

# Understanding the Blue Patient

Amy Newfield, CVT, VTS (ECC)  
BluePearl Veterinary Partners  
Waltham, Massachusetts, USA  
NewfieldAmy@hotmail.com

## INTRODUCTION

As a technician you will likely be the first person to assess an animal's condition. Owners often mistake labored breathing as "panting" or shallow breathing as "sniffing." Any change in an animal's breathing is an emergency. Administering oxygen effectively and understanding how to test and treat for oxygen deficiency is important when dealing with critical patients.

## OXYGEN IN THE BODY

Oxygen is necessary for all normal metabolic processes involving cellular function in the body. Oxygen delivery to the body depends on three things: cardiac output, arterial oxygen content, and blood flow. Cardiac output is dependent on stroke volume and heart rate. Arterial oxygen content is a function of dissolved oxygen and hemoglobin saturation. Adequate blood flow ensures that there is enough hemoglobin and appropriate gas exchange.

Oxygen is delivered to the cells in two forms: dissolved oxygen in arterial blood or attached to hemoglobin. The oxygen pathway is a six part process. The animal breathes in oxygen known as  $PIO_2$ . This is transported to the pulmonary alveoli by the process of alveolar ventilation to determine the alveolar  $O_2$  partial pressure ( $P_{AO_2}$ ). From the alveoli the oxygen is carried to the pulmonary capillary blood by mechanisms known as pulmonary gas exchange which determines the arterial partial pressure ( $PaO_2$ ). The  $PaO_2$  is the principal figure in determining the arterial hemoglobin saturation ( $SaO_2$ ). This relationship between these two is known as the oxygen-hemoglobin saturation curve. Arterial oxygen content ( $CaO_2$ ) is a function of hemoglobin concentration and  $SaO_2$ . Ultimately oxygen delivery to the tissues occurs because of the arterial oxygen content and cardiac output.

## MONITORING OXYGEN

Being able to determine the overall function of a patient's respiratory system in a quick and timely fashion is important. It is equally as important to be able to determine if treatment to correct any respiratory dysfunction is helping to maintain adequate respiratory function in that patient. In general any patient who appears to have some alteration in the respiratory status should receive oxygen until it is proven that it is not needed. In a clinical setting we can monitor the five parameters: respiratory rate/effort, mucous membrane color,  $SpO_2$ , end tidal  $CO_2$  and blood gas.

Respiratory rate and effort are some of the easiest parameters to monitor. If a patient is "breathing differently", then it is important to look at the reason why. Look at the rate as well as the effort. Signs of respiratory distress include, any open mouth breathing in a cat, anxiety, restlessness (won't lie down), extension of the head/neck, abducted elbows, and tachypnea. Normal respiration is characterized by concurrent outward movement of both the chest and abdomen during inhalation. If you notice prolonged inspirations, it may indicate upper airway obstruction. If you are noticing prolonged expiration it may indicate lower airway disease.

Auscultation of the chest should occur if increased respiratory effort or rate are noted. Detection of wheezes, crackles, harshness or increased bronchial sounds will indicate respiratory distress and therefore a need for supplemental oxygenation.

Along with respiratory rate and effort, mucous membrane color is one of the easiest parameters to monitor and should be part of every physical exam. Though not completely accurate (because lighting, anemia or icterus hides the appearance of cyanotic membranes) any presence of cyanosis indicates a life threatening oxygenation issue which needs to be addressed immediately.

Pulse oximetry ( $SpO_2$ ) is less invasive, and the equipment is significantly cheaper than that required to obtain a  $PaO_2$  measurement. A pulse oximetry machine measures the oxygen saturation of hemoglobin, which is a very insensitive measure of oxygenation. Normally animals should have a range from 98-100% on room air. The drawback to a pulse oximetry machine is that, at times, it is not very accurate. Patient movement, poor perfusion, hair, or any color other than pink mucous membranes (icterus, cyanosis, anemia) can cause the reading to be inaccurate. However, the pulse oximetry machine continues to be a fairly quick and easy test to use to determine overall oxygenation. The  $SpO_2$  reading tends to follow the  $PaO_2$  reading. In general a patient with a  $SpO_2$  reading of 96% equals a  $PaO_2$  reading of 80 mmHg and a reading of 91% estimates to about a  $PaO_2$  reading of 60 mmHg.

