UPDATE ON NEONATAL RESUSCITATION

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Needs Assessment

Clinical practice has changed over recent decades, especially in obstetrical care and in neonatal management. An appreciation of current guidelines physiological considerations, equipment modalities, and therapeutic interventions, is necessary to provide successful neonatal resuscitation.

Introduction

The transition from a fetus to a neonate involves complex changes in physiology. A delay in these adaptations can result in significant neonatal morbidity and mortality. In the United States, 10% of newborns require some assistance with breathing and about 1% require extensive ventilatory assistance[1-4]. Furthermore, anesthesiologist's practice in a spectrum of facilities with varying levels of care. Smaller practices or rural settings can limit consistent practices. Thus, it is vital for all clinical anesthesiologists and delivery room personnel to understand the physiological adaptation of the newborn, ensure proper preparation and maintenance of equipment (Table 1), perform an adequate risk assessment to predict possible resuscitative needs, and respond appropriately with resuscitation efforts[5-14].

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Table 1
Neonatal Resuscitation Equipment

Neonatal Resuscitation Equipment

Suction Equipment

Bulb Syringe
Suction (mechanical)
Suction catheters
Meconium aspirator

Bag and Mask

Resuscitation bag
Pressure relief valve
Face masks
Oral airways
Oxygen
Flowmeter and tubing

Intubation

Laryngoscopes
Straight blades (#0 and #1)
Extra bulbs/batteries
ETT 2.5 to 4.0 mm with stylets
Scissors

Miscellaneous

Warmer
Stethoscope
ECG
Tape
Extra syringes/needles
Alcohol pads
Gloves

Adaptations

In order for a fetus to transit from intrauterine to extrauterine environment, successful changes in the cardiopulmonary and other organ systems are required. Poor adaptation due to prematurity, congenital anomalies or the delivery itself, can result in significant neonatal morbidity and mortality, necessitating the need for appropriate and prompt resuscitation[2]. Therefore, it is important to have adequate knowledge of the physiological transition of the newborn in order to better understand the needs of the neonate during resuscitation efforts.

Pulmonary Adaptations

Prior to birth, fetal lungs secrete fluid which keeps the alveoli inflated near normal neonatal lung volumes[2]. Additionally, the relative hypoxemia of the pulmonary circulation contributes to constriction of the blood vessels that perfuse the lungs increasing resistance to flow on the pulmonary side of the circulatory system. As a result, a large portion of the right ventricular output is shunted across the ductus arteriosus bypassing the pulmonary circuit. Thus, the fetal lungs play no role in intrauterine gas exchange[1].

In order for the neonate to assume the responsibility of extrauterine gas exchange, there has to be an elimination of fluid from the lungs, production of surfactant and stimulation of the respiratory centrer[1]. Compression of the thoracic cage during the passage through the birth canal lays a limited role in the removal of fetal lung fluid. On the other hand, sodium channels in alveolar epithelial cells are thought to play the main role in the elimination of fluid from the fetal lungs[3]. Their expression is largely regulated by developmental changes during the last few weeks of pregnancy and hormonal changes associated with labor. Reabsorption of sodium through the sodium channels creates an osmostic gradient leading to clearance of a large portion of fetal lung fluid. This process allows for air to fill the lungs and leads to the establishment of an air-fluid interface. The surfactant lining the alveoli reduces surface tension and prevents collapse of the alveoli. The maturation of alveoli and capillary networks along with surfactant production allows for the commencement of gas exchange[1-3].

The process of spontaneous breathing begins with the initial stimulation of the respiratory center and further contributes to fetal adaptation to the outside environment[1-2]. Asphyxia, a collective term given to hypercapnea, respiratory acidosis and hypoxia, along with tactile and thermal stimuli associated with labor and delivery are believed to play a role in switching on the respiratory center[1-2].

The initiation of ventilation and inflation of lung volumes contributes to an increased systemic vascular resistance, decreased pulmonary vascular resistance, increased arterial partial pressure of oxygen (PaO_2) and decreased partial pressure of carbon dioxide (PCO_2)[1-2]. Failure of any of these processes can result in neonatal problems such as transient tachypnea of newborn and respiratory distress[2].

Cardiovascular Adaptations

As a result of low systemic vascular resistance in utero, 40% of cardiac output is received by the placenta and there is right to left shunting of blood across the foramen ovale and ductus arteriosus[1]. Clamping of the umbilical cord significantly increases systemic vascular resistance and contributes to a functional closure of the foramen ovale within the first few minutes of birth. A left to right reversal of the shunt across the ductus arteriosus results.. Because it takes days to weeks for the ductus arteriosus to anatomically close, there may be a right to left reversal of the shunt anytime pulmonary vascular resistance rises above systemic. Several states can predispose the infant to this reversal during this "transitional phase"[1]. Conditions such as meconium aspirations can result in a more persistent fetal circulation.

