos en prestigiosas revistas internacionales sobre tópicos referidos a la reanimación neonatal.
Su más reciente contribución ha sido su activa participación en la redacción de las nuevas Guías Internacionales para la reanimación Neonatal.

Dra. M. T. MAZZUCCHELLI

BACKGROUND/OVERVIEW

Neonatal resuscitation has developed into a distinct sub-discipline of pediatric resuscitation, which itself stands apart from adult cardiopulmonary resuscitation. What justifies this separate and special status? Does neonatal resuscitation, in fact, deserve a special chapter? This lecture will present the unique facets of physiology and pathophysiology in the newly born infant that necessitate an approach to resuscitation different from any other time in the lifespan. Using this physiology as a basis, the specific steps in neonatal resuscitation will be examined for their differences from the general pediatric recommendations.

Changes in the International Guidelines for Neonatal Resuscitation published in 2000 will be presented in the context of the supporting evidence evaluation. Future directions for neonatal resuscitation will be examined with respect to the basic science of resuscitation, clinical applications, and the unique opportunities for prevention and prenatal intervention.

The physiology of the newly born infant differs from that at any other point in the lifespan of a human being. The newly born infant must make a rapid transition from reliance on the placenta as the organ of respiration to use of the lungs for oxygenation and ventilation. Within a matter of seconds, the alveoli change from sacs distended with fluid to air-filled spaces where gas exchange occurs between the atmosphere and the blood. During fetal life, pulmonary blood flow represents only a small fraction of cardiac output, as much of the fetal venous return is shunted through the foramen ovale (from the right to the left heart) and ductus arteriosus (from the pulmonary artery to the aorta) [Figure 1]. Pulmonary blood flow rises dramatically after birth as the lungs expand physically with air. Both physical expansion of the lung and the vasodilatory effect of higher oxygen concentrations in the alveoli and the bloodstream contribute to a relaxation of pulmonary arteries and arterioles and a fall in pulmonary vascular resistance and pulmonary artery pressure. With lowering of right-sided pressures, the fetal shunts at the level of the foramen ovale and ductus arteriosus close functionally, and then anatomically.

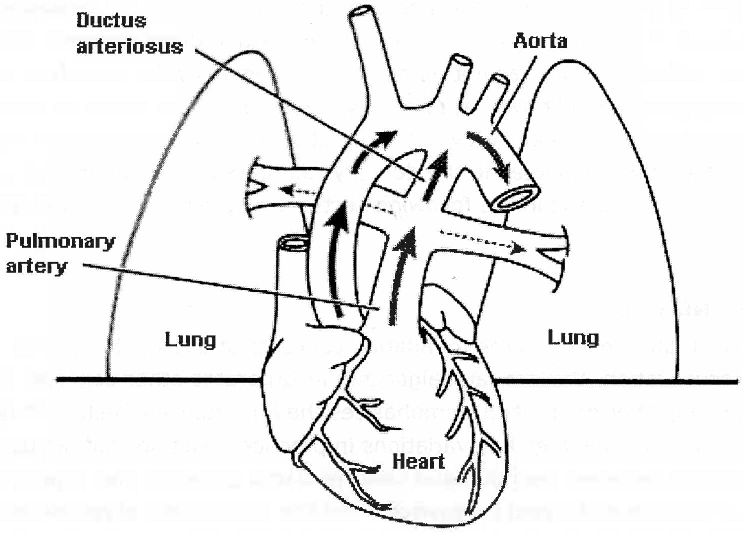

Figure 1. The fetal pattern of circulation is characterized by right-to-left shunts at the level of the patent foramen ovale and the ductus arteriosus. These shunts close after birth with successful transition to the neonatal circulatory pattern.

(Kattwinkel J (ed). Textbook of Neonatal Resuscitation, 4th Edition. American Heart Association, American Academy of Pediatrics. Elk Grove Village, IL. 2000, p. 1-4. Copyright American Academy of Pediatrics. Used with permission.)