End-tidal  $CO_2$  can be another way to assess the overall health of the respiratory system, but is limited to patients that are intubated. The capnograph measures the amount of exhaled and inhaled carbon dioxide ( $CO_2$ ) during the respiratory cycle. Inspired and expired  $CO_2$  values change over the course of the breath cycle. Normal end-tidal  $CO_2$  is between 35-45 mmHg in dogs and cats.  $PaCO_2$  readings are having than end-tidal  $CO_2$  usually by 5-10 mmHg. Unfortunately an accurate measurement of  $CO_2$  in a normal exhaled breathe cannot be obtained, so end-tidal  $CO_2$  is reserved for patients that are on ventilators or under anesthesia.

Partial pressure of oxygen in venous blood ( $PvO_2$ ) is not very reliable and ideally should not be used. This is because the measurement depends on three components: cardiac output, oxygen consumption by the tissues and, to a lesser extent, arterial oxygen content. If there is a change in any of the three components then the  $PvO_2$  reading will be low. If you cannot obtain an arterial sample, then you should obtain a venous sample from the jugular vein or vena cava as these will often provide the most accurate results. Normal  $PvO_2$  measurements are above 40 mmHg. Most veterinarians will agree that a  $PvO_2$  below 30 mmHg is concerning and requires intervention while a  $PvO_2$  below 20 mmHg is an emergency.

Partial pressure of oxygen in arterial blood ( $PaO_2$ ) is still considered the gold-standard test when monitoring for overall oxygenation ability of a patient. It is not a measurement of how much oxygen is in the blood, but is the pressure exerted by the dissolved oxygen molecules. Only a small percentage of oxygen is actually dissolved into a physical form that it can be read in plasma. Some blood gas analyzers will offer the reading as  $PO_2$ . It is important to know if the sample was venous or arterial or the reading could be misinterpreted. Normal  $PaO_2$ , at sea level, is between 80 and 110 mmHg. When  $PaO_2$  is less than 80 mmHg the patient is suffering from hypoxemia. Severe hypoxemia occurs with a  $PaO_2$  less than 60 mmHg.  $PaO_2$  is the most sensitive test of oxygenating ability and is also very reliable. Any small change in oxygenation will cause the  $PaO_2$  to change as well. Unfortunately, in order to obtain this measurement, you must obtain an arterial blood sample, which may not be possible in some patients.

## **INTERPRETING THE BLOOD GAS VALUES FOR OXYGENATION**

Once a blood gas sample is obtained you must interpret the results. While a patient may have a change in their respiratory pattern (shallow, heavy, etc) it may not necessarily require oxygen. Conversely, many have been fooled by a patient's slow "normal" looking panting only to find out it was in great need of oxygen.

#### *PaO<sub>2</sub>/FiO<sub>2</sub> Ratio:*

Once an arterial blood gas is obtained, you can then figure out the ratio of arterial oxygen pressure (PaO<sub>2</sub>) to fractional inspired oxygen (FiO<sub>2</sub>). The FiO<sub>2</sub> is the amount of oxygen in a gas mixture (like room air). It is expressed as a number from 0 (0%) to 1 (100%), written either as a decimal or percentage. No matter what sea level the blood sample is drawn at, the FiO<sub>2</sub> of normal room air is always 0.21 (21%). Most commercial oxygen machines keep the FiO<sub>2</sub> at 40%.

In general, the PaO<sub>2</sub> should be approximately five times the FiO<sub>2</sub>. Therefore a patient under anesthesia on 100% oxygen should have a PaO<sub>2</sub> of approximately 500 mmHg. Room air has a FiO<sub>2</sub> 0.21. Therefore a normal PaO<sub>2</sub>/FiO<sub>2</sub> ratio is 476 (100/0.21). In general a normal ratio is > 400. A pet with a ratio between 300-400 should be considered slightly-moderately hypoxic and oxygen should be provided until other tests are performed. A ratio of 200-300 indicates moderate pulmonary dysfunction and less than 200 is severe.

While other parameters must be met, if a patient has a ratio less than 300, then the definition of acute lung injury may be applied. If the patient has a ratio of less than 200 (pending other parameters are met), then the patient may be suffering from acute respiratory distress syndrome. For example, the patient has a PaO<sub>2</sub> of 59 mmHg on room air, the PaO<sub>2</sub>/FiO<sub>2</sub> (59/0.21) ratio is 281, which could lead to the patient being diagnosed as having acute lung injury.