Metabolic Adaptations

In utero, the fetus depends on a continuous supply of glucose from the placenta. Around 36 weeks gestational age there is a rapid increase in the amount of glycogen stores. The onset of labor causes a surge in adrenaline, noradrenaline and glucagon and a decrease in insulin allowing for mobilization of the glycogen stores. These stores can be depleted more quickly if demand is high. As a result, an inadequate supply of available glucose substrate can lead to hypoglycemia[3].

Thermoregulation

Intrauterine temperature regulation is a passive process requiring no energy expenditure on the part of the fetus[1-2]. In utero, thermoregulation depends upon maternal transfer of heat via the placenta and uterus[4]. Therefore, transitioning to the outside world poses a serious problem to the neonate in regards to regulating body temperature. At birth, in addition to being cold and wet, neonates have thin skin, a high body surface area to mass ratio, limited insulation and metabolic reserves and an inability to shiver. As a result, the temperature drops suddenly after birth[2].

In order to survive in the extrauterine environment, one important physiological adaptation newborns have in place is the ability to rapidly increase body temperature by non-shivering thermogenesis (NST), which is initiated minutes after birth[4]. NST is an oxygen dependent process that relies on an uncoupling protein specific to brown adipose tissue[4]. Prior to birth, inhibitors of non-shivering thermogenesis, mainly adenosine and prostaglandin E2, allow the fetus to accumulate a sufficient amount of brown adipose tissue. After birth the presence of brown adipose specific uncoupling protein allows for heat production by uncoupling ATP synthesis in the mitochondria during fatty acid oxidation[4].

Thus, a distressed newborn with hypoxemia is unable to produce a sufficient amount of heat because the decreased PaO_2 results in reduced nonshivering thermogenesis[4]. Common practice in the care of newborns stresses they be kept dry and warm at birth. Hypothermia increases metabolic rate resulting in increased oxygen and energy consumption[2]. Cold stress can also cause a shift from aerobic to anaerobic metabolism resulting in further tissue hypoxia and metabolic acidosis. Finally, prolonged hypoxemia and metabolic acidosis can cause persistent pulmonary hypertension and is one example of transitional circulation returning the infant to its previous fetal circulation and increasing hypoxia. Therefore, preventing excessive heat loss is vital in neonatal resuscitation especially if there is respiratory compromise[2].

Risk Assessment

The anticipation of resuscitative needs can be determined by performing a thorough assessment of risk. By evaluating maternal and fetal risk factors in addition to intrapartum and postpartum events, the need for resuscitation can be identified in more than half of all neonates[14]. There are several methods used to evaluate fetal well being during the intrapartum period. The primary purpose of these methods is to detect hypoxic ischemia in the fetus, which can result in significant morbidity and mortality in the neonate[5]. Thus, information gathered from the intrapartum assessment can be utilized to determine the possible need for resuscitative measures.

Fetal Heart Rate Monitoring

There are two commonly used methods for assessing intrapartum fetal heart rate: continuous electronic fetal heart rate monitoring (EFM) and intermittent auscultation (IA). The latter form is more tedious for nursing staff and used in some centers for low risk pregnancies. Electronic fetal heart monitoring, which records fetal heart rate changes relative to

Table 2
The five criteria of the APGAR score

Score:	0	1	2
Appearance (skin color)	blue (whole body)	blue extremities, pink body	normal
Pulse (heart rate)	absent	<100 bpm	>100 bpm
Grimace (irritability)	no response to stimulation	grimace or weak cry	sneeze/cough/pulls away
Activity (muscle tone)	no movement	some flexion at joints	full body movement
Respiration	absent	weak/irregular	strong

uterine contraction, has replaced IA in most centers and is considered the primary mode of evaluating fetal well being[5].

The main purpose of electronic fetal heart monitor (EFM) is to identify fetuses with hypoxic acidemia[5-6]. A reassuring EFM consists of accelerations and variability in fetal heart rates; while decreased variability and the presence of decelerations are indications of fetal distress. EFM has a 90% accuracy rate in predicting 5 minute Apgar (Table 2) of >7. However, because of its very high false positive rate, it is generally accepted that an increase in cesarean sections and instrumental vaginal deliveries is associated with the use of EFM. Thus, several other methods of assessing fetal well being are often used in conjunction with non-reassuring fetal heart tracings[5-6].

Scalp and Acoustic Stimulation

In the presence of non-reassuring fetal heart tones, further evaluation can be done through the use of scalp or acoustic stimulation[5]. Fetal scalp stimulation involves using a finger or instrument (i.e. Allis clamp) to apply pressure to the vertex.