What happens when this rapid and complex series of changes fails to occur? Consider the newly born infant who fails to initiate spontaneous respirations. Such an infant fails to expand the lungs with air and fails to initiate gas exchange. Consider the infant who has experienced fetal distress. The fetus under stress may pass meconium into the amniotic fluid, and under conditions of severe prenatal acidosis, may experience fetal gasping which draws meconium-stained amniotic fluid into the airways. This infant may be born with airway obstruction, inflammation at the level of the air spaces, and potential hypertrophy of pulmonary arteriolar smooth muscle, preventing gas exchange and impeding the normalization of pulmonary circulation. Consider the preterm infant who has surfactant deficiency, resulting in incomplete lung expansion, atelectasis, and intrapulmonary shunting. Finally, consider the near-term infant delivered by Caesarian section without labor. This fetus may not have initiated the shift from lung liquid production to reabsorption before birth, and after birth, the infant may experience retained fetal lung fluid, incomplete lung expansion, and impaired gas exchange. Each of these circumstances is unique to neonatal resuscitation. Each circumstance is primarily pulmonary, rather than cardiac, in its pathophysiology. Yet, each circumstance can result in the need for cardiopulmonary resuscitation because of pre- and/or post-natal asphyxia (hypoxia, hypercarbia, acidosis) compromising cardiac function and resulting in bradycardia and/or cardiac arrest.

In response to the need for specific approaches to the resuscitation of the newly born infant, in 1978 the Working Group on Pediatric Resuscitation of the American Heart Association (AHA) called for development of a neonatal resuscitation training program that would emphasize ventilation rather than cardiac defibrillation. With the cooperation of the AHA and the American Academy of Pediatrics (AAP), the Neonatal Resuscitation Program (NRP) was launched in 1987 as a separate educational program, focusing on resuscitation of the newly born infant in the delivery room (1). The AAP Neonatal Resuscitation Program Steering Committee, the Subcommittee on Pediatric Resuscitation of the AHA Emergency Cardiovascular Care Committee, and the International Liaison Committee for Resuscitation (ILCOR) have continued the intra-organizational cooperation, in a 3-year process which led to publication of the ILCOR Advisory Statement on Resuscitation of the Newly Born Infant (2) the most recent International Guidelines for Neonatal Resuscitation (3).

In formulating the neonatal resuscitation chapter of the Guidelines 2000 for Resuscitation and Emergency Cardiovascular Care, the same rigorous process of evidence evaluation used for basic and advanced pediatric and adult life support was applied to the neonatal setting. However, in recognition of the time-sensitive nature of perinatal physiology and the distinctive developmental attributes of premature infants and newly born infants, all studies not performed in neonates were classified as extrapolated evidence. Even within the neonatal literature, relatively few studies have been conducted in the delivery room setting, and thus, their conclusions may not be strictly generalizable to resuscitation at birth. Important examples of studies conducted in the delivery room, and their role in changing the neonatal guidelines, will be discussed in detail in the following sections regarding specific neonatal resuscitation recommendations.

SPECIFIC RECOMMENDATIONS

Though neonatal resuscitation shares the foundation concepts of airway, breathing, and circulation with adult and pediatric resuscitation, the neonatal algorithm incorporates other concepts central to the care of the newly born infant (e.g. thermal control), emphasizes the importance of establishing adequate lung expansion and ventilation, and dictates key variations in practice resulting from anatomic and developmental differences between neonatal and older pediatric patients. The algorithm for neonatal resuscitation [Figure 2] begins with rapid assessment and the initial steps of resuscitation, then continues through positive-pressure ventilation (including intubation), chest compressions, medications, and special considerations.

