11ème Congrès
de médecine et chirurgie équine
Genève, du 15 au 17 décembre 2009

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11. Kongress für Pferdemedizin und -chirurgie
Genf 15. bis 17. Dezember 2009

11th Congress on Equine Medicine and Surgery
Geneva 15th to 17th December 2009

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FUNCTIONAL INVESTIGATION OF RESPIRATORY DISEASES
(PULMONARY FUNCTION TESTS, BLOOD GAS ANALYSIS)

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Summary: Respiratory function tests are useful for both qualitative and quantitative evaluation of airway diseases. They may assess resulting respiratory functional impairment, severity and reversibility of respiratory disorders and monitor the efficiency of therapeutic interventions. If respiratory function tests are routinely used in human medicine, in equine practice, they are limited by noncooperation of patients and must comply with specific prerequisites relative to size and anatomy. Because equipment is often cumbersome, expensive or complicated, use is generally limited to research facilities. However more practical and portable equipments are now being developed and may encourage future expansion of these tests in routine practice.

In horses, the respiratory system represents the first limiting factor at maximal exertion even in healthy individuals. It is the only system that does not undergo significant changes with training. Because normal horses experience physiological hypoxemia, even at submaximal levels of exercise; it is of foremost importance that optimal respiratory capacity be maintained and respiratory diseases prevented if horses are to achieve peak performance. Current diagnostic techniques enable to diagnose respiratory disease through sampling or imaging, however neither techniques provide relevant information regarding the impact of disease on respiratory function and capacity. Besides allowing the investigation of respiratory physiology, functional investigation of the respiratory system gives additional information on the consequences of a particular disease and helps monitor recovery with therapy. Respiratory functional testing may evaluate ventilation, diffusion and/or perfusion.

In human medicine, respiratory function testing is used routinely, for instance in asthmatic patients, to assess the evolution of the disease and adapt therapeutic regimens. In the same manner, respiratory function tests in horses will inform on the progression of a disease, on its localization (upper, ventral or lower airways), if it is restrictive or constrictive and if can be efficiently alleviated by specific treatments. In a horse with dyspnoea, functional testing after the administration of an immediately acting bronchodilator is a valuable indication regarding the reversibility of the problem and the underlying pathology. The challenge is to find respiratory function tests which are sensitive enough to detect early on subtle changes due to subclinical disorders. To be applicable in routine practice, these tests should be non invasive, portable and easy to perform and interpret. Some simple portable devices are available and may be used in practice.

ARTERIAL BLOOD GAS ANALYSIS

Blood contained in the arteries comes directly from the lungs via the aorta and has not yet gone through areas of gas exchange. Therefore gases contained in arterial blood reflect the capacity of the respiratory system to vehicle air to and from the alveoli (ventilation) and to load O₂ and unload CO₂ (diffusion). Blood gas analyzers measure partial pressures in O₂ (paO₂) and CO₂ (paCO₂) and possibly other parameters such as pH, base excess or electrolytes. Blood is drawn from an easily accessible arterial vessel such as the carotid artery or transverse facial artery. Air bubbles should be evacuated from the sample and the syringe should be sealed from air with a cap immediately after collection to avoid gas exchanges. Timely analysis or temporary sample cooling (max 60 minutes on ice) is important to avoid alterations in gas partial pressures due to ongoing metabolism of blood cells. Simultaneous measurement of body temperature is important as it directly influences values of partial pressure.

Normal values for partial pressures in adult horses are respectively 90-100 mmHg for O₂ and 38-45 mmHg CO₂. At birth, foals have lower paO₂ values ranging...
between 75-80 mmHg. Stressed horses or horses sampled after exercise will hyperventilate and may display high paO2 as well as low paCO2. Functional problems which may lead to blood gas alterations are namely hypo- or hyperventilation, reduced diffusion, pulmonary or cardiac shunting and ventilation/perfusion mismatch. Horses with respiratory diseases often have a combination of several problems such as for instance alveolar hypoventilation due to broncho-constriction or mucus plugging of small airways + decreased diffusion due to interstitial inflammation and edema. Evaluation of respiratory function through arterial blood gas measurements is particularly interesting in foals with respiratory compromise, dyspnoeic adults or anesthetized horses. In other circumstances, arterial blood gas analysis is often insufficiently sensitive to detect milder changes in respiratory function. Measurement of arterial blood gases is also possible during exercise; however some essential technical requirements should be implemented such as placement of an arterial catheter and concomitant evaluation of central body temperature. For this reason, it is difficult to apply without a treadmill. Subsequent interpretation may also be difficult as well trained racehorses may be more hypoxemic than some average poorly trained horses at an identical level of exercise. Nonetheless, several studies have shown that IAD and EIPH could lead to aggravated exercise-induced hypoxemia (Morris 1991, Couetil & Denicola 1999).

