Respiratory Support in Developing Countries Where Resources Are Limited

20

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Educational Goals

- Review the definition of hypoxemia that might require oxygen therapy in various conditions.
- Review the basic rules on how and when to wean oxygen therapy.
- Review the concept of a stepwise approach towards respiratory support (noninvasive and invasive methods).
- Review the use of adjuvant nonventilatory treatment options for respiratory failure in children and neonates.

20.1 Oxygen Therapy

20.1.1 Definition of Hypoxaemia and Indications for Oxygen Therapy

The range of means for haemoglobin–oxygen pulsed saturation (SpO_2) at sea level is 97–99 %, with the lower limits (mean, 2 SD) being 94 % (Lozano 2001). Therefore, the normal range at sea level is 94–100 %. The normal range of SpO_2 becomes progressively lower in populations living in mountainous regions because of lower PaO_2 at higher altitude (see Fig. 20.1) (Lozano 2001). This was estimated using data from 16 studies in children outside the neonatal period. The continuous line predicts the level of SpO_2 below which oxygen should be given at different altitudes.

Changing the point at which hypoxaemia is defined and oxygen is given results in a major variation in the amount of oxygen used. A report from one hospital found that 13 % of children with pneumonia were hypoxaemic using a definition of SpO_2 <85 %, 26 % were hypoxaemic using SpO_2 <90 and 44 % were hypoxaemic using SpO_2 <93 % (Laman et al. 2005).

The best cut-off point for giving supplemental oxygen may be the level of blood oxygen that is associated with increased morbidity or risk of death or delayed recovery, rather than a certain level of haemoglobin–oxygen saturation below normal for the population. With normal cardiac output, haemoglobin concentration and pH, arterial oxygen saturations of 68 % or more are prob-

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P.C. Rimensberger (ed.), *Pediatric and Neonatal Mechanical Ventilation*,
DOI 10.1007/978-3-642-01219-8_20,