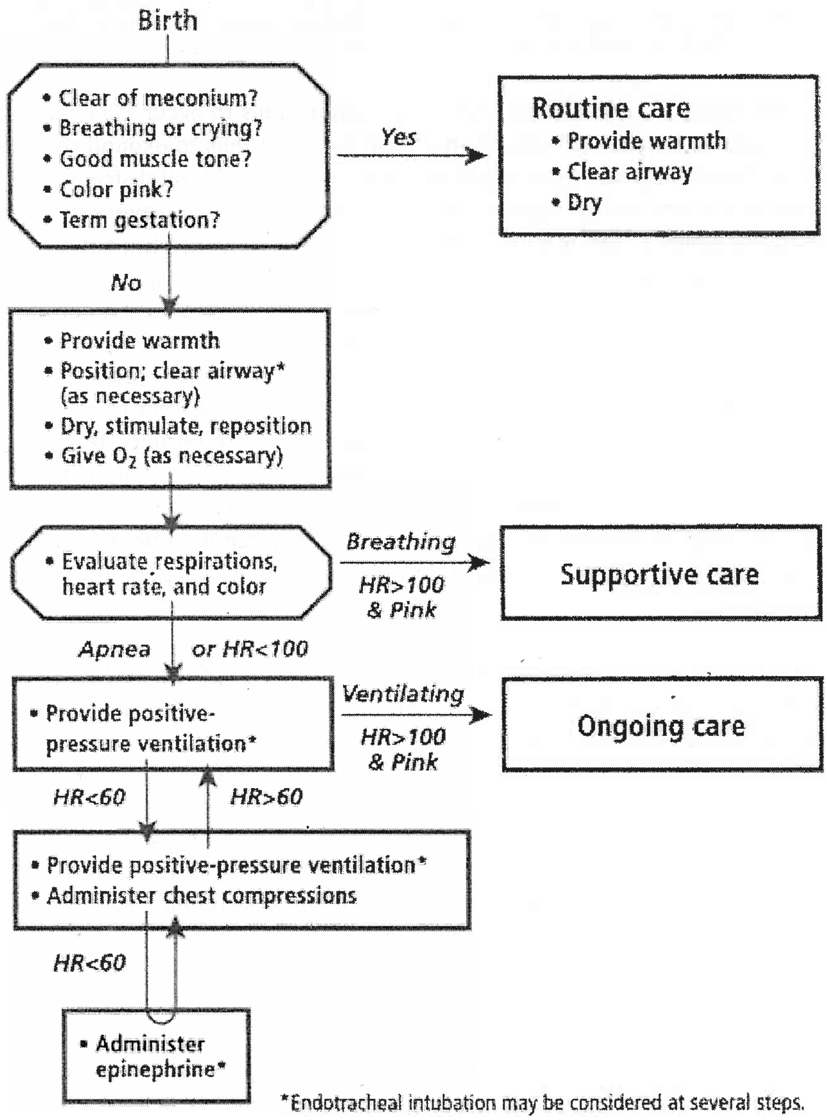

Figure 2. The algorithm for neonatal resuscitation begins with a rapid assessment of the infant and continues through the initial steps of resuscitation, positive-pressure ventilation, chest compressions, and medications. Endotracheal intubation may be considered at several steps during resuscitation. (Kattwinkel J (ed). Textbook of Neonatal Resuscitation, 4 th Edition. American Heart Association, American Academy of Pediatrics. Elk Grove Village, IL. 2000, p. 1 -15. Copyright American Academy of Pediatrics. Used with permission.)

