Oxygen delivery systems for infants and children

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INTRODUCTION — Rapid and effective oxygen delivery is an essential component of the care of critically ill or injured children. A variety of systems are available to deliver oxygen to children who are breathing spontaneously. Factors that influence the appropriate choice for any given situation include the dose of oxygen required and how well the child accepts the device. For children who require assisted ventilation, oxygen can be delivered with either a self-inflating or flow-inflating ventilation bag.

This topic will review various devices that are available to deliver oxygen to spontaneously breathing and nonbreathing children. The amount of oxygen that each system can deliver and the advantages and disadvantages of each method are discussed. Oxygen therapy for newborns is discussed elsewhere, as are conditions that require oxygen and procedures for airway management. (See "Oxygen therapy and monitoring in the newborn", see "Initial assessment and stabilization of children with respiratory or circulatory compromise", see "Airway maintenance techniques and assessment of ventilation in pediatric resuscitation", and see "Airway management in children").

GENERAL CONCEPTS — General principles regarding oxygen delivery include the following:

- The choice of system will depend upon the clinical status of the child and the desired dose of oxygen (show table 1). A blow by system may be suitable for an alert child in moderate respiratory distress who requires a low dose of oxygen. In comparison, an obtunded infant with irregular respirations needs bag-mask ventilation with as high a dose of oxygen as possible.

- Young children in respiratory distress may become frightened or agitated when oxygen is administered, causing their clinical conditions to deteriorate. Therefore, they should remain in a position of comfort whenever possible. A parent or caregiver can often hold the oxygen source in proximity to or over the child's face.

- Oxygen should be humidified, whenever possible, to prevent dried secretions from obstructing smaller airways.

- The effectiveness of oxygen delivery should be monitored with pulse oximetry. (See "Oxygen therapy and monitoring in the newborn", section on Pulse oximetry and see "Pulse oximetry").

BLOW BY — Blowing (or wafting) oxygen past a child's face is not a reliable means of oxygen delivery. However, this method can temporarily provide oxygen to infants and toddlers who become agitated and more distressed with other methods of oxygen delivery, particularly during the initial evaluation and treatment for a reversible cause of respiratory distress such as croup or bronchospasm.

Blow by oxygen is provided with oxygen tubing, corrugated tubing, or a simple mask. It is typically held at a short distance from the child's face by a parent or other caregiver. Limited evidence suggests that low concentrations of oxygen can be provided using these systems [1-3].

Self-inflating (Ambu) ventilation bags do not reliably deliver oxygen to spontaneously breathing children and should not be used for this purpose [1,4]. This type of system typically has a one way

valve to prevent rebreathing. Oxygen flows through the valve when the bag is squeezed. With a mask tightly applied to the face, some spontaneously breathing patients may be able to generate sufficient inspiratory pressure to overcome the valve. However, children cannot reliably accomplish this. In comparison, a flow-inflating (anesthesia) ventilation bag that is connected to an oxygen source provides a constant flow of oxygen. (See "Ventilation bags" below).

The following points should be considered when providing blow by oxygen to children:

- Oxygen can be best delivered at a flow rate of at least 10 L/min through a reservoir (such as a simple mask or large cup) [1].
- The reservoir must remain in proximity to the child's face.
- Oxygen saturation should be monitored.
- Alternative oxygen delivery systems should be considered for children who require greater than 30 percent oxygen or prolonged oxygen therapy.

NASAL CANNULA — A nasal cannula provides oxygen through oxygen supply tubing with two soft prongs that are inserted into the patient's anterior nares. Oxygen flows from the cannula into the patient's nasopharynx. Oxygen flowing into the nasopharynx mixes with room air. Consequently, the concentration of oxygen that can be delivered by this method varies between 25 and 40 percent, depending on factors such as the patient's respiratory rate, tidal volume, and extent of mouth breathing.

One hundred percent oxygen is typically run through a bubbler humidifier at a rate of 1 to 4 L/min. Flow rates greater than 4 L/min are very irritating to the nares and are not tolerated by most children. Flow rates greater than 2 L/min are not recommended for newborns and infants because inadvertent administration of positive airway pressure may occur at higher flow rates [5,6].

A nasal cannula may be used to deliver oxygen to a child with patent nares who requires low levels of supplemental oxygen and does not accept a simple mask. This system is lightweight, inexpensive, and mobile. In addition, the infant can feed without interruption of oxygen delivery. A nasal cannula is of limited use during the stabilization of acutely ill patients, since it cannot reliably deliver high concentrations of oxygen. The nares may become dry after prolonged use.

