GUIDELINE 13.4
AIRWAY MANAGEMENT AND MASK VENTILATION OF THE NEWBORN INFANT

EFFECTIVE VENTILATION IS THE KEY TO SUCCESSFUL NEONATAL RESUSCITATION

All personnel involved in the birth and care of newborn infants must be familiar with the ventilation equipment and be proficient in basic neonatal resuscitation techniques.

POSITIONING AND THE AIRWAY

The newborn infant who needs resuscitation should be placed on his or her back with the head in a neutral or slightly extended position (the sniffing position) [Class A, expert consensus opinion]. Particularly if moulding during birth has caused a very prominent occiput, a 2cm thickness of blanket or towel placed under the shoulders may be helpful in maintaining good positioning [Class B, expert consensus opinion].

Hyper-extended        Slightly extended        Flexed

The slightly extended, or sniffing position of the baby illustrated in the middle panel results in optimal airway patency for resuscitation.

If respiratory efforts are present but not producing effective ventilation (the heart rate does not rise above 100/min) the airway may be obstructed and consideration should be given to other methods to improve airway patency, including support of the lower jaw, opening the mouth, or in some cases upper airway suction [Class A, expert consensus opinion].

Mouth and Pharyngeal Suction
Normal newborn infants do not require suctioning of the nose, mouth or pharynx after birth [Class A, expert consensus opinion]. They clear their airways very effectively, and suctioning can delay the normal rise in oxygenation.¹
The airway is sometimes obstructed by particulate meconium, blood clots, tenacious mucous or vernix and may need to be cleared. However, pharyngeal suction can cause laryngeal spasm, trauma to the soft tissues and bradycardia. It can also prolong cyanosis and delay the onset of spontaneous breathing [LOE II1, 2]. Therefore, any pharyngeal suction should be done briefly and with care.

In general, suction should not be used except when babies show obvious signs of obstruction either to spontaneous breathing or to positive pressure ventilation [Class A, expert consensus opinion]. Pharyngeal suction may be required to visualise the vocal cords during intubation.

If suction is needed, a large bore suction catheter (10-12 Fg) should be passed not more than 5 cm from the lips in a term infant, and the suction should be limited to a few seconds in duration. The negative pressure used should not exceed 100 mm Hg (13 kPa, 133 cm H2O, 1.9 Psi) [Class A, expert consensus opinion].

**MANAGEMENT OF THE AIRWAY IN THE PRESENCE OF MECONIUM STAINED LIQUOR**

Aspiration of meconium before or during birth, or during resuscitation can cause meconium aspiration syndrome (MAS) and all infants born through meconium stained fluid must be regarded as at risk.

**Intrapartum pharyngeal suction**

Suctioning the infant’s mouth and pharynx before the delivery of the shoulders makes no difference to the outcome of babies with meconium stained liquor and is not recommended [LOE II3, 4]

**Endotracheal suction**

Routine endotracheal suctioning of babies who have meconium stained liquor, and who are vigorous (breathing or crying, good muscle tone), is discouraged because it does not alter their outcome and may cause harm [Class A, LOE II5, 6]

Observational studies suggest that depressed infants born with meconium stained amniotic fluid are at increased risk to develop MAS [LOE IV7, 8]. However, for non-vigorous infants, available evidence does not support or refute the value of routine endotracheal suctioning in preventing MAS. Therefore, there is insufficient evidence on which to recommend a change in current practice of performing endotracheal suctioning of non-vigorous infants who have been exposed to meconium stained fluid [Class B, expert consensus opinion9-11]. Nevertheless, potential benefits of removing meconium from the trachea need to be weighed against what is likely to be an urgent need for other resuscitation manoeuvres.

If tracheal suction is performed, it must be accomplished before spontaneous or assisted respirations have commenced, and very promptly so as to minimise delay in establishing breathing [Class A, expert consensus opinion]. Stimulation to breathe should not be provided beforehand.
A meconium aspirator device attached (after intubation) to the adapter of an endotracheal tube, then connected to a negative pressure source not exceeding 100 mm Hg (13 kPa, 133 cm H$_2$O, 1.9 Psi) can be used to suction the trachea by occluding the side port and removing the endotracheal tube over a few seconds. There is no evidence to support repeated intubation for endotracheal suction, and it is likely to cause further delays in resuscitation.