MECHANICAL FUNCTION TESTS

Most other functional tests used in horses are based on the analysis of respiratory mechanics. They evaluate respiratory frequency, ventilation volume, flow and pressure either during spontaneous breathing (conventional techniques) or generated by external signals which are superimposed to the horse’s breathing (oscillometry). Mechanical parameters may be derived from these measurements such as respiratory resistance or dynamic compliance. In some instances, bronchoprovocation tests are necessary to detect hyperreactivity linked to underlying airway disease: in horses with respiratory inflammation, inhalation of substances such as histamine induces an exacerbated functional response which may then be measured and compared to normal reference values.

Conventional technique

The conventional technique is based on the simultaneous measurement of pleural pressure and respiratory flow during tidal breathing (Derksen & Robinson 1980). This technique requires introduction of an esophageal catheter for measurement of transpulmonary pressures and placement of a facemask equipped with a pneumotachograph to measure flow and derived volume. Although it is slightly invasive, it has been the gold standard method for research on respiratory physiology and diseases for many years. It is too cumbersome to adapt to routine use in practice and is a relatively insensitive method which often detects mechanical dysfunction when clinical signs are already apparent. It may be used in combination with bronchial challenge to improve sensitivity.

Forces oscillation techniques (oscilometry)

Alternative techniques which overcome many disadvantages of the conventional technique are the forced oscillation techniques (FOT). FOT are noninvasive and require no particular cooperation from the patient. Instead of using breathing signals, the FOT superimposes external test signals to generate a pressure-flow response from the respiratory system. Respiratory mechanical parameters similar to those of the conventional technique are calculated, but they may be expressed in the frequency domain, which allows differentiating various levels of dysfunction (upper, central or lower airways). These techniques are quickly performed and are more sensitive than the conventional technique. They may be used in a research or clinical setting but more practical systems need to be elaborated for routine practice tests. The impulse oscillometry system (IOS) may detect functional alterations associated with IAD, EIPH and RAO, without prior bronchoprovocation (Richard et al, 2009; Van Erck et al., 2004).
RESPIRATORY INDUCTANCE PLETHYSMOGRAPHY

Plethysmography is based on the external measurement of the variations in thoracic volume by using inductance straps which are sensitive to distension around both the chest and abdomen. Respiratory rate and thoraco-abdominal asynchrony can be measured by plethysmography. Simultaneous measurement of airflow at the nose is a benefit. It enables a quantitative comparison between flow characteristics at the airway opening and body surface. Gas compression due to airway obstruction will cause a measurable discrepancy between both measurements (Hoffman, 2002). This method requires to be performed with a histamine challenge to improve sensitivity for lower airway inflammatory diseases but presents the advantage of being non invasive and portable, therefore applicable in field practice.

FORCED EXPIRATION

Forced expiration is the most common lung function test used in human medicine. However unlike in humans, active respiratory maneuvers are impossible to obtain from equine patients. A system has recently been developed to measure forced expiration in sedated horses. The horse’s lungs are artificially inflated to total lung capacity through a nasotracheal tube. Expiratory flow-volume data is subsequently recorded. This technique allows measuring functional reduction in lung capacity in horses suffering from various degrees of obstructive diseases and identifying alterations in RAO horses in remission (Couetil et al, 2000).

SCINTIGRAPHY

Scintigraphy is an imaging technique which gives a functional picture of the lung. Radioactive isotopes may be given intravenously to evaluate lung perfusion or aerosolized to investigate ventilation. It has been used mainly for research in respiratory physiology (Votion et al, 1996). It has low diagnostic value but is currently applied to evaluate the efficiency of aerosol delivery systems.

REFERENCES


VOTION ET AL, 1999: Analysis of scintigraphical lung images before and after treatment of horses suffering from chronic pulmonary disease. Vet Rec. 27, 144, 232-236