#### *Alveolar-arterial Gradient (A-a gradient):*

The Alveolar-arterial gradient (A-a gradient), is a measure of the difference between the alveolar concentration of oxygen and the arterial concentration of oxygen. While it can be complicated to calculate out, it takes CO<sub>2</sub> into consideration and provides a method to compare lung function over time. The P<sub>A</sub>O<sub>2</sub> is calculated out by taking the pressure of the inspired air (760 mmHg at sea level), subtracting water vapor pressure (47 mm Hg) which is then multiplied by FiO<sub>2</sub>. In places with high altitude (like Denver, Colorado) barometric pressure needs to be factored in place of the 760 mmHG at sea level. PaCO<sub>2</sub> (value from your arterial blood gas) is divided by a "respiratory quotient" (which in a clinical setting is always 0.8) and subtracted from the first number. The formula looks like this:

$$P_{A}O_{2} = (760 - 47) \times FiO_{2} - PaCO_{2} / 0.8$$

In animals breathing room air the A-a Gradient should be less than 10 mmHg (some texts suggest less than 15 mmHg), with greater than 25 mmHg being clearly abnormal and the pet definitely needs oxygen. As the FiO<sub>2</sub> increases, so does the gradient which makes it hard to assess what is "normal". Many animals are on supplemental oxygen can cause the value to be greater than 25 and in animals on 100% oxygen the value could be as high as 100 mmHg. Patients who are hypoxemic due to hypoventilation alone should have normal A-a gradient so that hypoventilation can be ruled out as a source of hypoxemia in post-operative patients. Trends should be measured instead, which makes the A-a gradient a valuable way to follow a patient's oxygenating ability over time.

Examples:

PaO<sub>2</sub> of 60 and PaCO<sub>2</sub> of 65 with the pet on room air, the A-a gradient would be:

$P_{A}O_2 = 760 - 47 = 713 \times 0.21 = 149.73 - 65/0.8 = 68.48$ . Then subtract  $P_{A}O_2 - PaO_2 = 68.68 - 60 = 8.48$

Normal value which suggests that hypoventilation, not parenchymal disease is responsible for the hypoxemia

PaO<sub>2</sub> of 112 and PaCO<sub>2</sub> of 15 on room air the A-a gradient would be:

$P_{A}O_2 = 760 - 47 = 713 \times 0.21 = 149.73 - 15/0.8 = 131$ . Then subtract  $P_{A}O_2 - PaO_2 = 131 - 119 = 19$

High and suggests that parenchymal disease is present and the pet could benefit from oxygen

## HOW TO ADMINISTER

Animals should be allowed to assume any position that provides them the most relief. Oxygen should be provided initially by the least-stressful route. Sedation should be considered in patients that are very stressed. Sedating a patient will calm them and decrease any hyperventilation that may have been occurring because of stress.

### *Oxygen Hoods*

Oxygen hoods made from Elizabethan collars tend to be well tolerated in dogs, but not as much in cats. It is made by covering 75% of the ventral aspect of an Elizabethan collar with plastic wrap. The Elizabethan collar should be 1 size larger than would normally be used for the patient. The oxygen tubing is placed along the inside of the collar and taped in place ventrally. FiO<sub>2</sub> levels can get up to 60% oxygen very quickly and in many cases 80% using 1 L/10 kg body weight of oxygen. The oxygen hood is only for short-term use because humidity will build quickly and may cause a panting patient to overheat.

### *Oxygen Cages*

Oxygen cages are popular because they are convenient. Turn them on and put the patient in them and walk away. There are three main problems with commercial oxygen cages. 1) The length of time it takes for an oxygen cage to get up to 40% FiO<sub>2</sub> is long and varies on size. Small oxygen cages (infant incubators) can be utilized for cats and FiO<sub>2</sub> levels can get up to 40% very quickly, but larger oxygen cages can take anywhere from 15-40 minutes for the FiO<sub>2</sub> to get to 40% (this is assuming the oxygen is at 10-15L/min). 2) You also cannot work with your patient if they are in a cage. Every time the door is opened, the oxygen escapes and plummets the FiO<sub>2</sub> to room air very quickly so the patient becomes dyspnic again. The patient experiences an oxygen rich environment-room air-oxygen rich environment very quickly. 3) Cost. The cost of the cage itself is expensive as well as the cost of the oxygen. The oxygen cost can be up to 10 times greater than with other methods.