**TACTILE STIMULATION**

Drying and stimulation are both assessment and resuscitative interventions. If, in response, the infant fails to establish spontaneous, effective respirations and heart rate does not increase to more than 100/min, positive pressure ventilation is required.

**POSITIVE PRESSURE VENTILATION**

After stimulation, positive pressure ventilation should be started if the heart rate is less than 100/min and either the infant remains apnoeic or the breathing is inadequate. The primary measure of effectiveness of ventilation is a prompt improvement in heart rate, which is then sustained. Chest wall movement should be assessed if the heart rate does not improve.

If there is little or no visible chest wall movement the technique of ventilation should be improved. This includes assuring the face mask fits well on the face with minimal leak, and that the head and jaw position are correct. Two people may be able to provide mask ventilation more effectively than one, with one person supporting the jaw and holding the mask in place with two hands, and the other providing positive pressure breaths [Class B, expert consensus opinion]. If these manoeuvres are ineffective in moving the chest wall and increasing the heart rate, the inflating pressure must be increased until chest wall movement is seen and the heart rate increases [Class A, expert consensus opinion]. Suctioning of the airway is sometimes required.

**MANUAL VENTILATION DEVICES**

A T-piece device, a self-inflating bag, and a flow-inflating bag are all acceptable devices to ventilate newborn infants either via a facemask or endotracheal tube. [Class A, extrapolated evidence$^{12-18}$].

**T-piece resuscitation devices**

T-piece devices require a compressed gas source, the flow from which should be kept constant during resuscitation in order to keep inspiratory and expiratory pressures consistent. With a T-piece device, gas flows into a face mask or endotracheal tube through a ‘patient supply line’. Inflation is achieved by interrupting the escape of gas through an outlet hole on the T-piece using a thumb or finger so that the pressure rises and is displayed by a manometer.
A maximum pressure relief valve is used as a safety measure and it should be set before resuscitation commences. Adjusting a variable release valve limits the applied peak inspiratory pressure (PIP). Adjusting the outlet valve varies positive end expiratory pressure (PEEP) (or continuous positive airway pressure; CPAP). This controls the rate of escape of gas when the outlet is not occluded (i.e. during expiration) and generates a set level of PEEP or CPAP. Varying the duration of occlusion of the outlet hole alters the inflation time.

Altering the flow into the system will alter the maximum, inspiratory and expiratory pressures, so if flow rate is changed, all three pressure settings will need to be adjusted. The inspiratory and expiratory pressure settings can be altered upwards or downwards as needed during use, depending on the infant’s response.

The target pressures cannot be delivered if there are large leaks at the face mask, other leaks in the system, or too low a flow, and this will become evident from the manometer. As with flow-inflating bags, this can be regarded as an advantage because it indicates to the operator that remedial action is needed.

In mechanical models, target PIP and PEEP are delivered more consistently and the ability to deliver a sustained breath is better with T-piece resuscitators, than with flow-inflating or self-inflating bags.15, 17, 18

**Self inflating bags**

Following compression, a self-inflating bag re-expands due to its elastic recoil. It does not depend on a gas source for inflation. Therefore, a self-inflating bag should always be available as a back up to flow-dependent devices in case of failure of compressed gas supply.

The automatic re-expansion of the self-inflating bag, effective operation without a pressurised gas supply, simplicity of use, and portability, are the greatest assets of this device.

However, it is very difficult to deliver consistent inflating pressures with a self-inflating bag and it is easy to generate unnecessarily high pressures. The maximum pressure is limited to some extent by a pressure-release valve, which is factory set to activate at approximately 40 cm H₂O, but these valves activate at an inconsistent and wide range of pressures.19 The pressure-release valve can be over-ridden, should a higher pressure be required to achieve chest wall movement.

