Continuing Medical Education

Neonatal resuscitation: the NRP guidelines

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The Neonatal Resuscitation Programme, sponsored by the Canadian Heart and Stroke Foundation and by the American Heart Association, is a structured learning package and workshop for all individuals who provide resuscitation for newborns. The emphasis is on rapid, decisive action using algorithms based on clearly stated criteria. This CME article serves as an introduction to the NRP and discusses some of the new guidelines regarding concurrent ventilation and chest compressions, tracheal suction for meconium and the use of medications. The author encourages readers who find this article helpful to register in an accredited NRP course to receive the extensive illustrated textbook and to benefit from the "hands-on" nature of the workshop.

Le programme de réanimation néonatale (PRN), parrainé par la Fondation des Maladies du Coeur du Canada et l'American Heart Association constitue un module structuré d'enseignement et de formation pour tous ceux qui ont à pratiquer la réanimation du nouveau-né. On y met l'accent sur une action rapide et décisive à partir d'organigrammes basés sur des critères clairement énoncés. Cet article d'EMC sert d'introduction au PRN et traite des nouvelles lignes de conduites élaborées pour la ventilation et les compressions thoraciques simultanées, l'aspiration trachéale de méconium et l'administration des médicaments. Les lecteurs qui trouvent cet article utile sont incités par l'auteur à s'enregistrer à un cours de PRN accrédité pour recevoir le manuel illustré et bénéficier du de l'apprentissage que procure l'atelier.

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Approximately one of every sixteen newborns will require resuscitation of some kind in the delivery room. Every individual who is involved in providing care for both mother and baby at the time of delivery should ensure that he or she has the knowledge and skills needed for neonatal resuscitation. In much the same way that adult cardiopulmonary resuscitation was standardized in the recent past, a major effort is now under way to give delivery-room care-providers a set of neonatal resuscitation guidelines within a structured learning package. The result, based on the pioneering work by Ronald S. Bloom, MD, and Catherine Cropley, RN, MN, is the Neonatal Resuscitation Program (NRP), supported in the United States by the American Heart Association and the American Academy of Pediatrics. In Canada, support for the NRP has come mainly from the Heart and Stroke Foundation, at both national and provincial levels, working with a dedicated group of nurses, paediatricians, respiratory technologists and anaesthetists.

The purpose of this CME article is to introduce the reader to the Neonatal Resuscitation Programme and to stimulate interest in developing neonatal resuscitation skills, perhaps by attending an NRP Workshop and becoming a certified NRP Provider.

Overview

The NRP has been carefully designed in a modular fashion, with each module emphasizing a particular skill vital for a successful resuscitation. The modules represent the progressive steps that would occur during a full resuscitative effort of a severely depressed neonate. The modules are as follows:

1 Preparation for delivery
2 Initiation stabilization
3 Ventilation – bag and mask
4 Chest compressions
5 Tracheal intubation
6 Medications

The modular form of the NRP allows tailoring the instruction to the qualifications of the care-provider taking the course. A nurse might be trained up to and including chest compressions and how to assist with tracheal in-

tubation, while physicians would be trained to provide all resuscitative steps. For either nurse or physician, the instructional material is the same for each module, thus ensuring a common ground for good communication and teamwork during an actual resuscitation.

Asphyxia – the basics

Apnoea

1 the asphyxiated infant passes through a series of events:
   - rapid breathing and decrease in heart rate
   - *primary apnoea*
   - irregular gasping, further decrease in heart rate and drop in blood pressure
   - *secondary apnoea*
2 Most infants in primary apnoea will resume breathing when stimulated. Once in a secondary apnoea, infants are unresponsive to stimulation.
3 Apnoea at birth should be treated as secondary apnoea of unknown duration (i.e., began *in utero*) and resuscitation should begin at once.

Clearing fetal lung fluid

1 The first few breaths of a normal infant are usually adequate to expand the lungs and clear the alveolar lung fluid.
2 The pressure required to open the alveoli for the first time may be two to three times that for normal breaths.
3 Expect problems in lung fluid clearance with:
   - apnoea at birth
   - weak initial respiratory effort caused by
     - prematurity
     - depression by asphyxia, maternal drugs, or anaesthesia

Pulmonary circulation

1 At birth, pulmonary blood flow increases rapidly as the lung arterioles open up and blood is no longer diverted through the ductus arteriosus.
2 With asphyxia, hypoxaemia and acidosis perpetuate pulmonary vasoconstriction and maintain the fetal pattern of circulation.

Systemic circulation and cardiac function

1 Early in asphyxia, vasoconstriction in the gut, kidneys, muscles and skin redistributes blood flow to the heart and brain as an attempt to preserve function.
2 With progressive hypoxaemia and acidosis, myocardial function deteriorates and cardiac output declines.

Preparation for delivery

ANTICIPATE NEED FOR RESUSCITATION

1 Antepartum and intrapartum history may help to alert delivery-room staff about the possibility of a depressed or asphyxiated newborn (Table I).

TABLE I

Antepartum factors	*Intrapartum factors*
Age >35 yr	Abnormal presentation
Maternal diabetes	Operative delivery
Pregnancy-induced hypertension	Premature labour
Chronic hypertension	Premature rupture of membranes
Other maternal illness (e.g., CVS, thyroid, neuro)	Precipitous labour
Previous Rh sensitization	Prolonged labour
Drug therapy (e.g., magnesium, lithium, adrenergic-blockers)	Indices of fetal distress (FHR abnormalities, biophysical profile)
Maternal substance abuse	Maternal narcotics (within four hours of delivery)
No prenatal care	General anaesthesia
Previous stillbirth	Meconium-stained fluid
Bleeding – 2nd/3rd trimester	Prolapsed cord
Hydramnios	Placental abruption
Oligohydramnios	Placenta previa
Multiple gestation	Uterine tetany
Post-term gestation	
Small-for-dates fetus	
Fetal malformations	

Personnel

1 At *every* delivery, at least one individual should be capable of performing a complete resuscitation (i.e., including tracheal intubation and the use of medications). In many cases, this is the person delivering the infant.
2 A second person who will be primarily responsible for the infant must be present in the delivery room, even for cases when a normal infant is expected. This person must be able to initiate a resuscitation and, if a complete resuscitation becomes necessary, assist the fully trained person.
3 When neonatal asphyxia is anticipated, two individuals whose sole responsibility is to the infant should be present in the delivery room and be prepared to work as a team to perform a complete resuscitation. The person delivering the mother must not be considered as one of the two resuscitators.
4 With multiple births, a team is needed for each infant.
5 There should be no delay in initiating resuscitation; waiting a few minutes for someone "on-call" to arrive is an unacceptable practice and invites disaster.