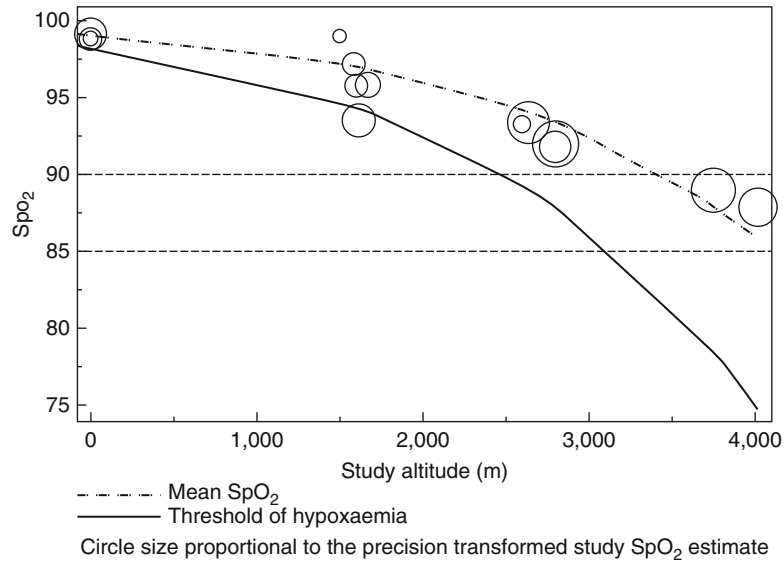

Fig. 20.1 Threshold of hypoxaemia at different altitudes

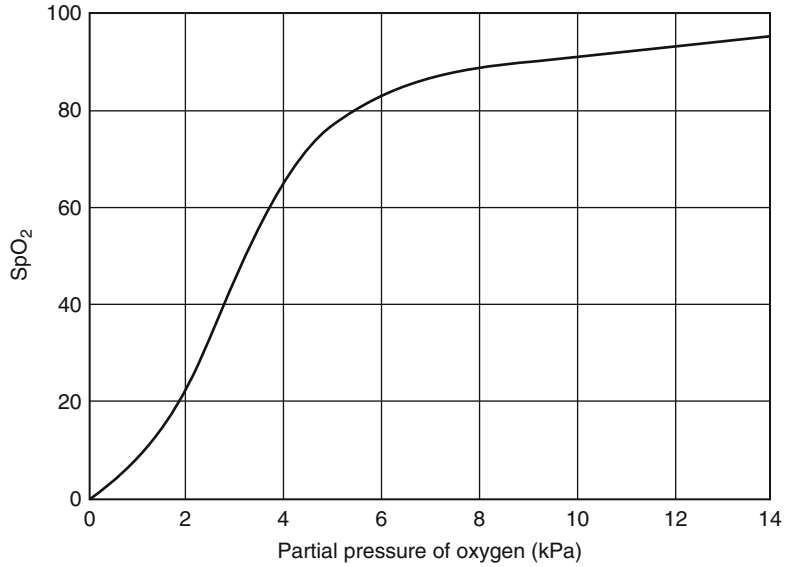

Fig. 20.2 Haemoglobin–oxygen dissociation curve

ably not dangerous (Nunn 1993). However, there are few data about the exact SpO_2 below which the risk of adverse outcomes increases. This risk will be different for different ages, disease states and comorbidities and at different altitudes, and a safe margin for error is required.

The gold-standard measure for the oxygen content of the blood is the arterial oxygen tension or PaO_2 (measured in mm Hg or kilopascals). PaO_2, however, can only be measured by blood gas analysis. This method is invasive, painful and distressing to the patient, and blood gas machines and reagents are very expensive and, therefore, not appropriate in most district hospitals in developing countries. Therefore, we use SpO_2, which is related to PaO_2, to define hypoxaemia in these guidelines (see Fig. 20.2).

In practice, most studies have adopted a threshold at which to give oxygen of SpO_2 <90 %. This corresponds to the beginning of the steep part

Table 20.1 Clinical indications for oxygen therapy

Clinical presentation for severe pneumonia with	Priority for oxygen
Central cyanosis	Very high priority
Decreased consciousness, unresponsiveness or responsive to painful stimuli only	Very high priority
Head nodding or grunting	Very high priority
Severe palmar or conjunctival pallor (severe anaemia) with severe lower chest wall indrawing or fast breathing	Very high priority; high priority should also be given to urgent correction of the underlying abnormality (i.e. blood transfusion and/or antimalarials)
Acute coma or convulsions lasting more than 15 min	Very high priority until respiratory effort has returned to normal; also protect airway and ensure adequate ventilation
Inability to drink or feed	High priority
Severe chest indrawing	Priority

of the haemoglobin–oxygen dissociation curve, which is shown in Fig. 20.2. Small reductions in SpO_2 below 90 % may represent dangerous falls in PaO_2. This represents a safe margin for error where oxygen supplies are sufficient.

There will be conditions that require oxygen therapy at higher thresholds than 90 % SpO_2. These are conditions where oxygen delivery from the lungs to body tissues is seriously impaired or where vital organs may be particularly susceptible to low oxygen levels. Examples include severe anaemia, severe heart failure, severe sepsis or brain injury. In these conditions, many clinicians recommend giving oxygen if the SpO_2 is <94 %.

It is important to note that small changes in SpO_2 between 90 and 100 % reflect large changes in PaO_2, because the haemoglobin–oxygen dissociation curve is relatively flat. Below an SpO_2 of 90 %, however, the curve is steep and small falls in PaO_2 may result in much larger falls in SpO_2.

The clinical signs of hypoxaemia have been evaluated in many studies and reviewed (Rojas et al. 2009; Ayieko and English 2006). In situations where the oxygen supply is very limited, for children aged over 2 months, provide oxygen according to the priority listing suggested in Table 20.1. Infants aged <2 months with signs of severe respiratory distress (tachypnoea, severe chest indrawing, head nodding or grunting) should be given oxygen because hypoxaemia puts them at greater risk of apnoea and death.

Even the best combinations of clinical signs commonly misdiagnose hypoxaemia in some patients with normal oxygen saturation or fail to detect some hypoxaemic patients. Pulse oximetry has been found to correctly identify 20–30 % more children who have hypoxaemia than will be found using clinical signs alone (Usen et al. 1999; Weber et al. 1997; Duke et al. 2002a). When used correctly, pulse oximetry provides reliable monitoring with little or no distress to the patient; in industrialized countries, it is the accepted standard for detecting hypoxaemia (Schnapp 1990).

When monitoring with oximetry, as a general rule, any child with an SpO_2 <90 % should receive oxygen. This rule best applies to health facilities located between sea level and 2,500 m above sea level and where oxygen supplies are ample (such as when using concentrators) for altitudes higher than 2,500 m.