Self-inflating bags do not provide PEEP, and although a PEEP valve can be fitted to some models, the PEEP declines rapidly between inflations, especially at lower inflation rates.20, 21 Self-inflating bags cannot be used to provide CPAP, or to deliver a sustained inflation longer than about one second.22

A compressed gas source can be attached for the delivery of supplemental oxygen. If a source of compressed oxygen is attached, self-inflating bags can deliver high concentrations of oxygen even if no reservoir bag or tube is attached23-25, and so cannot be relied on to deliver intermediate concentrations of oxygen.
Because the flow of oxygen delivered to the infant is unreliable\textsuperscript{26-28}, these devices should not be used to deliver free flow oxygen.

The 240 mL self-inflating neonatal resuscitation bag is the most appropriate size for ventilating newborn infants of all sizes, despite suggestions to the contrary.\textsuperscript{22} This is because the infant’s tidal volume is approximately 5 – 10 mL/kg body weight. A volume of 240 mL, even when compressed, should be more than adequate to inflate any newborn’s lungs. If ventilation is inadequate with a bag of this size it is most likely to be due to a large leak between the mask and the infant’s face, or incorrect positioning of the head, neck and jaw. Other causes include stiff lungs, blocked airway, or faulty equipment.

**Flow-inflating bags**

A flow-inflating (or anaesthesia) bag requires a compressed gas source to inflate the bag when in use. Large leaks at the face mask, or too low a flow, will result in collapse of the bag and inability to deliver any tidal volume. While this makes it more difficult to use, it is an advantage as the operator is immediately aware and can take steps to rectify the problem. In addition, using a flow-inflating bag allows the experienced operator to vary the pressure profile very rapidly in response to the condition of the neonate. As with the other devices, proper use requires training and experience.

Flow-inflating bags can be used to deliver sustained inflations or CPAP. Some flow-inflating bags are used with a circuit that includes an adjustable blow-off valve that can be used to regulate end-expiratory pressure. In most cases, the end of the bag is open and is pinched between the operator’s fingers to regulate end-expiratory pressure.

**Before any resuscitation, check the equipment**

**T piece device**

a) Connect compressed gas supply to the gas inlet port (lower left of the device in the illustration), and adjust gas flow to 10 L/min. The T-piece resuscitation device must have a compressed gas supply.

b) Connect the patient circuit, with T-piece, to the gas outlet port (lower right of the device in the illustration).

c) Occlude both the patient outlet end, where the face mask fits and the outlet (PEEP) valve during both the next two steps.

d) Test the Maximum Pressure Relief Valve by first turning the Inspiratory Pressure Control knob (PIP valve) fully clockwise, so that it does not limit the pressure. Adjust the Maximum Pressure Relief valve so that the manometer reads 50 cm H\textsubscript{2}O.

e) Set desired peak inspiratory pressure (PIP) by turning the Inspiratory Pressure Control knob until the required pressure is shown on the manometer. The recommended initial pressures are 30 cm H\textsubscript{2}O for term infants and 20-25 cm H\textsubscript{2}O for premature infants.

f) Maintain occlusion of the patient outlet end of the T-piece, but take the finger off the outlet (PEEP) valve and twist the valve until the manometer shows the desired PEEP (5-8 cm H\textsubscript{2}O).

g) Fit an appropriate sized face mask.
h) Ventilate the newborn infant by placing a finger over the outlet aperture (hole in the PEEP valve) and removing it. This is done about 40-60 times a minute with an inspiratory time of about 0.3-0.5 seconds.

T-piece resuscitation device, connected to flow meter and air/oxygen blender.

Self-inflating bag
a) Check the device is assembled correctly.

b) Ensure a reservoir bag or tube is available.

c) If attaching a gas supply, set flow to 10 L/min (though the device does not need a gas supply).

d) Obstruct the open end, where the face mask fits, squeeze the bag firmly to see that a pressure is achieved and the pressure blow off valve opens.

e) At the end of inflation check that the bag re-inflates quickly.

f) Ventilate the newborn infant by squeezing the bag between the thumb and two fingers. This is done about 40-60 times a minute with an inspiratory time of about 0.3-0.5 seconds.

