The Respiratory System

EQS 110
Lecture – The Respiratory System

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Role of the Respiratory System

The main function of the respiratory system is to inhale air, which contains oxygen to be delivered to the cells via the circulatory system, and to exhale carbon dioxide; this act of inhaling and exhaling air is better known as respiration. At rest, a healthy adult horse will have a respiration rate of 8 – 16 breaths per minute.

While oxygen is vital for all life processes, for a horse to provide sustained performance, blood must take in oxygen from the lungs and transport it efficiently to the muscles. Therefore, the health and management of a horse’s respiratory system is not only crucial for its overall well-being, but for its performance as an equine athlete! Respiratory-related health conditions are the second leading cause of poor performance in athletic horses.

Take this into consideration – in the Kentucky Derby, a horse respires approximately 4,000 liters of air in and out of the lungs. That equates to two five gallon buckets of air in and out of the lung every second! The ability for the horse to intake enough air and for the blood to get oxygen from the lungs and transport it efficiently to the muscle is key; the more efficient the process, the more stamina the horse will have.
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Anatomy of Respiration

A horse’s respiratory system is divided into two parts:

- **Upper Respiratory Tract**
- **Lower Respiratory Tract**

The *diaphragm*, which separates the abdominal and chest cavities, is the primary muscle used for breathing. The abdominal muscles are only used for labored breathing.

### Upper Respiratory Tract

The upper respiratory tract consists of the:

- Nostrils
- Nasal cavity
- Pharynx/Nasopharynx
- Larynx
- Trachea

We will review the process of respiration within the upper respiratory tract step-by-step, with an emphasis on the structures involved.
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Nostrils & Nasal Cavities
Air is drawn into the nasal cavities through the nostrils as the horse cannot breathe through his mouth. The air that is drawn in through the nostrils is filtered and cleaned in the nasal cavities by moist, mucous membranes and tiny hairs called cilia. Cilia move in a wave-like action, pushing dust, germs, and debris back up into the throat where it either drains out of the nostrils, is swallowed, or coughed up. Horses may typically have a mild degree of translucent/clear, thin nasal discharge if in an environment that is prone to dust or following exercise, but thick, colored mucous discharge is abnormal and an indicator that something is wrong. Evaluating your horse’s discharge, or lack thereof, should be a daily task as it could be the first sign of illness or disease.

The horse’s nasal cavity is separated from the mouth by a structure called the hard palate, a bone that forms the roof of the mouth and the base of the nasal cavity.

Respiration in Practice – Equine Nasal Strips
Taken in part from Flair Equine Nasal Strips – Learn

Since horses can only breathe through their nose, all the oxygen required for exercise can only come through the nasal passages; a significant portion of which is unsupported by bone or cartilage. This unsupported portion of the nasal passage collapses inward when a horse breathes during exercise — reducing the size of the airway and greatly increasing resistance to airflow. This is significant because during exercise over 50% of resistance to air flow to the lungs comes from the nasal passages, with some studies suggesting this percentage can be as high as 80%. In addition, anatomical disorders of the upper airway and the way the horse’s head is being held during exercise can create additional increases in the work of breathing. All of these factors can make it difficult to move air into the lungs, reducing the efficiency of the respiratory system.

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One way to combat this is through the use of an equine nasal strip, such as a FLAIR Strip. Nasal strips can gently support the nasal passages and reduce soft tissue collapse that can cause narrowing of the airways during exercise.

Pharynx, Larynx, Trachea

Once air is filtered by the nasal cavities it makes its way to the pharynx (also called the nasopharynx), a chamber lined with mucous membranes that connects the nasal passages to the larynx. Horses can get pharyngitis (commonly known as a sore throat), which is an inflammation of the pharyngeal airway. This issue often follows a respiratory infection or may be due to a heavily contaminated environment (dust, debris, etc.).

After passing through the pharynx, air reaches the larynx, a structure located on top of the trachea, the horse’s windpipe. The larynx is responsible for directing air into the trachea, controlling airflow into the lungs during breathing, and producing vocal noises.

The larynx is protected by five rings of cartilage that can be felt between the two lower jawbones. The rings provide areas for muscle attachments which open and close the epiglottis and arytenoid cartilages. The epiglottis and arytenoid cartilages both serve similar roles in that they help close the airway when a horse is swallowing so that foreign bodies do not enter the trachea.