Where there is sufficient oxygen to treat all children with hypoxaemia, it is the practice in some hospitals to give oxygen if the SpO_2 is <93 %. Some doctors suggest oxygen should be "discretionary" between an SpO_2 of 90 and 92 % and "mandatory" at SpO_2 <90 %. There are certainly some children who will benefit more than others from oxygen when the SpO_2 is in the range of 90–92 %: those with very severe anaemia, severe heart failure, septic shock and acute neurological illness. These children will be less able to withstand moderately low oxygen levels than children with only lung disease.

Because the normal SpO_2 range is lower at higher altitudes, it may be appropriate to only give oxygen for an SpO_2 of 85 % or less to children living at an altitude above 2,500 m, if oxygen supplies are limited (e.g. when using oxygen cylinders and transport difficulties or cost limit supply) (Duke 2003). Oxygen concentrators, which provide continuous, unlimited oxygen, largely overcome this problem. If these are available, a universal threshold of 90 % SpO_2 will be appropriate.

20.1.2 What to Do if the Child Does Not Improve or Deteriorates After Oxygen Is Given

It is very important that after starting oxygen therapy, the child is checked within 15–30 min to see if the treatment is working. In severely hypoxaemic children, correction may not be complete and clinical signs may remain, or the SpO_2 may still be low. This does not mean that oxygen therapy has failed and should be abandoned. Other children will deteriorate rapidly or slowly despite receiving oxygen. There are a number of possible causes for a lack of response.

Oxygen delivery is inadequate, so check that:

- Flow is occurring (hold the tubing close to your face to feel the flow).
- There are no leaks from oxygen tubing.
- The nasal prongs or nasal catheter are fitted correctly and not blocked.
- If delivery is via an oxygen concentrator, the concentration of oxygen being delivered is adequate (>85 %).

There are other problems (see the *WHO Pocket Book of Hospital Care for Children*, Chapter 4) (World Health Organization 2005), such as:

- Pleural effusion. Listen with a stethoscope for breath sounds on both sides of the chest; do a chest X-ray.
- Pneumothorax. Listen with a stethoscope for breath sounds on both sides of the chest; do a chest X-ray.
- Upper airway obstruction (e.g. from croup or a foreign body). Listen for stridor.
- Bronchospasm (e.g. severe asthma). Listen with a stethoscope for wheeze.
- Cyanotic heart disease or congestive heart failure.
- Ventilatory failure. The child's respiratory effort is inadequate; the child will have slow or shallow breathing and be lethargic.

If nasal prongs are being used at maximum flow and the child is still hypoxaemic, sometimes it is useful to give a second source of oxygen, if it is available, via an oxygen mask (ideally with reservoir bag) to increase the fractional concentration of inspired oxygen.

If a second source for mask oxygen is not available, an N-P catheter can give a higher fractional concentration of inspired oxygen than nasal prongs (but never use nasal prongs and an N-P catheter together).

20.1.3 Monitoring the Progress of Children on Oxygen

In most hospitals, the most appropriate form of monitoring will be regular checks with pulse oximetry on children who might need oxygen, those who are already on oxygen, those who have developed respiratory distress and those who show other clinical signs of deterioration. Oximetry can also be used to determine how long children need to be treated with oxygen. In severe pneumonia the duration of hypoxaemia may be anything from several hours to several weeks; the usual time is 2–5 days (Duke et al. 2000, 2002b). The duration of hypoxaemia may be longer at higher altitudes than at sea level for a similar severity of pneumonia (Weber et al. 1995).

Children who are receiving oxygen should be monitored clinically at least twice a day with pulse oximetry. Children in a stable condition should be tried off oxygen once a day to determine if they still require oxygen.

It is important to be aware that pulse oximeters provide no information on carbon dioxide concentration in the blood and thus no direct information on ventilatory efficiency. It is unlikely that a child who has normal oxygen saturation while breathing room air has impaired ventilation. However, once oxygen is administered, SpO_2 can be maintained at normal levels despite severe hypercapnoea. In a child receiving supplemental oxygen, oximetry cannot be used to monitor the adequacy of ventilation. For children receiving oxygen, therefore, clinical monitoring of respiratory effort, respiratory rate and consciousness level is a better guide to the adequacy of ventilation. A child with inadequate ventilation will have slow or shallow breathing and be lethargic.