Equipment

1 Equipment and medications should be checked as a daily routine and then prior to anticipated need. Used

TABLE II Resuscitation equipment in the delivery room

Radiant heater	Suction with manometer
Stethoscope	Bulb syringe
ECG monitor	Suction catheters (5F or 6F, 8F and 10F)
Wall oxygen with flowmeter and tubing	Endotracheal tubes (2.5, 3.0, 3.5, and 4.0 mm
Neonatal resuscitation bag with manometer	ET tube stylet
Face masks, oral airways (newborn and premature)	Laryngoscope with straight blades, # 0 & 1
Medications	Umbilical vessel catheterization tray
- Epinephrine (1:10,000)	Umbilical catheters 3.5 and 5F
- Naloxone (0.4 or 1 mg · ml^{-1})	Needles, syringes
- Volume expander	Feeding tube 8F + syringe
Sodium bicarb (0.5 mEq · ml^{-1})	

items should be replenished as soon as possible after a resuscitation (Table II).

2 The delivery room should be kept relatively warm and the radiant heater should be preheated when possible. Prewarming of towels and blankets can also be helpful in preventing excessive heat loss from the neonate.

Initial stabilization (Flow Chart)

Prevent heat loss

1 Place the infant under an overhead radiant heater to minimize radiant and convective heat loss.

2 Dry the body and head to remove amniotic fluid and prevent evaporative heat loss. This will also provide gentle stimulation to initiate or help maintain breathing.

Open the airway

1 Position the infant supine or on his or her side with the neck either in a neutral position or slightly extended. Avoid overextension or flexion which may produce airway obstruction. A slight Trendelenburg position may also be helpful.

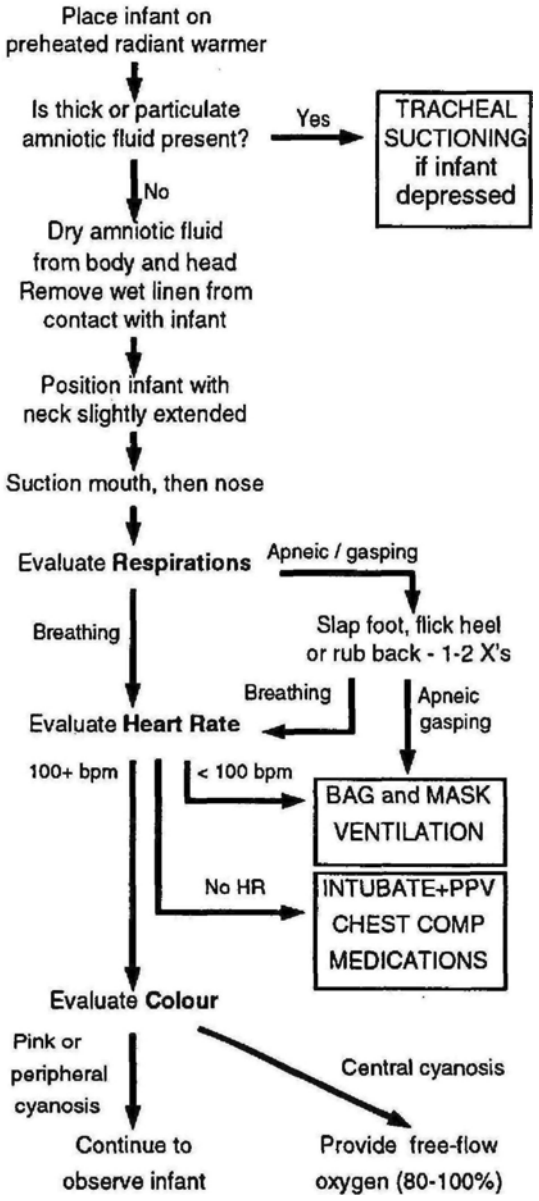
2 A folded towel (approximately 2.5 cm thick) placed under the infant's shoulders may be useful if the infant has a large occiput.

3 If the infant has *absent, slow or difficult respirations*, apply suction first to the mouth and then to the nose. If the nose were cleared first the infant may gasp and aspirate secretions into the pharynx. If mechanical suction with an 8F or 10F catheter is used, make sure the vacuum does not exceed −13.3 kPa (−100 mmHg). Limit suctioning to five seconds at a time and monitor heart rate for bradycardia which may be associated with deep oropharyngeal stimulation.

4 If meconium is present in the amniotic fluid, special suctioning may be required in the *depressed* infant. (See Tracheal Intubation below.)

Flow Chart: Initial Stabilization

The steps in this section should take no longer than 20 seconds.



Tactile stimulation

1 If drying and suctioning do not induce effective breathing, additional safe methods include:
- slapping or flicking the soles of the feet
- rubbing the back gently

2 Do not waste time continuing tactile stimulation if there is no response after 10–15 sec.

Evaluate the infant

1 *Respirations*: Infants who are apnoeic or gasping despite brief stimulation attempts should receive positive-pressure ventilation. If there is adequate spontaneous breathing, go to next step.

