How to Assess Oxygenation

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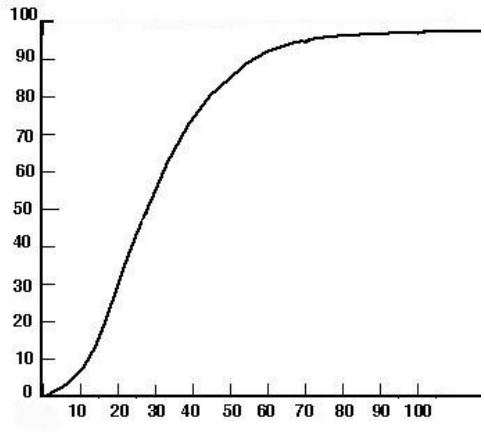
All the tissues of the body require oxygen to function. Oxygen enters the body via the airways, then goes to the lungs. Oxygen crosses over the very, very thin membranes in the lung where it enters the blood stream and binds to hemoglobin. Hemoglobin is a special protein found in red blood cells (RBC). Hemoglobin does an excellent job of holding onto oxygen in the RBC, but then releasing it to the tissues when the time is right.

Hypoxemia is when the oxygen tension in the blood is to low. This differs from tissue hypoxia, which means that the tissues are not provided with adequate oxygen. It is a bit like the old saying that "a house is a home, but a home is not necessarily a house." Animals with hypoxemia will generally have tissue hypoxia, but tissues can be hypoxic without the animal having hypoxemia. For example, cats with "saddle thrombus" lack blood flow to the back legs resulting in tissue hypoxia of the affected muscles, but the oxygen tension in their blood is fine. Another example might be the severely anemic animal. An animal with very few RBC may have tissue hypoxia, but they do not have hypoxemia.

There are only a few ways that animals develop hypoxemia. These include breathing a reduced amount of oxygen in the air (decreased fractional inspired [F_I] oxygen), not bringing the oxygen down into the lungs (hypoventilation), thickening of the lung membranes (diffusion impairment), mismatching blood flow with oxygen (ventilation-perfusion mismatching), or shunting blood so that it bypasses the opportunity to load up on oxygen altogether (pulmonary shunting, or "backwards" patent ductus arteriosus [PDA] heart defects).

To deal effectively with hypoxemia, it must first be recognized. In veterinary medicine, there are three basic means of assessing hypoxemia. One is to simply look for cyanotic (blue) mucus membrane color, another is to measure arterial oxygen tension via arterial blood gas assay, and the third is assessment of hemoglobin oxygen saturation (pulse oximetry). Each provides distinct information with unique advantages and disadvantages. Before these can be discussed, a basic understanding of certain relationships must be established. We will refer repeatedly to the hemoglobin-oxygen disassociation curve (Figure 1).



In health, oxygen tension of arterial blood should be 5 X whatever concentration of oxygen is in the air. Room air is ~20% oxygen, so 5 X 20 = 100 mmHg is the "ideal" oxygen tension (PaO2) of a healthy animal on room air. If an animal is under anesthesia breathing 100% oxygen, 5 X 100 = 500 mmHg would be the expected PaO2. By definition, an animal is hypoxemic when the PaO2 while breathing room air falls to less than 80 or 85 mmHg (depending on reference source). Hypoxemia becomes "severe" when the PaO2 reaches ~60 mmHg, the point where even very small changes in oxygen tension lead to big changes physiologically; at this point the animal is "falling down the steep part of the curve" (see figure). To give some comparison, the oxygen tension of venous blood from a healthy animal, that is, blood that has already been "used" to provide oxygen to tissues, is about 40 mmHg.

Simply looking at mucus membranes for cyanosis is simple, free, and non-invasive. However, it is very, very insensitive as a test for hypoxemia. Animals become blue due to the presence of unsaturated hemoglobin, meaning hemoglobin without attached oxygen. Hemoglobin is found inside RBC. If an animal is anemic and lacks RBC, it also lacks hemoglobin. In that case, it may NEVER become cyanotic, even if it is extremely hypoxemic! Cats have less hemoglobin than dogs, and so are less likely to become cyanotic when they are hypoxemic. Even when an animal has plenty of RBC and plenty of hemoglobin, cyanosis isn't apparent until the oxygen tension is near 50 mmHg or less – a state of marked hypoxemia.

Arterial blood gas analysis provides a direct measure of oxygen tension. It requires needle puncture of an artery, and so is relatively contraindicated in animals with abnormal bleeding. It also requires that the blood be evaluated immediately. Because special

equipment is needed to do this test, only practices that have this equipment can realistically measure PaO2. Aside from the measuring device, other materials needed for this test are very inexpensive and readily available. A heparinized needle and a syringe are all that is needed. Several arteries can provide adequate samples and obtaining blood requires just a little practice. The femoral artery is relatively easy to "hit', but may bleed worse afterwards if not held off well. The dorsal pedal arteries are good alternatives and can be used to place arterial catheters if frequent monitoring is required. Because an artery is punctured, hematoma is a possible complication of arterial blood gas measurement. Sometimes, the blood collected is either not arterial or is a mixed arterial and venous sample which can provide misleading results. The really nice thing about this test is that you get lots of other information. For example, measuring the carbon dioxide in the arterial blood can help you tell if the animal is having hypoventilation which might be the cause of hypoxemia.

Pulse oximetry offers a third way to assess hypoxemia. It provides an estimation of arterial hemoglobin saturation with oxygen by transmitting a light through a fold of tissue (lip, tongue, skin, rectal, etc). It uses the difference in light absorption between pulses (assumed to be arterial blood flow) and background to calculate a percent saturation of hemoglobin with oxygen (SpO2). It also provides a count of the pulse rate, and this rate must accurately match the "real" pulse rate at the time to have any validity; therefore, you should always count a pulse just prior to using the pulse oximeter. The information from pulse oximetry is not identical to measurement of PaO2, but rather is complimentary. In reality, however, many veterinarians have the equipment to measure SpO2 but not PaO2. Pulse oximetry is non-invasive and can provide immediate and continuous information. However, it is not a perfect technique. There are many potential sources of interference, including skin color, decreased tissue perfusion, hypothermia, anemia and icterus.