Acoustic stimulation is a less invasive alternative whereby an electronic device placed on the mother's abdomen sends sounds to the baby. In either situation, if the fetal heart rate increases to greater than 15 beat per minute above baseline for more than 15 minutes, a pH of 7.20 is likely[5].

Biophysical Profile Score

Studies have shown some benefit in using the Biophysical Profile Score in conjunction with non reassuring fetal heart rate monitoring[8,9]. Biophysical profile score provides a direct and accurate measure of normal tissue oxygenation by combining sonographic assessments of (1) fetal breathing movements, (2) heart rate reactivity, (3) gross body movements and (4) fetal tone with (5) amniotic fluid volume. Each parameter is given a score of 0 (if criteria are not met) or 2 (if criteria are met) with 0/0 being the lowest attainable score and 10/10 being the highest. A score of >8 out of 10 indicates normal tissue oxygenation, a score of 0-4 out of 10 suggests significant acidemia and a high risk of asphyxia within one week if there is not intervention. A score of 6 out of 10 is equivocal and

Table 3
Biophysical Profile Tests and Criteria

Biophysical Profile Test	**Criteria** (0 points for any criteria not met)
Nonstress Test	2 points if reactive
Fetal Breathing Movements	2 points if one or more episodes of rhythmic breathing for greater than 20 seconds within a 30 minute period
Fetal Tone	2 points for one or more episodes of extension of extremities or spine with subsequent return to flexion
Amniotic fluid volume	2 points if a single pocket of fluid measures greater than 2 cm in vertical axis
Fetal Ultrasound	2 points for two or more discrete body or limb movements in 30 minutes

Adapted from: Manning FA. Fetal biophysical profile. *UpTo Date* 15.3. May 3, 2006.

should be closely evaluated in the context of amniotic fluid volume[8-9] (Table 3).

Fetal Pulse Oximetry

Fetal pulse oximetry is another method currently used for intrapartum fetal assessment in the presence of non-reassuring fetal heart pattern[5]. Three systems have been developed for commercial use[10]. The OB Scientific sensor is shaped like a tongue depressor and can be placed along the fetal torso during a vaginal exam, with or without rupture of the membranes. Nonin Medical system incorporates the pulse oximeter into the fetal scalp electrode. Finally, the Nellcor sensor is directed to lie against the fetal temple or cheek after rupture of the membranes. A fetal SpO_2 >30%, which is the oxygen saturation above which acidosis is unlikely to occur, can be considered reassuring while a SpO_2 <30% may be associated with acidosis. If SpO_2 <30% persist longer than 10 minutes, this may predict a scalp pH of 7.20 less and demand the need for intrauterine resuscitation or expedited delivery[5,10].

Fetal Scalp pH and Umbilical Cord Blood Gas

The fetal scalp pH and umbilical cord blood gas analysis are two methods used to determine fetal acid base status[5]. A fetal scalp pH <7.2 for two consecutive readings indicates significant fetal distress and imminent need for delivery. In the United States the use of fetal scalp sampling has declined and is not available in many obstetrical departments[5], primarily due to technical difficulties in performing the procedure and other inherent limitations.

On the other hand, umbilical cord blood gas analysis is considered to be the gold standard for evaluating fetal acid-base status and uteroplacental function[5]. It measures values for pH, pCO_2 and base excess from the umbilical artery and vein. The umbilical artery depicts fetal and immediate neonatal acid base status while the umbilical vein depicts maternal status. The umbilical artery base excess is considered to be the most direct measure of fetal metabolic status. A base excess greater than –12 mmol L^{-1} and a pH <7.10 suggests significant metabolic acidosis and is a sign of fetal compromise[5,7]. With a pH of less than 7.10 there is an increased risk of intracranial hemorrhage, seizures, respiratory distress syndrome and death[5].

Fetal Doppler Ultrasound Study

The Doppler ultrasound study is a method for evaluating fetal well being often used in conjunction with the BPP score[11]. Fetal Doppler studies utilize the flow velocity waveforms and pulsatility indices as diagnostic and prognostic evaluators of fetal adaptation. There are four main types of Doppler studies used to evaluate maternal, fetal and placental circulation. Uterine artery Doppler is often used in the second trimester to assess the effect of maternal circulation on the fetus. Information gathered can be useful in predicting pre-eclampsia and intrauterine growth retardation. The umbilical artery Doppler assesses the effects on placenta deficiency on multiple organ systems in the fetus in addition to intrauterine growth retardation. If abnormal flow is detected, further evaluation of fetal systemic circulation with either middle cerebral artery or ductus venosus Doppler studies is warranted. In response to hypoxia, the middle cerebral arteries dilate to preserve flow to the brain, "brain sparing effect". Loss of the brain sparing effect seen as reduced middle cerebral artery flow on the Doppler, signifies a critical event and can result in fetal demise. Doppler of the ductus venosus is used to predict right heart failure in the hypoxic fetus. Therefore, reversal of flow in the ductus venosus Doppler is often seen as an ominous sign[11].