2 *Heart rate*: Monitor either by auscultating the apical beat or by palpating the base of the umbilical cord. If the heart rate is below 100 bpm, begin positive-pressure ventilation, even if the infant is making some respiratory efforts. If the heart rate is above 100 bpm, go to the next step.

3 *Colour*: The presence of central cyanosis indicates that although there is enough oxygen passing through the lungs to maintain the heart rate, the infant is still not well oxygenated. Free-flow 100% oxygen at 5 L · min^{-1} using a mask held closely to the infant's face should be administered until the infant becomes pink, when the oxygen should be gradually withdrawn.

Ventilation – bag and mask (Flow Chart)

Equipment and technique

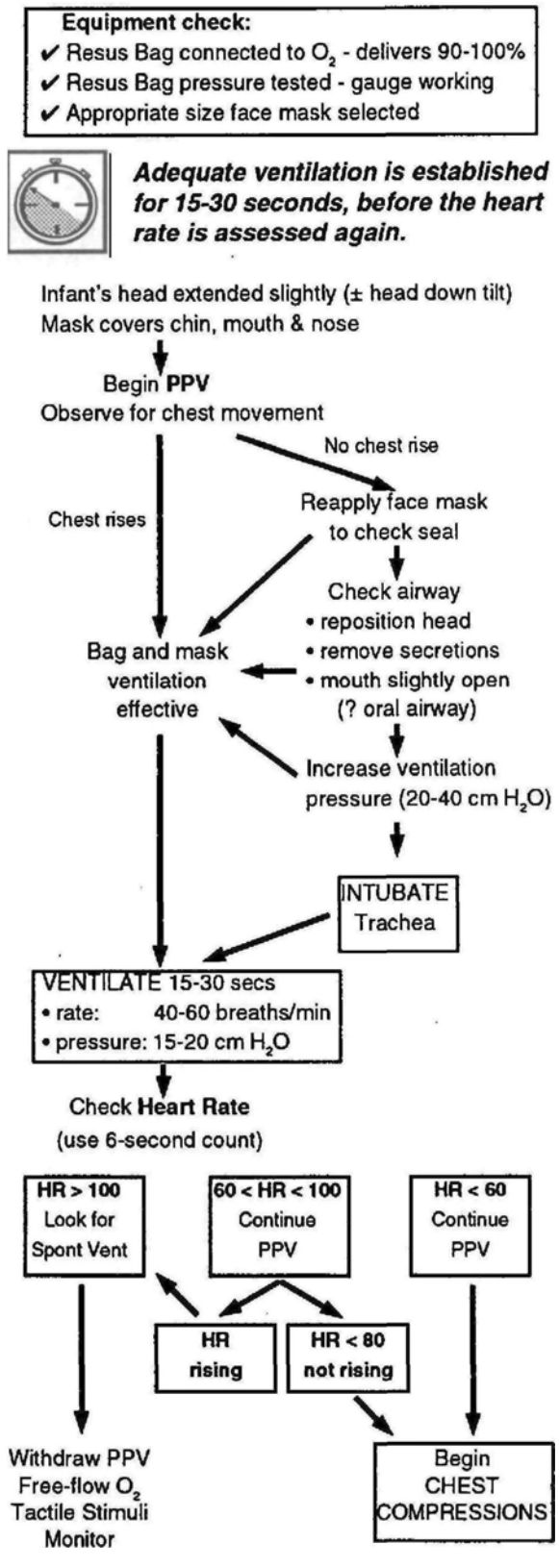
1 *Anaesthesia bag*: This piece of ventilating equipment requires a gas flow source to inflate. Maintaining the appropriate degree of inflation during bag and mask ventilation requires practice. With the oxygen flowmeter set to 5–8 L · min^{-1} and the oxygen tubing attached to the gas inlet nipple, inflation depends on a tight seal between face and mask and control of the gas outflow at the end of the reservoir bag. Control is probably best accomplished by the resuscitator's own thumb and index finger squeezing the open end of the reservoir bag and regulating the resulting pressure in the bag by observing an attached pressure gauge. If the reservoir bag has a flow-control valve at the distal end, inflation control is a balance between the amount the valve is closed and the flow-rate of the incoming oxygen.

The advantages of the anaesthesia bag are:

- it delivers 100% oxygen to the infant
- higher peak inspiratory pressures are possible if required (pressure gauge mandatory)
- free-flow 100% oxygen can be administered through the circuit (without bag inflation)

2 *Self-inflating bags*: Inflation is dependent on the inherent elasticity of the reservoir bag and not on the rate of gas flow. These bags have a second gas inlet in addition to the one for oxygen. This inlet enables air to be entrained as the bag reinflates to allow rapid expansion but thereby reduces the inspired oxygen concentration to approximately 40%. By adding an extra reservoir on this secondary inlet one can increase the delivered oxygen concentration to the 90–100% range.

Flow Chart: Ventilation



Other points of note regarding the self-inflating bag include:
- most are equipped with a pressure-limiting pop-off valve that is pre-set to 30–35 cm H_2O (may not be able to generate enough pressure in some circumstances)
- delivery of O_2 occurs *only* when the bag is compressed (not suitable for free-flow O_2!)

3 *Face masks*: Every delivery room should have a variety of sizes: preterm, term and large newborn (i.e., sizes 0, 1 and 2). Anatomically shaped face masks with cushioned rims are recommended because of better fit and tighter seal. A properly fitting mask should cover the chin, mouth and nose and not put pressure on the infant's eyes.

Ventilating procedure

1 When ventilatory support is required, the lungs of most neonates can be adequately ventilated with a bag and mask. Positive-pressure ventilation (PPV) is indicated when:
- apnoea or gasping respiration is present
- the heart rate is less than 100 beats · min^{-1}
- central cyanosis persists despite 100 O_2

2 Ventilation should be adequate with 40 to 60 assisted breaths per minute. Initial lung inflation may require a pressure as high as 30–40 cm H_2O but subsequent breaths should be in the 15–20 cm H_2O range.