INITIAL STEPS

The initial steps of neonatal resuscitation (provide warmth; position and clear the airway; dry, stimulate and reposition; provide oxygen as necessary) highlight many of the fundamental differences between resuscitation of a newly born infant and an older child or adult. Providing warmth and minimizing heat loss assume special importance for newly born infants who emerge wet and vulnerable to rapid heat losses through a large surface area-to-mass ratio (4). Any neonatal resuscitation must begin with proper preparation to maintain a neutral thermal environment for the patient; both hypothermia and hyperthermia can compromise the success of neonatal resuscitation (5-7). Likewise, clearing the airway is fundamental to any resuscitation, but especially so in newly born infants who are making the transition from fluid-filled to air-filled lungs. The airway must be effectively cleared (bulb or catheter suction), but in a manner which does not result in pharyngeal stimulation, triggering a vagal response, and resulting in compromise of respirations and heart rate. The frequency and variety of possible aspiration risks (clear amniotic fluid, blood, meconium-stained amniotic fluid) are great in the newly born. The presence of meconium-stained amniotic fluid and a depressed infant constitutes an indication for immediate tracheal intubation for suctioning - certainly a different approach from airway management in the older child, or even in the neonate with clear amniotic fluid (3). In the situation of a depressed infant with clear amniotic fluid, the first step is to stimulate breathing by tactile stimulation - often provided by drying the infant, but also by specific stimulation of flicking the feet. Such an approach is directed toward an infant experiencing primary apnea [Figure 3]; however, because primary and secondary apnea are virtually indistinguishable in the delivery room, the infant who does not respond rapidly to tactile stimulation requires positive-pressure ventilation.

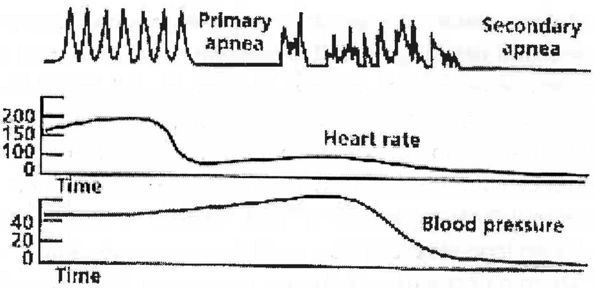

Figure 3. Primary apnea is responsive to tactile stimulation; however, secondary apnea does not. Primary apnea may occur in utero, thus apnea present after birth may be either primary or secondary. Because it is clinically difficult to distinguish between the two in the delivery room, positive-pressure ventilation is indicated if brief stimulation does not result in spontaneous respirations. (Kattwinkel J (ed). Textbook of Neonatal Resuscitation, 4th Edition. American Heart Association, American Academy of Pediatrics. Elk Grove Village, IL. 2000, p. 1-7. Copyright American Academy of Pediatrics. Used with permission.)

Significant changes in the Initial Steps were introduced in the 2000 Guidelines. These include the concept of simultaneous assessment and action and a change in the basis for decision-making regarding intubation for meconium-stained amniotic fluid. The resuscitation of a newly born infant begins with Rapid Assessment of 5 points in the several seconds after birth: 1) Is the baby clear of meconium? 2) Is the baby breathing or crying? 3) Is there good muscle tone? 4) Is the baby pink? 5) Is the baby term? The answers to these Rapid Assessment questions determine the need for further resuscitation vs. routine care (warmth, clearing the airway, drying). As the actions of the Initial Steps are initiated, the infant's responses (breathing, heart rate, color) are evaluated simultaneously to guide further intervention.

With the latest revision of the neonatal resuscitation guidelines, the basis for tracheal suctioning with meconium-stained fluid shifted to the vigor of the infant, rather than the consistency of the meconium (3,8). When the infant is not vigorous (defined as inadequate respirations, poor tone, or heart rate < [less than] 100 bpm), intubation and tracheal suctioning should be performed intubation and tracheal suctioning should be performed regardless of the consistency of the meconium (thick or thin). Under the new guidelines, the vigorous infant (good respiratory effort, adequate tone, heart rate > 100 bpm) may be managed expectantly, even in the setting of thick meconium. However, an infant who develops signs of airway obstruction, apnea, or respiratory distress subsequently during the acute resuscitation should be intubated prior to beginning positive-pressure ventilation.