Effects of Maternal Drugs on Neonate

Regional anesthesia

Regional anesthetic techniques such as epidurals, spinals and combined epidural-spinals are the preferred methods of providing labor analgesia and anesthesia for cesarean sections[15]. Although these methods provide excellent pain control with limited exposure of the fetus to drugs, there are still some concerns associated with their use.

Due to temporary sympathectomy caused by the anesthetic, a transient period of mild maternal hypotension is relatively commonly associated with regional analgesia. However, prolonged severe maternal hypotension often results in significant impairment in uteroplacental perfusion and places the infant at risk to acidemia[16]. Therefore, efforts should be made to prevent maternal hypotension such as placement in the left lateral position (to reduce aortocaval compression), utilizing lower leg compressive stocking, and intravenous fluid loading[15].

Ephedrine and phenylephrine are currently the drugs of choice to treat maternal hypotension[15]. Ephedrine is the drug most commonly used and is often associated with fetal tachycardia and fetal acidosis. The prophylactic use of ephedrine does not reliably prevent maternal hypotension and should be reserved for treatment. For maternal patients with significant cardiac disease, phenylephrine is the drug of choice. Also, phenylephrine is associated with lower catecholamine concentration in the neonate and improved acid base status in comparison to ephedrine[15].

Systemic Drugs

Although the use of epidural analgesia and combined spinal-epidural techniques are increasingly used as methods of pain control in labor, systemic medications such as opioids are still widely used[15]. The initial effect of opioids seen during the intrapartum period is decreased fetal heart rate variability and decreased gross fetal movements[16]. The effects of their use during the postpartum period include neonatal respiratory depression and decreased alertness, reversible with naloxone.

Meperidine is a commonly used systemic opioid in labor analgesia worldwide[15,16]. Babies at the greatest risk of respiratory depression are those born within one to five hours after meperidine is given. Additionally, those born to mothers who received multiple doses of meperidine are also at increased risk. Repetitive administration of meperidine results in an accumulation of its metabolite, normeperidine, in both the mother and fetus. Normeperidine is associated with seizures and depressed respiratory status in neonates that is not reversed by naloxone[16].

General Anesthesia

General anesthesia is still used for cesarean sections in special situations when regional techniques are contraindicated as in coagulopathies, severe maternal hemorrhage, hypotension, or in failure of the regional anesthetic, and severe fetal distress when there is no time to perform a regional technique[15]. An important aspect related to neonatal outcome associated with general anesthesia is the time between the induction of anesthesia and delivery time[15-16]. This represents the total time of fetal exposure to maternally administered medication and is associated with lower Apgar scores (Table 2) and increase in the base deficit (i.e. neonatal acidosis). An additional factor is time from uterine incision to delivery of the baby. The longer the incision to delivery time the greater the likelihood of fetal asphysia leading to respiratory depression. In order to prevent these complications, the induction to clamp time should be less than ten minutes and the uterine incision to delivery time should be less than three minutes[15]. In a crisis situation where the mother cannot be intubated or ventilated, a cesarean section under local anesthesia should be considered.

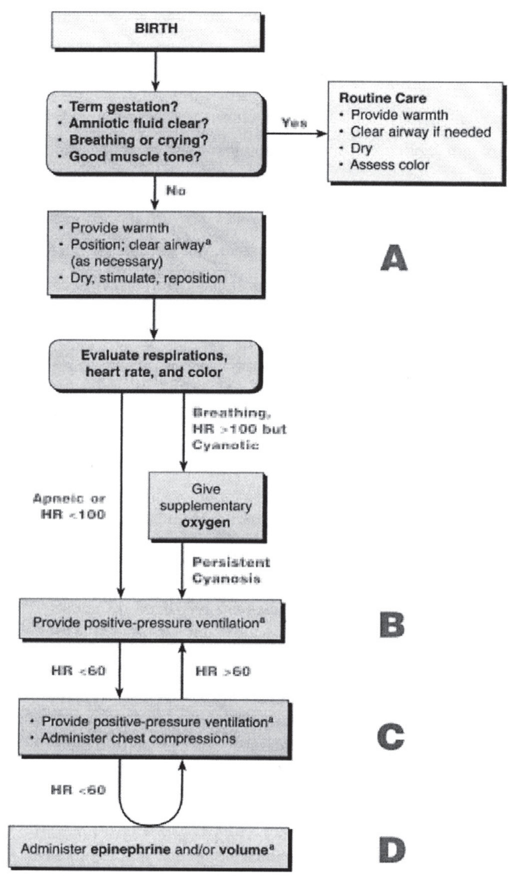
Additionally, though the mechanism is thought to be linked to serum cortisol suppression, the use of etomidate as an induction agent in mothers undergoing cesarean sections is associated with neonatal hypoglycemia[15]. Therefore, close monitoring of the neonate's glucose is warranted. It should be noted that inhalational agents have a reduced minimum alveolar concentration in pregnancy as well as in the neonate. All of the common utilized inhalational agents, e.g. desflurane, sevoflurane, and isoflurane, have been used successfully in both pregnancy and in neonates.