3 Adequate ventilation is assessed by observing chest wall motion and hearing breath sounds bilaterally. If chest expansion is inadequate, the following steps should be followed in sequence:
- reapply the face mask to rule out a poor seal
- reposition the head – extend the head a bit further – reposition the shoulder towel
- check for secretions – suction if necessary
- try ventilating with the infant's mouth slightly open – perhaps with an oral airway
- increase pressure to 20–40 cm H_2O
- abandon bag and mask – intubate trachea

4 After 15–30 sec of effective ventilation, the heart rate of the neonate should be evaluated. To save valuable time, the heart rate over a six-second period is counted and multiplied by ten to given an approximation of the one-minute heart rate (e.g., eight beats in six seconds = 80 bpm).

The next step in the resuscitation depends on the heart rate which is determined:

HR>100	If spontaneous breathing efforts are present, gradually reduce PPV and provide gentle tactile stimulation plus free-flow O_2.
HR<60	Immediately begin chest compressions and ensure that ventilation is adequate and that 100% O_2 is being delivered.
60<HR<80 (not increasing)	Continue ventilation and begin chest compressions.
60<HR<100 (increasing)	Continue ventilation

Chest compressions (Flow Chart)

Rationale

1 Asphyxia in the neonate not only slows the heart rate but also decreases myocardial contractility, resulting in diminished flow of blood and oxygen to vital organs. Chest compressions can temporarily increase circulation and oxygen delivery.

2 Chest compressions must always be accompanied by ventilation with 100% oxygen.

3 Pressing on the sternum compresses the heart and increases the intrathoracic pressure, causing blood to be pumped into the arterial circulation. Release of the sternal pressure will increase venous blood to return to the heart.

Indications

1 *When to begin chest compressions*:
After 15–30 sec of PPV with 100% O_2
- the heart rate is <60 bpm
- the heart rate is between 60 and 80 and not increasing

2 *When to stop chest compressions*:
- the heart rate is 80 bpm or greater

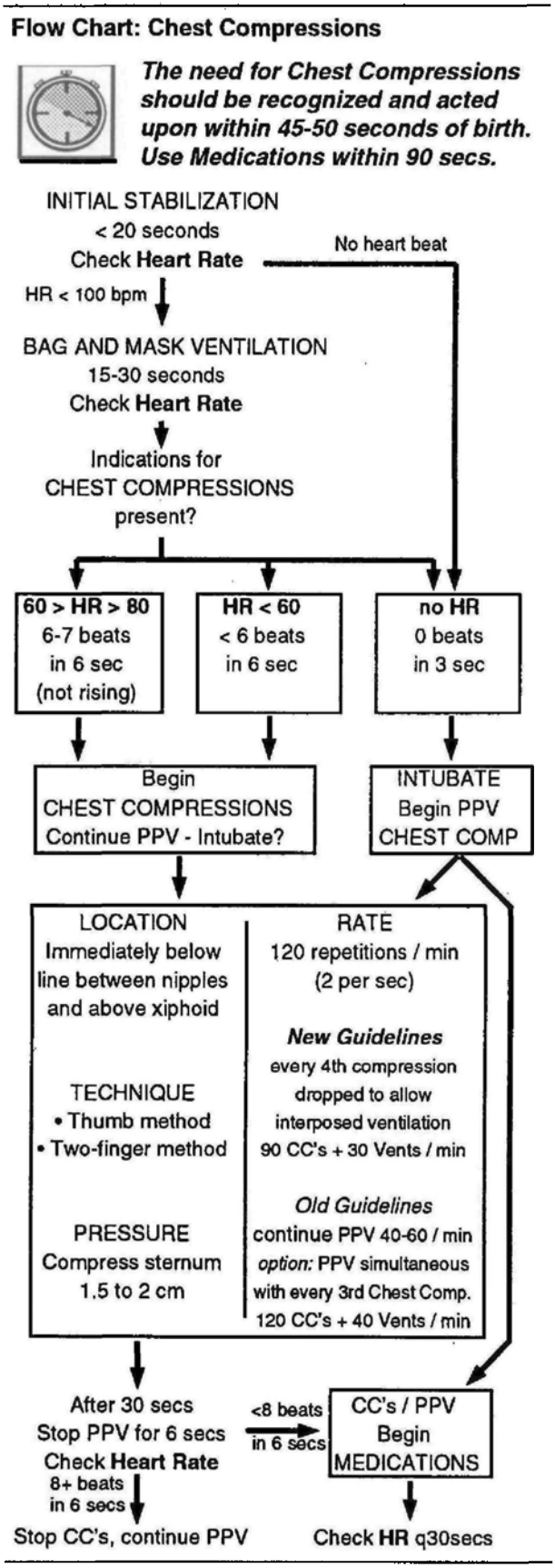
Technique (Figure 1)

1 *Location*: Pressure should be applied to the middle third of sternum, just below an imaginary line drawn between the nipples. Take care not to apply pressure to the xiphoid.

2 *Thumb method*: Encircle the torso with both hands and compress the sternum with both thumbs side-by-side while the fingers support the back. In very small neonates the thumbs may have to be superimposed. Use just the tips of the thumbs to compress to avoid squeezing the whole chest wall and fracturing ribs.

3 *Two-finger method*: This method is used if the resuscitator's hands are too small to encircle the chest properly or if access to the umbilicus is necessary for medications. The middle and ring fingers of one hand are held perpendicular to the chest and the tips apply pressure to the sternum while the other hand is used to support the back from below.

