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**POOR PERFORMANCE SECONDARY TO  
AIRWAY OBSTRUCTIONS IN HORSES**

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## List of abbreviations

ACC	arytenoid cartilage collapse
ADAF	axial deviation of the aryepiglottic folds
BAL(F)	broncho-alveolar lavage (fluid)
COPD	chronic obstructive pulmonary disease
CO <sub>2</sub>	carbon dioxide
DDSP	dorsal displacement of the soft palate
EE	epiglottic entrapment
ER	epiglottic retroflexion/retroversion
EIPH	exercise induced pulmonary haemorrhage
EPM	equine protozoal myeloencephalitis
HSTE	high-speed-treadmill-endoscopy
HYPP	hyperkalaemic periodic paralysis
IAD	inflammatory airway disease
ILLHP	idiopathic left laryngeal hemiplegia
LRT	lower respiratory tract
OE	overground endoscopy
O <sub>2</sub>	oxygen
PHC	pharyngeal collapse
PI	palatal instability
RAO	recurrent airway obstruction
RBC	red blood cells
RE	resting endoscopy
RLN	recurrent laryngeal neuropathy
SPAOPD	summer pasture associated obstructive pulmonary disease
TW	tracheal wash
URT	upper respiratory tract
VCC	vocal cord collapse
VRDDL	ventro-rostral displacement of the dorsal laryngeal mucosa
4BAD	fourth brachial arch defect

## **1. Introduction**

Competitive horses are constantly being pushed to and past their limits. We are seeing higher fences jumped, faster speeds reached and more intricate dressage movements performed by horses than ever before. Due to the horse and rider performing at such a high standard, even a small decline in the health status of the horse can have a substantial impact on its performance. A change in performance going unnoticed or ignorance to a change could lead to worsening of the horse's health and predisposition of the horse to secondary pathogens or illness, exacerbating the original problem. Therefore early detection of poor performance is very important.

## **2. Literature Review**

### **2.1 Common Causes of Poor Performance in Horses**

The nature of complaints of a horse's poor performance differ in presentation. For example, some horsemen report that their horse is just "off", they cannot describe the exact problem but they feel there is something wrong. Other times it is a little more obvious; noticeably lengthened race times; pulling up in races; showing a clear disinterest or fence refusal. At other times the problem seems very obvious and can be described as "exercise intolerance". This term is usually used when the horse is in obvious discomfort or even distress during exercise. For example, a horse with an upper respiratory tract (URT) obstruction, that is restricting the breathing will show distress during exercise as it struggles to breathe under the increased demand for oxygen (O<sub>2</sub>). Or recurrent exertional rhabdomyolysis will incur muscle soreness even with light exercise. In both scenarios the horses show an intolerance to exercise (Geor, 2000).

General signs of disease or bad health such as lameness, dyspnea or coughing can be observed in any type of horse but there is also a wide variety of symptoms of poor performance according to the horse's discipline as outlined in table 1.

DISCIPLINE	POSSIBLE MANIFESTATIONS OF POOR PERFORMANCE
DRESSAGE HORSES	May have trouble coming onto the bit, or may refuse to perform a manoeuvre that they have had no trouble with in the past.
SHOW-JUMPERS	May start to refuse, or may take down rails.
EVENTERS	Show poor recovery - such as prolonged high heart rate, respiratory rate, and temperature - from the more strenuous phases of the event, or may have trouble making times.
ENDURANCE HORSES	Similar to event horses, may show poor recovery, or inability to finish the ride.
RACEHORSES	May suddenly quit during the race, slow down at the 3/4 pole, or have a general loss of form.
<i>OTHER SIGNS</i>	Going off feed, decreased faeces production, 'crabby attitudes', or general loss of bloom.

**Table 1: Possible manifestations of poor performance according to the equestrian discipline.**

Source: adapted from Tufts University, 2005-2006.

Common causes of poor performance in sport horses can be categorized by the body system that they affect:

1. The respiratory system (nasal passages, upper airways, trachea, lungs)
2. The cardiovascular system (heart, blood vessels, volume of blood and number of red blood cells (RBC))
3. The musculoskeletal system (bones, joints, tendons, ligaments and muscle)
4. The nervous system (brain, spinal cord, nerves)
5. The gastrointestinal system (stomach, intestines)

For superior athletic performance, not only good structural conformation and a strong will to compete are needed, but all of the above body systems must be in optimal working condition. Even a slight decline in the health of one of these systems can hinder a horse from reaching peak performance. Diagnosis of the cause of the poor performance depends on a precise anamnesis, a thorough physical examination of all the body systems and the competent usage of diagnostic tools for example ultrasonography, endoscopy and blood tests.

The aims of the present study were to describe the upper airway abnormalities detected by OE in racehorses and sport horses presented with poor performance and/or abnormal respiratory noise at exercise. It was hypothesised that the major abnormalities detected during OE would be similar to those detected in other populations of racehorses and sport horses presented for poor performance and/or respiratory noise.

### 2.1.1 Respiratory System Causes of Poor Performance in Horses

Respiratory problems are the most common cause, after musculoskeletal problems, of poor performance in horses. The athletic ability of the horse is dependent on a harmonious functioning of the respiratory tract and a number of other systems in the body, for example the musculoskeletal system, the cardiovascular system and the nervous system. A disorder in any of these body systems can cause exercise intolerance and therefore a decline in performance. Interestingly, it has been stated that in a healthy horse it appears to be the respiratory system that is the limiting factor for athletic success (Rush and Mair, 2004a).

The respiratory tract disorders can be classified into four basic categories (Rush and Mair, 2004b)

- Contagious URT (nasal passages, upper airways and trachea): E.g. Strangles (*Streptococcus equi*).
- Non-contagious URT: E.g. guttural pouch mycosis, arytenoid chondritis (infectious) or structural and functional problems (non-infectious).
- Infectious lower respiratory tract (LRT): E.g. pneumonia and pleuropneumonia.
- Non-infectious LRT: E.g. recurrent airway obstruction (RAO), inflammatory airway disease (IAD) and exercise induced pulmonary haemorrhage (EIPH).

Below are some common respiratory tract-associated causes of poor performance:

COMMON URT FUNCTIONAL DISEASE	COMMON LRT PROBLEMS
Idiopathic left laryngeal hemiplegia (ILLHP) /arytenoid cartilage collapse (ACC)	RAO
Dorsal displacement of the soft palate (DDSP)	IAD
Dynamic nasopharyngeal collapse	EIPH
Epiglottic entrapment (EE)	

**Table 2: Common disorders of the respiratory tract.**

\*ACC: arytenoid cartilage collapse, DDSP: dorsal displacement of the soft palate, EE: epiglottic entrapment, EIPH: exercise induced pulmonary haemorrhage, IAD: inflammatory airway disease, ILLHP: idiopathic left laryngeal hemiplegia, RAO: recurrent airway obstruction.

Dynamic URT collapse is a common cause of poor performance in horses (Dart et al., 2001; Parente et al., 2002; Tan et al., 2005; Lane et al., 2006). Upper airway conditions cause poor performance primarily through obstruction of the airways. Two studies evaluating poor performance problems showed that more than 40% of the horses examined in the studies had

some type of upper airway obstruction during exercise (Morris and Seeherman, 1991; Martin et al., 2000). Most affected horses will produce abnormal respiratory sounds at rest or during exercise as a result of an upper airway obstruction. Racehorses demanding the highest O<sub>2</sub> flow through the airways are very sensitive to structural and functional disorders of the URT and usually only exhibit abnormal respiratory sounds during intensive exercise, easily recognizable by the jockey during training. This is in contrast to horses that perform less strenuous work, where a larger degree of dysfunction is needed to induce a decline in performance of the horse. These horses may exhibit abnormal respiratory sounds at less intensive work. Abnormalities, either dynamic or fixed lesions of the URT, restrict air flow causing turbulence in the airways. The air turbulence produces the abnormal respiratory sounds either on inspiration or expiration or both. Some affected horses however, do not produce these characteristic sounds (Geor, 2000) but nonetheless show a decline in performance and this situation also prompts a thorough veterinary examination of the upper airways.

Similarly, non-infectious LRT diseases are also common and typically limit the athleticism of horses. IAD is characterized by excessive tracheal mucus, airway hyperactivity and poor exercise performance in young horses (Merck 2010, p. 1330). RAO is triggered by the inhalation of organic dust particles by horses with a genetic predisposition to allergies and is characterized by bronchoconstriction and excessive mucus production (Merck 2010, p. 1330). EIPH is more commonly seen during short but maximal exercise efforts, for example horse racing.

### 2.1.2 Physiology of URT

Diseases of the respiratory tract are common among the equidae family. The basic requirements of the respiratory tract include the transfer of a sufficient amount of O<sub>2</sub> that is needed by the body's tissues from inspired air to the arterial blood and the transfer of carbon dioxide (CO<sub>2</sub>) as a metabolic product from venous blood to the expired air at the alveolar gas exchange sites. The demands placed on the respiratory tract are hugely increased during exercise. The horse's respiratory tract is designed to try to meet this demand with the URT airflow increasing from 240 litres/minute at rest to 4500 litres/minute during maximal exercise (McCann, 2000). During this time the horse is experiencing arterial hypoxaemia, O<sub>2</sub> desaturation and hypercapnia. Anything preventing normal air flow and the transfer of O<sub>2</sub> into and out of the lungs will further impair ventilation and gas exchange and thereby decrease the horse's ability to generate the energy needed for exercise. Since there is such an increased demand for O<sub>2</sub> during exercise, a restriction of air flow in the horses body causes O<sub>2</sub> starvation and the horse will tire sooner than under healthy conditions.

There are many possible causes of abnormal respiratory sounds, usually associated with nasopharyngeal stenosis. For example a nasal or pharyngeal abscess or tumor, guttural pouch tympany or empyema, maxillary cysts and chronic paranasal sinusitis all produce a degree of nasopharyngeal obstruction (Greet, 1986). All of the common URT functional diseases listed in table 2 will cause abnormal respiratory sounds to some degree. It may be found that there is either an increase in the loudness of the sound, indicating an increase in turbulence due to an obstruction, or a previously inaudible inspiratory sound now becomes audible, or a change in pitch of the sound which is usually associated with a type of obstruction that is moveable, for example a dorsal displacement of the soft palate (DDSP) (Gerring, 1985). An irregular sequence of abnormal sounds is typically heard due to excessive swallowing during exercise, the frequency of which would be increased during a bacterial or fungal infection for example, with the gathering of any fluid, mucus or fungi in the pharyngeal region (Gerring, 1985).

The horse is an obligatory nasal breather. The larynx lying normally in an intranarial position is the narrowest section of the airway, with the area of most angulation at the pharynx due to the natural atlanto-occipital joint flexion. A palatopharyngeal ring firmly surrounds the larynx. This anatomical positioning is usually only disturbed during swallowing when the palatopharyngeal arch is elevated and the larynx descends into the oropharynx and the



epiglottis folds caudally over the rima glottis to allow food or water to pass to the oesophagus (Gerring, 1985).

At rest, normal breathing in horses is characterized by a bi-phasic, “double-effort” of respiration (Rush and Mair, 1994c). The process of inspiration and expiration in horses is slightly different to that of other domestic species. Inspiration is normally an active process with the diaphragm and the intercostal muscles contracting to expand the thoracic cavity allowing the lungs to expand as they are filled with air. In contrast, expiration is normally a passive process as those same muscles then relax, the lungs expel the air and the thoracic cavity returns to its normal resting diameter. Whilst expiration by horses is predominantly passive, the last phase of expiration is active as the abdominal musculature contract to expel the last bit of air from the lungs. The first phase of inspiration is then passive as the abdominal musculature then relaxes and air is drawn into the lungs without effort. The abdominal musculature efforts during expiration may be misinterpreted as a respiratory difficulty in horses (Rush and Mair, 1994c). In a fit and healthy horse there are no audible respiratory sounds at rest or upon inspiration during exercise. However, we can hear a normal blowing expiratory sound during canter or a slow-gallop. The nostrils, pharynx and larynx dilate to accommodate the increased airflow during exercise but still very little sound is produced by fit and healthy horses. In an unfit, over weight horse we may hear also an inspiratory sound during exercise. In addition we may hear a harsh sound varying in pitch, referred to as “high blowing” which is thought to be as a result of resonance in the cavity of the false nostril during expiration (Gerring, 1985). These are all considered “normal”, non-pathological respiratory sounds. Clinical signs of respiratory distress include flaring of the nostrils, an anxious appearance and extension of the head and neck. Good knowledge and recognition of these normal sounds and their differentiation from exercise-related abnormal sounds and recognition of true clinical signs is essential to diagnosing abnormal, pathological respiratory sounds. The ability to assess the significance of these sounds with regard to exercise capacity and use of the horse is also important (McCann, 2000).

Exercise-related noises can be characterized by the following points (McCann, 2000):

- At which gait does the noise occur?
- Is it continuous or intermittent?
- Is it inspiratory or expiratory or both?
- Does the horse pull up abruptly or slow down when it occurs?
- Does the rider stop the horse?
- Is the noise performance limiting?
- Does it resolve as soon as exercise ceases?
- Does the horse rapidly recover from post-exercise dyspnea?

It is important to note whether the sound is produced upon inspiration or expiration. Recognizing which phase of respiration that the sound occurs in can help diagnostically. This may help to define the location of the disorder in the URT and also the type, either obstructive or restrictive.

Difficulty during inspiration and particularly in the presence of inspiratory noise indicates a URT obstruction. During inspiration, the intra-airway negative pressure exacerbates dynamic airway narrowing by drawing soft tissues into the airway. During expiration, intra-airway pressure is positive which expands the diameter of the URT.

Prolonged expiration, associated with excessive abdominal effort, indicates an obstruction of the LRT. During expiration the diameter of small airways narrows. Inflammation of the small airways or causes of broncho-constriction contribute further to the narrowing of the small airways, and this may result in small airway collapse. During inspiration, intra-thoracic pressure is negative, small airways are pulled open by parenchymal attachments, minimizing the effects of broncho-constriction and inflammation.

In contrast, restrictive pulmonary disease is likely to produce rapid, shallow respiration with prolonged inspiration and abbreviated expiration. Pleural effusion, pneumothorax and diaphragmatic hernias are extra-pulmonary restrictive disorders, while pulmonary fibrosis and granulomatous pneumonitis are intrapulmonary restrictive diseases that may hinder the expansion of the lower airways (Rush and Mair, 1994c).

In order to establish if the abnormal sound is produced during inspiration or expiration, one should exercise the horse in such a gait where there is coupling of respiration to gait. These gaits are canter and gallop.

COUPLING OF STRIDE AND RESPIRATION	
Expiration occurs as the leading leg hits the ground during canter and gallop due to: <i>(all these factors compress the thorax aiding expiration)</i>	<ul style="list-style-type: none"><li>• Impaction of the abdominal viscera on the diaphragm.</li><li>• Flexion of the neck as the forelimbs hit the ground.</li><li>• Transmission of force to the chest as the forelimbs strike the ground.</li></ul>

**Table 3: Coupling of stride and respiration phases.**

Source: McCann, 2000.

In canter and gallop there is always a leading leg and respiration and locomotion are linked in these gaits. There is one breath per stride, expiration taking place when the leading forelimb hits the ground. Knowing this, an inspiratory sound can be distinguished from an expiratory sound. To enhance the abnormal sounds heard, it may be helpful to examine the horse at a collected canter since the angle of flexion of the head influences the air turbulence through the airways. At rest the head is usually held at around a 50° angle at the point of the pharynx, the narrowest region of the airways, this is why the horse extends the neck during gallop to open the angle up to 130° at the pharynx, increasing the diameter of the airways to allow maximum entry of air. However, in a collected canter, the opposite occurs. The head is carried at an angle slightly less than 45°, decreasing the diameter of the airways and thereby worsening any abnormal respiratory sounds associated with an upper airway obstruction (Gerring, 1985). This amplification of sound can help with our diagnosis.