Overview of Steps of Neonatal Resuscitation

Neonates born at term, who have clear amniotic fluid with no signs of meconium, are actively breathing and crying and have muscle tone require routine care, including drying, providing warmth and clearing the airways by simply wiping with a towel[12,14]. One the other hand, neonates not meeting these requirements should be assessed for the initial steps of resuscitation. An Apgar score at different time periods post delivery is particularly useful and is common practice in many parts of the world.

The sequences of steps involved in neonatal resuscitation are (1) initial steps in stabilization, (2) ventilation, (3) chest compression, and (4) medications[12,14]. Each step is allowed 30 seconds for completion[12]. The decision to progress to the next category is based on the cumulative assessment of respirations, heart rate and color. For example, gasping and apnea may serve as an indication for assisted ventilation. Increasing or decreasing heart rate may suggest an improvement or worsening in overall condition. Finally, central cyanosis may serve as an indication of decreased cardiac output, hypothermia, acidosis or hypovolemia necessitating further resuscitative efforts[13] (Figure 1).

Fig 1
Neonatal Resuscitation Flow diagram



American Heart Assocaition (AHA) Guidelines for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiovascular Care (ECC) of Pediatric and Neonatal Patients: Neonatal Resuscitation Guidelines American Heart Association, American Academy of Pediatrics Pediatrics 2006; 117; e 1029-e 1038 DOI: 10.1542/peds. 2006-0349.

Initiation of Resuscitation

The initial steps in stabilizing the neonate involves minimizing heat loss, positioning the head in "sniffing" position to open the airway, clearing the airways, and stimulating the infant[12].

Provide warmth

Thermoregulation is a critical component of the initial resuscitative effort. This can be accomplished by simply placing the neonate under a radiant warmer. The infant should be uncovered to allow for full visualization and adequate heat transference. Thermoregulation is particularly important in very low birth weight preterm infans[12]. Infants weighting less than 1500 grams are placed at a significantly increased risk of hypothermia. Thus, it is recommended that the infant be covered in plastic wrapping in addition to being placed under a radiant warmer.

There has been some concern about hyperthermia, particularly in infants born to febrile mothers, resulting in respiratory depression, seizures and cerebral injury[2]. Therefore, the goal in neonatal resuscitation is to achieve normothermia by adequately monitoring the temperature, thus avoiding iatrogenic hyperthermia[12].

Position Head and Clear Airways

Once the neonate has been placed underneath a radiant warmer, the baby should be positioned on the back or side with the neck slightly extended in a "sniffing position"[14]. Then, the airway should be cleared as determinied by whether or not meconium is present. If meconium is not present, simple wiping the nose and mouth with a towel or suctioning with a bulb syringe or suction catheter is appropriate. It is important to remember to suction the mouth prior to the nose to ensure that there is nothing present in the mouth that would cause the neonate to aspirate. Also, it is important to avoid vigorous or deep suctioning to prevent a severe vagal response which can lead to bradycardia or apnea[14].

If meconium is present but the baby is vigorous, as defined by a heart rate greater than 100 beats per minute, appropriate respiratory effort and muscle tone, simply suctioning the mouth and nose with a bulb syringe or large bore suction catheter is appropriate[14].

Severe aspiration pneumonia can be a sequela of meconium aspiration before delivery, during birth or during resuscitation[13]. Therefore, if meconium is present and the infant shows poor respiratory effort and muscle tone and has a heart rate less than 100 beats per minute, direct suctioning of the trachea is recommended and should occur immediately following birth. This is done by performing direct laryngoscopy and inserting a 12 French (F) or 14 F suction catheter to clear the mouth and posterior pharynx, followed by insertion of an endotracheal tube, then attaching the tube to a suction source and slowly withdrawing the tube as suction is applied. This latter step should be repeated until either very little meconium is recovered or a need to proceed with resuscitative efforts is dictated by the heart rate.

Dry and Stimulate Baby

Once the airway is cleared the neonate should be dried thoroughly to prevent further heat loss and then repositioned. If the neonate still does not have appropriate respiratory effort, additional tactile stimulation in the form of gently slapping or flicking the soles of the feet or gently rubbing the newborn's trunk and extremities can be performed. It is important to note that if the newborn has primary apnea (e.g. when asphyxiated, an infant responds with an increased respiratory rate) any form of stimulation will stimulate breathing. However, if the neonate has secondary apnea (e.g. when asphyxia is allowed to continue after primary apnea) the infant responds with a period a gasping respirations, falling heart rate, and falling blood pressure. The infant takes a last breath and then enters the secondary apnea period. The infant will not respond to stimulation and death will occur unless resuscitation begins immediately and no form of stimulation will trigger the baby's respiratory effort and positive pressure ventilation should be initiated immediately[13].