MASKS — Masks are the most frequently used oxygen delivery system for patients who are breathing spontaneously. General considerations when using a mask include the following:

- The mask should fit over the patient's nose and mouth. It is secured around the head with an elastic strap.
- A variety of sizes must be available from which to choose the proper size for any given patient.
- Transparent masks should be used whenever possible.
- Masks may be difficult to use for some young children who become more anxious and uncooperative when a mask is strapped to their face.

Characteristics of the mask, mask fit, and the addition of a reservoir determine the amount of oxygen that can be delivered. The types of masks that are typically used include simple, partial rebreathing, and nonrebreathing systems.

Simple masks — Simple masks fit loosely over the nose and mouth. With oxygen flow rates between 6 and 10 L/min, simple masks can provide concentrations of oxygen between 35 and 50 percent, depending on the patient's respiratory rate and the mask fit [6,7].

The plastic mask itself serves as a reservoir for oxygen that is delivered through a small-bore tube connected at the base of the mask. Exhaled gas escapes through holes (exhalation ports) on each side of the mask. Room air enters through these ports and mixes with oxygen, thereby decreasing the percentage of oxygen delivered to the patient. An oxygen flow rate greater than 5 L/minute is recommended to prevent rebreathing of CO2 [6,8].

A simple mask is useful for children who need moderate amounts of oxygen to maintain an acceptable oxygen saturation. It can provide higher concentrations of oxygen than a nasal cannula. However, precise concentrations of oxygen cannot be reliably delivered.

Partial rebreathing masks — A partial rebreathing mask consists of a simple mask with an attached reservoir. Oxygen concentrations from 50 to 60 percent can be achieved with oxygen flow rates between 10 and 12 L/min [6,9].

With this system, air is drawn during inspiration predominantly from the fresh oxygen inflow and the reservoir. Entrainment of room air through the exhalation ports is minimized.

Gas in the reservoir is oxygen rich, despite the fact that it contains some exhaled gas. This is because the early exhaled air that flows into the reservoir (from respiratory dead space in the mouth and upper airways) is oxygen rich and contains little carbon dioxide [9-11]. In order to maintain a high percentage of oxygen in the reservoir and minimize CO2 rebreathing, the oxygen flow rate must be adjusted to keep the reservoir from collapsing.

A partial rebreather mask is used primarily to conserve oxygen supply (for instance, during patient transport) for children who require higher oxygen concentrations. Although the concentration of oxygen that is delivered is more reliable, it is diluted by room air that can still be drawn into the system through the exhalation ports.

Nonrebreathing masks — A nonrebreathing mask is a mask and reservoir system modified with two valves that limit the mixing of exhaled gases and room air with the oxygen supply. With oxygen flow rates of 10 to 15 L/min and a mask with a good seal, inspired oxygen concentrations of up to 95 percent can be achieved with a nonrebreather mask [9,12].

A one-way valve over one of the exhalation ports of the mask allows the egress of expired gas during exhalation and prevents room air from entering the mask during inspiration. As a safety precaution, only one of the two exhalation ports on the mask has a one-way valve. That way, the patient can still receive room air through the open port if the flow of oxygen to the mask is inadvertently interrupted [13].

The second one-way valve is located between the reservoir and the mask. It prevents flow of exhaled gas into the reservoir [9-11]. In addition, oxygen flow into the mask is adjusted to prevent collapse of the reservoir.

A nonrebreather mask reliably supplies the highest concentration of oxygen that can be provided to a spontaneously breathing patient.

ENCLOSURE SYSTEMS — Enclosure systems such as oxygen hoods or tents may be used for infants or children who require prolonged administration of oxygen but cannot tolerate a nasal cannula or mask. Hoods and tents can also supply good humidification and temperature control. Both systems are very noisy for the patient [14].

Hoods — Oxygen hoods are clear, plastic cylinders that encompass the infant's head. Oxygen concentrations of 80 to 90 percent can be achieved with oxygen flow rates of ≥10 to 15 L/min [9].

Oxygen enters the hood through a gas inlet. Exhaled gas exits through the opening at the neck [14].

The hood is usually well tolerated by newborns. Infants in an oxygen hood are accessible for monitoring and other care. Most hoods are too small to use for infants older than one year of age [9].

Tents — Oxygen tents are clear, plastic shells that surround the child's head and upper body. Although a tent can provide up to 50 percent oxygen using high oxygen flow rates, mixing with room air occurs whenever the tent is opened. As a result, oxygen tents are generally not a sufficient source of oxygen for children who require concentrations greater than 30 percent [9].