The arytenoid cartilages are located on each side of the horse’s larynx whereas the epiglottis sits on top of the soft palate, a structure that is responsible for separating the larynx from the esophagus.
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Horses can have anatomical issues with their arytenoid cartilages, epiglottis, and soft palate, resulting in restrictive airflow that can cause poor performance. Dorsal Displacement of the Soft Palate (DDSP) and Laryngeal Hemiplegia (“Roaring”) are two of the most common anatomical respiratory disorders seen in racehorses.

Breathing & Eating

While the focus of this lecture is respiration, keep in mind another activity that is often going on in the mouth – eating. In order to make sure the right things go down the right pipes, the soft palate, epiglottis, and arytenoid cartilages work together in opening and closing the correct junctions. By doing this, air is allowed to pass into the trachea to the lungs while food is allowed to pass into the esophagus to the stomach. Click here to see a visual representation of this process.

Flow of the Upper Respiratory Tract
Lower Respiratory Tract

The lower respiratory tract consists of the:

- Trachea (continuation from the upper respiratory tract)
- Bronchi
- Lungs

Similar to our discussion of the upper respiratory tract, we will continue the process of respiration within the lower respiratory tract step-by-step, with an emphasis on the structures involved.

Trachea and Bronchi

The trachea, a cartilaginous ringed tube, goes from jaw to chest. Just above the heart, the trachea divides into two tubes called bronchi. Each bronchi enters into a lung – a horse has a right and left lung.

Lungs

The lungs of a horse are an amazing piece of engineering. Consisting of an enormous surface area of spongy, elastic tissue that increases and decreases as the horse breathes, the lungs, as well as the heart and spleen, fill the horse’s thorax. Within the lungs, the bronchi continue to divide and subdivide, like the branches of a tree. The smallest branches are called the bronchioles, which are scarcely larger than a hair. Each bronchiole ends in millions of tiny air sacs called alveoli, which are responsible for the exchange of oxygen and carbon dioxide.
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Gaseous Exchange

A thin membrane, called the blood-gas barrier, surrounds each alveolus and this is where the exchange of oxygen and carbon dioxide occurs. Deoxygenated blood (blood without oxygen) flows into the lungs through the capillaries embedded in the semi-permeable walls of the alveoli. Carbon dioxide is then extracted and exhaled as waste. Inhalation brings in fresh, dry air high in oxygen. This reaches the alveoli where it is extracted by the blood, which then returns back to the heart and is pumped to the rest of the body where it is absorbed and used. This complex process is known as gaseous exchange.

Flow of the Lower Respiratory Tract
Respiration & Exercise

Even in a race lasting less than a minute, the majority of energy generated must come from using oxygen to “burn” fuel, such as carbohydrates. The oxygen absorbed by the lungs is used to perform a process called aerobic metabolism, which was discussed briefly in the lecture on the Muscular System. Remember that slow and fast twitch muscle fibers produce energy via two forms of metabolism – aerobic and anaerobic.

Of the total amount of energy the racehorse needs to get from the starting gate to the finish line in a 5 furlong race, around 70% of this will come from aerobic metabolism. This underlies the importance of a well-functioning respiratory system. The remaining energy comes from anaerobic metabolism, which is a fast, but inefficient source of energy production.

The respiratory system is one equine body system that training will actually not improve. While you might have heard that certain training regimens can build a strong respiratory system, numerous scientific studies have shown the reverse. The amount of air moved in and out by an unfit horse at a fixed speed will be the same when the horse is fully fit.

What we as equine caretakers do have an impact on is the health of the respiratory structures. Unfortunately, respiratory stress and ailments are often human caused – poor ventilation, dusty bedding or forage, and lack of turnout are often the root causes of respiratory distress.

Management of the Respiratory System - IAD

Inflammatory Airway Disease (IAD) is a common issue among stabled horses, especially those that are young. Common signs and symptoms of this ailment include:

- Persistent cough that lingers more than one month
- No fever
- Poor performance, taking longer to return to a normal resting respiration following exercise
- Mild, watery, or white nasal discharge, especially after exercise

Most horses suffering from IAD maintain a good appetite and appear bright and alert, which can help you differentiate this issue from other infectious, and sometimes contagious, respiratory ailments.