Evaluate Respiration, heart rate and color

Finally, the last step in the initial resuscitative efforts involves an evaluation of respiration, heart rate and color[14]. The neonate should have good chest movements and should not be gasping. Gasping is indicative of ineffective respiratory effort and requires the use of positive pressure ventilation. Additionally, the heart rate should be greater than 100 beats per minute (bpm), determined by feeling for a pulse around the umbilical cord or auscultating the left chest wall. If the heart rate is less than 100 bpm, positive pressure ventilation should be administered. Finally, color should be assessed by looking at the neonate's lips and trunk for signs of central cyanosis. Central cyanosis indicates hypoxemia and supplemental oxygen should be given. If the neonate remains cyanotic after the administration of supplemental oxygen, positive pressure ventilation should be administered even if the heart rate is greater than 100 bpm. If ventilation is adequate and the baby continues to have central cyanosis, a congenital cyanotic heart defect or persistent pulmonary hypertension should be considered[13]. Peripheral cyanosis (acrocyanosis) is a normal finding in the newborn.

Assessment and Management of Airway

Airway Assessment

As previously mentioned, properly assessing and managing the airway of a newborn involves clearing the airway, properly positioning the neonate in sniffing position to open up the airway and monitoring for satisfactory respiratory effort. In addition to evaluating respirations, heart rate and color should also be carefully monitored because an abnormality in any one of these vital signs usually improves with ventilation. Thus, in neonatal resuscitation, providing adequate ventilation of the compromised newborn is the most crucial and effective step[13].

Supplemental Oxygen

Supplemental oxygen is recommended whenever the neonate is breathing, has a heart rate greater than 100 beats per minute, but has central cyanosis[13]. Free flow oxygen, which is passively blowing oxygen over the baby's nose, may be given by an oxygen mask, flow inflating bag and mask, T-piece resuscitator, or oxygen tubing, with the latter being the least reliable method. *(see discussion on devices)* In order to ensure that the neonate receives a high concentration of oxygen, the mask should be held close to the face, but not so tight as to cause a build up of pressure similar to Continuous Positive Airway Pressure (CPAP) or Positive End Expiratory Pressure (PEEP). If using oxygen tubing, the hand should be cupped around the tubing and baby's face[13]. It is also recommended that administering unheated dry air at a flow rate greater than 10 L/min for an extended period of time be avoided. A flow rate of 5 L/min is usually sufficient during initial resuscitative efforts.

The standard approach to oxygen delivery in neonatal resuscitation has been to use 100% oxygen[12-14,18]. However, growing evidence suggest that resuscitating with room air (21% oxygen) may be just as effective as 100% oxygen. According to current recommendations, there is insufficient evidence to recommend a specific concentration of oxygen and/or oximetry goal during the initial resuscitative efforts in term neonates. Therefore in term infants, it is recommended that O_2 100% continue to be used.

On the other hand, concerns have been raised over the adverse effects of reactive oxygen intermediates which may potentially injure lung and tissues, especially in premature infants[18]. Thus, it is currently recommended that preterm infants are resuscitated with less than 100% oxygen, achieved by using an oxygen blender which allows for the mixing of oxygen and air from a compressed source to deliver a desired oxygen concentration. In infants with congenital heart disease such as single ventricle disorders, resuscitation with 100% oxygen can be detrimental to tissue perfusion. In general, the goal should be to maintain oxygen saturations between 85-95%, with 70-80% being acceptable during the first few minutes of life[13].

Supplemental oxygen is also recommended in neonates requiring positive pressure ventilation. Indications for positive-pressure ventilation with supplemental oxygen are infants who remain apneic, have a heart rate of <100 beat per minute after 30 seconds and/or continue to have central cyanosis after supplemental oxygen delivery[12-14].

Initial ventilation strategies in term infants

Studies have shown that in an infant who is apneic or gasping, administering positive pressure ventilation at a rate of 40-60 breaths per minute with 100% oxygen is usually effective in achieving a heart rate greater that 100 beats per minute[17]. The average initial peak pressures required to successfully ventilate an unresponsive term or preterm infant ranges from 30-40 cm H_2O; although 20 cm H_2O may be effective. It is recommended to use the minimum amount of pressures necessary to achieve adequate ventilatory response which is primarily indicated by a rapid improvement in heart rate. If there is no increase in the neonate's heart rate, chest wall movement should be assessed, the head and facemask should be repositioned, airway cleared and suctioned. After several failed attempts at assisted non-invasive ventilation, intubation is indicated[12-14].