POSITIVE-PRESSURE VENTILATION

The key to successful neonatal resuscitation is the establishment of adequate lung volumes and effective ventilation. This physiology differs significantly from that underlying most pediatric and adult resuscitation, and results in positive-pressure ventilation - rather than chest compressions - being the most important element of neonatal resuscitation. Neonatal resuscitation differs from pediatric/adult resuscitation in that a heart rate check is not part of the initial Rapid Assessment, nor are chest compressions begun simultaneously with positive-pressure ventilation. In an infant who is apneic or gasping, positive-pressure ventilation is performed for 30 seconds before reassessing respirations, checking heart rate, and noting color. Positive-pressure ventilation may also be initiated for the indication of heart rate < (less than) 100 bpm; however, even in the case of a heart rate (less than) 60 bpm, 30 seconds of positive-pressure ventilation should be provided first, before beginning chest compressions. This difference recognizes that bradycardia secondary to asphyxial changes (rather than primary cardiac arrest or non-perfusing rhythm) is the most common neonatal cardiac pathology. Effective lung expansion, unimpeded by chest compressions, is the most efficacious approach to initiating spontaneous respiration and reversing the bradycardia.

Changes in the 2000 Guidelines place more emphasis on the importance of ventilation as the cornerstone of successful neonatal resuscitation. This element of resuscitation encompasses significant complexities, due to the variety of pulmonary pathology encountered in the newly born infant. Term infants may have normally compliant, mature lungs or may have retained fetal lung fluid, aspiration of clear fluid, blood, or meconium, or perinatal pneumonia compromising their airways and lung compliance. Preterm infants often experience compromise of their lung function due to surfactant deficiency or pneumonia. Extremely preterm infants may have formed virtually no mature gas exchange spaces. Each of these circumstances requires an individualized approach to achieve adequate, but not excessive lung expansion and ventilation. Opening breaths with longer inspiratory times may be useful to establish lung expansion (9); higher pressures may also be necessary with parenchymal disease. Overdistention of airways and air spaces can lead to acute complications of air leak, and especially in preterm infants, can set the stage for later chronic lung disease.

During the evidence evaluation leading to the 2000 guidelines revision, extensive evidence in animals and short-term evidence in human infants was considered regarding the role of 100% oxygen vs. room air in resuscitation of newly born infants (10, 11). Traditionally 100% oxygen has been used to rapidly reverse hypoxia and overcome diffusion barriers. However, evidence suggests that vital signs normalize as rapidly or more rapidly with room air, and short-term survival and outcome at 1-month were no different in groups resuscitated with room air and oxygen. Nevertheless, before a guidelines change can be recommended, data on long-term survival and quality of survival are needed, as the primary theoretical advantage to resuscitation with room air is less oxidative injury, hypothesized to mediate neurodevelopmental damage as well as chronic lung disease. In recognition of the importance of ventilation and the equivalency of room air and 100% oxygen in many neonatal resuscitations, the 2000 Guidelines recommend that when 100% oxygen is not readily available, positive-pressure ventilation should be initiated promptly with room air (3).

CHEST COMPRESSIONS

In most neonatal resuscitations, if adequate ventilation is achieved, the need for chest compressions can be avoided (12). However, in certain cases of advanced asphyxia and myocardial depression or severe pulmonary dysfunction in which adequate ventilation cannot be readily achieved, chest compressions are necessary to support the circulation during more extensive resuscitation. Thus, the indication for chest compressions in the newly born differs significantly from that in older children and adults. The mechanics of the thoracic cage and the physical forces of the circulation of blood also differ, especially in preterm infants. The predominance of pulmonary dysfunction, already discussed, necessitates a relatively lower ratio of compressions to ventilations. The 3:1 ratio of compressions to ventilations is performed with 90 compressions and 30 interposed breaths per minute (or one cycle of 4 events every 2 seconds). The preferred method for chest compressions is the two-thumb-encircling-hands method (13), which provides firm support for the back and generates higher systemic arterial pressure and better coronary perfusion pressure than the two-finger method [Figure 4].