4 *Pressure*: Use just enough pressure to depress the sternum 1.5 cm, then release the pressure to allow the



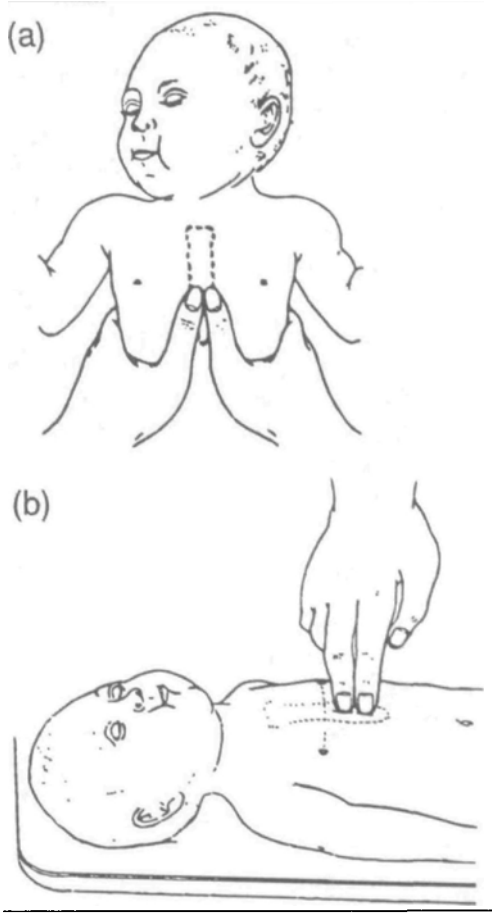


FIGURE 1 (a) Thumb method of chest compression. (b) Two-finger method of chest compression. Reproduced with permission. © Textbook of neonatal resuscitation, 1987, 1990. Copyright American Heart Association

heart to fill. One compression consists of the downward stroke plus the release.

5 *Rate*: To match the heart rate of the normal neonate, the compress/release action should be repeated 120 times per minute (two per second).

6 *Cautions*: Do not remove the tips of your fingers from the chest. You may waste time relocating the compression site or end up compressing the wrong area, producing broken ribs with the possibility of pneumothorax or a lacerated liver. To make sure the circulation produced by the chest compressions is adequate, the rate and the depth of the compressions must be consistent.

Ventilation during chest compressions

1 Positive-pressure ventilation must always accompany chest compressions. The most recent guidelines recommend interposing chest compressions with ventilation, suggesting that simultaneous PPV and chest compres-

sions may affect the efficiency of ventilation, particularly when using a bag and mask, by forcing air into the stomach. (This is probably less of a factor if the infant's trachea is intubated.)

2 A 3:1 ratio of chest compressions to ventilation is recommended. The three compressions are followed by a pause to interpose an effective breath. The combined rate of compressions with ventilation should be 120 per minute – resulting in 90 compressions and 30 ventilations each minute.

3 Although bag and mask ventilation can be performed effectively over a prolonged period of time, ventilation is much easier if the infant's trachea is intubated. However, it is vital that one remembers that the priority is ventilation and not intubation, particularly if the intubation proves difficult. Should prolonged PPV by bag and mask be necessary, an orogastric tube should be passed to prevent distension of the stomach.

4 In the neonate whose trachea is intubated, particularly with mechanical ventilation, one may wish to perform the chest compressions (120 per minute) and ventilation (40–60 per minute) independently of each other.

Evaluating the heart rate

1 After the first 30 sec of chest compressions, the heart rate should be checked.

2 During the heart rate check, the chest compressions are interrupted for no more than the six seconds it takes to count the heart beats and make the calculation.

3 If the infant is showing a positive response to the resuscitative efforts then one should check the heart rate every 30 sec in order to stop chest compressions when the infant's own heart rate increases to 80 or above. Ventilation should be continued until the heart rate is >100 bpm.

4 Should the infant's heart rate remain <80 bpm despite *at least 30 sec of adequate chest compressions and ventilation*, resuscitation should progress rapidly to the next step of giving medications.

Tracheal intubation

Indications

1 In most cases, when positive-pressure ventilation is required, it should be initiated with the bag and mask. Although some resuscitators will be very skilled at intubation, others with less experience may waste valuable time, delaying resuscitation.

2 Tracheal intubation is indicated in the following circumstances:
- prolonged PPV required
  (to avoid gastric distension)
- bag and mask ineffective
  (poor chest expansion, continuing low HR)
- tracheal suctioning required
  (thick or particulate meconium – see discussion below)
- diaphragmatic hernia suspected
  (prevent bowel distension in the chest)

TABLE III

Tube size (ID mm)	*Weight (gm)*	*Gestational age (wk)*
2.5	<1000	<28
3.0	1000–2000	28–34
3.5	2000–3000	34–38
3.5–4.0	>3000	>38

Tracheal tubes

1 *Tube style*: Sterile, disposable tubes with a uniform internal diameter (not tapered) should be used.

2 *Vocal cord guide*: Most ET tubes for neonates have a heavy black line set back from the tip which is meant to be aligned with the vocal cords during tube insertion. This should position the tip of the tube above the bifurcation of the trachea.

3 *Centimeter markings*: These markings identify the distance from the tip of the ET tube. After intubation, the marking level with the upper lip should be noted for later reference when checking for any change in the tube position. A rule-of-thumb for the "tip-to-lip" distance is: *6 cm + weight in kg*

4 *Size selection*: Tube size will depend on the infant's weight and/or gestational age (Table III).

5 *Tube preparation*: The ET tube should be shortened to 13 cm to make handling during the intubation easier and to lessen the chance of placing the tube too far into the trachea. The use of a stylet to provide rigidity is optional but, if used, care must be taken that the stylet tip does not protrude beyond the end of the ET tube or that the stylet cannot advance during intubation. Experienced intubators keep the ET tubes well away from the radiant heater to retain some rigidity.

Other equipment

1 *Laryngoscope*: Attach to the handle the appropriate size straight (Miller) blade: #0 for preterm infants and #1 for full term infants. Check that the bulb is screwed in tightly and then click the blade into position and ensure that the light is bright and does not flicker.