Initial ventilation strategies in preterm infants

The lungs of preterm infants are more easily injured by large inflation volumes, yet tend to be more difficult to ventilate[13]. The same strategies used to initiate positive pressure ventilation in term infant may be employed in neonates as well. If positive pressure ventilation is required during the initial stabilization of a preterm infant, initial inflation pressure of 20-25 cm H_2O is usually adequate. Continuous positive airway pressure, about 4-6 cm H_2O, should also be considered in neonates who are demonstrating signs of poor respiratory effort and/or cyanotic. As in term infants, if after several failed attempts of assisted ventilation the neonate should be intubated[13,17].

Ventilation Devices

Ventilation of the neonates lungs can be achieved using several different devices: self-inflating bags, flow-inflating bags, T-piece resuscitator, laryngeal mask airways, and endotracheal tube[13]. Self-inflating bags are the most commonly used manual ventilation device due to accesibility[13]. They contain a pop off safety valve with a limited inflation pressure of 35 cm H_2O. However, when the bags are used vigorously, the pop off valves are not very effective. Bags of more than 450 ml have been shown to provide more consistent ventilation volumes. Obviously, these larger bags are designed for adults and would be inappropriate in the newborn. Positive end-expiratory pressure (PEEP) may be administered if a PEEP valve is attached but cannot be used to deliver CPAP. Also self-inflating bags cannot be used to deliver free-flow oxygen[13,17,19-20].

Flow inflating bags or anesthesia bags only fill when there is a source of compressed gas. They do not have a fixed safety pop off valve but may be used with or without manometer to regulate pressure. PEEP or CPAP can be administered using flow inflating bags and is controlled by an adjustable flow valve. Flow inflating bags can be used to deliver free-flow oxygen and are preferable in newborn resuscitation1[3,17,19-20].

T-piece resuscitator is an apparatus that is designed to not only control flow but also limit pressure. Compressed gas is delivered at a user determined pressure through one of the ports. The pressure delivered is depicted on the manometer. Target inflation pressures and inspiratory times are more consistently achieved with T-piece devices versus flow-inflating or self-inflating bags. There are some commercially available T-pieces which also allow for the maintenance of positive end-expiratory pressure between inflations. Finally, the T-piece can also be used to deliver free-flow oxygen[13,17,19-20].

The laryngeal mask airway (LMA) is capable of applying effective ventilation in situations where bag mask ventilation has been ineffective and endotracheal intubation is not possible in near or full term infant[13]. Traditionally the size 1 is used. (IS THERE A SIZE 0???) Currently there is not enough evidence to recommend its use as a primary airway in neonatal resuscitation, the setting of meconium stained amniotic fluid, delivery of drugs via the trachea, or when chest compressions are required[12-14,17].

Endotracheal tube placement is indicated for meconium suctioning of the trachea, mechanical ventilation after ineffective bag-mask ventilation, coordination of chest compression with ventilation, administration of epinephrine, and special resuscitative circumstances (i.e. congenital diaphragmatic hernia)[12-14].

Endotracheal intubation may take place at various points during resuscitation (see Figure 1-labeled A,B,C,D). In order to minimize hypoxia associated with intubation, the neonate should be pre-oxygenated, given free-flow oxygen and the procedure should be limited 20 seconds. Pre-oxygenation may not be possible if the reason for intubating is for suctioning of meconium[13]. Usually a straight blade is preferred for the procedure[13]. The No. 1 blade is used for term, No. 0 for preterm and No. 00 for extremely preterm. The size of the endotracheal tube chosen is based on weight of the neonate (see Table 4). Proper placement of the endotracheal tube is indicated by a rapid increase in heart rate, exhaled CO_2 detection, positive breath sounds, presence of chest movement, vapor in the tube, and no gastric distention with ventilation. If there is no improvement in heart rate and CO_2 is not detected, placement must be checked by direct laryngoscopy[13].

Table 4
Endotracheal Tube Size in Neonate

Tube size (mm)	Weight (g)	Gestational age
2.5	<1000	<28
3.0	1000-2000	28-34
3.5	2000-3000	34-38
3.5-4.0	>3000	>38

Adapted from AAP/*AHA Neonatal Resuscitation.* 5th Ed.