Self-inflating bag with reservoir.
**Flow-inflating bag**

a) Check the device is assembled correctly and ensure that a manometer is attached.

b) Set the gas flow to 10 L/min (the flow-inflating bag must have a gas supply).

c) Obstruct the open end where the face mask fits, then while pinching the open end of the bag to partly occlude it, see that the bag fills quickly.

d) While continuing to pinch the open end of the bag, squeeze the bag and see that a pressure is achieved.

e) While continuing to pinch the open end of the bag, see that the bag re-inflates quickly at the end of inflation, when the bag is not being squeezed.

f) Ventilate the newborn infant by pinching the open end of the bag between the thumb and forefinger to partly occlude it (in order to maintain PEEP), then squeeze the bag to provide positive pressure breaths. This is done about 40-60 times a minute with an inspiratory time of about 0.3-0.5 seconds.

**FACE MASKS**

The appropriate size of face mask must seal around the mouth and nose but not cover the eyes or overlap the chin. Therefore, a range of sizes must be available for different sized babies. Masks with a cushioned rim are preferable to masks without one [Class A, LOE III-2\(^2\)]. With bag-mask ventilation it can be difficult to establish and maintain a good seal between the mask and the infant’s face\(^3\) and so it cannot be assumed that just because the mask is on the face, there is a good seal.

Suitable face masks, with cushioned rims, are shown on the left. The one in the centre has an inflatable rim, which should be filled with air using a syringe until the rim is firm. The Rendell Baker style mask on the right should not be used.

**INITIATING VENTILATION**

The aim of ventilation is initially to establish functional residual capacity (FRC).\(^3\) The optimal strategy for this in newborns needing resuscitation has not been established, but some studies suggest that sustained initial breaths\(^3\) and positive end expiratory pressure\(^3\) are helpful, particularly in premature lungs. There is good support for these concepts from animal studies, but care must be taken to avoid high tidal volumes during resuscitation, which can cause sustained damage to immature lungs.\(^3\)
To establish initial lung inflation in apnoeic newborn infants, initiation of intermittent positive pressure ventilation at birth can be accomplished with or without several initial prolonged inflation breaths. Various regimens have been suggested, from 5 breaths lasting 2-3 seconds to one breath lasting 5-10 seconds, but there is insufficient evidence to recommend a particular approach. \(^{37}\)

Higher inflation pressures may be required to open the lungs during the first few inflations than for subsequent inflations, particularly in infants who have not made any respiratory effort. Peak inflating pressures necessary to achieve an increase in heart rate or movement of the chest are variable and unpredictable and should be individualized as positive pressure ventilation is applied. For term babies, an initial inflation pressure of 30 cm H\(_2\)O will usually achieve improvement in heart rate and chest expansion [Class B, LOE IV\(^{32, 34}\)]. Occasionally, higher pressures are needed. \(^{38}\) If pressure is not being monitored, the minimal inflation required to achieve visible chest wall movement and an increase in heart rate should be used. When it becomes evident that the infant is responding to ventilation, in many cases inflation pressures and rate can (and should) be decreased.

For preterm infants, it is particularly important to avoid creation of excessive lung expansion during ventilation immediately after birth. Although measured PIP does not correlate well with volume delivered in the context of changing respiratory mechanics, monitoring of inflation pressure may help provide consistent inflations and avoid unnecessarily high pressures and excessive volumes. If positive pressure ventilation is required, an initial PIP of 20-25 cm H\(_2\)O is adequate for most preterm infants [Class B, LOE III-3\(^{39}\)]. If prompt improvement in heart rate or chest movement is not obtained, then after measures to check airway patency, higher pressures to achieve effective ventilation may be needed.

For most infants, ventilation can be accomplished with progressively lower pressures and rates as resuscitation proceeds [Class A, expert consensus opinion].

**PEEP DURING RESUSCITATION**

PEEP has been shown to be very effective for improving lung volume, reducing oxygen requirements and reducing the incidence of apnoea in premature babies with respiratory distress syndrome. \(^{40}\) Studies in intubated premature animals demonstrate that it is helpful in establishing functional residual capacity of the lungs. There are no randomised controlled trials to show that the use of PEEP will improve the outcome of term or premature babies when used during resuscitation, however, it is likely to be helpful, and unlikely to cause harm.

