OXYGEN THERAPY IN PEDIATRIC PRACTICE

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Oxygen is the most commonly used intervention in the management of any critically ill child(1). Its ubiquitious nature tends to foster a casual attitude towards its application. However, it must be realized that oxygen at enriched levels is a drug with well characterized toxic effects. It therefore, must be used carefully, like any another pharmacological agent(1).

Indications for Oxygen Therapy(1)

These include: (*i*) Hypoxemia secondary to any cause–respiratory, cardiovascular or neurological; (*ii*) To raise the arterial and alveolar oxygen levels above physiologic limits as in carbon monoxide poisoning; and (*iii*) Acceleration of reabsorption of nitrogen from the intrapleural space in pneumothorax and in the treatment of gas gangrene.

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Clinical Parameters of Hypoxemia

Hypoxemia affects practically every system in the body. As a result the clinical manifestations are nonspecific. There is no consensus as to which of the clinical signs correlates well with hypoxia. Some of the clinical manifestations are listed in *Table I.* Clinical assessment should be supported by blood gas measurement, wherever possible(2).

TABLE I– *Clinical Features of Acute Hypoxemia(2)*

Symptoms	Signs
Mental confusion	Tachypnea
Personality changes	Tachycardia
Restlessness	Hypertension (in mild)
Dyspnea	Hypotension (in severe)
Palpitation	Arrhythmias
Angina	Heart failu, Seizures, Coma, Cyanosis

The WHO recommends, that oxygen should be given to a child with acute respiratory infection(1) with central cyanosis, or inability to drink, if there is only a limited supply of oxygen(2), or when grunting (in infants <2 months of age), tachypnea (>70 breaths/min in a child 2 months 7 years old), restlessness which improves on oxygenation, or chest indrawing are present if there is an ample supply of oxygen(3). The appearance of cyanosis is a late indicator of hypoxemia, and therapy should be started well before its appearance.

A rising pulse rate, respiratory rate and alteration in higher functions, in an appropriate clinical setting are pointers to hypoxia and laboratory tests should be per-

formed to confirm the diagnosis.

Laboratory Parameters

Blood gas monitoring by arterial blood gas sample was, till recently, the only method of monitoring hypoxemia. This involved repeated arterial punctures or placement of an indwelling arterial cannula both of which had their own complications. Pulse oximetry is a new noninvasive method of estimating the oxygen content of blood. A pulse oximeter measures the oxygen saturation of blood. A pulsating vascular bed (finger, toe or ear lobe) is positioned between the pulsating light source and detector. The pulsating bed creates a change in the length of the path that light has to traverse from source to detector. This alters the amount of light detected at a particular moment which is related to the oxygen saturation of blood. This test has limitations in that it cannot be used in patients with shock. It cannot be used to measure PaO_2 levels more than 80 mm Hg, as this is associated with an oxygen saturation of 100%.

Sources of Oxygen

The two main sources are oxygen cylinders and oxygen concentrators.

Oxygen Cylinders: These are reusable cylinders which are filled from a bulk supply and then transported to the point of use. Their bulk, short life span and cost, are major hurdles in the use of this form of oxygen.

Oxygen Concentrators: These were first produced in the 1960s to provide long term home oxygen therapy. Most use an electric pump to force compressed air through synthetic aluminium silicate which reversibly binds nitrogen(4). They deliver about 2-4 L/min of gas containing 90% oxygen.

The concentration of oxygen depends upon the flow rate. At higher flow rates the oxygen concentration drops. A semipermeable membrane that permits selective diffusion of oxygen and water has been used as an alternative design. The machines produce gas with a high humidity but deliver only 40% oxygen(4,5).

The initial cost of those concentrators are more than the oxygen cylinders but the running cost is lower. They, however, need a continuous electric supply. At present they should be used only where there are reliable electric supply and adequate servicing facilities.

Methods of Oxygen Administration

Several methods (*Table II*) are available for use in the pediatric age group:

TABLE II– *Flow Rate and Approximate FiO_2 with Different Methods of Oxygen Administration(9)*

Method	Flow rate	FiO_2(%)
Nasal cannula	1	24
Nasopharyngeal catheter	3	32
	6	44
Simple face mask	5-6	40
Partial rebreathing (with reservoir bag)	7-8	60
	6-10	70
Nonrebreathing (with reservoir bag)	6-10	95
Venturi mask	3	24
	6	36
	10	50
Incubator	–	40
Head box	–	95.