In a small hospital, any concern over the adequacy of ventilation should prompt efforts to ensure that the airway is clear and protected and that the patient is positioned to facilitate chest expansion (e.g. sitting in a semi-recumbent position of 20–30°, head up to reduce diaphragmatic splinting if there is abdominal distension, passing a nasogastric tube to deflate the stomach).

Referral to a high-dependency area or intensive care unit should be arranged if CPAP or mechanical support is available.

All methods of oxygen administration need supervision by trained personnel to detect and manage complications appropriately. A nurse should check every 3 h that the prongs or catheter are in the correct position and not blocked with mucus, that all connections are secure, that the oxygen flow rate is correct, that the airways are not obstructed by mucus and that there is no gastric distension. Prongs or catheters should be removed and cleaned at least twice a day.

All severely ill children need regular monitoring of vital signs and general condition. Many deaths in hospitals occur overnight, often when monitoring is infrequent or absent. SpO_2 is the most vital of clinical signs, so pulse oximetry is an invaluable, routine monitoring tool.

20.1.4 Trials Off Oxygen and When to Stop Oxygen

At least once each day, children in the ward who are clinically stable (have no emergency signs and SpO_2 >90 %) should be disconnected from oxygen for 10–15 min and carefully examined for changes in clinical signs and SpO_2, to assess whether supplemental oxygen is still required. Trials off supplemental oxygen are best done first thing in the morning, when there is likely to be adequate staff to observe the child throughout the day. If trials off supplemental oxygen are started in the late afternoon, low staff numbers overnight and the oxygen desaturation that sometimes occurs during sleep mean that there is a risk of hypoxaemia developing unrecognized overnight.

Children who have an SpO_2 <90 % while still on oxygen or who are unstable or very unwell should not be given trials on room air.

Before a trial off oxygen, the SpO_2 should be checked to determine if the trial is safe (i.e. SpO_2 >90 %). The child should then be disconnected from the oxygen source and observed carefully to avoid any adverse complications of hypoxaemia. If severe hypoxaemia (SpO_2 <80 %), apnoea or severe respiratory distress occurs, children should be immediately restarted on oxygen. Some children will become hypoxaemic very rapidly when they are taken off oxygen, and this is a marker of very severe disease and a high risk of death. Parents and nursing staff should be advised to watch the child to see if he/she develops cyanosis or severe respiratory distress.

Where oxygen supplies are ample, children should receive supplemental oxygen until their SpO_2 on room air is 90 % or greater. If the SpO_2 is 90 % or more after a trial on room air, they should remain off oxygen and the SpO_2 should be rechecked after 1 h, as late desaturation can sometimes occur. Any child who appears to deteriorate clinically should have their SpO_2 checked to determine whether they need oxygen. If bed space allows, children should not be discharged until their SpO_2 has been stable at 90 % or more while breathing room air for at least 24 h, until all danger signs have resolved and until appropriate home treatment can be organized. This of course does not apply to children with cyanotic congenital heart disease, who have chronic hypoxaemia. For children with right to left intracardiac shunts (such as tetralogy of Fallot), oxygen will not be effective in relieving cyanosis or improving SpO_2.

The chest X-ray appearance does not provide any useful guide to the need for oxygen therapy or when it is appropriate to stop.

20.1.5 General Care for Children with Hypoxaemia or Severe Respiratory Distress

Nursing care of children with hypoxaemia is very important. The following describes the main things to consider, including minimal handling, positioning, fluids and nutrition and close monitoring.

20.1.5.1 Minimal Handling

Handling can be upsetting to severely ill children, and activity consumes more oxygen. Handling should be gentle, and unnecessary stress or painful procedures should be avoided.

20.1.5.2 Positioning

Children will often find their own most comfortable position in the bed or on their mother's lap, but sometimes their breathing may improve if they are nursed with their head raised about 30 ° with neck support, rather than lying flat. Some

hypoxic neonates and young infants may be more stable in the prone position, as long as their face is not obstructed.