EXERCISE-RELATED ABNORMAL RESPIRATORY SOUNDS	
STRIDOR	A shrill, harsh, high-pitched inspiratory sound. Associated with pharyngeal or laryngeal obstruction, arytenoid chondritis, bilateral laryngeal paralysis or pharyngeal collapse (PHC) as seen in hyperkalaemic periodic paralysis (HYPP).
STERTOR	Snoring, sonorous respiration, usually due to partial obstruction of the upper airway.
WHISTLING	Stridorous, musical sound made by forced breathing through a narrow opening. This noise is usually indicative of static or dynamic stenosis of a passage.
ROARING	Stertorous sound; short, low-pitched sound made by air passing through a stenosed larynx, usually due to ILLHP in the horse.
GURGLING/CHOKING UP	A fluttering, snoring type of respiratory noise (stertor), low-pitch, made during inspiration or expiration. Associated with DDSP, nasal septal dysplasia or nasal masses.

**Table 4: Exercise related abnormal respiratory sounds.**

Source: adapted from McCann, 2000; Rush and Mair, 1994d.

\*LHP: left laryngeal hemiplegia, HYPP: hyperkalaemic periodic paralysis, PHC: pharyngeal collapse.

As described above, some sounds are typical of an abnormality in the URT. A DDSP can give a “gurgling” sound, whilst idiopathic left laryngeal hemiplegia (ILLHP) tends to create a “roaring” or “whistling” sound. However, no one sound is pathognomic of a cause. A horse with epiglottic entrapment (EE) can produce a sound that is identical to that produced by DDSP. The definitive diagnosis is based on the nature and occurrence of the sound, the use of other diagnostic tools, for example an endoscope is very informative and the behavior of the horse itself can be helpful – horses with a dorsally displaced soft palate tend to pull up suddenly after the displacement whereas ILLHP causes a more gradual slow down in the horse.

An endoscopic examination of the equine patient during rest is extremely useful in the diagnosis of URT obstructions. However, this is not always representative of the state of the URT during exercise (Barakzai and Dixon, 2011). Table 11 on page 32 below shows common URT disorders and whether their dysfunction is static or dynamic or both.

### 2.1.3 Functional Disorders

Common abnormalities diagnosed by endoscopic examination include ILLHP, palatine dysfunction and pharyngeal collapse (PHC).

#### 2.1.3.1 ILLHP and Arytenoid Cartilage Collapse (ACC)

ILLHP is a distal axonopathy of the recurrent laryngeal nerve (RLN) with clinical manifestation predominantly (95%) on the left side. It is most common in larger horses, typically taller than 16hands for example Thoroughbreds, heavy height hunter types and draught breeds such as Clydesdales (Cahill and Goulden, 1987; Dixon et al., 2001). It is characterized by paresis or paralysis of the left arytenoid cartilage and vocal fold (Merck 2010, p. 1344). For reasons that are not well understood, the *nervus laryngeus recurrens sinister* that serves the muscle that opens the left side of the larynx, begins to die. When nerve function is lost, the muscle is no longer stimulated, and so it atrophies. The end result is that the left side of the larynx becomes paralyzed and can no longer abduct. Clinical signs include exercise intolerance and inspiratory noise such as roaring or whistling during exercise typically during canter or higher activity (American College of Veterinary Surgeons; Merck, 2010). Asynchrony of the laryngeal cartilages occurs commonly and with variable clinical relevance. However, horse's that show exercise intolerance or abnormal respiratory noise during exercise or if laryngeal asynchrony is detected during resting endoscopy (RE) should have their laryngeal function evaluated during exercise also.

Table 5 describes the Havemeyer grading system whereby the grades are appointed according to the severity of laryngeal dysfunction observed during rest.

<b>I.</b> All arytenoid cartilage movements are synchronous symmetrical and full arytenoid cartilage abduction can be achieved and maintained.	
<b>II.</b> Arytenoid cartilage movements are asynchronous and/or the larynx is asymmetrical at times but full arytenoid cartilage abduction can be achieved and maintained.	<ol style="list-style-type: none"> <li>1. Transient asynchrony, flutter or delayed movements are seen.</li> <li>2. There is asymmetry of the rima glottidis much of the time due to reduced mobility of the affected arytenoid and vocal fold but there are occasions typically after swallowing or nasal occlusion when full symmetrical abduction is achieved and maintained.</li> </ol>
<b>III.</b> Arytenoid cartilage movements are asynchronous and/or asymmetric. Full arytenoid cartilage abduction cannot be achieved and maintained.	<ol style="list-style-type: none"> <li>1. There is asymmetry of the rima glottidis much of the time due to reduced mobility of the arytenoid and vocal fold but there are occasions typically after swallowing or nasal occlusion when full symmetrical abduction is achieved but not maintained.</li> <li>2. Obvious arytenoid abductor deficit and arytenoid asymmetry. Full abduction is never achieved.</li> <li>3. Marked but not total arytenoid abductor deficit and asymmetry with little arytenoid movement. Full abduction is never achieved.</li> </ol>
<b>IV.</b> Complete immobility of the arytenoid cartilage and vocal fold.	

**Table 5: Havemeyer scale of laryngeal function.**

Source: Robinson, 2004.

During exercise, the corniculate process of the arytenoid cartilage moves towards the midline of the rima glottidis during inspiration and may even collapse into the right side of the rima glottidis (Franklin, 2008). Vocal cord collapse (VCC) of the same side always accompanies arytenoid cartilage collapse (ACC) (Franklin, 2008) and in some cases, bilateral VCC may be seen (Lane et al., 2006a). Partial ACC is also possible, with the arytenoid cartilage not fully abducted but there is no collapse into the midline of the rima glottidis during inspiration (Franklin, 2008). This prevents the horse from breathing freely during intense exercise (Tufts University, 2005-2006). The degree of obstruction of the rima glottidis and the type of work the horse performs will determine the clinical significance of the ACC (Franklin, 2008). It is mainly seen in racehorses or high level eventing horses as it is not until horses are competing in races greater than one mile or upper level three-day events, that laryngeal paralysis will actually interfere with performance (Tufts University, 2005-2006). Table 6 shows a grading system developed for ACC detected during exercise.

Grade	Interpretation
A	Full abduction of arytenoid cartilages during inspiration
B	Partial abduction of the affected arytenoid cartilages (between full abduction and the resting position)
C	Abduction less than resting position including collapse into the contralateral half of the rima glottidis during inspiration.

**Table 6: Grading system of arytenoid cartilage collapse.**

Source: Rakestraw et al. 1991

In table 7 Barakzai and Dixon (2011) portray the correlation of Havemeyer grades during RE and the degree of ACC and VCC detected during dynamic endoscopy.

Laryngeal Function at Rest	ACC grade A	ACC grade B	ACC grade C	VCC
1 (n=49)	47 (96%)	2 (4%)	0	2 (1 grade A, 1 grade B)
2 (n=169)	155 (92%)	12 (7.7%)	2 (1.9%)	25 (17 grade A, 6 grade B, 2 grade C)
3 (n=51)	17 (56%)	23 (46%)	11 (20%)	34 (2 grade A, 21 grade B, 11 grade C)
4 (n=3)	0	0	3	3 (3 grade C)
<b>TOTAL</b>	219 (81%)	37 (14%)	16 (6%)	<b>62</b>

**Table 7: Correlation of resting and dynamic endoscopic findings.**

Source: Barakzai and Dixon 2011.

\*ACC: arytenoid cartilage collapse, n: number of cases, VCC: vocal cord collapse.

Those cases where grade 4 ILLHP is detected at rest predictably showed a total collapse of arytenoid cartilage during exercise. However, in grade 2 and grade 3 ILLHP seen during rest, it is not possible to predict with confidence the degree of arytenoid cartilage dysfunction. Therefore an endoscopic examination during exercise is needed.

The surgical treatments for ILLHP include ventriculectomy, ventriculocordectomy where VCC is involved also and may be performed alone or with a prosthetic laryngoplasty (LP) (Michigan University). The latter is also known as a “tie-back” surgery and is the most common treatment for ILLHP in horses. However, recently a high prevalence (11-79%) of palatal dysfunction occurs after horses have undergone LP (Davidson et al., 2010; Barnett et al., 2011; Compostella et al., 2012).

Right sided arytenoid collapse may also be observed but much less frequently (Lane, 2003). Right sided collapse may be attributed to fourth branchial arch defects (4BAD) (Kannegeiter et al., 1986; Lane, 2001) and non-RLN laryngeal hemiplegia secondary to localized injury to the vagus nerve or RLN at any site along their courses (McGorum and Dixon, 2013). 4BAD

has two typical manifestations: right sided ACC and rostral displacement of the palatopharyngeal arch.

Laryngeal paralysis involving both sides of the larynx has been found to occur due to various reasons such as primary hepatic disease (Gorum et al., 1999; Dixon et al., 2001), organophosphate poisoning (Duncan and Brook, 1985), hyperkalaemic periodic paralysis (HYPP) (Carr et al., 1996) and over extension of the neck during general anaesthesia (Dixon et al., 1993). However more recent studies (Olsen et al., 2010; Barakzai, 2006) investigating poor performance and/or abnormal respiratory noise have reported bilateral dynamic laryngeal collapse related to gaits in which there was high poll flexion.

### **2.1.3.2 Palatal Dysfunction**

Palatal dysfunction is most commonly diagnosed in Thoroughbred and Standardbred racehorses but also in horses whose discipline requires them to exercise with their head and neck carried in a flexed position, like dressage horses and Saddlebreds (Franklin et al., 2006). Palatal dysfunction (PI) and DDSPP are both syndromes of palatal dysfunction which is the most commonly diagnosed cause of upper airways obstruction in horses (Barakzai and Hawkes, 2010). However it is still unclear if PI and intermittent DDSPP are two individual forms of palatal dysfunction, or if they are different severities of the same disorder (Lane et al., 2006a; Franklin et al., 2006; Pollock et al., 2009; Barakzai et al., 2011).

#### **PI**

PI has been described as a wave-like “billowing” of the rostral and caudal soft palate but without actual displacement of the caudal border of the soft palate to the epiglottis (Barakzai and Hawkes, 2010), caudal retraction of the larynx, billowing of the soft palate, flattening of the tip of the epiglottis against the palate with the tip of the epiglottis pointing dorsally and increased frequency of swallowing (Allen and Franklin, 2013). Allen and Franklin (2013) found that of 72 horses with PI examined by dynamic endoscopy on a high-speed treadmill, 46% subsequently developed DDSPP. PI may be a precursor to DDSPP and may be the only sign of palatal dysfunction in horses not exercised to exhaustion (Smith and Greet, 2013). DDSPP may also occur alone, without PI preceding it (Barakzai and Hawkes, 2010).



## DDSP

During DDSP, the caudal free margin of the soft palate moves dorsal to the epiglottis, creating a functional obstruction within the airway (Merck 2010, p. 1345). The cross-sectional area of the pharynx is reduced and airflow resistance and turbulence are increased (Merck 2010, p. 1345). Persistent DDSP is typically identified at rest (Ortved et al., 2010) whilst intermittent DDSP may be detected at rest or during exercise (Lane et al., 2006a; Franklin et al., 2006; Pollock et al., 2009; Van Erck, 2001). DDSP has previously been associated with abnormal epiglottic conformation or epiglottic hypoplasia (Linford et al., 1983; Robertson, 1991). However, more recent studies report that the majority of horses with DDSP have in fact a normal epiglottic appearance (Tan et al., 2005; Lane et al., 2006b). In addition, there is both clinical (Parente et al., 1998) and experimental (Holcombe et al., 1997) evidence to support the theory that the epiglottis is not required to maintain the soft palate in a normal subepiglottic position.

Whilst several theories have been proposed, there is little evidence to support a definitive aetiology and pathogenesis of palatal dysfunction. As described above, DDSP has various manifestations, the reason for which is still unknown but is most probably as a result of a multi-factorial aetiology (Barakzai and Hawkes, 2010).

Extrinsic causes of DDSP	Intrinsic causes of DDSP
Caudal position of the larynx, pharynx and basihyoid bones.	Structural anomalies: e.g. sub-epiglottic cysts, epiglottic granulomas.
	Neuromuscular weakness: e.g. URT infection

**Table 8: Aetiology of dorsal displacement of the soft palate (DDSP).**

\*URT: upper respiratory tract.

The treatment of DDSP must be tailored to the cause (Ducharme, 2009) and research has mainly focused on three theories with the main aim being to improve treatment. These theories are neuromuscular dysfunction of the intrinsic soft palate muscles (Hawkes et al., 2010), positioning of the laryngohyoid apparatus (Ducharme et al., 2003; Woodie et al., 2005) and the role of the distal hypoglossal nerve in maintaining nasopharyngeal stability (Cheetham et al., 2009). Horses with structural abnormalities of the larynx and nasopharyngeal region leading to DDSP must have the primary lesions or disorders corrected first. However, when no structural anomaly of the larynx is identified, the cause of the DDSP

is more difficult (Ducharme, 2009). The lack of knowledge of the pathophysiology of DDSP is a major contributing factor to limited success of most treatments (Beard and Waxman, 2007). Controversial yet frequently used topical nasopharyngeal anti-inflammatory preparations may be applied. In racehorses the choice of surgical intervention is a “laryngeal tie-forward” surgery. In sport horses the results of surgical intervention are less predictable unless an intrinsic cause is found (Ducharme, 2009). Thermocautery of the soft palate is performed to increase rigidity in the soft palate. Despite being widely performed throughout the UK, Barakzai (2015) reported that the success of thermocautery is only modest (28-59%) and suggests further investigation of the technique, specifically the evaluation of mechanical and histological changes in the cauterized palate, is warranted.

### **2.1.3.3 PHC**

PHC is a common finding in sport horses (Franklin, 2008). It was found to be more common in sport horses than in racehorses with neck flexion being cited as an important contributing factor (Davidson et al., 2002; Franklin et al., 2006). Pharyngeal wall collapse has also been associated with URT inflammation (Atlas of Equine Endoscopy) and HYPP (Carr et al., 1996). However, the aetiology is unknown in the majority of cases (Franklin, 2008). Dynamic PHC may involve either the lateral pharyngeal walls or the dorsal wall or a combination of both with an upward movement of the soft palate, causing a pronounced circumferential collapse of the pharynx (Boyle et al., 2006). Horses with PHC make a rough or musical sound upon inspiration during exercise, which may be confused with a laryngeal collapse but most afflicted horses have no notable findings at rest (Franklin, 2008). When performing an endoscopic examination, it is necessary to position the endoscopy rostrally in order to observe lateral pharyngeal wall collapse. If the upper airways are only observed from the normal endoscope position closer to the larynx, pharyngeal wall collapse may be missed (Franklin, 2008).

Treatment options include systemic and topical anti-inflammatory drugs to help reduce the collapse due to inflammation. Also, modification by the rider of poll flexion in the affected horse may improve the condition. Surgical options for nasopharyngeal obstructions caused by poll flexion include trans-endoscopic laser surgery, whereby trans-endoscopic laser fenestration of the median septum and resection of the salpingopharyngeal fold of the guttural pouch is performed (Barton et al., 2014).