1. *Nasal cannula:* This is a small tube of hard plastic held beneath the nostrils by

tape. It has two prongs placed at the anterior nares. Oxygen flows through the tube and prongs into the nose. These prongs can be cut off it they cause irritation. The advantages are that this is a more comfortable way of administration of oxygen than a nasal catheter and the risk of gastric distension is minimal. However, the effectiveness is limited. Even at flow rates of 4 min the required oxygen concentration is only about 30-40% and this falls substantially if the child breaths through the mouth.

2. *Nasal catheter:* This consists of a soft catheter inserted into the nostrils to a length equal to the distance from the side of the nose to the tragus. The nasopharynx and oropharynx act as natural reservoirs. This is probably the most effective way to oxygenate children with respiratory infections. It is cheap and requires lower flow rates of oxygen. However, gastric distension can occur if the catheter is pushed in too far. The gas must also be humidified. Some children will not tolerate the tube and will gag. If this continues for a few minutes then the tube must be pulled back by 1-2 cm. A flow rate of 2L/min can achieve an FiO_2 of up to 70% in small infants. The nasal catheter must be cleared frequently so that the holes in the tube are not blocked by nasal secretions.

3. *Oxygen masks:* Oxygen masks can be divided into four groups:

1. Simple masks
2. Partial rebreathing masks
3. Non-rebreathing masks
4. Venturi devices.

The simple mask consists of a face piece that is fitted over the patient's nose and mouth. The mask has a central entry port for gas and holes at the sides that serve as exhalation ports. Flow rates of about 6-10 L/min will provide an inspired oxygen concentration of about 50%. This however is variable and is dependent on a number of factors like the peak inspiratory flow rate and the patient's respiratory rate.

Partial rebreathing masks have in addition to the simple mask a small reservoir where oxygen has collects during expiration. Although this too has pitfalls like the simple masks, FiO_2 of up to 70% can be achieved with oxygen flow rates of 6-10 L/min.

Non-rebreathing masks have one way valves on the exhalation port and between the reservoir and mask. As a result the exhaled gases do not enter the reservoir bag during exhalation. Close to 100% oxygen can be administered using the mask if used properly(6).

Venturi masks are based on the Venturi principle. Oxygen is delivered through a narrow orifice in the mask. As a result of acceleration of the oxygen flow due to the progressive narrowing of the tubing just proximal to the orifice, a negative pressure is set up which sucks in room air through the air entrainment ports in the masks. Varying concentration of oxygen can be administered depending on the size of nozzle and air entrainment ports. At flow rates of 6-10 L/min FiO_2 can vary from 24-40%.

Oxygen hood: An oxygen hood is a small box of transparent plastic. Oxygen enters through an aperture at the top of the box. A continuous flow of gas ensures flushing out of exhaled gases. Disadvantages include the need for high rates to achieve adequate FiO_2 and the development of oxygen concentration gradient. Oxygen concentration in these hoods can vary by as much as 20% between the top

and bottom of the hood(7).

Humidification

Humidification of gases is essential for proper oxygenation. Humidity represents the amount of water vapor in the gas. Normally inspired gases contain some degree of humidity. These are further humidified as they pass through the upper respiratory tract so that gases reaching the lungs are at 100% relative humidity. Since delivery of oxygen sometimes involves the use of pathways which bypass the upper respiratory tract, humidification of gases does not occur, leading to increased insensible water loss, drying up of respiratory secretions resulting in airway obstruction and impaired mucociliary function. A number of devices are, therefore, devised to overcome this problem.

(*a*) *Simple humidifiers:* These have no mechanism to heat the delivered gas mixture to body temperature. They can thus achieve a relative humidity of 100% only at room temperature. The simplest is a pass-over humidifier in which the gases are passed over the surface of water prior to administration. Bubble humidifiers are devices where the gases are bubbled through water. The level of humidification falls drastically if the water level in these humidifiers falls below a specific level.

(*b*) *Heated humidifiers* involve a heating element that heats the mixture of inspired gases besides humidifying them. These are more efficient but complex to operate. The degree of humidification of gases leaving the unit depends on a number of factors including the temperature setting of the thermal unit, the flow rate and length of circuit.

Unheated bubble humidifiers give acceptable results when used with low flow rates in tropical countries (where ambient temperatures are high)(8).