2 *Suction equipment*: Mechanical suction should be available and adjusted so that when the tubing is occluded the negative pressure does not exceed 13.3 kPa

(100 mmHg). A suction catheter sized 10F or larger should be present. Smaller catheters for suction through ET tubes should be available.

3 *Resuscitation bag and mask connected to 100% O_2*: The bag and mask should be convenient to ventilate between intubation attempts or should intubation be unsuccessful. The bag itself will be used to ventilate through the ET tube.

Technique

The NRP Textbook of Neonatal Resuscitation describes in detail and with many excellent diagrams how to intubate the trachea of a neonate. In addition, each NRP workshop allows lots of opportunity to practice on mannikins under the direction of experienced instructors. In this CME discussion only some of the important tips will be highlighted.

1 *Positioning the infant*: The best position for intubation is on a flat surface with the head in the midline and the neck slightly extended, perhaps with a rolled towel under the shoulders. Hyperextending the neck will raise the trachea out of the line-of-sight during laryngoscopy.
2 *Inserting the laryngoscope blade*: Slide the blade beyond the base of the tongue into the vallecula and lift the tongue with the entire blade by pulling the laryngoscope handle upwards and away from you. (In very small infants it may be necessary to lift the epiglottis gently as well.) *Do not rotate the handle towards you.* The glottis should then come into view. Sometimes gentle pressure on the neck over the larynx will help bring the glottis into line of sight.
3 *Placing the ET tube*: Introduce the ET tube down the right side of the mouth to prevent it from obstructing your view of the glottis. You must be able to see the tip of the ET tube as it passes through the vocal cords.
4 *Timing*: Intubation attempts should be limited to 20 sec to minimize hypoxia. Between attempts, ventilate with a bag and mask.

Confirmation of ET tube placement

1 If the ET tube is correctly placed in the mid-tracheal region, the following signs should be present:
   - air enters *both* sides of the chest
     (Listen in the axillae to avoid mistaking air entering the stomach for breath sounds.)
   - breath sounds are equal in intensity
   - symmetrical rise of the chest with each breath
   - *no* air heard entering the stomach
   - *no* abdominal distension
   - improvement in colour, heart rate and activity of the neonate
2 A chest *x*-ray should be obtained for final confirmation if the tube is to stay in place beyond the initial resuscitation (Table IV).

TABLE IV Complications of intubation

Hypoxia	Taking too long to intubate Incorrect placement of tube
Bradycardia/Apnoea	Hypoxia Vagal response due to stimulation posterior pharynx (laryngoscopy, suction)
Pneumothorax	Excessive pressuring during ventilation or ET tube in right mainstem bronchus
Contusions or lacerations (tongue, gums, epiglottis, cords)	Rough handling of laryngoscope or ET tube Laryngoscope blade too long or too short
Perforation of trachea or oesophagus	Insertion of tube too vigorous or stylet protrudes beyond end of ET tube
Infection	Organisms introduced via equipment or hands

Tracheal suction for meconium aspiration

1 About one in eight deliveries is complicated by the presence of meconium in the amniotic fluid. Thorough suctioning of the nose, mouth and posterior pharynx before delivery of the shoulders does appear to decrease the risk of meconium aspiration and should be performed whether the meconium is thin or thick. A large-bore (12F or 14F) suction catheter should be used with mechanical suction.
2 If meconium is present in an infant with respiratory difficulties, then immediately after delivery the posterior pharynx should be cleared under direct vision using a laryngoscope and suction catheter. If the meconium is thin and the newborn is vigorous, then tracheal suctioning is probably not required.
3 If the neonate is depressed or the meconium is thick or particulate, then direct endotracheal suctioning should be performed (see note #6).
4 If indicated, tracheal suctioning should be performed as soon as possible after delivery. Once the ET tube is placed in the trachea, suction is applied directly to the tube to evacuate the thick, tenacious material. The suction is controlled by placing an adapter called a meconium aspirator between the ET tube connector and the suction tubing. Continuous suction not exceeding −13.3 kPa (−100 mmHg) is applied as the tube is slowly withdrawn (Figure 2).
5 Reintubation and suctioning should be repeated as long as considerable amounts of meconium are removed,

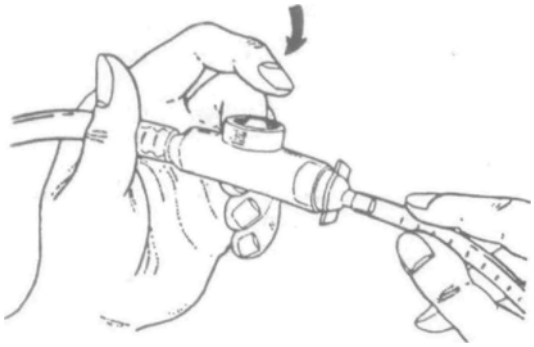


FIGURE 2 Meconium aspirator device. Reproduced with permission. © Textbook of neonatal resuscitation, 1987, 1990. Copyright American Heart Association

although twice is usually adequate. It may not be possible to remove all meconium from the trachea before the status of the infant requires positive-pressure ventilation with oxygen. When one should stop will be a judgement call usually based on what is happening with the neonate's heart rate.

6 Canadian experience concerning meconium aspiration has been recently examined and somewhat different guidelines are being developed for Canada. A major premise is that attempts to suction meconium from the trachea appear to have a limited impact on the incidence of meconium aspiration syndrome, probably because hypoxia *in utero* plays a central role in the pathogenesis. The risk of morbidity associated with tracheal intubation may be greater than the chance of modifying the incidence or severity of the illness. The new Canadian guidelines will recommend that an infant born with meconium (either thin or thick), who is breathing and crying *vigorously*, should *not* be subjected to direct visualization of the larynx or attempts to suction the trachea.