20.1.5.3 Fluids and Nutrition

The following guidelines should be followed when dealing with fluids and nutrition of hypoxaemic children:

- Withhold oral feeds while the child has severe chest indrawing or severe respiratory distress because of the risk of aspiration.
- Use an intravenous drip or a nasogastric tube, depending on what can be managed most safely.
- Do not give large volumes of intravenous fluids as this may make the lungs "wet" and worsen hypoxaemia.
- Do not give large nasogastric feeds to children with severe respiratory distress, because the child may vomit and aspirate.
- Make sure that as soon as severe respiratory distress has settled, the child receives good nutrition, preferably breast milk.

20.1.6 Overcoming Parents' Concerns About Oxygen Use

Education of parents about the need for oxygen is important to alleviate fears. Many parents are afraid of oxygen and oxygen catheters. Sometimes they will have seen other children receive oxygen just before they died, and they may fear that the oxygen caused the death. It can be very helpful to show parents the pulse oximeter in operation and explain to them why the child's oxygen level is low. It is useful also to show them the clinical signs (such as chest indrawing or cyanosis of the gums or tongue). When oxygen is then applied, parents will see that the SpO_2 increases and the child's respiratory distress lessens. They will have much more confidence in the treatment and be more likely to accept it. In one hospital in Papua New Guinea, the absconding rate of mothers fell significantly (from about 25 % down to 8 %) when daily checking of children using pulse oximetry was introduced (Duke et al. 2000, 2002b). This was mostly the result of explanation of the monitoring and its implications (for needing oxygen, needing to stay in hospital or readiness for discharge). It is also a daily demonstration that some special attention is being paid to their child, and mothers appreciate this greatly. Even when illiterate, most of these mothers were still able to understand the significance of the number generated by the pulse oximeter and thresholds for safe discharge when these were explained in their own language.

20.1.7 Sources of Oxygen

The most common sources of oxygen are oxygen cylinders, oxygen concentrators and oxygen pipelines.

Oxygen for cylinders is produced by cooling air until it liquefies, then distilling the liquid to separate pure oxygen from it. This is an expensive, energy-consuming process that can only take place in large manufacturing plants. Cylinders need to be transported to and from the bulk supply depot for refilling. Transport is difficult, expensive and often unreliable in developing countries, so small hospitals can be without oxygen supplies for long periods.

Oxygen concentrators entrain air from the environment, which usually contains 21 % oxygen, 78 % nitrogen and 1 % other gases. By extracting nitrogen from the air, they can produce almost pure oxygen. Most concentrators supply oxygen at a concentration of 90–96 %. In paediatric care, with a continuous and reliable power source, one oxygen concentrator can supply continuous oxygen for up to four patients. (In case of power failure, a power generator or a power-independent oxygen source should be available as a back-up.) Concentrators need regular maintenance to ensure proper function, but they are a reliable and independent oxygen source that is also cost-efficient. To get the most out of concentrators, they should be used with flow splitters or flow meters that allow oxygen to be provided to multiple patients at the same time.

In many larger hospitals, oxygen is distributed through a system of copper pipes from a central source of oxygen, usually located outside the building. The source may be liquid oxygen, high-pressure gaseous oxygen cylinders, a large oxygen concentrator or a combination of these. Pipeline systems supply oxygen at high pressure,

which enables equipment such as anaesthetic machines and ventilators to be supplied with the gas. A pipeline system has many safety advantages: it reduces the risk of fire and avoids handling and transportation between hospital wards of heavy cylinders. However, the high cost of installing centralized oxygen sources with copper pipelines and their maintenance make these systems of oxygen delivery unsuitable for district-level hospitals in developing countries.

20.1.8 Devices for Giving Oxygen

Methods for giving oxygen may be noninvasive (delivery through a face mask, into a head box, incubator or tent or through tubing held close to an infant's face) or semi-invasive (insertion of nasal prongs or catheters into the upper airway) (Frey and Shann 2003). The pros and cons of different methods have been reviewed (Rojas et al. 2009; Frey and Shann 2003).

Noninvasive methods require high oxygen flow and are therefore inefficient and uneconomical where resources are limited. Semi-invasive methods use lower flows and are therefore more appropriate where oxygen supplies are scarce. Some semi-invasive devices have an additional beneficial effect on lung function by producing positive end-expiratory pressure (PEEP) (Frey et al. 2001). This kind of PEEP production can also be effective in the management of apnoea (associated with prematurity or with bronchiolitis) (Sreenan et al. 2001).