Complications of Oxygen Therapy

It is well known that high concentration of oxygen is damaging to the lung, but its exact importance is not known. However, it now seems that FiO_2 more than 40% worsen the changes of acute lung injury. This toxicity is manifested by decrease in surface active substances, atelectasis and impaired mucociliary activity which lead to ventilation perfusion abnormalities.

The effect of high oxygen concentrations on the retina of premature is also well known. Besides the above two complications, a high inspired concentration of oxygen also leads to a reduction in the ventilatory drive secondary to hypoxia and also atelectasis. Atelectasis occurs because nitrogen is washed out of the alveoli secondary to high concentrations of oxygen in inspired air. Oxygen, which takes its place, diffuses rapidly into the blood and as a result the alveolus collapses. Efforts must, therefore, be made to reduce the inspired oxygen concentration to the minimum, compatible with a greater than 95% of oxygen saturation.

Oxygenation in the Neonate and Very Small Child

Improved oxygen therapy is one of the therapeutic interventions that has resulted in a major improvement in neonatal morbidity and mortality in the last two decades.

Oxygen is administered to maintain arterial oxygen tensions between 60 and 80 torr in term infants and 50 and 70 torr in premature babies. Methods of administration are similar to older children. Certain precautions must, however, be taken. Oxygen should be adequately humidified to prevent increased insensible water losses.

The gases should be warmed to body temperature to prevent hypothermia.

Monitoring Oxygenation

Besides the usual invasive methods of measuring oxygen concentration by indwelling arterial catheter, intermittent punctures and capillary sampling, two noninvasive techniques are now available: (*i*) Pulse oximetry (discussed earlier), (*ii*) Transcutaneous oxygen monitoring. This uses a skin electrode that is heated to about 44°C. This results in dilation of the underlying capillary bed and the gas tension is then measured. The electrode is placed on the trunk of the patient and the site needs to be changed every 4-6 hours. The main advantage is that a continuous record of the oxygen tension is obtained.

Toxicity

Oxygen toxicity is commoner in neonates affecting the alveoli of the lungs and cells of the retina resulting in retinopathy of prematurity (ROP) and lung disease. Although the precise contribution of oxygen to bronchopulmonary dysplasia (BPD) is controversial, newborns receiving high concentration of oxygen for prolonged periods should be followed up for development of BPD and ROP.

One Oxygen Source for Several Patients

If one needs to give oxygen from one source to more than one patient, four way adaptors with separate flow meter and humidifiers must be used for each patient. One should not put a Y connector to the tubing from the humidifier to the patients. It may not deliver adequate oxygen to all cases.

When to Stop Oxygen Therapy ?

Oxygen therapy should not be stopped in a child who is still very ill. Before stopping this the child should have a trial period without oxygen. If the child remains comfortable and does not become cyanosed, oxygen therapy is no longer needed.

REFERENCES

1. Goia FR, Stephenson RC, Alterwitz SA. Principles of respiratory support and mechanical ventilation. *In:* Textbook of Pediatric Intensive Care, Vol. 1. Ed Rogers MC. Baltimore, Williams and Wilkins. 1987, pp 139-144.
2. Pagtakhan RD, Chernick V. Intensive care for respiratory disorders. *In:* Disorders of the Respiratory Tract in children, 4t edn. Ed Kendig, Chernick. Philadelphia, W.B. Saunders 1983, pp 147-148.
3. Acute Respiratory Infections in Children. Case Management in Small Hospitals. Doctors Manual. New Delhi, Ministry of Health and Family Welfare, Government of India, 1990, pp 84-85.
4. Harris ND, Stamp JM. Current developments in Oxygen concentration technology. J Med Eng Tech 1987; 11: 103-107.
5. Evans TW, Waterhouse J, Howard P. Clinical experience with the oxygen concentrator. Br Med J 1983, 287: 459-461.
6. Redding JS, McAffe DD, Parham AM, *et al.* Oxygen concentrations received from commonly used delivery sytem. South Med J 1978, 71: 169-172.
7. McPherson SP. Gas administration devices in Respiratory Therapy Equipment, 2nd edn. St Louis, CV Mosby Co, 1981, p 69.
8. Shann F. Nasopharyngeal oxygen in children. Lancet 1989, i: 1077-1078.
9. Vijayasekaran D, Giridhar Rao BK, Vaidyanathan K. Oxygen therapy. *In:* Essentials of Pediatric Pulmonology. Ed. Somu N, Subramanyam L. Madras, Siva and Co, 1990, pp 198-200.