Pediatric Oxygen and Humidity Therapy:

Adapting Therapy to Fit the Clinical Picture

by Steven E. Sittig, RRT

Not many other areas of respiratory care are as challenging as delivery of oxygen and humidity therapy to the pediatric population. It is because this population encompasses such a varied patient size from very low birth weight premies, who weigh not much more than a pound, to adolescent children. One must always remember that oxygen is a drug that has side effects and hazards associated with its administration that may cause more harm to the patient then one might believe.

Not all that long ago, oxygen was added to increasing numbers of surviving premature infants to help treat apnea and cyanosis. Unfortunately, it was many years before this adjunctive therapy was noted to be the cause of retrolental fibroplasia — also known as retinopathy of prematurity.

Since the patient population's size and underlying pathology can vary so widely, precise delivery of a specific fraction of inspired oxygen (FIO_2) can be a technical challenge. There are instances where even 21 percent normal room air can contain too high a level of oxygen.

When everyone went through their respective program to learn respiratory care, we had to memorize different liter flow rates to different delivery systems. While many of these delivery devices are adaptable to the pediatric population, the old learned rules of liter flow to approximate oxygen concentration are of little use in pediatrics because inspired minute ventilation can vary from as little as 250 cc's a minute to levels that approach adult minute ventilation. Therefore, the normal entrainment ratios that allow us to approximate FIO_2 from those guidelines are really not much use since the inspired minute volume is so varied.

Indications for oxygen therapy

The main logic behind the administration of oxygen is to prevent or treat tissue hypoxia that occurs whenever the body's demand for oxygen cannot be met from available oxygen stores. This hypoxia would then affect normal metabolic functions. Left untreated, this hypoxia can have significant and long-term irreversible consequences on vital organ function. Hypoxemia should be suspected

when the patient shows signs of respiratory distress such as tachypnea, grunting, nasal flaring, retractions, and sometimes cyanosis. If hypoxia is present due to congenital cardiac disease, then only tachycardia, tachypnea, and cyanosis may be present.[1]

It is important to remember that for cyanosis to be present, 5 grams of hemoglobin has to become desaturated before it will be evident. If the patient has an extremely low hemoglobin level, a significant level of hypoxemia may be present with no visual cyanosis. One must remember, too, that central cyanosis is often a very late sign of hypoxia in an infant.

Arterial hypoxemia is the reason most patients receive supplemental oxygen. There are four main pathophysiologic mechanisms for hypoxemia: alveolar hypoventilation, diffusion defects, ventilation/perfusion (V/Q) defect, and right-to-left cardiac or pulmonary shunts. Hypoxemia due to simple diffusion or V/Q defects responds to oxygen therapy, while hypoxemia due to right-to-left shunting is often unresponsive to oxygen therapy.

The RT's expertise is invaluable in determining the appropriate oxygen level and delivery device needed for the pediatric patient.

Delivery devices

Many of the delivery devices used in the adult population have been modified to better fit the pediatric population. Nasal cannulas are now small enough to fit micropremies; and even a small, simple mask and nonrebreather are on the market for newborns.

The challenge comes when you have patients who fight and pull off the device because they are most likely scared and want to have nothing on their face. Those of you who are parents or work with pediatric patients a lot know that trying to reason with a two-year-old is an exercise in futility. I have worked in pediatrics for 14 years now, and I have yet to win an argument with a two-year-old to wear their oxygen mask for more than 30 seconds like it was designed. Unless they are so sick that they can't fight, then a new set of concerns should be on your mind.

Despite the development of varied sizes to meet the needs of pediatric patients, sometimes "good old RT know-how" can come through to modify the device to help ensure patient comfort and compliance. Nasal cannulas are a very popular method of delivering oxygen in all patient populations. Many times simply trimming the prongs off the cannula so that it lies just below the nares allows for better patient comfort and compliance.

There is much controversy in the literature and among practitioners on how best to deliver oxygen to this smaller patient

population using a simple cannula. It has been shown that relatively low flows in the range of 25 to 200 mL/min. via nasal cannula can produce extremely high pharyngeal oxygen levels, especially in children under 1,500 grams.[2]

In another study it was found that inadvertent nasal continuous positive airway pressure (CPAP) could be generated by excessive gas flow delivered by nasal cannula. During a study of an infant nasal cannula with an outside diameter of 0.3 centimeters and a gas flow of 2 L/min., a CPAP level of 9.8 cm H_2O was generated.[3] Some institutions are trying to avoid such problems by using blenders to deliver specific FIO_2 via nasal cannulas, and this has the added benefit of warming and humidifying the oxygen. Still, one must be aware of inadvertent CPAP with seemingly low cannula flows.