#### 2.1.3.4 Other Functional Disorders

In case of EE, the aryepiglottic fold completely envelops the apex and lateral margins of the epiglottis. The general shape of the epiglottis is visible, and the position (dorsal to the soft palate) is appropriate. However, the margins of the epiglottis are obscured by a fold of aryepiglottic mucosa. Clinical signs of EE include inspiratory and expiratory respiratory noise during exercise and poor exercise performance. Less common signs include cough, nasal discharge, and headshaking (Merck 2010, p. 1346).

Epiglottic retroflexion/retroversion (ER) is a rare laryngeal disorder. ER occurs when the epiglottal apex regresses into the rima glottidis during inspiration, causing an obstruction at the entrance to the trachea and then returns to the normal resting position during expiration (Parente et al., 1998). The result of ER is significantly reduced airflow during inspiration and inspiratory noise. Whilst the aetiology of ER is still unknown, ER has been recreated experimentally by anaesthetizing the geniohyoid muscle and the hypoglossal nerves at the level of the guttural pouch (University of Sydney a). ER has also been reported by Franklin (2008) in cases following severe respiratory infections or following surgeries that caused damage to the hypoglossal nerves, supporting the suggestion that the hypoglossal nerves and subsequent paresis of the geniohyoid muscles are involved in the pathogenesis.

Axial deviation of the aryepiglottic folds (ADAF) is an inspiratory laryngeal disorder that occurs during exercise. The aetiology is as yet unknown. However, immaturity and fatigue have been cited as playing a role in the pathogenesis of ADAF (King et al., 2001). During ADAF, the membranous portions of the aryepiglottic folds move in an axial direction, towards the centre of the airway lumen resulting in a dynamic URT obstruction. ADAF may be bilateral or unilateral with the right side being more commonly affected (King et al., 2001; University of Sydney, b). Typical clinical signs include abnormal respiratory noise and exercise intolerance (University of Sydney b), However, according to Smith and Greet (2013) ADAF is more typically a cause of respiratory noise without poor performance. ADAF is a true dynamic disorder of the URT and only occurs during strenuous exercise (Odelros, 2012). For this reason high speed treadmill endoscopy (HSTE), where speed and exercise intensity can be controlled by the veterinarian, is widely accepted as the gold standard for the diagnosis of this disorder (Lane et al., 2006a; Parente and Martin, 1995) but there are recent studies showing ADAF can be successfully diagnosed during OE (Kumaş, 2013; Smith and Greet, 2013), the important issue is that the horses are strenuously exercised and fatigued with less

importance on the movements of the horse and head position. ADAF may be identified as the sole cause of a URT obstruction, or it may occur with multiple other disorders (Odelros, 2012), particularly PI and be the first indicator of palatal dysfunction (Smith and Greet, 2013).

In both racehorses and other sport horses it has recently been reported that many – up to 69% of cases (Strand and Skjerve, 2012), have multiple concurrent abnormalities (Dart et al., 2001; Tan et al., 2005; Lane et al., 2006; Davidson et al., 2011; Strand and Skjerve, 2012). A previously unreported condition, ventro-rostral displacement of the dorsal laryngeal mucosa (VRDDL), has been reported to commonly occur with other upper airway abnormalities (Pollock et al., 2013). In this report, Pollock and others examined the URT of 600 horses by OE and identified VRDDL in 12 of the horses. 8 of which also had concurrent abnormalities, including vocal fold collapse, ADAF and intermittent DDSP. According to this report, the exact aetiology of VRDDL is as yet unknown, although they do propose that general airway inflammation or airway instability may predispose the horse to this condition.

#### **2.1.4 LRT Disorders**

In addition to upper airway problems, the LRT also has its own collection of problems that can lead to poor performance in both race and other sport horses. Therefore when we are investigating possible respiratory causes of poor performance in the sport horse we must investigate the whole respiratory tract.

Traditionally the term “chronic obstructive pulmonary disease” (COPD) was used to describe equine lower airway disease, a pulmonary hypersensitivity to inhaled allergens including *Micropolysporum faeni* and *Aspergillus fumigatus*, which are found in hay and straw (McGorum, 1994). However, in 2000 a workshop was held to discuss the misuse of the term COPD in equine medicine, since the disease in horses was more similar to human asthma than the human COPD. The new terms “heaves” or “recurrent airway obstruction” (RAO) were recommended for use instead (Robinson, 2001). RAO is characterized by reversible airway narrowing due to bronchospasm and referred to any accumulation of neutrophils and mucus in the airways in the absence of active infection. The term also refers to both older horses with severe heaves and young horses with reduced performance (Allen and Franklin, 2007). Endoscopy, a tracheal wash (TW) and a broncho-alveolar lavage (BAL) are indicated in the diagnosis of RAO. While endoscopy is useful for the visualization, a mucopurulent discharge

in the trachea is not pathognomic for RAO and merely indicates the presence of some equine pulmonary disease. An endoscopic image of the RAO trachea showing mucopurulent secretions cannot be differentiated from summer pasture associated obstructive pulmonary disease (SPAOPD) or a post viral airway disease (McGorum, 1994). The most valuable diagnostic indication is the level of neutrophilia in the broncho-alveolar lavage fluid (BALF) and TW (McGorum, 1994). Diagnosis of SPAOPD is based on history and clinical signs (McGorum, 1994). Since the clinical signs are similar to RAO, knowledge that SPAOPD affects horses at pasture that do not have access to hay or straw and the seasonal property of SPAOPD could have helped in differentiating from RAO. To differentiate from a post viral airway disease, an absence of neutrophilia in the BALF and TW and evidence of recent sero-conversion to a respiratory virus should be demonstrated (culture of a virus is generally non-informative since most viruses are excreted only 24-72 hours post-infection) (McGorum, 1994).

The syndrome of lower airway disease particularly seen in young horses was newly termed “inflammatory airway disease” (IAD) (Hoffman et al., 2003). The exact definition of IAD is still under investigation and it is thought that further “subsets” of the disorder will emerge due to the cellular variability (predominance of neutrophils or mast cells or eosinophils) in the TW and BALF (Allen and Franklin, 2007).

RAO	IAD
<ul style="list-style-type: none"> <li>▪ Affects middle aged and older horses (&gt; 7yrs)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Affects horses of any age.</li> </ul>
<ul style="list-style-type: none"> <li>▪ Signs: obstructive airway disease, coughing, increased respiratory rate and expiratory effort.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Signs are vague and limited, possibly including poor performance, coughing and nasal discharge.</li> </ul>
<ul style="list-style-type: none"> <li>▪ Tracheal accumulation of a muco-purulent discharge.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Tracheal accumulation of a muco-purulent discharge.</li> </ul>
<ul style="list-style-type: none"> <li>▪ Increased proportions of neutrophils found in the TW &amp; BAL fluids.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Increased proportions of inflammatory cells found in the TW &amp; BAL fluids.</li> </ul>
<ul style="list-style-type: none"> <li>▪ Recurrent episodes of disease.</li> </ul>	
<ul style="list-style-type: none"> <li>▪ Partly reversible, by change in environment and use of bronchodilators.</li> </ul>	

**Table 9: Properties of recurrent airway obstruction (RAO) and inflammatory airway disease (IAD).**

\*BAL: broncho-alveolar lavage, TW: tracheal wash.

There are a number of papers attempting to differentiate between RAO and IAD, for example Couëtil et al., (2007) and Haltmayer et al., (2013) but the aetiological differentiation of these two disorders is still quite unclear. It is not yet known if they are separate clinical disorders or if IAD progresses into RAO if left untreated (Allen and Franklin, 2007). A nine year old horse presenting a cough, tracheal mucus and a decrease in performance levels could have mild RAO or IAD.

IAD was first recognized in racehorses. The reason being, that the effects of IAD only become apparent when the horse is exercised strenuously. In horses performing maximal exercise (e.g. racehorses), any pulmonary dysfunction is likely to be apparent at an earlier stage than in horses performing less strenuously (Allen and Franklin, 2007). The horse having a substantial respiratory reserve does not use a large proportion of its lungs at rest or even light exercise and so it is only when the horse exercises at maximal capacity does he use the full proportion of lung tissue available for ventilation and then the effects of IAD are shown. However it is not a disorder specific to racehorses as IAD has now been identified in horses of all ages and disciplines. It is reported that up to 70 per cent of stabled sport horses may be affected by IAD (Allen and Franklin, 2007). Endoscopy, TW and BAL examinations are recommended for diagnosis of IAD (Allen and Franklin, 2007).

EIPH is most typically seen in Thoroughbred racehorses and Standardbred trotters. Forty four to 75% of Thoroughbreds experience EIPH while racing (Pascoe et al., 1981; Raphel and

Soma, 1982) and 38 – 66% of Thoroughbreds experience EIPH during intense training (Raphel and Soma, 1982). Twenty six to 78% of Standardbred horses experience EIPH during a race or intense training (MacNamara et al., 1990; Lapoint et al., 1994). EIPH can be seen in any horse undergoing strenuous exercise and therefore may also be seen in sport horses, for example event horses during the cross country phase.

Haemorrhage originates from the pulmonary vasculature in the caudodorsal lung fields (Archer, 2008) and a variety of aetiologies have been proposed, including stress failure of the pulmonary capillaries (Archer, 2008), where the pressure becomes so great in the capillaries that they rupture. The pulmonary circulation, as opposed to bronchial circulation is probably the source of pulmonary haemorrhage (West et al., 1993; Manohar et al., 1993; West and Mathieu-Costello, 1994). The increased cardiac output and blood viscosity due to exercise probably causes the pulmonary vascular hypertension (Manohar et al., 1993; Weiss and Smith, 1998) which leads to stress failure of the capillaries causing EIPH.

A theory put forward by Tufts University (2005-2006) suggests that horses that have a low-grade blockage somewhere in their respiratory tract need to pull air in harder creating a vacuum in the lungs which furthers explodes vessels. The results of a study by Ducharme et al., (1999) suggest that both inspiratory obstruction and inspiratory obstruction combined with expiratory obstruction in exercising horses cause an increase in intramural pulmonary capillary pressure gradient which may contribute to loss of pulmonary capillary integrity and lead to EIPH. Therefore, whilst the sheer intensity of the race horse's exercise may lead to EIPH, this disorder may also be seen in the sport horse undergoing less intensive exercise than the race horse, but who suffers from an URT disorder causing an inspiratory obstruction such as ILLHP. It is obvious then that an obstruction of this type coupled with intensive exercise may lead to even more haemorrhaging in the horse.

Still another theory contends that a "shock wave" travels up from the weight-bearing forefeet through the chest wall to the lungs, which shake so violently that there is rupture of vessels (Tufts University, 2005-2006). It seems logical to assume that horses who suffer an extensive amount of blood loss via the nostrils on competition day, their performance would be affected negatively due to the sheer amount of fluid in the respiratory tract. However we do not know yet how extensive the bleeding should be in order to affect performance (Tufts University 2005-2006). Others believe that repeated episodes of pulmonary bleeding can cause permanent damage to the lungs and consequential scarring could limit the ventilation capacity

of the lungs thereby affecting performance (Geor, 2000). Although EIPH is widely considered a possible cause of poor performance, there is little evidence yet to support this belief (Geor, 2000). Nonetheless, it is advised that EIPH should be considered in horses that show a sudden loss of speed during exercise, coughing and increased swallowing as epistaxis may only be evident in 0.5 to 2% of affected animals (Archer, 2008). Diagnosis may be achieved by endoscopic examination of the trachea and bronchi after galloping exercise (Mair, 1994). This is the most useful diagnostic tool in cases of epistaxis (Archer, 2008). Endoscopy of the respiratory tract may show the lesion responsible or at least the original location of the haemorrhage. If this is not achieved, radiography of the paranasal sinuses is indicated. Mair's paper (1994) also indicates the use of radiography of the caudodorsal lung fields, as they are the most usual site of haemorrhage. However this may now be outdated as Archer (2008) more recently states that radiography of the thorax is less common in this case but indicated if pulmonary neoplasia or pulmonary abscessation is suspected.



## 2.2 Diagnosing the Cause(s) of the Poor Performance

The components involved in the investigation of poor performance in sport horses includes: a good history, a thorough physical examination of the body systems and the following additional examinations:

RESPIRATORY EXAMINATIONS	CARDIO-VASCULAR EXAMINATIONS	MUSCULO-SKELETAL EXAMINATIONS	NERVOUS EXAMINATIONS	GASTRO-INTESTINAL EXAMINATION
<ul style="list-style-type: none"> <li>▪ RE</li> <li>▪ Exercising endoscopy</li> <li>▪ TW</li> <li>▪ BAL</li> <li>▪ Lung function testing</li> <li>▪ Ultrasound</li> <li>▪ Radiography</li> </ul>	<ul style="list-style-type: none"> <li>▪ ECG</li> <li>▪ Telemetric ECG</li> <li>▪ Polar</li> <li>▪ Echocardiogram</li> <li>▪ Treadmill stress test with ECG &amp; echo-cardiogram.</li> </ul>	<ul style="list-style-type: none"> <li>▪ Lameness exam</li> <li>▪ Nerve &amp; joint blocks</li> <li>▪ Radiography</li> <li>▪ Ultrasound</li> <li>▪ Scintigraphy</li> <li>▪ Blood chemistry</li> <li>▪ Urinalysis</li> <li>▪ Muscle biopsy</li> </ul>	<ul style="list-style-type: none"> <li>▪ Static/dynamic neurological examination, nociception, neuro-anatomical localization.</li> <li>▪ Electro-myelography</li> <li>▪ CSF tap</li> </ul>	<ul style="list-style-type: none"> <li>▪ Gastroscopy</li> </ul>

**Table 10: Possible examinations involved in diagnosing causes of poor performance.**

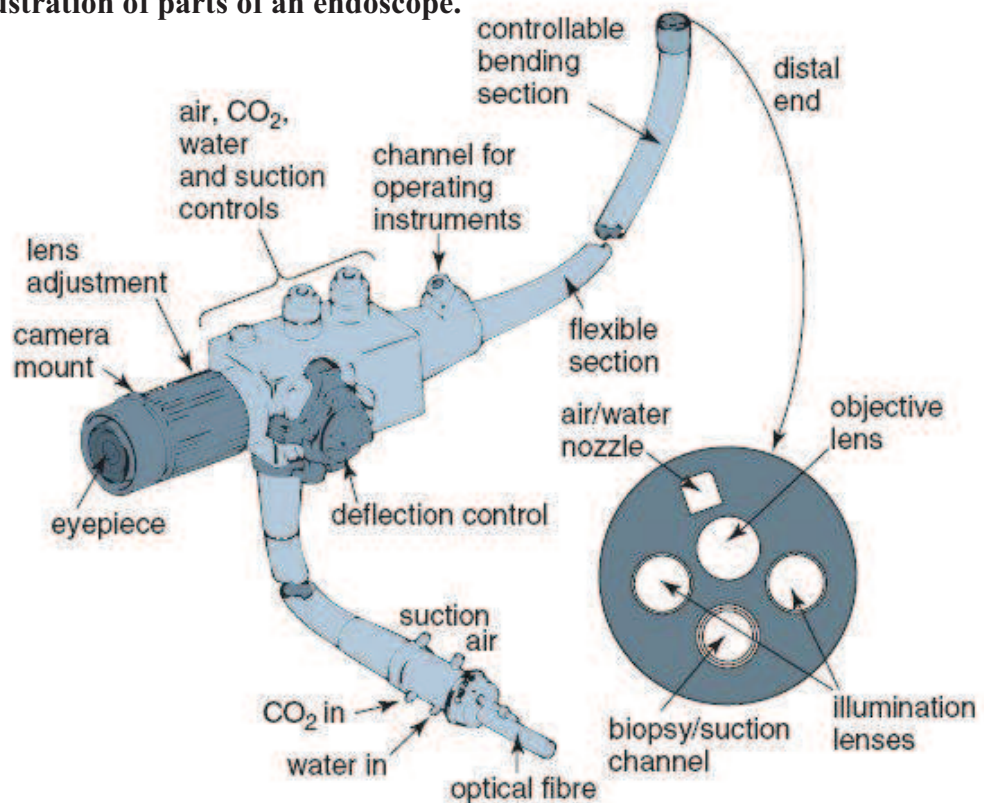
\*BAL: broncho-alveolar lavage, CSF: cerebrospinal fluid, DJD: degenerative joint disease, ECG: electrocardiogram, EPM: equine protozoal myeloencephalitis, RE: resting endoscopy, TW: tracheal wash.