### *Flow-By Oxygen*

This method can be effective, but usually only if the owners are there to administer it. The reason is simple: Pets don't like to have air blow on their noses. Using face masks will certainly make it more effective, but it they are poorly tolerated. It is important to remember to remove the diaphragm on the bottom of the oxygen face mask. Having a tight seal around the pet's face will not allow for appropriate ventilation. The efficacy of this technique is still debated since it is

unknown how much of the oxygen the animal actually intakes. The oxygen tubing must be less than an inch away from the animal's nose in order for it to be effective. If it is more than an inch away much of the oxygen is likely dissipated into the room air surrounding the patient. Animals sometimes will tolerate this technique if an owner holds the animal and the oxygen line.

### *Nasal Cannula*

This is a technique that is well tolerated by most dogs and cats. This consists of a short human nasal cannula that has two sections of tubing coming from a small nose piece. There are three sizes: infant (cat and small dog), pediatric (medium sized dog) and adult (large dog > 25 Kg). By using a few drops of proparacaine or lidocaine in each nostril, most patients will allow the tips of the cannula to be placed into the nostrils. The tubing is brought to the side of the nose and secured with staples or suture. The remaining tubing is brought behind a patient's head and secured so it doesn't flop in front of the face. Ideally a humidifier should be attached to this so that the nasal passages are kept as moist as possible. Oxygen rates depend on the patient. In general a rate of oxygen is started at 50-100 ml/kg up to a maximum rate of 5-6 Liters/minute. While it is known that this method provides at least a 40% nasal oxygen concentration, it is possible to administer too much oxygen causing them to be at risk for oxygen toxicity. Arterial blood gas should be checked at least once a day to ensure the patient is appropriately oxygenating.

### *Nasal Catheters*

This is one of the most effective ways to provide oxygen to the patient. The technique was first developed in 1984 and was published in 1986. A red rubber tube(s) is placed into the ventral nasal meatus. It is then sutured/stapled to the patient's nose and on the side of the face or on the bridge of the nose between the eyes. Generally 5fr are used for cats/small dogs, 8Fr is used for medium/large dogs. By using a few drops of proparacaine or lidocaine in each nostril, some patients will allow the red rubber to be placed into the nostrils. Most patients will require some sedation. Measurement should be from the tip of the nose to the lateral canthus (nasopharyngeal). Marking the red rubber with a line will ensure correct placement. Flow rates are the same for the nasal cannula. Patients can have two nasal lines placed if the first is not improving the patient's oxygenation status. A nasal line can be placed into the trachea via the nose. This is particularly useful in patients with collapsing trachea or laryngeal paralysis. For a nasotracheal catheter the tube is measured to the level of the thoracic inlet. The patient's head should be held in an extended position to facilitate blind passage into the trachea. Oxygen into the trachea should be reduced by 50% than what would have been used for a nasal catheter. Oxygen being administered into nasal lines should always be humidified to avoid nasal passages drying out. With patients with head trauma, severe thrombocytopenia and nasal disease, nasal lines should not be used. Sneezing will elevate intracranial pressure.

## **OXYGEN TOXICITY**

Oxygen toxicity is a very real concern for patients that require long term exposure of high concentrations of oxygen. The lung is the organ most vulnerable to oxygen toxicity and the associated damage is often severe and irreversible. A continuous FiO<sub>2</sub> level of 33% at sea level (PiO<sub>2</sub> of 255 mmHg) is considered the safe level for long-term exposure in people. Higher levels are generally tolerated well over short periods of time. Human patients suffering from oxygen toxicity report chest pains, coughing and severe effort to breathe. Acute lung injury

generally follows. Studies performed in dogs describe symptoms that start with lethargy, restlessness and coughing. Eventually the signs progress to anorexia, dyspnea and eventually death. Studies have shown that dogs exposed to 100% oxygen survive an average of 2-5 days while dogs exposed to 75-80% oxygen lived to about 14 days. Interruption of the exposure to oxygen can also reduce its toxicity. Unfortunately the signs/symptoms of the pet often mirrors the disease process that is causing the pet to need oxygen in the first place. Performing arterial blood gases and reducing oxygen rates is important to help decrease the chance of oxygen toxicity.

## **CONCLUSION**

Understanding how to recognize respiratory distress may mean the difference between life and death for a patient. Being able to monitor and then effectively administer oxygen is imperative to the success of any respiratory patient.

## **REFERENCES AVAILABLE UPON REQUEST**