Anatomy & Physiology of Neonates

Physiology of Asphyxia –
The Lungs and Circulation

During intrauterine life, the lungs serve no ventilatory purpose because the placenta supplies the fetus with oxygen. At the time of birth, however, several changes need to take place for the lungs to take over the vital function of supplying the body with oxygen.

**Fetus**

Since the oxygen supplied to the fetus comes from the placenta, the lungs contain no air. The alveoli (air sacs) of the fetus are filled instead with fluid that has been produced by the lungs.

Since the fetal lungs are fluid filled and do not contain oxygen, blood passing through the lungs cannot pick up oxygen to deliver throughout the body. Thus, blood flow through the lungs is markedly diminished compared to that which is required following birth. Diminished blood flow through the lungs of the fetus is a result of the partial closing of the arterioles in the lungs. This results in the majority of blood flow diverted away from the lungs through the ductus arteriosus.

Following birth, the lungs expand as they are filled with air. The fetal lung fluid gradually leaves the alveoli.
Birth

At birth, as the infant takes the first few breaths, several changes occur whereby the lungs take over the lifelong function of supplying the body with oxygen.

In an attempt to establish normal respirations, the infant can develop problems in two areas:
- Fluid may remain in the alveoli;
- Blood flow to the lungs may not increase as desired.

Fetal Lung Fluid

At birth, the alveoli are filled with “fetal lung fluid.” It takes a considerable amount of pressure in the lungs to overcome the fluid forces and open the alveoli for the first time. In fact, the first several breaths may require two to three times the pressure required for succeeding breaths.

Approximately one-third of fetal lung fluid is removed during vaginal delivery as the chest is squeezed and lung fluid exits through the nose and mouth. The remaining fluid passes through the alveoli into the lymphatic tissues surrounding the lungs. How quickly fluid leaves the lungs depends on the effectiveness of the first few breaths.

Fortunately, the first few breaths of most newborn infants are generally effective, expanding the alveoli and replacing the lung fluid with air.
Problems Clearing Fluid

Problems clearing fluid from the lungs occur in infants whose lungs do not inflate well with the first few breaths. These are:
• Apnea at birth
• Weak initial respiratory effort

Apnea at Birth

With an infant who has never taken an initial breath, you can assume that no expansion of the alveoli has occurred and the lungs remain filled with fluid. When providing artificial ventilation to such an infant, additional pressure is often required to begin the process of expanding alveoli and clearing lung fluid.

Weak Respiratory Effort

Shallow, ineffective respirations may occur in premature infants or in infants who are depressed due to asphyxia, maternal drugs, or anesthesia. The gasping, irregular respiration’s that follow primary apnea may not be sufficient to properly expand the lungs. This means that you cannot rely on the presence of spontaneous respiration’s as an indicator of effective respirations in the newborn.

Pulmonary Circulation

It is not enough, however, merely to have air entering the lungs. There must also be an adequate supply of blood flowing through the capillaries of the lungs so that oxygen can pass into the blood and be carried throughout the body. This requires a considerable increase in the amount of blood flowing through (perfusing) the lungs at birth.

![Normal Pulmonary Perfusion](image1) ![Decreased Pulmonary Perfusion](image2)

Pulmonary Vasoconstriction

A term commonly used to refer to decreased pulmonary blood flow in the asphyxiated infant is pulmonary vasoconstriction.

Pulmonary + Vaso- + Constriction
(Of the lungs) (Vascular or Vessels) (Constricted)

This refers to the constriction of the vessels of the lungs. The vessels that open in the lungs of a normal infant remain in a constricted state in an asphyxiated infant.

![Newborn with Asphyxia](image3)  ![Normal Newborn](image4)
Cardiac Function and Circulation

Early in asphyxia, arterioles in the bowels, kidneys, muscles, and skin constrict. The resulting redistribution of blood flow helps preserve function by preferentially supplying oxygen and substances to the heart and brain.

As asphyxia is prolonged, there is deterioration of myocardial function and cardiac output. Therefore, blood flow to vital organs is reduced. This sets the stage for progressive organ damage.