## 2.2.1 Diagnosing Respiratory System Causes of Poor Performance

### 2.2.1.1 Resting -V- Exercising Endoscopy; How to Perform Examinations

Prior to beginning the examination, a complete history from the owner should be obtained. Specific questions should be asked about respiratory noise, dysphagia, exercise intolerance, coughing, nasal discharge, and any previous treatments or surgery (Parente et al., 2012). A thorough physical examination is also an essential part of any evaluation and all of this information should be interpreted in conjunction with the results of the other diagnostic procedures to establish a diagnosis. One of the most helpful diagnostic tools in the examination of the respiratory tract is the endoscope, which literally means to “look inside”. Despite having many other diagnostic aids available, for example radiography and extensive laboratory tests, there are some cases in which one would benefit greatly from being able to actually look inside the body system under investigation. The endoscope is a valuable tool for non-invasive exploration of body systems and cavities. A flexible fiberoptic endoscope is used to examine the respiratory tract, as shown in figure 1. Bundles of fibres are gathered together firstly to transmit light from a source to illuminate the tissues under inspection and secondly to carry the image back to the observer’s eyepiece (Lane, 1981).

**Figure 1: Illustration of parts of an endoscope.**



Source: [http://www.genesis.net.au/~ajs/projects/medical\\_physics/endoscopes/](http://www.genesis.net.au/~ajs/projects/medical_physics/endoscopes/)  
Assessed: April 2015

The endoscopic examination can be carried out with the help of two assistants, one to control the horse and one to hold the eyepiece of the endoscope while it's being inserted by the veterinarian. Endoscopy of the URT and the LRT can be performed on the conscious horse (Lane, 1981). In most cases, the passage of the endoscope through the nasal chambers is not resented by horses (Lane, 1981), although it may be slightly uncomfortable and some form of restraint is needed to insert the endoscope (Barakzai, 2007). Evaluation of nasopharyngeal or laryngeal function cannot possibly be made correctly in a sedated or anaesthetized patient since chemical sedation significantly affects the appearance and movements of these structures (Barakzai, 2007). In a small number of patients, there may be need to use a chemical restraint but artefacts such as asynchronous movements by the arytenoid cartilages and vocal cords, and a tendency to rostral displacement of the palatopharyngeal arch may be produced (Lane, 1981). A critical evaluation of subtle functional changes will no longer be possible under sedation and therefore diagnostic significance should be attached only to gross malfunctions (Lane, 1981). A physical restraint such as a twitch is usually sufficient with the horse in a stocks or even backed into the corner of a box (Barakzai, 2007; Lane, 1981).

A resting endoscopic examination is useful in identifying URT obstructive conditions and may also give information regarding the nasopharyngeal and laryngeal function (Franklin, 2008). A thorough endoscopic investigation of the URT should examine both nasal passages, the guttural pouch and the nasopharynx and larynx.

Holcombe et al (1996) found that nasal occlusion may stimulate the upper airway pressures achieved during high intensity exercise and so can mimic conditions by increasing the negative pressure experienced during exercise. Nostril occlusion during RE may be routinely used to assess pharyngeal muscle function and arytenoid function at rest (Archer et al., 1991). The induction of swallowing by introducing a small amount of water or a probe may assist to show laryngeal function and intermittent EE may be revealed also upon swallowing (Franklin, 2008). DDSP may occur spontaneously in response to nostril occlusion or the induction of swallowing (Franklin, 2008).

Another test which is performed at rest and may be used for the investigation of laryngeal function is the "slap test" (thoracolaryngeal reflex). Slapping one hemithorax, typically in the saddle area behind the withers causes a reflex adduction of the muscular process of the arytenoid cartilage on the contralateral side. This reflex is absent in animals with lesions of ascending cervical spinal cord tracts, other spinal cord lesions and ILLHP (Brazil et al.,

2014). However, a study carried out by Newton-Clarke et al., (1994) found the slap test performed in their study was unable to differentiate between horses with moderate to severe muscle changes and those without, making the slap test useless as a diagnostic tool for laryngeal adductor myopathy.

Some clinicians perform an endoscopic examination immediately after exercise in an attempt to improve the diagnostic value of RE. However, most forms of dynamic upper airway obstructions or collapse disappear within seconds of stopping exercise so the benefit of investigating the URT by endoscope at rest even after exercise is lost (Franklin, 2008). Since the emersion of exercising endoscopy in the 1990's with HSTE and video endoscopy, veterinary surgeons have readily adopted dynamic endoscopic examinations in addition to resting endoscopic examinations (Smith and Greet, 2013).

Indications for exercising endoscopy include abnormal respiratory noise, poor performance and horses with abnormal findings during endoscopy at rest (Smith and Greet, 2013). Before performing a dynamic endoscopic examination, it is important to inform clients of the possible outcomes from the investigation. If the disorder is intermittent in nature, then it may not be reproduced accurately during the examination. It is advisable to bring the usual tack and rider of the horse to most accurately mimic the relevant conditions at competition for the horse.

In the assessment of laryngeal function, it is recommended that the same nostril of the horse is used each time for the introduction of the endoscope (Robinson, 2004). This is due to the fact that the larynx is not viewable from a central position since the endoscope is introduced via either the right or left nostril, and such angled views can create perspective artefacts (Franklin, 2008). To counteract this, it is recommended to routinely view the larynx from the same side/nostril.

After the endoscope is inserted into the nostril, the positioning of the endoscope should be that both the arytenoid cartilages and the tip of the epiglottis are clearly visible in the same field of view (Smith and Greet, 2013). The external part of the endoscope should then be secured to the horse whilst maintaining as accurately as possible the normal head and neck position during exercise for the horse. After the endoscope is fitted to the horse, the picture should be adjusted so it is visible on a remote handheld computer for real time evaluation of the endoscopic examination. A USB may be used to record the endoscopic video for post-

examination scrutinisation and it may be useful to watch the video frame-by-frame in order to see subtle changes in the laryngeal and pharyngeal regions.

### **2.2.1.2 HSTE -V- Overground Endoscopy (OE)**

As discussed some URT disorders are apparent at rest or during exercise only. Therefore it is reported that RE alone may be inconclusive for the diagnosis of URT dysfunction in horses presenting with poor performance and/or respiratory noise (Hodgson and Rose, 1994; Lumsden et al., 1995; Stick et al., 1992). In one particular study (Tan et al., 2005), 291 horses in total were examined at rest and during exercise. 49% of those horses that had a normal URT at rest showed abnormalities when examined at exercise on a treadmill. This supports the suggestion that endoscopic examination at rest only, is not sufficient for the diagnosis of an URT disorder or to declare the URT healthy in a case of decreased performance.

Until recently, dynamic endoscopy has only been performed on high speed treadmills. HSTE has been an important component in the evaluation of poor performance, particularly in horses with a history of respiratory noise (Tan et al., 2005). Prior to the HSTE testing, both the horses must be trained to use the treadmill. Different protocols exist in different equine hospitals however a similar pattern is followed by each. Typically the horses to be examined are introduced to and schooled on the treadmill at a slow speed to begin with. The testing speeds, distances and inclines are decided upon by the examiner according to the capabilities of the individual horse. They are then fitted with their bridle only or sometimes with both their bridle and saddle. The horses are schooled until they have acclimatised to and are deemed proficient in exercising on the treadmill apparatus. Then the HSTE testing may be performed.

The development of another type of dynamic endoscopy now referred to as “overground endoscopy” (OE) has allowed horses to be examined during exercise under normal training conditions and in their normal environment (Desmaizieres et al., 2009; Pollock and Reardon, 2009; Pollock et al., 2009). The pioneering of OE proved to be very successful since treadmill exercise does not always allow reproduction of the exact conditions of dynamic obstructions of the equine URT (Desmaizieres et al., 2009). In 2009 an on-board endoscope referred to as a ‘dynamic respiratory scope’ (DRS) emerged and made exercising endoscopy readily available to more equine practices (Desmaizieres et al., 2009). The DRS was developed for use during exercise in ridden and harnessed sport horses performing in natural conditions (Desmaizieres

et al., 2009). It provides real-time visualisation of the URT and recorded video-endoscopy for post-test reviewing. It also provides a safe and effective system for imaging the equine URT during ridden exercise at speed (Pollock et al., 2009).

Both HSTE and OE have their advantages and disadvantages. The criticisms for HSTE and OE appear to stem from the suitability of each method to the horse's event discipline. For example, one argument against OE is that normal racing conditions may not be appropriately replicated (Allen and Franklin, 2010a). Strenuous exercise tests may be more easily performed on a treadmill than by performing multiple exercise intervals in the field (Allen and Franklin, 2010a). The extent of strenuous exercise that the horse is put under in HSTE is under the control of the veterinarian and not the rider, as most riders tend to pull the horse up when they hear the abnormal respiratory noise. With HSTE the horse can be brought up to maximum exercise, until the abnormality is apparent or the horse shows signs of fatigue (Kannegieter and Dore, 1995, Lumsden et al., 1995). Fatigue has been defined as the horse's inability to maintain their position at the front of the treadmill despite encouragement (Tan et al., 2005). It is stated in one report (McCann, 2000) that if a resting clinical examination, exercising the horse and then performing RE following the exercise fail to demonstrate the origin of the abnormal respiratory noise, treadmill videoendoscopy can be used to view the airway while the noise is being produced, as some abnormal sounds can be induced by treadmill exercise which could not be heard during ridden exercise. This benefit of HSTE would be most useful in the examination of the URT of racehorses presenting with poor performance and/or abnormal respiratory noise, since the racing discipline demands that the racehorses compete at maximal speeds, much more so than any non-racing sport horse.

The arguments against HSTE includes the cost of the equipment, the limited availability of high speed treadmills, the safety risk to the horses and the handlers and also the time taken to train both the handlers and the horses to be examined and also that HSTE fails to recreate normal exercise conditions with the influence of the rider being present (Trope, 2013). This is of particular importance in non-racing sport horses, as some of the manoeuvres or movements required of these sport horses could be contributing factors in the development of dynamic airway instability (Van Erck, 2011). A study comparing HSTE to OE in saddle horses found that some conditions could not be elicited on a treadmill due to the absence of rider intervention (Van Erck et al., 2009). For example, head flexion is a contributing factor to an increase in URT resistance (Petsche et al., 1995), therefore head flexion during ridden exercise could be important in the induction of an abnormal respiratory sound at exercise. Van

Erck (2011) concluded that in cases of upper airway dynamic obstruction, rider intervention during ridden exercise can contribute to increasing laryngeal and/or pharyngeal instability in sport horses and therefore OE should be the preferred method for evaluation of the upper airways in sport horses since these changes would not usually be seen with HSTE.

Prior to 2006, there was very little information in existence regarding dynamic airway collapse in non-racing sport horses. There was one study performed in 2006 (Franklin et al., 2006) with the aim of evaluating the endoscopic findings both at rest and during exercise in 93 sport horses presenting with poor performance and/or abnormal respiratory noise. However, in this study the investigation during exercise was performed on a treadmill.

There are however differences in the frequency of appearances of the different abnormalities when examined by HSTE or OE. DDSP was observed more commonly during HSTE than OE (Evans, 2004; Franklin et al., 2008; Allen and Franklin, 2010a; Van Erck et al., 2009), although there was no significant difference in the diagnosis of dynamic laryngeal collapse between HSTE and OE (Allen and Franklin, 2010a). The reason for these differences in diagnostic frequencies is not yet clearly understood. It is suggested that a lack of standardisation of exercise tests, shorter training distances and an inability to recreate race conditions may contribute to the differences (Allen and Franklin, 2010b; Allen et al., 2011). There are also reports of more subtle differences between treadmill and OE. The horses stride length and stride frequency differ on the treadmill and on the track (Barrey et al., 1993; Buchner et al., 1994), again emphasizing the difference in these two methods of dynamic endoscopy.

Allen and Franklin (2010b) reported on the exercise test parameters used during OE and investigated the potential effects of the parameters on the diagnosis of URT obstructions. The exercise test parameters varied widely between horses. There were no apparent associations between the presence or non-presence of URT obstructions and exercise test parameters, although DDSP was more likely to be observed when the tests were performed over longer distances. Their report concluded that it is difficult to standardise exercise tests in the field as training gallops can differ greatly between premises. It was not possible to establish exercise protocols to be used for every Thoroughbred racehorse and the same logic could be applied to the exercise protocols of non-racing sport horses.

Whilst OE has been used to evaluate racehorses, including Thoroughbred yearlings (Kelly et al., 2013) and Standardbred racehorses (Priest et al., 2012), literature regarding its usage and

standardisation in sport horses is still quite deficient (Franklin et al., 2008; Desmaizieres et al., 2009; Van Erck, 2011).

URT disorders	Static (S)/ Dynamic (D)	Diagnostics: RE, OE, HSTE
<b>Laryngeal instability</b>		
<b>ILLHP/ACC</b>	S/D	If grade 4 ILLHP: RE Sport horses: OE Race horses: OE/HSTE
<b>Bilateral ACC</b>	D	OE
<b>VCC</b>	D	OE > HSTE
<b>Nasopharyngeal collapse</b>		
<b>DDSP</b>	S/D	Sport horses: OE > HSTE Race horses HSTE > OE
<b>PI</b>	S/D	
<b>Nasopharyngeal collapse (lateral/dorsal/circumferencial)</b>	S/D	
<b>Disorders of the epiglottis</b>		
<b>EE (continual)</b>	S	RE
<b>EE (intermittant)</b>	D	Sport horses: OE > HSTE Race horses OE/HSTE
<b>ER</b>	D	Sport horses: OE > HSTE Race horses OE/HSTE
<b>ADAF</b>	D	OE/HSTE

**Table 11: Diagnostic endoscopic methods for upper respiratory tract (URT) disorders.**

\*ACC: arytenoid cartilage collapse, ADAF: axial deviation of the aryepiglottic folds, DDSP: dorsal displacement of the soft palate, D: dynamic, EE: epiglottic entrapment, ER: epiglottic retroflexion/retroversion, HSTE: high-speed treadmill endoscopy, ILLHP: idiopathic left laryngeal hemiplegia, OE: overground endoscopy, PI: palatal instability, RE: resting endoscopy, S: static, VCC: vocal cord collapse.



### 3. Materials and Methods

#### 3.1. Data Collection

The present study was investigating sport horses, pleasure horses and racehorses referred for OE with a history of poor performance and/or abnormal respiratory noise, between November 2013 and June 2014 were examined.

