**NOT SO CUTE: ACUTE RESPIRATORY DISTRESS SYNDROME**

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Respiratory disease is a common presenting complaint to emergency and critical care facilities. There are several causes of respiratory disease, and acute respiratory distress syndrome can occur as a primary disorder or secondary to a systemic critical illness. As such, understanding of the disease pathophysiology, clinical signs/risk factors, diagnostic testing, treatment, and nursing care is important for veterinary technicians/nurses.

**Pulmonary Anatomy & Physiology**

To review, the respiratory system (comprised of the upper airways and lower airways) has the primary responsibility to provide the body with continuous gas exchange between the environment and circulatory system through the processes of ventilation and oxygenation.

Normal pulmonary function involves the movement of air (78% nitrogen, 21% oxygen, trace gases) via inspiration and expiration. Air moves into the lungs, through the conducting pathways until it reaches the alveoli. The alveoli are the primary site of gas exchange within the lungs; gas exchange occurs across a blood-gas barrier. Oxygen ($O_2$) diffuses from the alveoli to the capillary blood supply across the barrier via passive diffusion. Carbon dioxide ($CO_2$) diffuses from the capillary blood supply to the alveoli across the barrier via passive diffusion. When thinking about diffusion of gases, it can be described by Fick's law: "the diffusion of a gas across a membrane is directly proportional to the area of the tissue membrane and the pressure gradient, and inversely proportional to the thickness of the membrane." When we consider normal respiration, there are three different partial pressures of oxygen ($PO_2$) and partial pressures of carbon dioxide ($PCO_2$): inspired, alveolar, and arterial. During inspiration of air, $PO_2$ is at its highest at 150mmHg and $PCO_2$ is 0mmHg. Once air has reached the alveoli, $PO_2$ drops slightly to 100mmHg and $PCO_2$ rises to 40mmHg; this is because $O_2$ and $CO_2$ rapidly diffuse across the blood-gas barrier ($O_2$ in, $CO_2$ out). Once diffusion occurs and the gases are at the level of the arterial capillaries, $PO_2$ and $PCO_2$ equal out to the systemic arterial circulation.

It is important to understand the normal physiologic process of respiration, as ventilation and oxygenation are two different processes, despite often being used synonymously. Ventilation is the process of appropriate gas exchange within the alveoli ($O_2$ is inhaled, $CO_2$ is exhaled). Once ventilation has occurred, we become concerned with oxygenation and the patient's oxygenating ability. Oxygenation refers to how well $O_2$ is diffused from the alveoli, then bound to hemoglobin, dissolved into the bloodstream, and delivered to bodily tissues.

**Acute Respiratory Distress Syndrome**

Acute respiratory distress syndrome (ARDS) can be defined as a severe respiratory disorder following an acute lung injury (ALI). Acute lung injury may be the result of a primary pulmonary disorder or a secondary complication of critical illness. ARDS is a severe form of ALI in which there is an inflammatory cascade that results in a clinical syndrome of hypoxemia from significant pulmonary damage. This results in a patient suffering from respiratory failure and potential multiple organ dysfunction syndrome (MODS).

**ARDS Pathophysiology**

Under normal conditions, pulmonary fluid is maintained in a balance between the interstitium and alveolar spaces. During ARDS, the body suffers from either a primary or secondary pulmonary insult that is the inciting cause of the pulmonary disease progression.

From the initial insult, there is a profound inflammatory response in which inflammatory mediators (tumor necrosis factor and cytokine interleukins) contribute to a loss of pulmonary vascular permeability. When the vascular permeability becomes compromised, there is an imbalance of Starling's Forces (the normal movement of fluid across the pulmonary membranes). This leads to an accumulation of fluid within the interstitial space that exceeds the lymphatic system's ability to remove and alveolar epithelium damage, leading to alveolar flooding. Once fluid penetrates the alveoli, gas exchange is impaired and there is profound hypoxemia. The fluid accumulation in the interstitium and alveoli leads to pulmonary congestion and decreased lung compliance. This sequence of events also contributes to a systemic inflammatory response and hypoxemic/hypoxic organ damage.

**ARDS Criteria**

In the critical care setting, ARDS should be considered in any patient that exhibits the first four of the following criteria:

1. Acute onset of respiratory distress
2. Presence of known risk factors
3. Evidence of pulmonary capillary leak without evidence of heart failure and/or fluid overload
4. Evidence of impaired gas exchange
5. Evidence of pulmonary inflammation

*Acute onset of respiratory distress*

The acute nature of ARDS is defined by an acute onset (less than 72 hours) of respiratory distress characterized by either tachypnea, dyspnea, or both. This inclusion criterion is determined based on the patient history and initial presenting status.