**Physiology of Asphxia – Apnea**

When infants become asphyxiated (either in utero or following delivery), they undergo a well-defined sequence of events.

**Primary Apnea**

When a fetus or infant is deprived of oxygen, an initial period of rapid breathing occurs. If the asphyxia continues, the respiratory movements cease, the heart rate begins to fall, and the infant enters a period of apnea known as *primary* apnea. Exposure to oxygen and stimulation during the period of primary apnea in most instances will induce respirations.

**Secondary Apnea**

If the asphyxia continues, the infant develops deep gasping respirations, the heart rate continues to decrease, and the blood pressure begins to fall. The respirations become weaker and weaker until the infant takes a last gasp and enters a period of apnea called *secondary* apnea. During secondary apnea the heart rate, blood pressure, and oxygen in the blood (PaO₂) continue to fall further and further. The infant now is unresponsive to stimulation, and artificial ventilation with oxygen (positive pressure ventilation) must be initiated at once.
It is very important to realize that once the child is in secondary apnea, the longer you delay starting ventilation, the longer it will take the infant to develop spontaneous respirations. Even a very short delay in initiating artificial ventilation can result in a very long delay in establishing spontaneous and regular respirations. Also, and of great importance, the longer an infant is in secondary apnea, the greater is the chance that brain damage will occur.

**Primary vs. Secondary Apnea**

It is important to note that, as a result of fetal hypoxia, the infant may go through primary apnea and into secondary apnea while in utero. Thus an infant may be born in either primary or secondary apnea. In a clinical setting, primary and secondary apnea are virtually indistinguishable from one another. In both instances the infant is not breathing, and the heart rate may be below 100 per minute.

![Diagram of primary and secondary apnea](image)

A newborn infant in primary apnea will reestablish a breathing pattern (although irregular and possibly ineffective) without intervention. An infant in secondary apnea will not resume breathing of his or her own accord. Positive-pressure ventilation will be required to establish respirations.

**Anticipation**

Most neonatal resuscitation can be anticipated.

- Crew should be prepared to handle problems more often than they are actually encountered.
- Delivery of asphyxiated infants often can be anticipated on the basis of the antepartum and intrapartum histories.

Two major factors for prompt, effective resuscitation are:

- Anticipation of need for resuscitation,
- Adequate preparation of equipment and personnel.
When Asphyxia Is Anticipated

High Risk Delivery: Possible Asphyxia

1) **Mother**
   - Age > 35
   - diabetes
   - alcohol/substance abuse
   - history – stillbirth

2) **Pregnancy**
   - antepartum haemorrhage
   - pre-eclampsia
   - multiple births
   - no antenatal care

3) **Delivery**
   - abnormal presentation
   - pre or post term
   - prolonged labour
   - prolapsed cord
   - meconium – stained fluid (amniotic)
   - fetal distress (heart rate < 120/min)
   - dry, discard wet towels, new warm towels and/or blankets
   - suction during birth when possible

The ABCs of Resuscitation

The steps in resuscitating newborn infants follow the well-known “ABCs” of resuscitation.

A- airway
B- breathing
C- circulation

The **components** of the neonatal resuscitation procedure as related to the ABCs of resuscitation are:

A- Establish an open **airway**:
   - Position the infant.
   - Suction the mouth and nose.

B- Initiate **breathing**:
   - Use tactile stimulation to initiate respirations.
   - Employ positive-pressure ventilation when necessary, using:
     - Bag and valve mask

C- Maintain **circulation**:
   - Stimulate and maintain the circulation of blood with:
     - Chest compressions
The Action/Evaluation/Decision Cycle

A very important aspect of resuscitation is evaluating the infant, deciding what action to take, and then taking action. Further evaluation data is the basis for more decisions and further actions. This cycle can be represented by the following diagram.

The Cycle

Efficient and effective resuscitation is brought about through a series of actions, evaluations, decisions, and further actions. As an example, at one point while you are providing tactile stimulation, you will evaluate the infant’s respirations. On the basis of that evaluation, you will decide what action to take.