While diagnosis of IAD can be apparent from clinical signs, your veterinarian may choose to perform an endoscopic examination, which involves passing a small camera through the airways after exercise to see if mucous is present. Swabbing mucous may also be performed to rule out any bacterial or viral infections.
Prevention and good stable management practices are the best ways to manage this issue. Your first step should be identifying any contaminants/irritants that may be the cause of IAD. For example, horses suffering from IAD do better on paper or wood shavings rather than straw.

While you may be limited on what you can change in a racing environment, you can implement the following to help reduce dust and contaminant exposure:

- Remove horses from the stall prior to cleaning stalls
- Minimize sweeping, raking, and other measures that can increase dust in the air
- Water down shedrows if raking is necessary
- Keep stall windows and barn doors open to increase airflow
- Pick up clutter in the barn and tack room to decrease areas where dust can settle
- Turnout as much as possible

In addition to environmental adjustments, horses suffering from IAD are often treated with an anti-inflammatory medication to help treat airway inflammation and/or prescribed a bronchodilator, which is a category of medication that can help expand the airways and loosen mucous.
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Respiratory Images – Upper Airway

[Diagram of the respiratory system with labeled parts like larynx, turbinates, and nostrils.]

Larynx

Turbinates

Nostrils

Air passage
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Respiratory Images – Lower Airway

The trachea and lungs showing the brachial tree in the left lung

Position of the lungs

Oxygen inhaled

Carbon dioxide released into the lungs and exhaled

Oxygen carried in the blood to the heart, where it is pumped to the tissues

Pulmonary arteriole

Carbon dioxide carried in the blood

Pulmonary venule

Pulmonary capillary

Alveoli

Gaseous exchange

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Self-Knowledge Checks

1. At rest, the normal respiration rate of a healthy adult horse is:
   a. 2 – 4 breaths per minute
   b. 8 – 16 breaths per minute
   c. 18 – 32 breaths per minute
   d. 60 – 80 breaths per minute

2. A horse that is having an issue with their pharynx would be having an issue with their:
   a. Upper respiratory tract
   b. Lower respiratory tract

3. Inhaled air will be filtered and cleaned in the:
   a. Hard palate
   b. Epiglottis
   c. Nasal cavities
   d. Larynx

4. 50 – 80% of resistance to airflow comes from the nasal passages.
   a. True
   b. False

5. The larynx is responsible for:
   a. Directing air into the trachea
   b. Producing vocal noises
   c. Controlling airflow into the lungs
   d. All the above

6. Which of the following are components of the larynx?
   (Circle all that apply)
   a. Pharynx
   b. Epiglottis
   c. Soft palate
   d. Bronchi
   e. Arytenoids

7. Just above the heart the trachea divides into two tubes called:
   a. Bronchioles
   b. Alveoli
   c. Bronchi
   d. Larynx

8. This structure is responsible for the exchange of oxygen and carbon dioxide.
   a. Bronchi
   b. Alveoli
   c. Pharynx
   d. Cilia

9. The equine respiratory system can improve with training.
   a. True
   b. False

10. What management strategies can help reduce dust and contaminant exposure, reducing the risk of IAD?
Answers

1. At rest, the normal respiration rate of a healthy adult horse is:
   - b. 8 – 16 breaths

   A healthy adult horse’s normal respiration rate (the inhalation and exhalation of air) is 8 – 16 breaths per minute (bpm)

2. A horse that is having an issue with their pharynx would be having an issue with their:
   - a. Upper respiratory tract

   The pharynx is part of the horse’s upper respiratory tract

3. Inhaled air will be filtered and cleaned in the:
   - c. Nasal cavities

   Air that is drawn into the nasal cavities through the nostrils is filtered and cleaned by moist, mucous membranes and tiny hairs called cilia

4. 50 – 80% of resistance to airflow comes from the nasal passages.
   - a. True

   A significant portion of the horse’s nasal passages is unsupported by bone or cartilage – this means when a horse’s breathes during exercise, the nasal passages collapse inward, reducing the size of the airway and increasing resistance to airflow. It would be like it if you tried to take a deep breath in and someone placed pressure on the unsupported tissue of your nose (give it a try!). Research has shown that over 50%, with up to 80%, of airflow resistance comes from the nasal passages