Oxygen tents limit access to the child by family and clinical staff. In addition, highly humidified air typically results in the formation of mist, which obscures the patient from view, preventing the early recognition of changes in the child's condition such as cyanosis or obtundation.

VENTILATION BAGS — Ventilation bags are typically used to provide oxygen and assisted ventilation, either with a mask or through an artificial airway (such as an endotracheal tube). (See "Airway management in children"). Flow-inflating bags can be used to provide supplemental oxygen to spontaneously breathing children. (See "Blow by" above).

Self-inflating bags — A self-inflating (Ambu) bag reinflates with a recoil mechanism. It does not require a gas source to re-expand. However, during reinflation with an oxygen source, room air is entrained in the system, diluting the concentration of oxygen that is delivered to the patient. Therefore, in order to consistently deliver high concentrations of oxygen, a reservoir must be attached to the bag. (See "Airway maintenance techniques and assessment of ventilation in pediatric resuscitation", section on Bag-mask ventilation).

Flow-inflating bags — Flow-inflating (anesthesia) bags require a gas source to remain inflated. When oxygen is used as the source, 100 percent oxygen can be delivered to the patient. These systems are more complicated to use than a self-inflating bag. The flow of oxygen and an outlet control valve must be adjusted to ensure safe and effective ventilation. Consequently, flow-inflating bags should only be used by clinicians with specific training and experience [15].

SUMMARY AND RECOMMENDATIONS — Critically ill or injured children frequently require oxygen therapy. The choice of an oxygen delivery system will depend upon the clinical status of the child and the desired dose of oxygen. For children who are breathing spontaneously, the appropriate delivery system depends upon the dose of oxygen that they require and how well they tolerate the system. These patients should remain in a position of comfort whenever possible. (See "General concepts" above).

- Blow by (wafting) oxygen can be provided with oxygen tubing, corrugated tubing, or a simple mask to children who require less than 30 percent oxygen for short periods of time. Self-inflating (Ambu) bags should not be used as a source of blow by oxygen. Pulse oximetry should be monitored to ensure that oxygen is being effectively delivered. (See "Blow by" above).

- A nasal cannula can deliver 25 to 40 percent oxygen, depending on the patient's respiratory rate, tidal volume, and extent of mouth breathing. Flow rates 2 L/min or less are recommended for infants. (See "Nasal cannula" above).

- A simple mask with 6 to 10 L/min of oxygen flow delivers 35 to 50 percent oxygen. Partial and nonrebreathing masks with oxygen reservoirs deliver maximum concentrations of 60 and 95 percent oxygen, respectively. (See "Masks" above).

- Enclosure systems include hoods and tents. Hoods can deliver up to 90 percent oxygen and may be used for infants less than one year of age. Tents deliver less oxygen (up to 50 percent). Mist that accumulates in the tent may obscure the child from view. (See "Enclosure systems" above).

- Ventilation bags are used to provide oxygen to patients who require assisted ventilation. A reservoir must be attached to self-inflating bags in order to provide high concentrations of oxygen. (See "Ventilation bags" above).

Oxygen delivery systems for infants and children

System	Percent oxygen delivered	Indications	Comments
Blow by	Less than 30 percent	Use for spontaneously breathing children who require low doses of oxygen and do not tolerate a mask	Monitor pulse oximetry
Nasal cannula	25 to 40 percent	Use to deliver low dose oxygen to spontaneously breathing patients	Percent oxygen delivered affected by respiratory rate, tidal volume, and extent of mouth breathing. Flow rate 2L/min or less for infants
Simple mask	35 to 50 percent	Use to deliver low dose oxygen to spontaneously breathing patients	Percent oxygen delivered affected by mask fit and respiratory rate
Partial rebreather mask	50 to 60 percent	Use to conserve oxygen	
Nonrebreather mask	Up to 95 percent	Use to deliver high dose oxygen to spontaneously breathing patients	Tight mask fit required to deliver higher concentrations of oxygen
Hood	80 to 90 percent	Infants less than one year of age	Noisy for patient
Tent	Less than 50 percent	Use for children who require 30 percent oxygen or less	Mist may obscure view of patient. Noisy for patient.
Self-inflating ventilation bag	95 to 100 percent, with reservoir	Use to provide assisted ventilation and oxygen	Do not use to provide blow by. Must use with a reservoir to provide higher oxygen concentrations.
Flow-inflating ventilation bag	100 percent	Use to provide assisted ventilation and oxygen	May use to provide blow by. Requires experience to use reliably.