If your evaluation of the respirations indicates that the infant is not breathing or that the respirations are inadequate, you have the basis for deciding that the next action is to provide positive-pressure ventilation. If, on the other hand, the respirations are normal, the next action should be to evaluate the infant’s heart rate. After the initiation of any action, you must evaluate its effect on the neonate and make a decision about the next step.

Signs to Evaluate

The Apgar score is not used in determining when to initiate a resuscitation or in making decisions regarding the course of resuscitation. Evaluation is primarily based on the following three signs:

- Respirations
- Heart Rate
- Colour
Principles of a Successful Resuscitation

The longer an infant is allowed to go without adequate resuscitation, the more difficult the resuscitation becomes.

Delayed or ineffective resuscitation efforts can:
- Make the resuscitation more difficult
- Increase the likelihood of brain damage

When resuscitation is delayed or incorrectly performed, resuscitating the infant will take longer and be harder than if prompt, appropriate action had been taken. Quickly clearing the airway and skillfully providing a brief period of ventilation may maintain oxygenation and pulmonary perfusion thereby negating the need for chest compressions.

An insufficient amount of oxygen can result in brain damage.

The brain must have a constant supply of oxygen in order to function properly. The longer the brain remains without oxygen, the greater the chance that irreparable damage to the cells will occur. Damage to other organs also can result from inadequate oxygen. In addition to the brain, those organs most likely to suffer damage are the bowel, lungs, kidneys, and heart.

The following five steps, if followed closely, will increase the likelihood of a successful resuscitation:

1. Readily Available Personnel/Team
   This should be the case even when a normal birth of a healthy infant is anticipated. One can never be certain that the need for resuscitation won’t arise. Each person should know what his or her specific responsibilities are, and he or she must be capable of carrying them out.

2. Skilled Personnel
   Personnel at the delivery must not only know what they have to do, but they must be able to do it efficiently and effectively. The required skills must be practiced before they are to be used. Also, steps should be taken to be certain that the skills (and the related knowledge) are maintained through frequent use or scheduled practice.

3. Coordinated
   Personnel involved in resuscitating an infant must work together as a coordinated team or unit. This concept is important throughout all stages of the resuscitative effort. Personnel must not only possess the skills and know exactly what their responsibilities are, but they must be able to coordinate their efforts for an efficient and effective resuscitation.

4. Resuscitation Tailored to the Patient Response
   The initial resuscitation procedures should be initiated promptly, and each further step must be selected on the basis of specific patient response.

   Neonatal resuscitation is not one procedure applicable to all infants, nor is it a collection of random events. The total resuscitation procedure is made up of a unified and coordinated series of steps. Each succeeding step logically follows the previous one, based on an evaluation of the infant’s condition and response.
5. **Available and Functioning**

Wherever newborn infants are cared for, appropriate resuscitation equipment should be immediately available and in working order. The consequences resulting from a delay in initiating therapy can be devastating. The cost of having appropriate resuscitation equipment at hand cannot begin to match the cost of a damaged infant.

**Neonatal Resuscitation**

It is important for all emergency health care providers to be knowledgeable and experienced in dealing with perinatal emergencies. Approximately 6% of all births require some degree of neonatal resuscitation, bearing in mind the majority of these infants are premature. Over the past decade a great emphasis has been given to neonatal resuscitation by the paediatric community.

The American Academy of Pediatrics and the American Heart Association have developed standards and guidelines for neonatal resuscitation. The emphasis is to provide each health care person with a standard approach to every neonate, providing more or less support as the infant requires. The care that may be required is depicted as an inverted pyramid. The interventions, which are most commonly required, are at the top of this pyramid. As you progress down the pyramid the interventions indicated become less commonly required.

**Assess and Support:**
- Temperature (warm and dry)
- Airway (position and suction)
- Breathing (stimulate to cry)
- Circulation (heart rate and color)

**Always Needed**

The inverted pyramid reflects relative frequencies of neonatal resuscitation efforts for the newborn who does not have meconium-stained amniotic fluid. Note that a majority of newborns respond to simple measures.

**The Normal Newborn**

Neonates are different than any other population of patients. A neonate is classified as all infants up to 28 days post due date. If the baby is born at 40 weeks gestation, he is a neonate for 4 weeks. If the infant is born at 30 weeks gestation, he will be a neonate for 14 weeks. 