Problems associated with oxygen delivery systems include dislodgement of nasal prongs and obstruction of catheters. Hypercapnoea (high levels of carbon dioxide in the blood) can result from inadequate flows through head boxes or face masks that allow build-up of carbon dioxide. Nasopharyngeal (N-P) catheters, and to a lesser extent nasal catheters, can obstruct airways or cause bleeding (Muhe and Weber 2001). Uncontrolled high PEEP production associated with inappropriately high oxygen flows through prongs or catheters may lead to gastric distension or pneumothorax. To minimize such problems, flow at the end of delivery tubing should be checked regularly using a detachable flow meter or sensor.

20.2 Continuous Positive Airway Pressure (CPAP) Systems

20.2.1 Bubble-Continuous Positive Airway Pressure (Bubble-CPAP)

A system of CPAP will be available in some hospitals but is only appropriate to use when basic, reliable, oxygen systems (described above) are in place, where staff are adequately trained and close monitoring is assured. CPAP delivers PEEP with a variable amount of oxygen to the airway of a spontaneously breathing patient to maintain lung volume during expiration. CPAP decreases atelectasis (alveolar and lung segmental collapse) and respiratory fatigue and improves oxygenation. Bubble-CPAP is an appropriate method for delivering CPAP and has been used successfully in some referral hospitals in developing countries (Koyamaibole et al. 2006). The bubble-CPAP system consists of three components:

1. Continuous gas flow into the circuit: CPAP requires a source of continuous airflow (often an air compressor). The gas flow rate required for generating CPAP is usually about 5–10 l/min. This alone can generate CPAP with a fraction of inspired oxygen (FiO_2) of 21 %, but many neonates require some supplemental oxygen. Therefore, bubble-CPAP also usually requires an oxygen blender that connects an oxygen source (cylinder or concentrator) with the continuous airflow to increase the FiO_2.
2. A nasal interface connecting the infant's airway with the circuit: short nasal prongs are generally used to deliver nasal CPAP. These must be carefully fitted to minimize leakage of air (otherwise CPAP will not be achieved) and to reduce nasal trauma.
3. An expiratory limb with the distal end submerged in water to generate end-expiratory pressure: in bubble-CPAP the positive pressure is maintained by placing the far end of the expiratory tubing under water. The pressure is adjusted by altering the depth of the tube under the surface of the water.

20.2.2 High-Flow CPAP

There is some recent experience with a simpler method of delivering CPAP to newborns using high gas flow (up to 6–8 l/min) through normal nasal prongs. Although PEEP can be generated by this method, it is not as simple as dialling higher flows from an oxygen source such as a cylinder or concentrator; this would be very dangerous. This method requires highly effective humidification to prevent drying of nasal mucosa, which can lead to bleeding and nasal obstruction. A heated humidifier is necessary; an unheated cold water bubble humidifier would not provide adequate humidification.

High-flow CPAP also requires an oxygen/air blender. It is dangerous to give high-flow oxygen to a preterm baby as the fractional inspired oxygen achieved would be very high, increasing the risk of eye damage. Unlike with bubble-CPAP, with high-flow methods, it is not certain what pressure is being delivered, and there is a risk of pneumothorax and gastric distension. All methods of CPAP require careful monitoring.

20.2.3 CPAP/BiPAP Drivers for Noninvasive Respiratory Support

Devices are now available for delivery of CPAP or biphasic positive airway pressure for use via a face mask. These are covered elsewhere in the book but may be applicable to hospitals in developing countries. These devices are modest cost (less than $1,000), but all have disposable circuits, and such recurrent costs can be difficult to maintain. Methods to clean and reuse CPAP and ventilator circuits need to be explored.

20.3 Mechanical Ventilation

Intensive care can best be defined as the provision of prolonged mechanical ventilation via an endotracheal tube and other expensive technology. When countries have child mortality rates above 30 per 1,000 live births, a major proportion of child deaths will be preventable or treatable by simple measures, such as immunization, primary care and good quality, but basic, curative services in hospitals. In these situations it does not make sense to spend vast resources on intensive care in tertiary institutions to which only a small proportion of children will have access, when simpler and cheaper life-saving treatments are not available to a substantial proportion of sick children.

The main argument against providing intensive care in high-mortality areas is that this would divert scarce resources away from more effective, low-cost interventions. Following the principles of equity, countries and hospitals should ensure that highly cost-effective health interventions that will reduce mortality are available to the vast majority of children, *before* funding intensive care services.