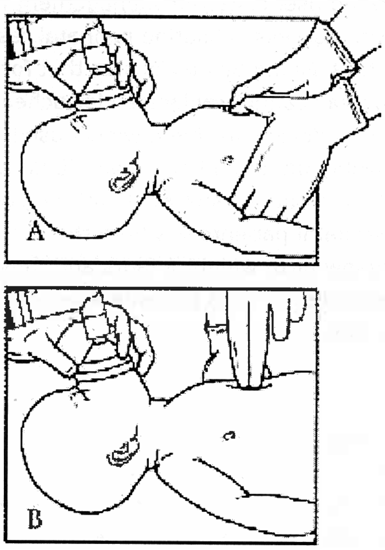

Figure 4. The two-thumb encircling hands method for chest compressions is preferred over the two-finger method. (Kattwinkel J (ed). Textbook of Neonatal Resuscitation, 4th Edition. American Heart Association, American Academy of Pediatrics. Elk Grove Village, IL. 2000, p. 4-5. Copyright American Academy of Pediatrics. Used with permission.)

Significant changes in the 2000 Guidelines relative to chest compressions include a change in the heart rate indication for initiation and standardization of the depth of compression relative to thoracic size. The previous indication for chest compressions, "heart rate < (less than) 60 beats/min or 60 to 80 beats/min and not rising", was simplified to "heart rate < (less than) 60 beats/min" on the basis of construct validity, or feasibility of accurate teaching, learning, and performance (14). The simplification of the indication for chest compressions also favors the adequate performance of positive-pressure ventilation. For similar reason of construct validity, the depth of chest compressions was standardized to one-third the depth of the anterior-posterior diameter of the chest. Relative depth of compression is more likely to result in a compression stroke which generates a palpable pulse, the accepted means to assess adequacy of chest compressions.

ENDOTRACHEAL INTUBATION

Endotracheal intubation of the neonate is one of the most difficult skills to learn and maintain. Anatomical differences from the older child and the adult account for much of this difficulty. The larynx is more anterior in neonates and may be very far anterior in preterm infants. The vocal cords are far less distinct in neonates than in children and adults, and appear pink rather than pearly white. Very small physical distances and operating tolerances mean that an error of a few millimeters can result in malposition of the endotracheal tube within the trachea or insertion of the tube into the esophagus instead of the trachea. Finally, airway and craniofacial anomalies can prove challenging even to those who are highly experienced in airway management. Furthermore, intubation is not an optional skill for those responsible for delivery room resuscitation. In contrast to the situation in most pediatric resuscitations, where an adequate airway can usually be maintained with bag and mask resuscitation, intubation is required for clearing the airway of the depressed infant with meconium-stained fluid or for administration of surfactant in the delivery room (3).

Two adjunctive airway devices (laryngeal mask airway and exhaled CO_2 detector) are considered for the first time in the 2000 revisions of the neonatal guidelines. The laryngeal mask airway offers an alternative to endotracheal intubation when bag-mask ventilation is ineffective and endotracheal intubation is not possible. The device has demonstrated usefulness for management of difficult airways (e.g. Pierre Robin sequence), and it has been used with success in routine neonatal resuscitation (15, 16). However, its wide applicability is limited by the need for training as rigorous as that for endotracheal intubation. Furthermore, the laryngeal mask airway cannot replace endotracheal intubation for clearing the airway of meconium. The exhaled CO_2 detection device has been widely used in pediatric anesthesia and intensive care for confirmation of tracheal positioning of endotracheal tubes; however its use in the delivery room has only recently been studied (17). Limitations still exist with respect to the sensitivity of the detectors, limiting their usefulness in those neonatal patients in whom the confirmation of endotracheal tube position could be most valuable - extremely low birth weight infants and those with low cardiac output (bradycardia) and poorly expanded lungs. In such patients adequate endotracheal tube position is the most difficult to confirm by strictly clinical signs.