5. The larynx is responsible for:
   - d. All the above

   The larynx is responsible for all three functions listed

6. Which of the following are components of the larynx? (Circle all that apply)
   - b. Epiglottis
   - c. Soft palate
   - e. Arytenoids

   The larynx is comprised of numerous structures that assist with main functions – the epiglottis, soft palate, and arytenoids

7. Just above the heart the trachea divides into two tubes called:
   - c. Bronchi

   The bronchi each enter into a lung

8. This structure is responsible for the exchange of oxygen and carbon dioxide.
   - b. Alveoli

   Alveoli are tiny air sacs found at the end of each bronchiole. Around each alveolus is a thin membrane that allows for the exchange of oxygen and carbon dioxide

9. The equine respiratory system can improve with training.
   - b. False

   Training has not shown to improve the equine respiratory system – the amount of air move in and out by an unfit horse at a fixed speed will be the same when the horse is fully fit. Equine caretakers can Unfortunately do more harm than good to the respiratory system because of poor stable conditions

10. What management strategies can help reduce dust and contaminant exposure, reducing the risk of IAD?

    There are many management strategies one can implement to help reduce dust and contaminant exposure - removing horses prior to stall cleaning, minimizing sweeping or raking, watering down shedrows, opening windows and doors, picking up clutter, and turning out when possible

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Glossary

**Aerobic Metabolism** – Is dependent on oxygen to break down fuel stores – inhaled oxygen during aerobic exercise is carried to the muscles and liver to metabolize (utilize) carbohydrates and fats for the production of ATP, the energy source for muscle contraction. Exercise is classified as aerobic if the heart rate is less than 150 beats per minute. The waste products of aerobic metabolism are carbon dioxide, water, and heat

**Alveoli** – Tiny air sacs that form on the end of each bronchiole, allows for the gaseous exchange of oxygen and carbon dioxide

**Anaerobic Metabolism** – Is not dependent on oxygen to break down fuel stores, provides a rapid means of producing a limited supply of energy during anaerobic exercise. Exercise is classified as anaerobic if the heart rate is greater than 150 beats per minute. In the absence of oxygen, only carbohydrates can be metabolized for ATP production and the waste products of anaerobic metabolism are heat and lactic acid

**Arytenoid Cartilages** – Located on each side of the horse’s larynx, closes the opening of the trachea when swallowing

**Bronchi** – Two tubes that subdivide from the trachea, enters into each lung

**Bronchioles** – Smallest branches of bronchi that go all throughout the lungs

**Cilia** – Tiny hairs found in the nasal cavities, move in a wave-like action to help filter air

**Diaphragm** – Primary muscle used for breathing, separates the abdominal and chest cavities

**Endoscope** – An instrument used to visually examine internal parts of the horse

**Epiglottis** – Elastic cartilaginous structure that prevents food from entering the trachea, sits on top of the soft palate

**Esophagus** – Soft walled muscular tube that takes food from the mouth to the stomach

**Gaseous Exchange** – The removal of carbon dioxide to be exhaled and extraction of oxygen by the blood from inhaled air

**Hard Palate** – A bone that forms the roof of the mouth and base of the nasal cavity, separates the nasal cavity and mouth

**Inflammatory Airway Disease (IAD)** – Inflammation of the airway due to airway contaminants, such as dust and debris

**Larynx** – Directs air into the trachea, controls airflow into the lungs during breathing, and produces vocal sounds

**Lower Respiratory Tract** – Consists of the trachea (lower portion), bronchi, and lungs

**Lungs** – Spongy, elastic tissue that increases and decreases as the horse breathes
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**Nasal Cavities** – Contains sinuses, mucous membranes, and cilia to filter dust, germs, and debris

**Nasopharynx** – See pharynx

**Nostrils** – Soft-walled, cartilaginous structure that allows for air to be drawn in

**Pharynx** – Chamber lined with mucous membranes that connect the nasal passages to the larynx

**Soft Palate** – Continuation of the hard palate, responsible for separating the larynx from the esophagus

**Trachea** – A structure comprised of cartilaginous rings, takes air to the lungs

**Upper Respiratory Tract** – Consists of the nostrils, nasal passages, pharynx (nasopharynx), larynx, and trachea (upper portion)