There are, however, good practical and ethical arguments for providing selective postoperative intensive care services even where national or regional mortality rates are high. Many patients who have undergone surgery die for want of appropriate supportive care, including mechanical ventilation, in the first 24 postoperative hours. The World Health Organization suggests that facilities for intensive care should be available in any hospital where surgery and anaesthesia are performed and has published standards for intensive care units in large referral hospitals, district/provincial hospitals and small hospitals in developing countries (World Health Organization 2003). These standards outline conditions that should be able to be managed, procedures that should be able to be performed and personnel, drugs and equipment that are necessary. Where mechanical ventilation is available, there is a good basis for providing intensive care for some other selected nonsurgical conditions, particularly neuromuscular paralysis after snakebite, which is time limited and likely to result in a good outcome if appropriate supportive care is provided.

Pre-existing conditions for the development of highly specialized paediatric intensive care are good vaccine services, good-quality primary- and first-referral-level care, under-5 mortality rates less than 30 per 1,000 live births, availability

of transportation, good access for the majority of the population and sufficient human resources. Until these are achieved, acute hospital clinical care should focus on improving triage, emergency care, supportive care (including oxygen, nutrition and safe administration of intravenous fluids), monitoring, discharge planning and follow-up, and not on mechanical ventilation or other high-technology interventions. These priorities are outlined in the *WHO Pocket book of hospital care for children* (World Health Organization 2005) and are the principles of high-dependency care.

20.4 Respiratory Stimulants (Methylxanthines) as Adjuvants in Neonatal and Infant Practice

Some medications (methylxanthines) can treat and prevent apnoea in premature neonates. In some hospitals, equipment for bubble-continuous positive airway pressure (bubble-CPAP) by nasal prongs will be available and is useful for the management of respiratory distress in neonates for whom basic support with oxygen is insufficient.

20.4.1 Methylxanthines

Aminophylline, theophylline and caffeine are methylxanthines and have several effects on the respiratory system. These include stimulation of the respiratory centre in the brain, and diaphragm contraction. There is encouraging evidence that in premature neonates with apnoea, aminophylline and caffeine are highly effective. These drugs may be more effective than continuous positive airway pressure (CPAP) in preventing the need for mechanical ventilation (Henderson-Smart et al. 2001) and more effective than tactile stimulation in prevention of apnoea (Osborn and Henderson-Smart 2000). Caffeine is associated with fewer adverse events than aminophylline and is equally effective in the treatment of apnoea in premature newborns (Comer et al. 2001).

Most studies of methylxanthines have been conducted in preterm babies, where the predominant pathologies are hyaline membrane disease and apnoea of prematurity. Whether such respiratory stimulants are beneficial for the treatment of apnoea in term babies and older infants has not been established in controlled trials. Aminophylline has, however, been used effectively in young infants with apnoea due to acute viral bronchiolitis.

Essentials to Remember

- The need for oxygen therapy should not only be based on SpO_2 values or invasively measured PaO_2 values but on the question whether oxygen delivery is adequate for metabolic needs. However a SpO_2 value >90 % can be judged as sufficient.
- With any flow O_2 delivery system inappropriately high oxygen flows through prongs or catheters may lead to gastric distension or pneumothorax. To minimize such problems, flow at the end of delivery tubing should be checked regularly using a detachable flow meter or sensor.
- Bubble-CPAP or variable flow CPAP systems require an oxygen blender that connects an oxygen source (cylinder or concentrator) with the continuous airflow in order to adjust the FiO_2.
- High-flow CPAP systems require a highly effective humidification to prevent drying of nasal mucosa, which can lead to bleeding and nasal obstruction. Therefore, such systems require a heated humidifier system since an unheated cold water bubble humidifier does not provide adequate humidification.
- Following the principles of equity, countries and hospitals should ensure that highly cost-effective health interventions such as invasive mechanical ventilation that might reduce mortality

are available to the vast majority of children, *before* funding such intensive care services. However, mechanical ventilation should be available in any hospital where surgery and anaesthesia are performed.

- Methylxanthines might be successfully used not only in newborns but also in bigger children for stimulation of the respiratory centre in the brain, and diaphragm contraction. These drugs may be more effective than continuous positive airway pressure (CPAP) only in preventing the need for mechanical ventilation.

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