MEDICATIONS

Neonatal resuscitation utilizes a relatively limited assortment of medications in the acute setting. Again, the focus of neonatal resuscitation is ventilation, not reversal of arrhythmias, and effective lung expansion and ventilation obviate the need for medications in most resuscitations. Epinephrine remains the principal medication used in neonatal resuscitation. In contrast to pediatric resuscitation, high-dose intravenous epinephrine has never been recommended for newly born infants. The unique risk of intracranial hemorrhage in preterm infants and evidence for direct myocardial damage from high-dose epinephrine make its use in neonates potentially harmful (18, 19). Bicarbonate may also pose special hazards in neonatal resuscitation, as the likelihood of incomplete lung expansion or primary pulmonary pathology preventing adequate ventilation is highest in this age group. Bicarbonate used in the setting of inadequate removal of CO2 can paradoxically worsen acidosis. Volume expansion in the newly born infant may be crucially important to replace acute blood volume loss; in this case rapid replacement and repeated doses may be necessary. However, determining the need for volume expansion in settings of asphyxia, hydrops, or sepsis can be more complicated and volume administration may be limited by myocardial insufficiency. Neonatal resuscitation guidelines continue to recommend an initial dose of 10 mL/kg of volume expander, followed by reassessment of the need for a repeat dose.

The newly revised neonatal resuscitation guidelines suggest isotonic crystalloid as the preferred volume expander. This recommendation rests on evidence that crystalloid is as effective as albumin-containing solutions in the acute treatment of hypotension (20). However, it is also based on the results of a meta-analysis of colloid vs. crystalloid which demonstrated higher mortality associated with the use of albumin-containing solutions across age groups (neonatal, pediatric, and adults) and across indications (hypotension, hypoalbuminemia, burns). Further limitations in terms of cost, availability, and infectious disease risk make albumin solutions less practical, as well.

The umbilical vein is the preferred route for administration of volume expanders and medications during resuscitation of the newly born infant; however, the intratracheal route continues to be an acceptable first line of administration for epinephrine. The newly revised guidelines omit any recommendation of high-dose epinephrine by this route. Instead, the dosage at the higher range of the intravenous dose (0.1 - 0.3 mL/kg of 1:10,000 solution) should be given by the endotracheal route. When umbilical venous access is not available as the definitive route for epinephrine, bicarbonate, or volume expansion, the intraosseous route may offer an acceptable alternative to venous access (21).

SPECIAL CONSIDERATIONS

The 2000 Guidelines include a discussion of non-initiation and discontinuation of neonatal resuscitation. The circumstances of these decisions differ dramatically from those encountered in other age groups. Non-initiation of resuscitation may be considered in the setting of confirmed lethal anomalies, such as anencephy, trisomy 13 or trisomy 18. Resuscitation may be withheld also in the setting of extreme prematurity, with birth weight < 400 grams and gestational age < 23 weeks (22-24). While these guidelines are not absolute, their purpose is to stimulate dialogue and offer a basis for discussion at the regional, hospital, and individual family level.

Discontinuation of resuscitation may be considered after full resuscitative efforts have not resulted in return of spontaneous circulation within 15 minutes after birth. While resuscitation of "recently" stillborn infants may result in return of spontaneous circulation, there is no agreement regarding the optimal management of infants who continue with prolonged and refractory bradycardia (25-27). In general, the preferred approach to discontinuation of resuscitation in such cases, or in cases of possibly lethal anomalies, is to defer decisions until complete information can be collected regarding the infant's status and prognosis. Decisions to stop support can then be made with adequate information and understanding of the family.

Special considerations also encompass the variety of congenital anomalies which may require an individualized approach to neonatal resuscitation - e.g. immediate intubation of an infant with congenital diaphragmatic hernia and respiratory distress or placement of a nasopharyngeal airway and prone positioning of an infant with Pierre Robin sequence. Causes of poor response to resuscitation overlap considerably with those encountered in pediatric resuscitation, but others - such as anatomical airway obstruction, complex congenital heart lesions or congenital heart block - may have their initial presentation in the setting of neonatal resuscitation.