After recording the medical history and performing a physical examination, all horses underwent endoscopic examination at rest and OE performed with a dynamic respiratory scope (Optomed, DR v3) saddle pad version. Information retrieved from the clinical records included age, breed, gender, discipline and presenting complaint. Endoscopy was performed using a 1 metre long, 9.8 millimetre diameter endoscope attached to a specific saddle pad on the horse, designed to carry the processor and the recorder. The saddle pad (figure 2a and 2b) was fitted on top of the numnah and under the horse's own saddle. A specific bridle designed to carry the endoscope was fitted over the horses own bridle (figure 3). The scope was passed from one of the nostrils in order to handle the horse, a nose twitch was applied and no sedatives were used.

Resting endoscopic examinations were done immediately prior to the exercise test. The morphology and the function of the larynx and the pharynx were evaluated. In order to induce a URT obstruction, the occlusion test as described on page 27 was performed.

In order to recreate accurately normal conditions for the horse during exercise, any accessory tack, for example boots normally worn by the horse were allowed. Each horse wore their usual tack. Racing Thoroughbreds wore their racing bridle and saddle. The sport horses wore their usual competitive bridle, saddle or dressage saddle, depending on their discipline.

**Figure 2a: Optomed saddle pad.**



**Figure 2b: Optomed saddle pad fitted under horses own saddle.**



**Figure 3: Horse undergoing overground endoscopy with the Optomed saddle pad and specific bridle.**



OE was performed in an outdoor arena. The horses were ridden by their usual riders. In the cases of sport and pleasure horses, riders were asked to exercise the horse as they normally would until the horse was showing signs of fatigue or the horse exhibited the clinical signs; a disorder of the URT and/or respiratory noise. The race horses' exercise test consisted of a period of walk and trot (approximately 900 metres), followed by canter and gallop (approximately 900 metres) followed by a period of trotting and walking as a cool down exercise.

During the endoscopic examinations, real-time videoendoscopic images were displayed on a remote handheld screen and recorded on a memory stick.

When the history, the physical examination and the clinical signs revealed a significant LRT obstruction then a BAL was performed. When URT inflammation was suspected a bacteriological sample from the trachea was taken.

### 3.2 Endoscopic Evaluation

Abnormalities found on RE and OE of the URT were recorded. The findings were graded as follows:

	RE	OE
<b>Morphological changes</b>	Yes/No	–
<b>Lymphoid hyperplasia</b>	I–IV	–
<b>Nasopharyngeal mucus</b>	–, +, ++, +++	–, +, ++, +++
<b>Pharyngeal collapse</b>	–, +, ++, +++ lateral /dorsal/circumferencial	–, +, ++, +++ lateral /dorsal/circumferencial
<b>PI</b>	–, +, ++, +++	–, +, ++, +++
<b>DDSP</b>	Yes/No	Yes/No
<b>LHP</b>	I, II/1, II/2, III/1, III /2,III/3, IV (Havemeyer grading system)	–
<b>ACC</b>	–	A, B, C
<b>VCC</b>	–	A, B, C
<b>RDPA</b>	–	Yes/No
<b>ADAF</b>	–	Yes/No
<b>When was the FD the most relevant?</b>	<ul style="list-style-type: none"> <li>• Occlusion test</li> <li>• Constantly appearing</li> <li>• No FD</li> </ul>	<ul style="list-style-type: none"> <li>• Low/high intensity work</li> <li>• Loose rains</li> <li>• Poll flexion &amp; low intensity work</li> <li>• Poll flexion + high intensity work</li> <li>• At fatigue</li> <li>• Constantly appearing</li> </ul>

**Table 12: Data documented during the endoscopic examinations.**

\*ACC: arytenoid cartilage collapse, ADAF: axial deviation of the aryepiglottic fold, DDSP: dorsal displacement of the soft palate, FD: functional disease, LHP: laryngeal hemiplegia, OE: Overground endoscopy, PI: palatal instability, RDPA: rostral displacement of palatopharyngeal arch, RE: resting endoscopy, VCC: vocal cord collapse.

## 4. Results

Nine horses underwent OE and were identified as 4 stallions (45%), 4 geldings (45%) and one mare (10%). They comprised 3 show-jumpers (Warmbloods) (33%), 3 pleasure horses (one Standardbred and two Warmbloods) (33%), 2 racehorses (Thoroughbreds) (22%) and 1 dressage horse (Warmblood) (12%). The mean age of horses examined was 8 years (range 2-15 years). The cases and results are summarized in tables 14, 15 and 16 on pages 41, 42 and 43.

### Case 1

A seven year old show-jumper was referred for an overground endoscopic examination with a history of abnormal inspiratory noise during intensive work for the two years previous. At the time of the OE the horse was competing successfully up to 120cm and according to the owner's report its performance was unaffected by the respiratory function. Two weeks prior to the OE examination the horse started to cough and had some seromucous nasal discharge. During the physical examination it was easy to induce coughing. There were no forced breathing sounds audible by auscultation and there was no visible dyspnoea. During the resting endoscopic examination it was possible to detect mild PI, a grade 1 lymphoid hyperplasia, a grade IV ILLHP and a moderate amount of mucus in the nasopharynx. During the exercise test with OE the rider was asked to perform a regular training session. During the warm up period the horse displaced the soft palate dorsally several times, moderate PI was visible prior to DDSP. Every displacement was followed by coughing. There was also moderate PI, an evident grade C ACC occurring with a bilateral grade C VCC.

### Case 2

An eleven year old dressage horse presented with abnormal respiratory noise, with no history of poor performance or coughing. During RE a grade IV intermittent ILLHP was detected. And during OE, a grade C ACC and VCC were detected with no other abnormalities.

### Case 3

A four year old Standardbred stallion used as a pleasure horse was referred for OE with the history of poor performance and respiratory noise during poll flexion. During RE it was possible to detect a grade 2 lymphoid hyperplasia and a grade II/2 ILLHP. During OE the dorsal pharyngeal wall collapsed and a grade C left-sided ACC was visible. After gathering

the reins and reaching an excessive poll flexion position the collapse of the dorsal pharyngeal wall exacerbated, however both ACC and PHC disappeared during high intensity work.

#### **Case 4**

A twelve year old pleasure horse presented with abnormal respiratory noise, coughing and reported poor performance. The resting endoscopic examination revealed a grade III/1 ILLHP and a grade 2 lymphoid hyperplasia. Upon OE examination moderate PI prior to DDSP was visible. Also a grade C ACC with grade C VCC was shown. Bacteriological culturing was performed from a TW. Results of the bacteriological culture showed the presence of beta-haemolytic streptococcus.

#### **Case 5**

A nine year old mare used for pleasure riding was referred for OE with a history of poor performance and coughing during exercise. The mare presented with dyspnea and upon auscultation forced breathing sounds with additional rhonchi and crackling sounds were present. Mild dorsal collapse of the pharynx with severe PI, flattening of the epiglottis and DDSP were visible at RE. Also shown at RE were a grade II/1 ILLHP and a moderate amount of mucous. During OE the PHC seen at rest had disappeared. However the severely increased PI and DDSP were still visible. A higher amount of mucous was detected during OE. A BAL, cytology and bacteriology culturing from a TW was performed. The BAL and cytology showed evidence of RAO. Bacteriology was negative.

#### **Case 6**

A ten year old show-jumper was referred for OE with a history of abnormal respiratory noise and poor performance. The resting endoscopic examination revealed a grade III/2 ILLHP and a small amount of mucous. During OE it was possible to detect grade C ACC and VCC and a moderate amount of mucous.

#### **Case 7**

A fifteen year old show-jumper presented with abnormal respiratory noise and poor performance. The horse was also unwilling to go into poll flexion, despite the rider repeatedly asking the horse to go on the bit. During RE moderate dorsal collapse of the pharynx was seen. During the OE examination, severe dorsal and lateral collapse of the pharynx was detected, secondary to poll flexion. Also mild PI was demonstrated during OE.

**Case 8**

A two and a half year old Thoroughbred stallion was referred with a history of poor performance and producing a gurgling sound at the peak of exercise. The OE was conducted on site at the trainer’s gallops. During RE it was possible to detect a flattened epiglottis and a grade 3 lymphoid hyperplasia. During OE marked PI was observed at high intensity work and DDSP observed at the peak of exercise.

**Case 9**

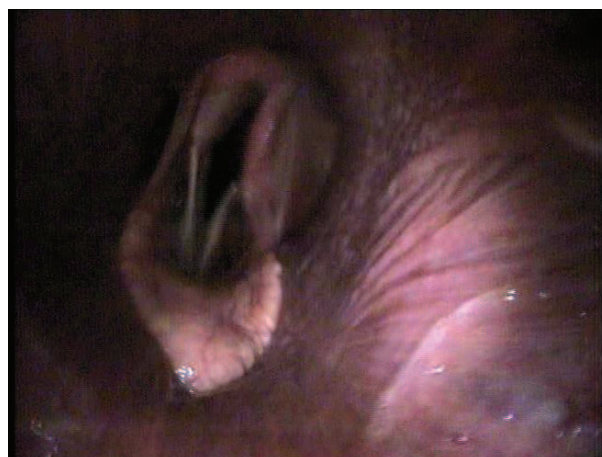
A three year old Thoroughbred stallion was referred with a history of poor performance and producing a gurgling sound at the peak of exercise. During RE a moderate PI, a flattened epiglottis, grade II/2 ILLHP and a grade 2 lymphoid hyperplasia were detected. During OE the same level of PI was detectable and also DDSP at the peak of exercise and grade B ACC and VCC at fatigue.

CASE	DISCIPLINE	SUSPECTED UNDERLYING CAUSES
<b>Cases 8 &amp; 9</b>	Race horses	Extrinsic cause: excessive caudal positioning of the larynx. Intrinsic cause: immature nasopharynx)
<b>Cases 1 &amp; 2</b>	Sport horse Pleasure horse	Intrinsic cause: neuromuscular weakness (secondary to a URT infection).
<b>Case 3</b>	Pleasure	LRT obstruction.

**Table 13: Summary of the suspected causes of dorsal displacement of the soft palate in this study.**

\*LRT: lower respiratory tract, URT: upper respiratory tract.

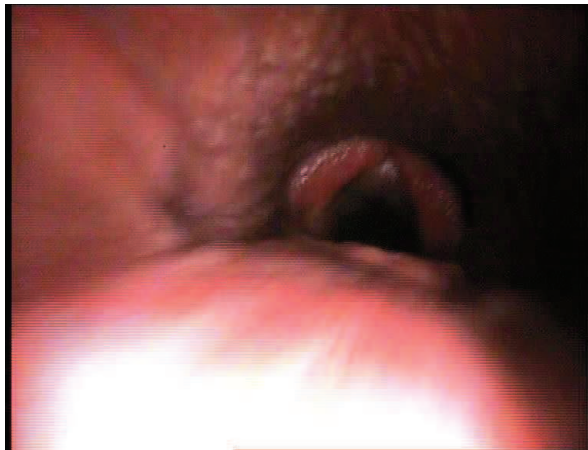
**Figure 4: Case 1, left-sided arytenoid cartilage collapse and bilateral vocal cord collapse during overground endoscopy.**



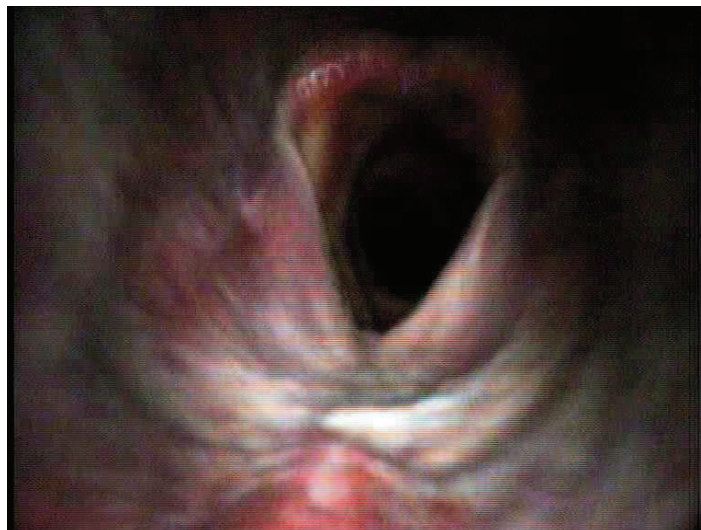
**Figure 5: Case 5, dorsal displacement of the soft palate detected at rest.**



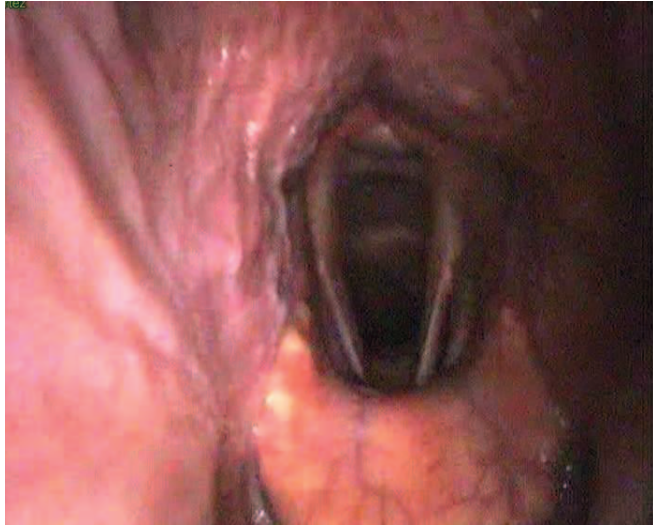
**Figure 6: Case 8, palatal instability detected prior to dorsal displacement of the soft palate during overground endoscopy at gallop.**



**Figure 7: Dorsal displacement of the soft palate during overground endoscopy at gallop.**



**Figure 8: Case 7, collapse of the pharyngeal wall in a sport horse in poll flexion.**





Horse	Age (years)	Breed	Discipline	Gender	Poor Performance	Respiratory Noise	Cough
Case 1	7	Warmblood	Show-jumping	Gelding	No	Yes	Yes
Case 2	11	Warmblood	Dressage	Gelding	No	Yes	No
Case 3	4	Standardbred	Pleasure horse	Stallion	Yes	Yes	Yes
Case 4	12	Warmblood	Pleasure horse	Gelding	Yes	Yes	Yes
Case 5	9	Warmblood	Pleasure horse	Mare	Yes	No	Yes
Case 6	10	Warmblood	Show-jumping	Gelding	Yes	Yes	No
Case 7	15	Warmblood	Show-jumping	Stallion	Yes	Yes	No
Case 8	2.5	Thoroughbred	Racehorse	Stallion	Yes	Yes	No
Case 9	3	Thoroughbred	Racehorse	Stallion	Yes	Yes	No

**Table 14: Summary of the cases in the present study.**

Name	Simple/ complex	Pharynx	PI	DDSP	ILLHP	Epiglottis	Lymphoid Hyperplasia	Mucus
Case 1	Complex	Ok	+	-	IV	concave	1	++
Case 2	Simple	Ok	-	-	IV	concave	1	-
Case 3	Complex	Ok	-	-	II/2	concave	2	-
Case 4	Complex	Ok	-	-	III/1	concave	2	-
Case 5	Complex	Mild dorsal collapse	+++	DDSP	II/1	flat	1	++
Case 6	Simple	Ok	-	-	III/2	concave	1	+
Case 7	Simple	Dorsal collapse	-	-	I	concave	1	-
Case 8	Simple	Ok	-	-	I	flat	3	-
Case 9	Complex	Ok	++	-	II/2	flat	2	-