*Presence of known risk factors*

There are several risk factors that can contribute to a patient being more susceptible to ARDS. These known risk factors include inflammation (i.e. pancreatitis), infection (i.e. pneumonia), shock, sepsis, systemic inflammatory response syndrome (SIRS), severe trauma (i.e. pulmonary contusions, penetrating thoracic wounds), head trauma/traumatic brain injury, multiple blood transfusions (transfusion-related acute lung injury), smoke inhalation, submersion injury, aspiration of gastric contents, or inhaled irritants/toxins.

*Evidence of pulmonary capillary leak without evidence of heart failure and/or fluid overload*

Fluid accumulation within the lungs is caused by changes in pulmonary capillary membrane permeability; the fluid overwhelms the alveoli and impedes their ability to perform adequate gas exchange. This pulmonary capillary leak results in a pulmonary edema that has a non-cardiac origin. The pulmonary edema that is produced from ARDS (noncardiogenic pulmonary edema) differs from cardiogenic pulmonary edema in that the fluid is high in protein, making it non-responsive to diuretic therapy.

*Evidence of impaired gas exchange*

Hypoxemia refers to low levels of oxygen in the bloodstream as the result of inefficient gas exchange. Hypoxemia can be defined as a partial pressure of arterial oxygen ($PaO_2$) less than 80mmHg (with

severe hypoxemia defined as a PaO2 less than 60mmHg) or an oxygen saturation (SpO2) of less than 90% (>95%).

A concept that relates to a patient's oxygenation status is the oxyhemoglobin dissociation curve. The oxyhemoglobin dissociation curve depicts the relationship between SpO2 and PaO2. What's unique about this curve is that it isn't linear, but rather sigmoid, meaning SpO2 and PaO2 are directionally, but not linearly, related. The curve is determined by hemoglobin's affinity for oxygen (how readily hemoglobin acquires and releases oxygen molecules). The most important clinical manifestation of this SpO2/PaO2 relationship is the difference between normoxemia and hypoxemia; small changes in SpO2 correlate with large changes (roughly 4x) in PaO2.

Hypoxemia can be further defined by evaluating an arterial blood gas to calculate the P:F ratio (PaO2:FiO2) and the alveolar-arterial (A-a) gradient. Identifying and recognizing hypoxemia is very important because if unaddressed, it can lead to hypoxia, or inadequate oxygen delivery (DO2) to meet tissue oxygen demand (VO2).

*Evidence of pulmonary inflammation*
Pulmonary inflammation is identified by performing a cytological fluid examination from a transtracheal or bronchoalveolar respiratory sample. On cytology, the fluid will have a predominance of neutrophils indicating an inflammatory response. The fluid sample can also be further tested for the presence of inflammatory cytokines (i.e. tumor necrosis factor, interleukin-1). Of the criteria to confirm ARDS, this is the only one that is optional.

**Clinical Signs**
The clinical signs associated with ARDS typically have an onset of 72 hours due to the acute nature of the disease process. These signs include lethargy, respiratory distress (tachypnea, dyspnea), cyanosis, hypoxemia, harsh lung sounds of auscultation (potentially a cough), orthopnea, and use of auxiliary respiratory muscles.

**Diagnostic Testing**
The two primary diagnostic testing tools utilized to determine the presence of ARDS is thoracic imaging modalities and arterial blood gas (ABG) analysis.

*Imaging*
Thoracic radiographs, echocardiogram, and computed tomography (CT) are all diagnostic imaging options for evaluating the pulmonary parenchyma. Due to the pulmonary edema accumulation, thoracic radiographs will show a bilateral or diffuse infiltrative pattern in more than one quadrant/lobe. To rule out primary cardiac disease an echocardiogram may be performed, or radiographs assessed for normal heart silhouette and pulmonary vasculature. CT is an advanced imaging modality that can show lung density, with affected areas having a hazy appearance of lung attenuation.

*ABG Analysis*
ABG analysis is specifically indicated in patients with respiratory compromise, as all aspects of pulmonary function can be assessed, and should be used whenever pulmonary parenchymal disease is suspected. The partial pressure of arterial blood (PaO2) is the primary value evaluated in ABG analysis as it is an indicator of the patient's oxygenation status in relation to the diffusion properties and lung perfusion. The PaO2 value from an ABG allows assessment of the P:F ratio and A-a gradient to further provide definitions of hypoxemia.