*(10 weeks to correct to term age and a subsequent 28 days).*
Anatomical Differences Include:

1. 1/3 of body length is the head which can lose a great deal of heat.
2. Molding of skull bones for delivery causes a prominent crown, which can flex the infants neck causing an airway obstruction.
3. Newborns breathe though their nares.
4. Copious secretions may be present for hours post delivery.
5. Babies near term have brown fat stores, which provide an internal heat source, they do not have the ability to shiver to generate heat.
6. Respiratory rates can be irregular and erratic.
7. Heart rates are typically 120 to 160 per minute.
8. Acrocyanosis (peripheral cyanosis) is a normal transient finding in most neonates which requires no intervention.
9. Mild jitteriness, and uncoordinated movements are normal.
10. Many newborns are quiet and very alert post delivery.
11. Infants have reflexes that they may exhibit such as the grasp reflex, sucking reflex, rooting reflex, and moro or startle reflex.
12. Physical features can also assist with estimation of gestational age. These include:
   
   a) Amount of subcutaneous fat  
   b) Amount of skin pigment  
   c) Nipple development  
   d) Ear cartilage development  
   e) Amount of lanugo (fine body hair)  
   f) Depth of sole creases  

13. The neonate should also be examined for congenital anomalies, which is estimated to occur in 3% of all live births.

   a) Life threatening  
      - airway problems  
      - cardiac anomalies  
      - facial anomalies  
      - open lesions of the spinal cord or of abdominal contents.  
      - bruising or pallor from birth trauma

   b) Non life threatening  
      - birth marks  
      - extra fingers or toes  
      - club foot

Standard Approach to all Neonates at Birth

Dry

Take the time to thoroughly dry the infant of all amniotic fluid and vernix. Place the infant on a dry surface and remove the used towels. Use warmed blankets or towels if possible. Warm towels in a clothes dryer, never a microwave. Artificial heat sources can cause burns and need to be used very cautiously. Cover all heat sources with a towel. Warm back of ambulance & blankets next to heaters.
Opening the Airway

Once the infant has been placed in a warm environment and dried, the next step is to assure the “A” of our ABCs – (the establishment of an open airway). This is accomplished by:
- **Positioning** the infant correctly, and
- **Suctioning** the infant’s mouth and then nose to clear the airway

Position

The neonate should be placed on his or her back or side with the neck slightly extended. A slight trendelenburg position may be helpful.

![Correct Position](image)

Care should be taken to prevent hyperextension or underextension of the neck since either may decrease air entry.

Incorrect

![Incorrect Position](image)

Clear the airway of any secretions by gently suctioning the mouth first, then the nose. Wall suction should be set at 80 - 100mHg pressure, attached to a # 8 or # 10 french suction catheter. A Delee with neosafe bulb suction may be used. Suctioning episodes should be limited to 3-5 seconds and only during withdrawal of the catheter. Be cautious while suctioning, stimulation of the posterior pharynx during the first few minutes after birth can produce a vagal response, causing severe bradycardia or apnea.
**Shoulder Roll** (optional)

To help maintain the correct position, you may place a rolled blanket or towel under the shoulders, elevating them ¾ to 1 inch off the mattress. This shoulder roll may be particularly useful if the infant has a large occiput resulting from molding, edema, or prematurity.

![Shoulder Roll Illustration]

**Turning Head**

If the infant has copious secretions coming from the mouth, you may turn the head to the side. This will allow secretions to collect in the mouth, where they can be easily removed, rather than in the posterior pharynx.

![Turning Head Illustration]

**Tactile stimulation**

Drying and suctioning will provide enough stimulation for most infants to initiate respirations. Sometimes babies will respond to flicking or slapping of the feet or firm rubbing of the back with an open palm. Take no longer than 20 seconds to try this before moving to assisted ventilation.

![20 seconds Timer]
**Practice** (complete within 20 seconds)
- Dry neonate
- Remove wet towels
- Position on back, slightly trendelenburg, neck slightly extended, roll under shoulders (optional)
- Suction: mouth then nose
- Tactile stimulation – flick feet, rub back

**Reassess**

Is the baby breathing?
What is the heart rate?
What is the colour?