**Table 15: Summary of the resting endoscopy results.**

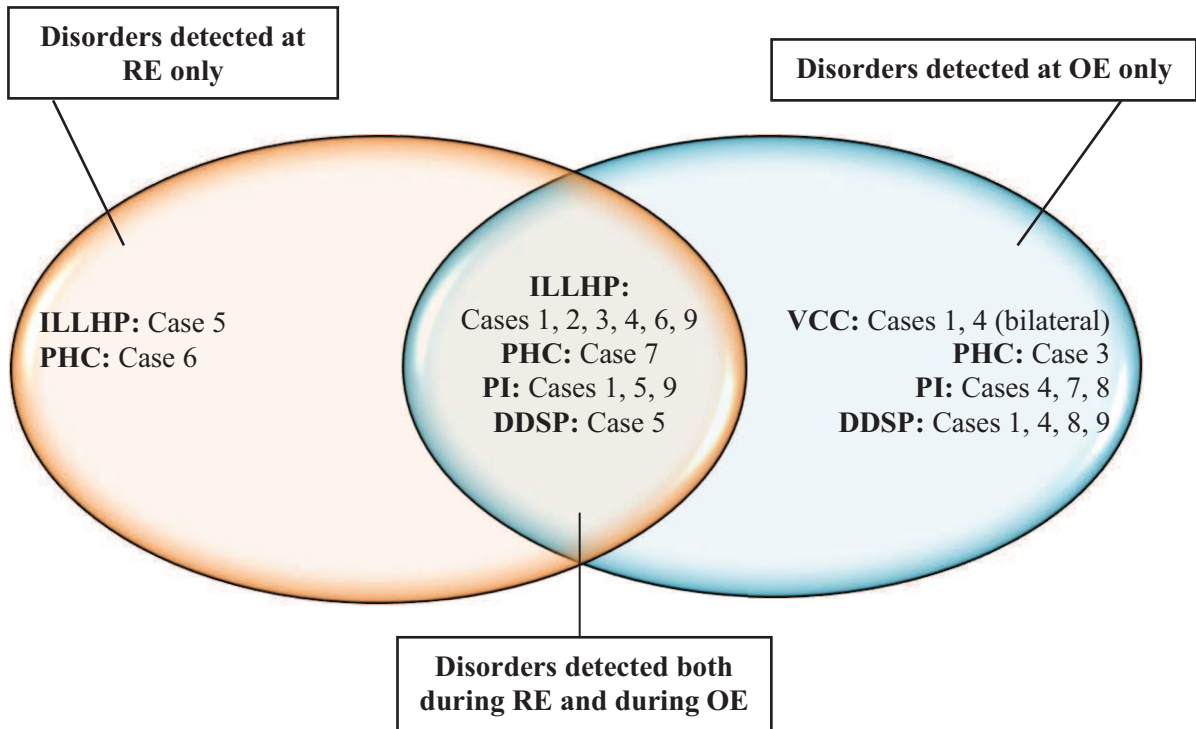
\*DDSP: dorsal displacement of the soft palate, ILLHP: idiopathic left laryngeal hemiplegia, PI: palatal instability.

Name	Simple/ complex	Pharynx	PI	DDSP	ACC	VCC	Mucus
Case 1	Complex	Ok	++	DDSP	C	Bilateral C	++
Case 2	Simple	Ok	-	-	C	C	-
Case 3	Complex	Dorsal collapse, compensated at high intensity work	-	-	B	A	-
Case 4	Complex	Ok	++	DDSP	C	Bilateral C	-
Case 5	Complex	Ok	+++	DDSP	A	C	+++
Case 6	Simple	Ok	-	-	C	C	++
Case 7	Simple	Dorsal and lateral collapse	+	-	A	A	-
Case 8	Simple	Ok	++	DDSP	A	A	-
Case 9	Complex	Ok	++	DDSP	B	B	-

**Table 16: Summary of the overground endoscopy results.**

\*ACC: arytenoid cartilage collapse, DDSP: dorsal displacement of the soft palate, PI: palatal instability, VCC: vocal cord collapse.

**Figure 9: Functional disorders identifiable in this study.**



\*DDSP: dorsal displacement of the soft palate, ILLHP: idiopathic left laryngeal hemiplegia, OE: overground endoscopy, PHC: pharyngeal collapse, PI: palatal instability, RE: resting endoscopy.

Figure 9 above depicts on the left the disorders that in some cases were identified only during RE and not seen at the OE examination. Also, the disorders on the right that were only identified during OE and not seen during the endoscopic examination performed at rest and in the centre, those disorders in some cases that were identifiable both at RE and during OE.

The present study investigated whether simple or multiple obstructions were visible during OE. In those cases where ACC and VCC were appearing simultaneously or in cases where PI and flattening of the epiglottis were appearing prior to DDSP, these were considered simple cases. Every other combination of URT obstructions were identified as complex cases.

## 5. Discussion

### 5.1 DDSP

As it has been already described in the introduction, DDSP can be attributed to several different underlying causes. Table 13 on page 38 depicts the most likely underlying causes in our DDSP cases.

In cases 8 and 9 the extrinsic cause is thought to be the relative position of the larynx, excessively caudal and ventral to the basihyoid bone and the soft palate (Chalmers et al., 2009). The reason why it may be so common in racehorses might be that at high galloping speeds there is a higher chance of developing DDSP, due to increased activity of the muscles that affect the interrelationship between the larynx, the pharynx and the hyoid apparatus (Rush and Mair, 2004e). In such cases with extrinsic origin tie forward surgery is the suggested choice of treatment (Woodie et al., 2005). The success rate of this surgery is 68-90%, so there is a non-negligible chance of failure in general (Ducharme, 2009). However in race horses another explanation of unsuccessful tie forward surgery could be that the immature nasopharynx of a young thoroughbred, which is an intrinsic cause, can lead to the appearance of DDSP, which can be resolved by resting the horse until the nasopharynx matures. This solution may not be feasible for many gallop horses, since the period while they can compete at a top level is quite short. This raises an issue whether immature nasopharynx might be stabilized by the sclerotisation (Jean et al., 2011) of the soft palate with a diode laser.

DDSP as observed in cases 1 and 4 that are suspected to develop secondary to neuromuscular weakness because of URT infections should be treated conservatively, with local or systemic anti-inflammatory and antibiotic therapy.

DDSP in case 5 was thought to develop because of a LRT obstruction. In these cases the highly increasing negative pressure driven by the LRT obstruction will lead to a simultaneous negative pressure increase in the URT resulting in a DDSP. Implicitly, treatment of the lower airways of these cases is essential.

The gurgling sound in case 8 and 9 is a typical manifestation of DDSP in race horses at the peak of exercise (Rush and Mair, 2004f). This symptom was relieved by coughing in cases 1, 4, and 5 which could be explained by the hypersensitive airway due to a URT/LRT inflammatory origin. Interpretation of the absence of the gurgling sound in sport and

pleasure horses might be that their expiratory airflow does not achieve the speed that makes the free border of the soft palate resonate like in race horses.

## **5.2 ILLHP and ACC**

Performing exercising endoscopy plays an important role in understanding ILLHP cases. First of all it is possible to observe if the condition worsens during exercise like in case 4, where a grade III/1 at rest turned into full paralysis at exercise (grade C). Or alternatively if it is compensated for during high intensity work like in case 3. Moreover even in those cases where we observed complete paralysis (cases 1 and 2), which cannot change during work, exercising endoscopy still plays a role by making it possible to gather information about VCC, which is commonly seen in horses with ILLHP and can be exclusively observed during exercise (Holcombe, 2003). These severe manifestations (grade 4 ILLHP) are common in sport horses, which can be explained by the progressive habit of the disease, which gets more severe with age.

In those cases where a significant ACC appears during exercise and leads to abnormal respiratory noise, it is rare that the resting examination remains subclinical, however ILLHP cannot be completely ruled out by resting endoscopic examination as it is described in the literature (Barakzai and Dixon, 2011; Martin et al., 2000; Lane et al., 2006b).

It is debated whether poll flexion impacts ILLHP. Rider intervention with poll flexion is thought to affect laryngeal function and stability in sport horses (Van Erck, 2011). According to another study (Go et al., 2014), there is no correlation between the laryngeal function and the flexion of the neck. In our case load there was a more excessive ACC visible in case 3 during poll flexion. Both this and cases with poll flexion-induced bilateral ACC highlight the advantage of OE compared to HSTE.

While management of DDSP must be tailored to the cause, treatment of ILLHP is independent from the underlying cause, with laryngoplasty and ventriculocordectomy being the preferred surgical choices (Michigan University; Ducharme, Cornell University).

### **5.3 PHC**

In all cases of dynamic PHC (cases 3 and 7) there was evidence of decreasing pharyngeal diameter visible on the OE image. In case 3 PHC disappeared during an intensive workload, in case 5 PHC was only visible at rest during the occlusion test; so we can conclude that increased neuromuscular activity during exercise could compensate for less severe cases. Poll flexion of the neck and fatigue of the horse showed parallel increases in abnormal respiratory sounds.

### **5.4 Lower and Upper Respiratory Tract is One Unit**

It is important to treat the URT and LRT as a unit, since on several occasions an LRT disorder can cause URT functional disease (e.g. RAO–DDSP) like in case 5. In these cases, the initial treatment of the LRT obstruction is essential.

On the other hand as it has been described in literature, URT obstructions can be the underlying cause of LRT problems (ILLHP–EIPH). EIPH is a common disorder of racehorses (Manohar, 1993). But it is not an exclusive characteristic of thoroughbreds and standardbreds. In the relation of ILLHP and EIPH Cook (1988) proposed that a horse may need less strenuous exercise for the development of EIPH with more severe URT obstruction. URT obstruction results in a higher negative pressure in the LRT and increased transmural capillary pressure resulting in the rupture of the pulmonary capillaries. According to the theory of EIPH caused by URT obstruction, the diagnosis and the treatment of a URT obstruction is essential in these cases.

### **5.5 RE, OE or HSTE**

Of those URT functional diseases which appear to be performance limiting, laryngeal and nasopharyngeal collapse appear most frequently (Go et al., 2014; Strand and Skjerve, 2012). Several factors can influence whether OE or HSTE is the appropriate diagnostic tool for these disorders (Woodie, 2012; French, 2012). There are some specific cases of URT functional disease where a resting examination can already give a diagnosis. However in other cases, RE alone does not offer any valuable information on a cause for the poor performance or abnormal respiratory noise and in these cases a dynamic endoscopic examination is warranted.

The correlation of resting and dynamic endoscopic examinations is a frequently investigated topic in literature. There are several factors which may influence whether OE or HSTE would yield superior results and therefore become the endoscopic diagnostic method of choice, if RE has not yet already supplied a diagnosis. These factors include the severity of the disease, the aetiology of the disease and the horse's discipline.

- i. Severity of the disease: although exercising endoscopy is deemed the gold standard in diagnosing URT disorders, there are circumstances in which RE can give a definitive diagnosis. For example: RE would be sufficient for a definitive diagnosis of a disorder as severe as a grade IV ILLHP. Both case 1 and case 2 showed grade IV ILLHP at rest and grade C ACC during OE.
- ii. Aetiology of the disease and the discipline of the horse: These factors are concerned with configuration problems. For example: if the underlying causes of the poor performance or abnormal respiratory noise are the caudal and/or ventral positioning of the larynx, pharynx or the basihyoid bones as is problematic in racehorses, then HSTE is more valuable in diagnosing a URT disorder. With a URT disorder like DDSP, the horse will pull up in order to avoid displacing the soft palate and so DDSP may not be detectable by OE. Rider cooperation is a limitation of DDSP diagnosis during OE. However, using a high-speed treadmill, the horse cannot pull up prior to displacement and so the disorder is observed and diagnosed. In the present study, both cases of DDSP in racehorses (cases 8 and 9) were detectable during OE because the riders were strongly encouraged not to allow the horse to pull up and the riders reciprocated.

Another configuration problem refers to an abnormally rostral positioned larynx which can induce a bilateral ACC during exercise. In these cases, OE is preferred over HSTE since the rostrally positioned larynx can cause a URT obstruction during poll flexion, a head position most prominently observed in sport horses.

This study proposes that configuration problems of the URT must be referred to the discipline of the horse. For example, in race horses a caudally and ventrally positioned larynx is disadvantageous. On the contrary in sport horses the rostral position of the larynx can lead to URT obstruction during poll flexion.



## **6. Conclusion**

Even a very small functional change in the URT can lead to poor performance in racehorses and usually manifests at strenuous exercise. But in the case of sport horses even a severe URT obstruction might not be obvious to the owner. Hence it is essential to find an objective way of measuring poor performance in sport horses.

After this preliminary study, the goal of the research group is to find an objective way of measuring poor performance in sport horses. Such measurements that have been suggested include heart rate variability (HRV) of the horse or the lactate content of the plasma.

The measurement of HRV can be used to assess autonomic nervous system regulation of cardiovascular function (Gehrke et al., 2011). Assessment of the autonomic nervous system and its regulation of cardiovascular function has been used as an indicator of acute and chronic stress in horses (Gehrke et al., 2011) and has also been used to analyse temperament and coping strategies (Von Borell et al., 2007). HRV would be of value in finding an objective way to measure poor performance in sport horses as it has been shown that the HRV parameters provide information which may be helpful in assessing mental stress in horses at exercise (Rietmann et al., 2004).

The production of lactate occurs when the body is in an anaerobic state. Strenuous exercise typically results in anaerobic conditions in the muscles and therefore increases plasma lactate levels. It would be interesting to investigate and compare plasma lactate levels at rest and during exercise in cases with a diagnosis of a URT obstruction, when O<sub>2</sub> supply is lower than in healthy URT cases.

## 7. Abstract

Upper respiratory tract (URT) obstructions are a common cause of poor performance in both racehorses and sport horses. The URT experiences changes in pressure throughout the different phases of respiration. During inspiration, when the diaphragm contracts, negative pressure develops in the upper and the lower respiratory tract, which is further increased during strenuous exercise and may exacerbate disorders of the URT. Whilst some disorders may be detected by endoscopy at rest, many are only seen during exercise and are referred to as dynamic disorders of the URT. Any of the factors that increase negative pressure in the URT – e.g. poll flexion, increased pressure in the lower respiratory tract or multiple obstructions – or constitutional changes can markedly influence URT mechanics.

This study was undertaken to describe the URT abnormalities detected during dynamic overground endoscopy in competitive and pleasure horses presenting with poor performance, abnormal respiratory noise and/or coughing. Following a clinical examination and recording the medical history, the upper airway was evaluated during rest and OE in 9 cases. The horses performed their normal training session. When the history and clinical examination suggested a lower airway obstruction, a broncho-alveolar lavage was performed. When URT inflammation was suspected a bacteriological sample was taken from the trachea.

The main abnormalities recorded at rest include pharyngeal collapse (PHC) (22%), palatal instability (PI) (33%), dorsal displacement of the soft palate (DDSP) (11%) and idiopathic left laryngeal hemiplegia (ILLHP) (77%). The main abnormalities detected during exercise include PHC (22%), PI (66%), DDSP (55%), arytenoid cartilage collapse (ACC) (66%) and vocal cord collapse (VCC) (66%). 55% of cases had concurrent abnormalities.

All racehorses presenting with DDSP were due extrinsic causes, which is different from findings in the sport and pleasure horses in our population, where DDSP was developing secondary to an inflammatory or an obstructive cause. ILLHP and PHC were not possible to predict based on findings at rest and increased neuromuscular activity during exercise could compensate in less severe cases. Poor performance in sport horses cannot be measured in such a standardised way as is possible in racehorses. Therefore following this study, the goal of the research group is to find an objective way to measure poor performance in sport horses (by investigating plasma lactate level and heart rate variability).