The P:F ratio is the ratio of arterial partial pressure of oxygen (P = PaO2) and fraction of inspired oxygen (F = FiO2). The P:F ratio is used to determine the severity of respiratory compromise and distinguish between ALI and ARDS. When calculating FiO2, the FiO2 percentage is converted into decimal form (i.e. 21% = 0.21, 100% = 1.0). The P:F ratio is a quick and easy calculation that can be helpful in assessing the severity of pulmonary injury and to determine how oxygen responsive the patient is. In a healthy patient breathing room air that has a PaO2 of 105mmHg, they would have a P:F ratio of 105:0.21 (105 ÷ 0.21) = 500. Since it is a ratio, the calculated value has no units and be used on patients receiving supplemental oxygen as the FiO2 is included calculation. A normal P:F ratio is ≥400. A P:F ratio <300 is diagnostically indicative of ALI, and a P:F ratio of <200 is diagnostically indicative of ARDS.

The A-a gradient (also known as the alveolar gas equation) is the difference between the alveolar oxygen concentration (PAO2, big A) and arterial oxygen (PaO2, little a) concentration. The A-a gradient is used to assess the efficiency of gas exchange and to distinguish hypoxemia due to primary pulmonary disease or secondary to hypoventilation. The equation = PAO2 – PaO2 where PAO2 is calculated as FiO2(Patm – PH20) – (PaCO2/RQ). In a healthy patient breathing room air, the PAO2 should be very close to PaO2 (5-15mmHg difference) which reflects normal gas exchange. A normal A-a gradient is <15mmHg and any increased value is indicative of decreased gas exchange ability.

**Treatment & Nursing Care**

Treatment for ARDS is mainly through addressing the underlying critical illness and supporting the respiratory system with oxygen and ventilator therapy. To address the primary or underlying critical illness (i.e. patient risk factor), specific and aggressive therapy (i.e. intravenous fluids, broad-spectrum antibiotics) should be provided.

To address hypoxemia, supplemental oxygen therapy must be provided. General guidelines for FiO2 values are flow-by/face mask delivery = 25-30%, nasal cannula delivery = 35-40%, oxygen cage = 40-60%, and anesthetic circuit = 100%. Another oxygen therapy option that is becoming more recently available is high flow nasal cannula (HFNC) oxygen delivery. HFNC provides oxygen support for patients who require a higher concentration of oxygen that can be provided from other supplemental oxygen methods. Regardless of the method of delivery used, the goal of oxygen therapy is to treat the hypoxemia and reduce the patient's work of breathing (respiratory effort). If the pulmonary edema is severe enough to cause hypoxemia from shunting, ventilatory therapy must be provided. Ventilatory support can include either intermittent manual ventilation or mechanical positive pressure ventilation (PPV). There are several ventilation modes that can be tailored to the patient when imitating PPV (IPPV, SIMV, A/C). The use of positive end-expiratory pressure (PEEP) can be utilized to increase the end-expiratory lung volume to allow positive pressure to remain in the alveoli at the end of expiration. If using PEEP, it's recommended to start at 5cmH20 and increase in 3-5cmH20 increments for a maximum level of 15-20cmH20. The goal of ventilatory support is to increase CO2 excretion, maximize alveolar oxygenation, and reduce the patient's work of breathing.

Nursing care of the ARDS patient can be very involved and dedicated depending on the level of respiratory support needs as part of the patient care. Careful monitoring of patient parameters in addition to respiratory parameters is crucial. This includes routine assessment of mentation, heart rate (+/- ECG), blood pressure, temperature, mucous membrane color, and capillary refill time. It is also important to monitor fluid balance and hemodynamic status due to the pulmonary vascular permeability. When monitoring fluid balance, careful recording of the amount of fluids in (i.e. crystalloids) and amount of fluids out (i.e. urine output) must be done. Serial lab work should be

performed to evaluate the specific parameters related to respiratory disease. These include a minimum database (i.e. PCV/TP, blood glucose, lactate) and arterial blood gas values. These values should be monitored at a minimum every 24 hours, more frequently depending on the patient's response and disease process. Analgesia is essential for patient comfort and well-being and should be administered as necessary. In general, opioids are the preferred analgesic choice because of their potency with minimal cardiovascular effects. In addition to providing analgesic relief, monitoring of a patient's pain should also be included as part of patient assessment. Pain can be monitored using pain scoring systems, such as the Colorado State University Canine/Feline Pain Scale. Other aspects of nursing care for the ARDS patient include advanced respiratory care such as oxygen therapy monitoring, managing ventilator settings, recumbent positioning, eye lubrication, oral rinsing, and endotracheal tube maintenance.

**Summary**

ARDS is a life-threatening condition encountered in the emergency and critical care setting. The prevalence of this disease has been well documented in the human literature and is becoming more prevalently researched in the veterinary literature. By understanding the pathophysiology and criteria of ARDS as well as the treatment and nursing care, veterinary technicians/nurses can be more involved in the recognition of the disease process and overall patient care.

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