- Ensure thermoregulation techniques are provided
- Warmed towels or blankets
- Wrap the baby tightly in blankets
- Cover head with a cap or in blankets
- Give baby to mother to hold
- Increase temperature in vehicle

For infants who require further stabilization based upon above reassessment the following may be required:
Overview of Neonatal Resuscitation

In Pre-Hospital Environment

1. Immediate confirmation after birth
2. Initial assessment for breathing
3. Immediate chest compressions, if necessary
4. Early endotracheal intubation
5. Respiratory support

Diagram:

- Above 100
- Below 60
- 60-80
- Below 60
- If HR below 60
- Continue CPR 30-60 seconds
- Continue ventilation
- Continue CPR
- Above 100
- If HR below 60
- Continue CPR
- Continue ventilation

Note: Diagram illustrates the steps in neonatal resuscitation, including checking for spontaneous breathing, assessing heart rate, and providing chest compressions if necessary.
Caution:
The blood vessels of the retina in the premature infant are extremely sensitive to hyperoxia. It is important to wean or remove oxygen from premature infants who are pink. Cyanotic infants do not suffer from hyperoxia therefore give 100% oxygen.

Positive Pressure Ventilation
Assisted ventilation is indicated for infants who are apneic or have gasping respirations, for infants with a heart rate less than 100, and for infants who remain cyanotic despite 100% oxygen.

Oxygen remains at 100% concentration through the self-inflating bagging system. This bagging system requires an oxygen reservoir to ensure high oxygen concentration during resuscitation. The mask should be cushioned and cover the chin, nose and mouth, but not place pressure over the eyes. The cushioned rim creates a good seal on most neonates, even when facial swelling has occurred at delivery. Ventilate at rate of 40-60 per minute and support of the infants head should be provided.

Assessment of ventilation includes looking for chest rise and improvement in colour. A symmetrical smooth chest rise is desirable rather than short bursts of inspiration. Auscultation for air entry is essential but may be difficult to assess as newborn lungs are often contain fluid.

After 15 to 30 seconds of PPV the infant’s heart rate should be assessed using the six-second check. Auscultate the apex or palpate the base of the cord stump for 6 seconds. Multiply this number by 10 and this is a 1-minute heart rate. The heart rate is a critical determinant of the neonate’s response to resuscitation.

Cardiac Compressions
Cardiac compressions are indicated for infants who fail to respond to PPV by remaining bradycardic, specifically infants with a heart rate less than 60 or with a heart rate of 60 – 80 and not improving.

The current recommended method of performing compressions include synchronizing compressions with ventilations at a 5:1 ratio. Compression rate is 100 per minutes with 20 ventilations. In order to ensure adequate compression and ventilation cycles the rate of each has been reduced from previous guidelines. Depth of compression is ½ -1”. There are 2 accepted hand positions. You can use the two-finger method with the middle and ring fingers placed on the sternum below the nipple line. If your hands are large enough you can place 2 thumbs on the sternum with the hands encircling the chest. This chest support is thought to provide better venous return to the heart.

Reassessment of the heart rate with a six-second check is done every 30 seconds. The neonatal chest is quite pliable, bruising with compressions is common, cuts and scratches from fingernails are also likely to occur.
**Oxygen Administration**

Oxygen should always be administered at 100% concentration for resuscitation purposes. Increase of the infants PaO2 enhances the perfusion of the lungs and closure of fetal cardiac shunts promoting transition to extrauterine life.

If respirations are/become adequate with previous measures, and heart rate is > 100/minute, but central cyanosis is present:

- Administer free flow humidified oxygen (5 – 6 L/minute) via oxygen tubing, hold tubing about ½” from the infant’s nose. Alternately, attach the tubing to an oxygen mask and hold the mask firmly over the infant’s face, or create a small “tent” above the infant’s head with tin foil or a blanket.

- Gradually withdraw oxygen when the infant become pink; re-administer and withdraw as required for recurrent central cyanosis.