SUMMARY OF DIFFERENCES

Neonatal resuscitation differs fundamentally from resuscitation at any other time in the lifespan because of the unique pathophysiology involved in the transition from intrauterine to extrauterine life. The need for resuscitation of the newly born infant usually arises from some degree of asphyxial insult, either prenatally as a result of compromise of placental respiratory function, or postnatally, as a result of cardiopulmonary pathology. The establishment of adequate initial lung expansion and ventilation are thus the central elements in successful neonatal resuscitation. Certain pathologies, such as aspiration of meconium-stained amniotic fluid or surfactant deficiency occur only in the neonatal age group and require immediate and very specific approaches to resuscitation.

Because of such different pathology and circumstances surrounding the need for resuscitation, the basic, initial approach to the newly born infant differs considerably from that of the older child or adult [Table 1]. Thermal control is of prime importance. Rapid assessment for the presence of meconium determines the approach to subsequent airway management. The heart rate check does not enter the resuscitation algorithm until either spontaneous or positive-pressure ventilation has been initiated.

Table 1

Summary of Differences between Neonatal and Pediatric Resuscitation	
Initial Steps	• Providing warmth, minimizing heat loss • Clearing the airway of meconium (intubation) • Tactile stimulation for primary apnea
Positive-Pressure Ventilation	• Initiation of positive-pressure ventilation for 30 seconds before beginning chest compressions • Opening breaths with longer inspiratory times • Ventilation bags with volume 200-750mL
Chest Compressions	• 3:1 ratio of compressions to ventilation • Interposed ventilation (between compressions) • Two-thumb encircling hand method preferred, except during umbilical catheter placement
Endotracheal Intubation	• Early intubation under certain circumstances: meconium-stained amniotic fluid and depressed infant surfactant administration in extremely premature infant
Medications	• High-dose epinephrine *not* recommended • Volume expansion 10mL/kg followed by evaluation for repeated dosage • Umbilical vein the preferred route for administration of medications and volume expanders
Special Considerations	• Consideration of non-initiation of resuscitation in cases of *confirmed* lethal anomalies or extreme prematurity • Consideration of discontinuation of resuscitation after 15 minutes of full resuscitative efforts without return of spontaneous circulation • Recognition and individualized approach to congenital anomalies resulting in poor response to resuscitation

Advanced resuscitation steps continue to emphasize the importance of ventilation. Chest compressions are delivered only after 30 seconds of positive-pressure ventilation and then with a lower ratio of compressions to ventilation (3:1). Endotracheal intubation may be indicated at various points in the resuscitation - immediately for clearing the airway of meconium in a depressed infant; early in the resuscitation of an extremely premature infant for administration of surfactant; later for cases in which bag and mask ventilation is either ineffective or of prolonged duration. Medications are necessary in only a small minority of resuscitations. Situations in which non-initiation or discontinuation of resuscitation are indicated relate to lethal congenital anomalies and extreme prematurity, as well as lack of response to resuscitation.

DIRECTIONS FOR THE FUTURE

As research continues to expand our understanding of the pathophysiology of perinatal asphyxial injury and perinatal pulmonary disorders and their treatment, the need for special focus on neonatal resuscitation will become even greater. In the field of basic-to-applied clinical science, better understanding of the role of ventilatory pressures and oxygen in long-term lung development, demonstration of optimal chest compression:ventilation ratio, and delineation of the long-term neurodevelopmental effects of oxidant injury associated with high oxygen concentrations will shape the future changes in neonatal resuscitation. Development of better equipment and better control mechanisms for positive-pressure ventilation, suctioning of meconium, endotracheal intubation, laryngeal mask ventilation, and confirmation of endotracheal tube placement will refine the delivery of resuscitation interventions. Finally, the opportunity for prevention and prenatal intervention, through improved prenatal diagnosis, manipulation of the *in utero* environment, and timing of delivery are unique to neonatal resuscitation, and offer the true promise of the future.

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