Medications

Routes of administration

1 *Endotracheal instillation*: Some drugs may be injected via the endotracheal tube to take advantage of rapid absorption through the bronchial mucosa. To ensure that enough drug gets beyond the end of the ET tube, one may wish to dilute the calculated volume of drug up to 1 to 2 ml with normal saline. Alternately, a 5F feeding catheter inserted down the ET tube can be used to inject these small volumes of drug, and then flushed with 0.5 ml of saline. To help distribute the drug deep into the bronchial tree positive-pressure ventilation should be given immediately after the drug is injected down the ET tube.

2 *Umbilical vein*: The umbilical vein, being fairly easy to isolate and cannulate, is the most common route for giving drugs during a major resuscitation event. An umbilical catheter is radiopaque, has a single end hole and is either 3.5 or 5.0F in size. The catheter is inserted under sterile conditions into the vein of the umbilical stump, advancing the tip until it lies just below the skin level with free flow of blood still present. The major concern is too deep an insertion with the risk of infusion of hypertonic and vasoactive medications directly into the liver.

Drugs and fluids

1 For the majority of infants who require resuscitation, the only "medication" needed will be 100% oxygen delivered with effective ventilation. Some will require chest compressions. In only a very few infants will this next step be necessary.

2 *Epinephrine*:

INDICATIONS:

- the heart rate stays below 80 despite effective ventilation with 100% oxygen and chest compressions for at least 30 sec
- the heart rate is zero

RATIONALE:

Epinephrine has both α- and β-adrenergic stimulating properties. The alpha effect causes vasoconstriction which raises the perfusion pressure during chest compressions, augmenting oxygen delivery to both heart and brain. The beta effect enhances cardiac contractility, stimulates spontaneous contractions and increases heart rate.

COMMENTS:

This drug can be given either *iv* or via an ET tube and can be repeated every three to five minutes if required. The ET tube route may result in lower plasma concentrations; therefore, neonates who fail to respond to epinephrine via the ET tube should have *iv* established. If *iv* access is unavailable and the infant has failed to respond to standard dosage, one should consider raising the endotracheal dose of epinephrine by a factor of ten (to 0.1–0.2 $mg \cdot kg^{-1}$).

2 *Volume expanders*:

INDICATIONS:

Signs of hypovolaemia. A 20% or greater loss in blood volume should be suspected when there is:

- pallor persisting after oxygenation
- a weak pulse despite a good heart rate
- decreased blood pressure (under 55/30)
- poor response to resuscitative efforts

RATIONALE:

Hypovolaemia occurs more frequently in the newborn than is commonly recognized. Blood loss is often not

TABLE V Medications for neonatal resuscitation

Drug	*Syringe*	*Dosage*	*Rate/Precautions*
Epinephrine (1:10,000)	1 ml	0.01–0.03 mg · kg^{-1} (0.1–0.3 ml · kg^{-1})	Give rapidly *iv* or ET Repeat q3–5 min (ET: dilute to 1–2 ml with NS)
Volume expanders - NS or RL - 5% Albumin - O-neg blood	40 ml	10 ml · kg^{-1}	Give *iv* over 5–10 min
Naloxone (0.4 mg · ml^{-1}) (1.0 mg · ml^{-1})	 1 ml 1 ml	0.1 mg · kg^{-1} (0.25 ml · kg^{-1}) (0.1 ml · kg^{-1})	Give rapidly *iv* or ET preferred
(The following two drugs are reserved for prolonged resuscitations only)			
Sodium bicarbonate (0.5 mEq · ml^{-1} = 4.2% soln)	10 ml (×2)	2 mEq · kg^{-1} (4 ml · kg^{-1})	Give *slowly* over at least 2 min *iv* ONLY Lungs *must* be ventilated
Dopamine (6 × weight in kg = mg of dopamine diluted to 100 ml)	100 ml	5–20 μg · kg^{-1} · min^{-1} (5–20 ml · hr^{-1})	Continuous infusion by pump

obvious and initial tests of haemoglobin and haematocrit are usually misleading. The increase in vascular volume secondary to a volume expander should improve tissue perfusion and reduce the development of metabolic acidosis.

COMMENTS:

The most commonly used volume expanders are:

- normal saline or Ringer's lactate
- 5% albumin-saline or other plasma substitute
- O-negative blood cross-matched with the mother's blood

The volume for infusion should be 10 ml · kg^{-1} and should be given over five to ten minutes

3 *Naloxone*:

INDICATIONS:

Naloxone is indicated in the infant for reversal of respiratory depression secondary to maternal opioids given within four hours before delivery.

RATIONALE:

Naloxone is a pure opioid antagonist without intrinsic respiratory depression activity. It acts very rapidly but attempts to give this drug should always be preceded by adequate ventilatory assistance. The duration of action of naloxone may be shorter than that of some opioids making continued respiratory monitoring mandatory for a further four to six hours.

COMMENTS:

Naloxone can be given either endotracheally or *iv*. If perfusion is adequate, then the *sc* or *im* routes may be appropriate but expect a delayed onset of action. If maternal opioid addiction is suspected, it is probably prudent not to give naloxone (to avoid a withdrawal reaction: severe neonatal seizures) but to support ventilation until respiratory drive is adequate.

4 *Other medications*:

In most cases the CPR involved with neonatal resuscitation will be brief. There is little evidence that during the acute phase of resuscitation in the delivery room that there will be much need for drugs such as atropine, calcium and sodium bicarbonate.

During a prolonged arrest, with confirmation of metabolic acidosis by arterial blood gas determination, sodium bicarbonate may be beneficial. Effective ventilation must precede and accompany the administration of sodium bicarbonate. The risk of intraventricular haemorrhage may be decreased if the 4.2% (0.5 mEq · ml^{-1}) solution is used and the drug is given slowly – *at least* over two minutes. The appropriate dose is 2 mEq · kg^{-1} *iv*.

An infant who has been resuscitated with epinephrine, a volume expander and possibly sodium bicarbonate and still has evidence of low cardiac output and poor peripheral perfusion may benefit from an infusion of dopamine, beginning at 5 μg · kg^{-1} · min^{-1} and increasing to 20 μg · kg^{-1} · min^{-1} as necessary.