Other oxygen devices such as a simple mask, nonrebreathers, air entrainment masks, and oxygen hoods are available; but many times masks are not well tolerated by the pediatric population. It is still important to remember that a minimum flow of 6 L/min. is recommended for simple masks, and 8 L/min. for oxygen hoods and a flow high enough to ensure the reservoir bag does not collapse (to remove any chance of rebreathing carbon dioxide).

When even 21 percent is too much oxygen

When dealing with the areas of pediatrics, especially newborns, there are times when even normal room air contains too much oxygen. In cases of hypoplastic left heart syndrome, excessive amounts of oxygen — even room air — may be severely detrimental to the patient. This is one of the more unique situations seen in pediatrics where clinicians must realize the effect oxygen has on the newborn's pulmonary system. In hypoplastic left heart syndrome, as the arterial oxygen tension rises, oxygen acts as a pulmonary vasodilator resulting in excessive pulmonary blood flow. Use of high levels of oxygen can be fatal to these patients. The left ventricle cannot pump oxygenated blood to the systemic circulation, so essentially an excessive amount of blood remains in the pulmonary bed and overloads the system. With the pulmonary bed overloaded with blood, the right heart — the only real functioning ventricle — would become overworked, hypertrophic, and eventually fail unless the condition is recognized and appropriate measures taken.

It is also imperative that the ductus arteriosus remains open by means of Prostaglandin E1 (PGE1) infusion to allow right-to-left cardiac shunting. This means the right side of the heart must provide systemic blood flow through the ductus arteriosus. The use of subambient oxygen therapy increases the pulmonary vascular resistance and keeps more blood flow in the systemic circulation. This subambient oxygen level is achieved by bleeding in nitrogen, typically into the ventilator circuit. It is not uncommon to need FIO_2 in the range of 16 to 18 percent to keep the oxygen percent saturation (SaO_2) in the range of 70 to 80 percent. These measures are used either until the infant can receive corrective surgery or a heart transplant. Otherwise this condition would be fatal. To read more about the pathology and treatment of hypoplastic left heart syndrome, please read the article by Donna Levine in this issue titled "Less Is More: Mechanical Ventilation for the Newborn with Hypoplastic Left Heart Syndrome."

Humidity therapy

Humidity therapy is as challenging an endeavor as providing

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Adapting Therapy

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appropriate levels of oxygen. The fact that the pediatric airway is smaller in diameter than an adult's, increases the risk of losing a patent airway by thickened secretions caused by dry medical gas. Anytime the upper airway is bypassed, as in the case of intubation, humidity needs to be supplied. Bypassing the upper airway removes the body's most efficient means of airway humidification. Within 10 minutes, reduced airway temperature can result in decreased ciliary activity, which can take several weeks to return to normal. When providing medical gas to the trachea via an endotracheal tube or a tracheostomy tube, the gas should be heated to 32 to 35 degrees Celsius and at 100 percent relative humidity or 36 to 40 mg/L absolute humidity.[4]

While supplemental humidity does help in removing the airway humidity deficit caused by dry medical gas, the most effective means of reversing this deficit is through systemic hydration. Use of heated wire circuits has greatly improved humidity delivery and cut down on rain-out and the potential of introducing to the patient pathogens that otherwise might grow in the ventilator circuit. When providing supplemental humidity, the clinician also needs to decide if heated or cool humidity is appropriate. In cases of newborns, humidity should be warmed to maintain a neutral thermal environment.

Conversely, in cases of croup, one of the standard treatments has been the use of cool humidified oxygen. However, there is some controversy on whether cool humidity aids in soothing inflamed mucosa and improves viscosity of secretions.[5]

The expertise of the respiratory clinician is invaluable in helping determine the appropriate oxygen delivery device and level of oxygen needed for the pediatric patient. Just as important is the need for determining the type and level of supplemental humidity necessary for ensuring that the airway remains patent. Working within the area of pediatrics is a very specialized practice where one size or flow rate does not fit all.

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