Therefore, if suitable equipment is available, PEEP (at least 5 cm H\(_2\)O) should be used during resuscitation \(^{37}\) to assist lung expansion, help establish a functional residual capacity and improve oxygenation [Class A, expert consensus opinion]. High levels of PEEP (8-12 cm H\(_2\)O) may reduce pulmonary blood flow and cause pneumothorax.
THE TECHNIQUE OF MASK VENTILATION

1. Ensure the airway is open:
   a) Adjust head/neck position to open the airway.
   b) Open the mouth slightly.
   c) Clear the airway of meconium or blood if necessary.
2. Inflate the lungs with sufficient pressure and volume so that the chest and upper abdomen move slightly. The chest wall movement should equal that seen in normal quiet respiration.
3. The ventilation rate should be about 40-60 inflations per minute.
4. If the chest does not move with inflation:
   a) Check the manometer to determine whether target pressures are being achieved. If not, the problem is likely to be a leak or inadequate gas flow. In these circumstances:
      i. If using a flow-inflating bag or T-piece device, ensure the gas flow is turned on and at 10 L/min.
      ii. Improve the seal between mask and face.
      iii. If the target pressures are still not achieved, check for a leak in the circuit. Use a self-inflating bag while this is done.
   b) If target pressures are achieved, the airway may be occluded or lung compliance may be very low, therefore:
      i. Adjust the head-neck position if necessary and ensure that the lower jaw is supported.
      ii. Consider suctioning the airway.
      iii. Increase the inflation pressure until the chest moves with each inflation.
      iv. Consider use of an oral airway, intubation, or a laryngeal mask airway.

ASSESSING THE EFFECTIVENESS OF VENTILATION

The effectiveness of ventilation is confirmed by observing three things:
1. Increase in the heart rate above 100/min.
2. A slight rise of the chest and upper abdomen with each inflation.
3. Oxygenation improves.

If the chest and abdomen do not rise with each inflation, or the heart rate does not increase above 100 beats per minute, the technique of ventilation needs to be improved.

Tracheal intubation (or use of a laryngeal mask airway) should be considered if ventilation via a face mask is still ineffective despite the above measures [Class A, expert consensus opinion].

CONTINUOUS POSITIVE AIRWAY PRESSURE (CPAP)

For spontaneously breathing preterm infants over 24 weeks gestation who have signs of respiratory distress, commencing CPAP in the first minutes after birth can reduce rates of mechanical ventilation and artificial surfactant administration without adverse effects on rates of death or oxygen requirement at 36 weeks postmenstrual age, when compared to initial intubation and ventilation [LOE II[41]].
However, there is a risk of pneumothorax, and there was no effect on the outcomes of death or oxygen requirement at 36 weeks post-menstrual age. CPAP has not been studied for resuscitation of the spontaneously breathing term newborn.37

For spontaneously breathing infants who have laboured breathing, or whose saturations are not meeting targets, a trial of CPAP is reasonable [Class B, expert consensus opinion].

MOUTH-TO-MOUTH/NOSE AND MOUTH-TO-MASK VENTILATION

Where neonatal inflation devices are not available, rescue breathing by mouth-to-mouth-and-nose ventilation should be used. [Class B, extrapolated evidence42]. To decrease the risk of infection to the resuscitator, maternal blood and other body fluids should first be wiped from the face of the infant. The rescuer should then apply the mouth over the mouth and nose of the infant and give small puffs at a rate of 40-60 breaths per minute to produce a small rise and fall of the chest, until the baby improves.

SUPPLEMENTAL OXYGEN DURING RESUSCITATION

There are now many studies showing that the blood oxygen levels of normal newborns can take up to 10 minutes to rise above 90%.43-49 While insufficient oxygenation can impair organ function or cause permanent injury, there is increasing evidence that even brief exposure to excessive oxygenation can be harmful to the newborn during and after resuscitation.9, 50-53 Furthermore, visual assessment of the presence or absence of cyanosis bears a poor relationship to oxyhaemoglobin saturation measured with an oximeter.54

Pulse oximetry

Oximetry is recommended when the need for resuscitation is anticipated, when positive pressure is administered for more than a few breaths, when persistent cyanosis is suspected, or when supplemental oxygen is used (see Guideline 13.3) [Class A, expert consensus opinion].