Postresuscitation care

1 Newborns who have been successfully resuscitated will require close monitoring in a neonatal intensive care unit or an area where special care by trained observers is possible.

2 Postresuscitation care may include:

- arterial pH and blood gas determinations
- correction of documented metabolic acidosis
- use of volume expanders and/or vasopressors if hypotension persists
- appropriate fluid therapy
- treatment of seizures
- screening for hypoglycaemia and hypocalcaemia
- chest *x*-rays for diagnostic purposes and ET tube position checks.

3 Complete documentation of all observations and actions should be entered in the infant's chart. This should include recording the APGAR scores calculated at one and five minutes. If the five-minute APGAR score is <7, then additional scores should be obtained every five minutes for up to 20 min or until two successive scores are 8 or greater. Although the APGAR score is not used as a decision-making tool, it has been of value in assessing the progress of the resuscitation.

Conclusion

This article is simply an overview of the Neonatal Resuscitation Program syllabus. An important part of an actual NRP course involves learning the necessary skills and then integrating them with the protocols in case scenarios. Only by working through a simulated resuscitation can one be sure that he or she can translate written guidelines into effective action.

References

1 *Bloom RS, Cropley C.* Textbook of Neonatal Resuscitation. Chameides L and the AHA/AAP Neonatal Resuscitation Steering Committee (Eds.). American Heart Association, 1990.

2 *Emergency Cardiac Care Committee and Subcommittees,* American Heart Association. Guidelines for cardiopulmonary resuscitation and emergency cardiac care, VII: neonatal resuscitation. JAMA 1992; 268: 2276–81.

3 *Christenson JM, Solimano AJ, Williams J, et al.* The new American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiac care: presented by the Emergency Cardiac Care Subcommittee of the Heart and Stroke Foundation of Canada. Can Med Assoc J 1993; 149: 585–90.

4 Canadian National Guidelines for Neonatal Resuscitation (draft – to be published Summer 1994). Personal communication with the Canadian Neonatal Resuscitation Program Committee.

Multiple Choice Questions

FOR EACH QUESTION, SELECT THE ONE CORRECT ANSWER

1 Regarding personnel for resuscitation:
- A For a *low risk* neonate, the prime resuscitator needs to be capable of taking the resuscitation only up to and including tracheal intubation.
- B For *every* delivery there must be one person present who is primarily responsible for the infant and who can initiate resuscitation immediately.
- C For a *high-risk* delivery, the obstetrical circulating nurse should be ready to assist the one person assigned to care for the neonate, if required.
- D As long as a person capable of initiating resuscitation is "in-house' on a pager, attendance at delivery is not mandatory.
- E With a *twin* birth, two resuscitators should be sufficient for two neonates.

2 During the initial stabilization phase of resuscitation:
- A Oropharyngeal suction should be vigorous and meticulous in all infants.
- B The *three* physical signs used to evaluate the infant are: respirations, heart rate and muscle tone.
- C Suctioning should begin with the nose and *then* the mouth.
- D Besides drying and suctioning, other acceptable methods of stimulation include flicking the soles of the feet and rubbing the back gently.
- E As long as the heart rate is >100 bpm in a neonate who only occasionally gasps, continue tactile stimulation for up to 45 sec before starting positive-pressure ventilation.

3 Regarding ventilation with a bag and mask:
- A *Both* the anaesthesia and self-inflating bags can deliver oxygen without squeezing the bag.
- B Positive-pressure ventilation is indicated *only* when the heart rate stays below 80 bpm.
- C Ventilation should be 20 to 40 breaths per minutes (without chest compressions).
- D The pressure necessary for breaths should be in the 15–20 cm H_2O range (although the first few breaths may require higher pressures).
- E Adding a reservoir on to the secondary inlet of a self-inflating bag will increase the delivered oxygen concentration from 40% to approximately 70%.

4 With respect to chest compressions:
- A One should start chest compressions *before* ventilation if no heart beat is present.

B The correct location for thumb placement is 2.5 cm below an imaginary line drawn between the nipples.
C One should start chest compressions after 15–30 sec of PPV with 100% oxygen, if the heart rate is still 90 bpm.
D Use just enough pressure to depress the sternum 2.5 cm.
E The new guidelines recommend a pause after every three chest compressions to interpose one effective ventilation, resulting in 90 compressions and 30 ventilations per minute.

5 Concerning the presence of meconium at a delivery:
A Intubation and tracheal suction should be repeated until no further meconium is returned despite a heart rate less than 60 bpm, because the mortality associated with meconium aspiration is so high.
B In a vigorously breathing and crying neonate, tracheal suctioning is required *only* when the meconium is thick and particulate (proposed Canadian guidelines).
C If the neonate is depressed or having respiratory difficulties, then tracheal suction is indicated even if the meconium is thin.
D Suctioning on the perineum before delivery of the shoulders of the nose, mouth and pharynx does *not* seem to reduce the risk of aspiration.
E Suction as high as −150 mmHg may have to be used to remove some meconium.

6 Regarding the use of medications during resuscitation of a 3 kg neonate:
A If there is *no* heart rate present at birth, ventilation with 100% O_2 and chest compressions should begin immediately, followed by epinephrine 0.3–0.9 ml of 1:10,000 diluted to 2 ml with NS down the ET tube.
B Naloxone 0.3 mg should be given if the mother is a known narcotic addict.
C If indicated, Ringer's lactate 30 ml should be given very cautiously over 15–20 min.
D Sodium bicarbonate 4.2% - 12 ml - should be given early in the resuscitation for suspected metabolic acidosis.
E If the infant fails to respond to standard doses of epinephrine down the ET tube, one may increase the dose to a maximum of *double* the recommended *iv* dosage.

ANSWERS

1 B 2 D 3 D 4 E 5 C 6 A