## 8. References

1. ALLEN, K., FRANKLIN, S. (2007) RAO and IAD: respiratory disease in horses revisited. In Practice, 29, 76-82.
2. ALLEN, K. J., FRANKLIN, S. H. (2010a) Comparisons of overground endoscopy and treadmill endoscopy in UK thoroughbred racehorses. Equine Veterinary Journal 42, 186-91.
3. ALLEN, K. J., FRANKLIN, S. H. (2010b) Assessment of the exercise tests used during overground endoscopy in the UK Thoroughbred racehorses and how these may effect the diagnosis of dynamic upper respiratory tract obstructions. Equine Veterinary Journal Supplement 38, 587-591.
4. ALLEN, K. J., TERRON-CANEDO, N., HILLYER, M. H. & FRANKLIN, S. H. (2011) Equitation and exercise factors affecting dynamic upper respiratory tract function: A review illustrated by case reports. Equine Veterinary Education 23, 361-368.
5. ALLEN, K. J., FRANKLIN, S. H. (2013) Characteristics of palatal instability in Thoroughbred racehorses and their association with the development of dorsal displacement of the soft palate. Equine Veterinary Journal 45, 454-459.
6. AMERICAN COLLEGE OF VETERINARY SURGEONS.  
<https://www.acvs.org/large-animal/laryngeal-hemiplegia> Assessed April 2015.
7. ANDERSON, B., KANNEGEITER, N., GOULDEN, B. (1997) Endoscopic observations on laryngeal symmetry and movements in young racing horses. New Zealand Veterinary Journal 45, 188-192.
8. ARCHER, R. M., LINDSAY, W. A., DUNCAN, I. D. (1991) A comparison of techniques to enhance the evaluation of equine laryngeal function. Equine Veterinary Journal 23, 104-107.
9. ARCHER, D., (2008) Differential diagnosis of epistaxis in the horse. In Practice, 30, 20-29.
10. ATLAS OF EQUINE ENDOSCOPY. Elsevier Health, chapter 13 "Treadmill Pharyngoscopy and Laryngocopy", page 235.
11. BAKER, G. J. (1983) Laryngeal asynchrony in the horse: Definition and significance. In: *Equine Exercise Physiology*, Eds: D. H. Snow, S.G.B. Persson and R. J. Rose, Granta Editions, Cambridge. Pp 46-50.

12. BARAKZAI, S. Z. (2006). Treadmill Endoscopy. In: Equine Respiratory Medicine and Surgery. Chapter 16 eds. McGorum, Robinson, Schumacher and Dixon, WB Saunders pages 235-248.
13. BARAKZAI, S. Z., HAWKES, C. S. (2010) Dorsal displacement of the soft palate and palatal instability. Equine Veterinary Education 22, 253-264.
14. BARAKZAI, S. Z., DIXON, P. M. (2011) Correlation of resting and exercising endoscopic findings for horses with dynamic laryngeal collapse and palatal dysfunction. Equine Veterinary Journal 43, 18-23.
15. BARAKZAI, S. Z. (2015) Is there a place for thermocautery of the soft palate? Equine Veterinary Education (2015).
16. BARNETT, T.P., DIXON, P.M., PARKIN, T.D.H., BARAKZAI, S.Z. (2011) Dynamic videoendoscopic assessment of the upper airway following laryngoplasty. European College of Veterinary Surgeons: 20th Annual Scientific Meeting, Ghent, Belgium.
17. BARNETT, T. P., O'LEARY, J. M., DIXON, P. M., BARAKZAI, S. Z. (2014) Characterisation of palatal dysfunction after laryngoplasty. Equine Veterinary Journal 46, 60-63.
18. BARREY, E., GALLOUX, P., VALETTE, J. P., AUVINET, B., WOLTER, R. (1993) Stride characteristics of overground versus treadmill locomotion in the saddle horse. Acta anatomica 146: 90-94.
19. BARTON, A. K., CEHAK, A., ROHN, K., OHNESORGE, B. (2014) Transendoscopic laser surgery to correct nasopharyngeal obstruction caused by head flexion in horses. Veterinary Surgery Journal 43(4), 418-424.
20. BEARD, W. L., WAXMAN, S. (2007) Evidence-based equine upper respiratory surgery. Veterinary Clinics of North America: Equine Practice 23, 229-242.
21. BOYLE, A. G., MARTIN, B. B. Jr., DAVIDSON, E. J., DURANDO, M. M., BIRKS, E. K. (2006) Dynamic pharyngeal collapse in racehorses. Equine Veterinary Journal 36, 546-550.
22. BRAZIL, T., BROWN, C., DIXON, P. (2014) Larynx: slap test <https://www.vetstream.com/equis/Content/Technique/teq00294> Assessed April 2015.
23. BROWN, J. A., HINCHCLIFFE, K. W., JACKSON, M. A., DREDGE, A. F., O'CALLAGHAN, P. A., MCCAFFREY, . P., SLOCOMBE, R. F., CLARKE, A. F. (2005) Prevalence of pharyngeal and laryngeal abnormalities in Thoroughbreds racing in Australia, and their association with performance. Equine Veterinary Journal 37, 397-401.

24. BUCHNER, H. H., SAVELBERG, H. H., SCHAMHARDT, H. C., MERKENS, H.W., BARNEVELD, A. (1994) Kinematics of treadmill versus overground locomotion in horses. Author: Koninklijke Nederlandse Maatschappij voor Diergeneeskunde. The Veterinary Quarterly 16:87-90. Pubmed 7801509.
25. CAHILL, J. I., GOULDEN, B. E. (1987) The pathogenesis of equine laryngeal hemiplegia – a review. New Zealand Veterinary Journal 35, 82-90.
26. CARR, E. A., SPIER, S. J., KORTZ, G. D., HOFFMAN, E. P. (1996) Laryngeal and pharyngeal dysfunction in horses homozygous for hyperkalaemic periodic paralysis. Journal of American Veterinary Medicine Association 209, 798-803.
27. CHALMERS, H. J., YEAGER, A. E., DUCHARME, N. G. (2009) Ultrasonographic assessment of laryngohyoid position as a predictor of dorsal displacement of the soft palate in horses. Veterinary Radiology Ultrasound. 2009:50:91-96.
28. CHEETHAM, J., PIGOTT, J. H., HERMANSON, J. W., CAMPOY, L., SODERHOLM, L. V., THORSON, L. M., DUCHARME, N. G. (2009) Role of the hypoglossal nerve in equine nasopharyngeal stability. Journal of Applied Physiology 107, 471-477.
29. COMPOSTELLA, F., TREMAINE, W.H., FRANKLIN, S.H. (2012) Retrospective study investigating causes of abnormal respiratory noise in horses following prosthetic laryngoplasty. Equine Veterinary Journal 43, 27-30.
30. COOK, W. R. (1988) Diagnosis and grading of hereditary recurrent laryngeal neuropathy in the horse. Journal of Equine Science 8, 432-455.
31. COOMER, R., THOMAS, H., MCKANE, S. (2013) Current concepts of navicular syndrome: diagnosis and treatment. In Practice, 35, 325-335.
32. COUËTIL, L.L., HOFFMAN, A.M., HODGSON, J., BUECHNER-MAXWELL, V., VIEL, L., WOOD, J.L., LAVOIE, J.P. (2007) Inflammatory airway disease of horses. Journal of Veterinary Internal Medicine. 2007 Mar-Apr; 21(2):356-361.
33. DART, A. J., DOWLING, B. A., HODGSON, D. R. & ROSE, R. J. (2001) Evaluation of high-speed treadmill videoendoscopy for diagnosis of upper respiratory tract dysfunction in horses. Australian Veterinary Journal 79, 109-112
34. DART, A. J., DOWLING, B. A. & SMITH, C. L. (2005) Upper airway dysfunction associated with collapse of the apex of the corniculate process of the left arytenoid cartilage during exercise in 15 horses. Veterinary Surgery 34, 543-547.
35. DAVIDSON, E.J., MARTIN, B.B., PARENTE, E.J., BIRKS, E. K. (2002) Dynamic evaluation of sport horses with poor performance: 80 cases (1992-2000). Proceedings of

- the 2002 Conference on Equine Sports Medicine: The Elite Dressage and Three-day Event Horse, Ed: A. Lindner, CESMAS, Jülich. pp 133-136.
36. DAVIDSON, E.J., MARTIN, B.B., RIEGER, R.H. and PARENTE, E.J. (2010) Exercising videoendoscopic evaluation of 45 horses with respiratory noise and/or poor performance after laryngoplasty. *Veterinary Surgery* 39, 942-948.
  37. DAVIDSON, E. J., MARTIN, B. B., BOSTON, R. C. & PARENTE, E. J. (2011) Exercising upper respiratory videoendoscopic evaluation of 100 nonracing performance horses with abnormal respiratory noise and/or poor performance. *Equine Veterinary Journal* 43, 3-8
  38. DESMAIZIERES, L. M., SERRAUD, N., PLAINFOSSE, B., MICHEL, A. & TAMZALI, Y. (2009) Dynamic respiratory endoscopy without treadmill in 68 performance standardbred, thoroughbred and saddle horses under natural training conditions. *Equine Veterinary Journal* 41, 347-352.
  39. DIK, K. J., VAN DEN BELT, A. J. M. & VAN DEN BROEK, J. (2001) Relationships of age and shape of the navicular bone to the development of navicular disease: a radiological study. *Equine Veterinary Journal* 33, 172-175.
  40. DIXON, P. M., RAILYON, D. I., MCGORUM, B. C. (1993) Temporary bilateral laryngeal paralysis in a horse associated with general anaesthesia and post anaesthetic myositis. *Veterinary Record* 132, 29-32.
  41. DIXON, P. M., MCGORUM, B. C., RAILTON, D. I., HAWE, C., TREMAINE, W. H., PICKLES, K., MCCANN, J. (2001) Laryngeal paralysis: a study of 375 cases in a mixed breed population of horses. *Equine Veterinary Journal* 33, 452-458.
  42. DUCHARME, N. G., HACKETT, R. P., GLEED, R. D., AINSWORTH, D. M., ERB, H. N., MITCHELL, L. M., SODERHOLM, L. V. (1999) Pulmonary capillary pressure in horses undergoing alteration of pleural pressure by imposition of various upper airway resistive loads. *Equine Veterinary Journal* 30, 27-33.
  43. DUCHARME, N. G., HACKETT, R. P., WOODIE, J. B., DYKES, N., ERB, H. N., MITCHELL, L. M., SODERHOLM, L. V. (2003) Investigations into the role of the thyrohyoid muscles in the pathogenesis of dorsal displacement of the soft palate in horses. *Equine Veterinary Journal* 35, 258-263.
  44. DUCHARME, N. G. (2009) Update on the treatment of soft palate disease. Published in *IVIS* with the permission of the WEVA. In: Proceedings of the 11<sup>th</sup> International Congress of World Equine Veterinary Association, 24-27 Sept. Guarujá, Brazil.

45. DUCHARME, N. G., CORNELL UNIVERSITY, College of Veterinary Medicine: Management of horses with partial paralysis of the left arytenoid cartilage. <http://www.vet.cornell.edu/Zweig/projects/ducharme04.cfm> Assessed April 2015.
46. DUNCAN, I. D., BROOK, D. (1985) Bilateral laryngeal paralysis in the horse. *Equine Veterinary Journal* 17, 228-233.
47. DYSON, S. (2000) Lameness and Poor Performance in the Sports Horse: Dressage, Show Jumping and Horse Trials (Eventing). In proceedings of the Annual Convention of the AAEP 2000 46:308-315. Available at <http://www.ivis.org/proceedings/aaep/2000/308.pdf> Assessed 24th March 2015.
48. EVANS, D. (2004) Exercise testing in the field. In *Equine Sports Medicine and Surgery*. Eds K. W. Hinchcliff, A. J. Kaneps & R. J. Geor, Philadelphia: W. B. Saunders. pp 19–31.
49. FEI Eventing (2013) About eventing. Available at <http://www.fei.org/fei/disc/eventing/about> Assessed 1st April 2015.
50. FEI Dressage (2013) About dressage. Available at <http://www.fei.org/fei/disc/dressage/about-dressage> Assessed 1st April 2015.
51. FEI Jumping (2013) About jumping. Available at <http://www.fei.org/fei/disc/jumping/about> Assessed 1st April 2015.
52. FRANKLIN, S. H. (2008) Dynamic collapse of the upper respiratory tract: A review. *Equine Veterinary Journal* 20 (4), 212-224.
53. FRANKLIN, S. H., NAYLOR, J. R., LANE, J. G. (2006) Videoendoscopic evaluation of the upper respiratory tract in 93 sport horses during exercise testing on a high-speed treadmill. *Equine Veterinary Journal* 36, 540-545.
54. FRANKLIN, S. H., BURN, J. F., ALLEN K. J. (2008) Clinical trials using a telemetric endoscope for use during over-ground exercise: a preliminary study. *Equine Veterinary Journal* 40, 712-715.
55. FRENCH, K. (2012) Dynamic video endoscopy. I: *The Horsemen's Journal*. <http://www.hbpa.org/HorsemensJournalDisplay.asp?section=3&key1=14352> Assessed April 2015.
56. GEHRKE, E. K., BALDWIN, A., SCHILTZ, P. M. (2011) Heart rate variability in horses engaged in equine-assisted activities. *Journal of Equine Veterinary Science* 31(2), 78-84.
57. GERRING, E. L. (1985) Differential diagnosis of equine respiratory noises. In *Practice*, 7 (4), 109-117.