Chest Compression

Ventilation is vital to resuscitation efforts. Since, chest compressions can potentially compete with effective ventilation, it is important to ensure that assisted ventilation has been optimized prior to the start of chest compressions[12-14]. Chest compressions are indicated when the heart rate is less than 60 beats per minute despite adequate ventilation with supplemental oxygen for 30 seconds[13]. Chest compressions should occur at a rate of 90 per minute with a ratio of compression to ventilation of 3:1 (90:30). Compressions should be delivered on the lower third of the sternum at a depth one third the anterior posterior diameter of the chest. There are two possible methods which can be employed: the 2 thumb-encircling hands and 2 finger method. The 2 thumb-circling hands method is recommended because it is less tiring and allows for better depth control. However, the 2 finger may be preferred when access to the umbilicus is required for the placement of an umbilical catheter[13]. Respirations, heart rate and color should be reassessed approximately every 30 seconds. Coordinated chest compression and ventilations should be sustained until the spontaneous heart rate is greater than or equal to 60 beats per minute. Furthermore, simultaneous delivery of chest compressions and ventilation must be avoided[13].

Administration of Medications

Bradycardia in a newborn is usually attributed to inadequate lung inflation and hypoxemia[12]. Thus, in neonatal resuscitation efforts, the use of drugs is rarely indicated because the most important step in correcting bradycardia is establishing adequate ventilation. However, if medications are required, they can be given by three possible routes: umbilical vein, endotracheal tube and intraosseous, in that order..

Epinephrine

If the heart rate remains less than 60 beats per minute despite adequate assisted ventilation for 30 seconds and chest compression for an additional 30 seconds, the administration of epinephrine, a cardiac stimulant and peripheral vasoconstrictor, is indicated[13]. The current recommended dose of epinephrine is 0.01 to 0.03 mg/kg intravenous and a higher dose of 0.3 to 0.1 mg/kg if given endotracheal. Epinephrine may be given through the endotracheal tube to allow for faster administration while IV access is being obtained[12,14]. It is important to note that the safety and efficacy of the endotracheal use of epinephrine has not been evaluated; further reinforcing preference for the intravenous route[12-14].

Blood Volume Expanders

Blood volume expanders such as 0.9% NaC1, Ringer's lactate and O Rh-negative packed red blood cells are seldom indicated unless there is clear evidence of acute blood loss or shock such as weak pulse, poor perfusion, pale skin, and an infant who is responding poorly to other resuscitative efforts[13]. In general, the recommend dose of 10 ml/kg should be given over 5 to 10 minutes to avoid the risk of intraventricular hemorrhage[12-14].

Naloxone

Naloxone reverses neonatal respiratory depression associated with maternal opioids given during labor[13]. Currently, naloxone is not recommended for use in the initial resuscitative efforts in infants with respiratory depression. Heart rate and color should first be restored through supportive ventilation prior to the use of naloxone. The preferred route of administration is 0.1 mg/kg intravenous or intramuscular[12,14]. Naloxone has a shorter half-life than opioids that may be present in the neonates system. Therefore, the neonate should be closely watched for recurrence of respiratory depression and given additional doses as needed. It is important to note that naloxone should not be given to an infant born to an opioid addicted mother because it may precipitate acute withdrawal and seizures[12,14].

Neonatal hypoglycemia

Although there has been an association between hypoglycemia and poor neurological outcome, currently there have been no clinical trials demonstrating a poor outcome in hyperglycemic infants. Based on current availability of evidence, the AAP recommends maintaining glucose in the normal range. The optimal range of blood glucose values has not been clearly defined by the AAP[12].

Post Resuscitation

Although vital signs may have normalized, neonates are at continued risk for deterioration after resuscitation efforts. Therefore, the infant should be maintained in an environment which will allow for attentive monitoring and can provide preventative care[12,13].

Discontinuing of Withholding Resuscitation

When should resuscitative care be withheld or discontinued? According to the AAP Neonatal Resuscitation Guidelines, care should be withheld in cases of significant prematurity <23 weeks, birth weight <400 grams and congenital anomalies associated with early deaths such as anencephaly and trisomy 13. In situations when the prognosis is uncertain and morbidity rate is very high, the parental desire to initiate or continue life supportive measures should be considered[12-13].

Studies have shown that infants without signs of life after 10 minutes of resuscitation have an increased mortality rate and risk of severe neurodevelomental disability. Therefore, discontinuing continuous and adequate resuscitation after 10 minutes, if there are no signs of life, is justifiable[12-13].

Summary

Although only 10% of neonates born in the United States require resuscitation, availability of well trained personnel skilled in neonatal resuscitation can result in a significant decline in neonatal morbidity and mortality. One important aspect of performing a successful resuscitation is having a good understanding of the complex dynamics of fetal/neonatal physiology and the adaptations that must be made to transition to extrauterine life. This knowledge will allow one to better serve the resuscitative needs of the neonate. Performing a risk assessment by evaluating maternal and fetal risk factors is important. Review of medical history including medications, may reveal other medical conditions (e.g. gestational diabetes, preeclampsia, etc.). Once the need for resuscitation is recognized, easy access to equipment, medication and supplies can result in a successful resuscitative effort.

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