Administration of supplemental oxygen

Meta-analyses of randomized controlled trials comparing neonatal resuscitation initiated in room air versus 100% oxygen showed increased survival in infants for whom resuscitation was initiated with air.55, 56 In the studies of term infants receiving resuscitation with intermittent positive pressure ventilation, 100% oxygen conferred no short term advantage and resulted in increased time to first breath and/or cry.57, 58 However, there are no studies in term infants comparing commencement in oxygen concentrations other than 21% or 100%.

In studies of premature infants < 32 weeks, initial use of air or 100% oxygen was found to be more likely to result in hypoxaemia or hyperoxaemia (as defined by the investigators) respectively than when initiating resuscitation with blended air and oxygen and titrating according to oxygen saturation [LOE II59, 60].

It is recommended that regardless of gestation, the goal of oxygen administration should be to aim for oxygen saturations resembling those of healthy term babies.
The interquartile range of pre-ductal saturations measured in normal term infants at sea level are suitable targets [Class A, expert consensus opinion9]. Although the 75th centile for normal infants rises above 90%49, in the following table the upper saturation targets while administering oxygen have been capped at 90%, to avoid risk of exposing infants to excessive oxygen. Some infants achieve saturations over 90% without supplemental oxygen.

<table>
<thead>
<tr>
<th>Time from birth</th>
<th>Target saturations for newborn infants during resuscitation</th>
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<tbody>
<tr>
<td>1 min</td>
<td>60-70</td>
</tr>
<tr>
<td>2 min</td>
<td>65-85</td>
</tr>
<tr>
<td>3 min</td>
<td>70-90</td>
</tr>
<tr>
<td>4 min</td>
<td>75-90</td>
</tr>
<tr>
<td>5 min</td>
<td>80-90</td>
</tr>
<tr>
<td>10 min</td>
<td>85-90</td>
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For term infants, air should be used initially with supplemental oxygen reserved for those whose saturations do not meet the lower end of the targets despite respiratory support [Class A, expert consensus opinion]. If, despite effective ventilation there is no increase in heart rate or oxygenation (assessed by oximetry wherever possible), a higher concentration of oxygen should be used.10, 11, 61 If the saturations reach 90% while supplemental oxygen is being administered, the concentration of oxygen should be decreased [Class A, expert consensus opinion].

As many preterm babies less than 32 weeks gestation will not achieve target saturations in air, it may be appropriate to commence respiratory support either using room air or blended air and oxygen [Class B, expert consensus opinion]. As for term infants, supplemental oxygen should be given judiciously, ideally guided by pulse oximetry [Class A, expert consensus opinion]. Both hyperoxaemia and hypoxaemia should be avoided. If a blend of oxygen and air is not available, resuscitation should be initiated with air [Class B, extrapolated evidence55-58].

**In all cases, the first priority is to ensure adequate inflation of the lungs, followed by increasing the concentration of inspired oxygen only if needed** [Class A, expert consensus opinion].
PACE OF RESUSCITATION

Each set of actions in the algorithm should be applied for about 30 seconds, then response should be assessed. If heart rate, breathing, tone and oxygenation do not improve or the infant is deteriorating, progress to the next step [Class A, expert consensus opinion].
REFERENCES


44. Gonzales GF, Salirrosas A. Arterial oxygen saturation in healthy newborns delivered at term in Cerro de Pasco (4340 m) and Lima (150 m). Reprod Biol Endocrinol 2005;3:46.


51. Solas AB, Kutzsche S, Vinje M, Saugstad OD. Cerebral hypoxemia-ischemia and reoxygenation with 21% or 100% oxygen in newborn piglets: effects on extracellular levels of excitatory amino acids and microcirculation. Pediatr Crit Care Med 2001;2:340-5.