58. GEOR, R. (2000) What causes poor exercise performance? 1<sup>st</sup> September 2000. TheHorse.com article 10117 <http://www.thehorse.com/articles/10117/what-causes-poor-exercise-performance> Assessed 1st April 2015.
59. GO, L., BARTON, A. K., OHNESORGE, B. (2014) Evaluation of laryngeal function under the influence of various head and neck positions during exercise in 58 performance horses. *Equine Veterinary Education* 26(1), 41-47.
60. GREET, T. (1986) Differential diagnosis of nasal discharge in the horse. *In Practice*, 8 (2), 49-57.
61. GUNN, H. M. (1972) Histological observations on laryngeal skeletal muscle fibres in 'normal' horses. *Equine Veterinary Journal* 4, 144-148.
62. HALTMAYER, E., REISER, S., SCHRAMEL, J. P., VAN DEN HOVEN, R. (2013), Breathing pattern and thoracoabdominal asynchrony in horses with chronic obstructive and inflammatory lung disease. *Research Veterinary Science* 95 (2), 654-659.
63. HAWKES, C. S., HAHN, C. N., DIXON, P. M. (2010) Histological and histochemical characterisation of the equine soft palate muscles. *Equine Veterinary Journal* 42, 431-437.
64. HODGSON, D.R., ROSE, R.J., 1994. Clinical exercise testing. In: Hodgson, D.R., Rose, R.J. (Eds.), *The Athletic Horse*. Saunders, Philadelphia, USA, pages 245–257.
65. HOFFMAN, A., ROBINSON, N. E. & WADE, J. F. (Eds) (2003) Workshop summary: Inflammatory Airway Disease: Defining the Syndrome. Havemeyer Foundation Monograph Series No 9. Proceedings of the World Equine Airways Symposium, Boston, 30<sup>th</sup> September – 3<sup>rd</sup> October 2002. Newmarket, R & W Publications. pp 89-91.
66. HOLCOMBE, S. J., DERKSEN, F. J., STICK, J. A., ROBINSON, N. E., BOEHLER, D. A. (1996) Effect of nasal occlusion on tracheal and pharyngeal pressures in horses. *American Journal of Veterinary Research* 57, 1258-1260.
67. HOLCOMBE, S. J., DERKSEN, F. J., STICK, J. A., ROBINSON, N. E. (1997) Effects of bilateral hypoglossal and Glossopharyngeal nerve blocks on epiglottic and soft palate position in exercising horses. *American Journal of Veterinary Research* 58, 1022-1026.
68. HOLCOMBE, S. J., DUCHARME, N. G. (2003) Abnormalities of the upper airway. In: Hinchcliff K. W., Kaneps, A. J., Geor, R. J., editors. *Equine Sports Medicine and Surgery*, Philadelphia: Saunders; 2004, pages 559-598.
69. JEAN, D., PICANDET, V., CELESTE, C., MACIEIRA, S., CESARII, C., MORISSET, S., ROSSIER, Y., MARCOUX, M. (2011) Palatal sclerotherapy for the treatment of



- intermittent dorsal displacement of the soft palate in 51 standardbred racehorses. *Canadian Veterinary Journal* 52(11): 1203-1208.
70. KANNEGEITER, N. J., GOULDEN, B. E., ANDERSON, L. J. (1986) Right-sided laryngeal dysfunction in a horse. *New Zealand Veterinary Journal* 34, 66-68.
71. K ANNEGIETER, N. J. & DORE, M. L. (1995) Endoscopy of the upper respiratory tract during treadmill exercise. A clinical study of 100 horses. *Australian Veterinary Journal* 72, 101-107.
72. KELLY, P., REARDON, R., JOHNSTON, M., POLLOCK, P. (2013) Comparison of dynamic and resting endoscopy of the upper portion of the respiratory tract in 57 Thoroughbred yearlings. *Equine Veterinary Journal* 45 (6), 700-704.
73. KING, D. S., TULLENERS, E. P., MARTIN, B. B. JR., PARENTE, E. J., BOSTON, R. (2001) Clinical experiences with axial deviation of the aryepiglottic folds in 52 racehorses. *Veterinary Surgery* 30(2), 151-160.
74. KUMAŞ, C., MADEN, M. (2013) Evaluation of the dynamic (overground) endoscopy procedure in the diagnosis of upper respiratory tract diseases affecting performance of racehorses. *Journal of the Faculty of Veterinary Medicine, Kafkas University (Kafkas Üniversitesi Veteriner Fakültesi Dergisi)*, 19(A), A55-A60.
75. LANE, J. G. (2001) Equine 4<sup>th</sup> branchial arch defects: A clinicopathological review. In: *Proceedings of the 2<sup>nd</sup> World Equine Airways Symposium*, July 19-22, Edinburgh, Scotland.
76. LANE, J. G. (2003) Non-RLN upper respiratory tract disorders found in a survey of 3,496 Thoroughbred yearlings. In: *Proceedings of a Workshop on Equine Recurrent Laryngeal Neuropathy*, Havemeyer Foundation Monograph Series No. 11. Pp 49-50.
77. LANE, J. G., BLADON, B., LITTLE, D. R., NAY LOR, J. R. & FRANKLIN, S. H. (2006a) Dynamic obstructions of the equine upper respiratory tract. Part 1: Observations during high-speed treadmill endoscopy of 600 thoroughbred racehorses. *Equine Veterinary Journal* 38, 393-399
78. LANE, J. G., BLADON, B., LITTLE, D. R., NAY LOR, J. R. & FRANKLIN, S. H. (2006b) Dynamic obstructions of the equine upper respiratory tract. Part 2: a comparison between endoscopic findings at rest and those recorded during high-speed treadmill endoscopy of 600 thoroughbred racehorses. *Equine Veterinary Journal* 38, 401-408.

79. LAPOINT, J. M., VRINS, A., MCCARVILL, E. (1994) A survey of exercise-induced pulmonary haemorrhage in Quebec Standardbred racehorses. *Equine Veterinary Journal* 26, 482-485.
80. LINFORD, R. L., O'BRIEN, T. R., WHEAT, J. D., MEAGHER, D. M. (1983) Radiographic assessment of epiglottic length and pharyngeal and laryngeal diameters in the Thoroughbred. *American Journal of Veterinary Research* 44, 1660-1666.
81. LUMSDEN, J.M., STICK, J.A., CARON, J.J., NICKELS, F.A., BROWN, C.M., GODBER, L.M., DERKSEN, F.J., 1995. Upper airway function in performance horses: videoendoscopy during high speed treadmill exercise. *The Compendium of Continuing Education of the Practicing Veterinarian* 17, 1134–1143.
82. MACNAMARA, B., BAUER, S., IAFE, J. (1990) Endoscopic examination of exercise-induced pulmonary haemorrhage and chronic obstructive pulmonary disease in association with poor performance in racing Standardbreds. *Journal of the American Veterinary Medical Association* 196, 443-445.
83. MAIR, T. (1994) Differential Diagnosis and treatment of acute onset coughing in the horse. *In Practice*, 16(3), 154-162.
84. MANOHAR, M., HUTCHENS, E., CONEY, E. (1993) Pulmonary haemodynamics in the exercising horse and their relationship to exercise-induced pulmonary haemorrhage. *British Veterinary Journal* 149, 419-428.
85. MANOHAR, M. (1994) Pulmonary vascular pressures of thoroughbreds increase rapidly and to a higher level with rapid onset of high-intensity exercise than slow onset. *Equine Veterinary Journal* 26(6), 496-499.
86. MARTIN, B. B., REEF, V. B., PARENT, E. J., SAGE, A. D. (2000) Causes of poor performance of horses during training, racing, or showing: 348 cases (1992-1996). *Journal of the American Veterinary Medical Association* 216: 554-558.
87. MCCANN, J. (2000) Differential diagnosis of abnormal respiratory noises in the exercising horse. *In Practice*, 22(7), 370-381.
88. MCGORUM, B. (1994) Differential diagnosis of chronic coughing in the horse. *In Practice*, 16(2), 55-60.
89. MCGORUM, B. C., MURPHY, D., LOVE, S., MILNE, E. M. (1999) Clinicopathological features of equine primary hepatic disease: a review of 50 cases. *Veterinary Record* 145, 134-139.
90. MCGORUM, B., DIXON, P. M. (2013) Non-recurrent laryngeal neuropathy (RLN) causes of equine laryngeal paralysis. In: Havemeyer Foundation Monograph Series no.

- 11, page 55. In: Proceedings of a Workshop on Equine Recurrent Laryngeal Neuropathy, 7-10<sup>th</sup> September 2003, Stratford-upon-Avon, UK.
91. MERCK VETERINARY MANUAL (2010) 10<sup>th</sup> edition. Editor: Khan, C.M. and Line, S. Whitehouse Station N.J. Merck & Co. Inc.
92. MICHIGAN UNIVERSITY, <http://cvm.msu.edu/research/research-labs/equine-pulmonary-laboratory/respiratory-diseases/laryngeal-hemiplegia> Assessed 5th April 2015.
93. MORRIS, E. (1991) Dynamic evaluation of the equine upper respiratory tract. *Veterinary Clinics of North America* 7(2): 403-416.
94. MORRIS, E. H., SEEHERMAN, H. J. (1991) Clinical evaluation of poor performance in the racehorse: the results of 275 evaluations. *Equine Veterinary Journal* 23: 169-174.
95. NEWTON-CLARKE, M. J., DIVERS, T. J., VALENTINE, B. A. (1994) Evaluation of the thoraco-laryngeal reflex ('slap test') as an indicator of laryngeal adductor myopathy in the horse. *Equine Veterinary Journal* 26 (5), 355-357.
96. ODELROS, E. (2012) Dynamic obstruction of the equine upper respiratory tract. Sveriges lantbruksuniversitet, Faculty of Veterinary Medicine and Animal Science. [http://stud.epsilon.slu.se/4161/1/odelros\\_e\\_120430.pdf](http://stud.epsilon.slu.se/4161/1/odelros_e_120430.pdf) Assessed April 2015.
97. OLSEN, S. H., RANNEM, L., STRAND, E. (2010) Bilateral dynamic laryngeal collapse associated with collection in "high poll flexion" in a gaited Icelandic horse.
98. ORTVED, K. F., CHEETHAM, J., MITCHELL, L. M., DUCHARME, N. G. (2010) Successful treatment of persistent dorsal displacement of the soft palate and evaluation of laryngo-hyoid position in 15 racehorses. *Equine Veterinary Journal* 42, 23-29.
99. PARENTE, E. J., MARTIN, B. B. (1995) Correlation between standing endoscopic examination and those made during high-speed exercise in horses: 150 cases. *American Veterinary Journal of Research* 41,170-175.
100. PARENTE, E. J., MARTIN, B. B., TULLENERS, E. P. (1998) Epiglottic retroversion as a cause of upper airway obstruction in two horses. *Equine Veterinary Journal* 30, 270-272.
101. PARENTE, E. J., MARTIN, B. B., TULLENERS, E. P. & ROSS, M. W. (2002) Dorsal displacement of the soft palate in 92 horses during high-speed treadmill examination (1993 to 1998). *Veterinary Surgery* 31, 507-512.
102. PARENTE, E. J., FRANKLIN, S. H., DERKSEN, F. J., WEISHAUP, M. A., CHALMERS, H. J., TESSIER, C. (2012). *Diagnostic Techniques in Equine Upper*

- Respiratory Tract Disease. In Auer J. A. and Stick J. A. (eds) *Equine Surgery* (4<sup>th</sup> edn). Elsevier Saunders. Pp 536-557.
103. PASCOE, J. R., FERRARO, G. L., CANNON, J. H., ARTHUR, R. M., WHEAT, J. D. (1981) Exercise-induced pulmonary haemorrhage in racing Thoroughbreds: a preliminary study. *American Journal of Veterinary Research* 42, 703-707.
  104. PETSCHKE, V. M., DERKSEN, F. J., BERNEY, C. E., ROBINSON, N. E. (1995) Effect of head position on upper airway function in exercising horses. *Equine Veterinary Journal, Supplement* 18, 18-12.
  105. POLLOCK, P.J., REARDON, R. J. M. (2009) Dynamic respiratory endoscopy without a treadmill: Initial experiences. *Equine Veterinary Education* 21, 367-370
  106. POLLOCK, P. J., REARDON, R. J. M., PARKIN, T. D. H., JOHNSTON, M. S., TATE, J. & LOVE, S. (2009) Dynamic respiratory endoscopy in 67 thoroughbred racehorses training under normal ridden exercise conditions. *Equine Veterinary Journal* 41, 354-360
  107. POLLOCK, P. J., KELLY, P. G., REARDON, R. J. M. & KELLY, G. M. (2013) Dynamic ventrostral displacement of the dorsal laryngeal mucosa in horses. *Veterinary Record* 172(19), 501.
  108. PRIEST, D. T., CHEETHAM, J., REGNER, A. L., MITCHELL, L., SODERHOLM, L. V., TAMZALI, Y., DUCHARME, N. G. (2012) Dynamic respiratory endoscopy of Standardbred racehorses during qualifying races. *Equine Veterinary Journal* 44, 529-534.
  109. RAKESTRAW, P. C., HACKETT, R. P., DUCHARME, N. G., NIELAN, G. J., ERB, H. N. (1991) Arytenoid cartilage movement in resting and exercising horses. *Veterinary Surgery Journal* 20(2), 122-127.
  110. RAPHEL, C. F. (1982) Endoscopic findings in the upper respiratory tract of 479 horses. *Journal of American Veterinary Medicine Association* 181, 470-473.
  111. RAPHEL, C. F., SOMA, L.R. (1982) Exercise-induced pulmonary haemorrhage in Thoroughbreds after racing and breezing. *American Journal of Veterinary Research* 43, 1123-1127.
  112. RIETMANN, T. R., STUART, A. E. A., BERNASCONI, P., STAUFFACHER, M., AUER, J. A., WEISHAUPT, M. A. (2004) Assessment of mental stress in Warmblood horses: heart rate variability in comparison to heart rate and selected behavioural parameters. *Applied Animal Behaviour Science, Official Journal of the International Society for Applied Ethology* 88(1-2), 121-136.

113. ROBERTSON, J. T. (1991) Pharynx and larynx. In: *Equine Respiratory Disorders*, Ed: J. Beech, Lea and Febiger, Philadelphia. pp 331-387.
114. ROBINSON, N. E. (2001) International workshop on equine chronic airway disease. *Equine Veterinary Journal* 33, 5-19.
115. ROBINSON, N. E. (2004) Consensus statements on equine recurrent laryngeal neuropathy: Conclusions of the Havermeier Workshop. *Equine Veterinary Education* 16, 333-336.
116. ROBINSON, N. E., SPRAYBERRY, K. A. (2009) *Current therapy in equine medicine*, 6<sup>th</sup> edition. Saunders Elsevier publishing.
117. RUSH, B., MAIR, T., (2004a) *Equine Respiratory Diseases*. Blackwell publishing. Introduction, page xvii.
118. RUSH, B., MAIR, T., (2004b) *Equine Respiratory Diseases*. Blackwell publishing. Introduction, page xviii.
119. RUSH, B., MAIR, T., (2004c) *Equine Respiratory Diseases*. Blackwell publishing. Section I: Examination of Equine Respiratory Tract, page 2.
120. RUSH, B., MAIR, T., (2004d) *Equine Respiratory Diseases*. Blackwell publishing. Section I, chapter 1: Examination of Equine Respiratory Tract, page 3.
121. RUSH, B., MAIR, T., (2004e) *Equine Respiratory Diseases*. Blackwell publishing. Section II, chapter 9: The Pharynx, page 84.
122. RUSH, B., MAIR, T., (2004f) *Equine Respiratory Diseases*. Blackwell publishing. Section II, chapter 9: The Pharynx, page 85.
123. SMITH, L., GREET, T. (2013) Approaches to successful use of dynamic equine endoscopy. *Veterinary Times*, 36: 09/09/2013: 9-14.
124. STICK, J.A., DERKSEN, F.J., NICKELS, F.A., BROWN, C.M., ARDEN, W.A., FULTON, I.C., PELOSO, J.G. (1992) Upper airway videoendoscopy during exercise in poorly performing horses. In: *Proceedings of the Annual Convention of the American Association of Equine Practitioners*, vol. 38, pp. 431–438.
125. STRAND, E., SKJERVE, E. (2012) Complex dynamic upper airway collapse: associations between abnormalities in 99 harness racehorses with one or more dynamic disorders. *Equine Veterinary Journal* 44(5), 524-528.
126. STRAND, E., STAEMPFLI, H.R. (1993) ‘Dynamic collapse of the roof of the nasopharynx as a cause of poor performance in a Standardbred colt’, *Equine Veterinary Journal* 25, 252–254.

127. TAN, R. H. H., DOWLING, B. A., DART, A. J. (2005) High-speed treadmill videoendoscopic examination of the upper respiratory tract in the horse: The results of 291 clinical cases. *Veterinary Journal* 170, 243-248
128. TROPE, G. (2013) Dynamic endoscopy of the equine upper airway – what is significant? *Veterinary Record* 172(19), 459-500.
129. TUFTS UNIVERSITY (2005-2006) Common causes of poor performance in a horse. Author: Tufts University, Cummings School of Veterinary Medicine, 200 Westboro Road, North Grafton, Massachusetts.  
<http://www.tufts.edu/vet/sports/performance.html> Assessed April 2015.
130. UNIVERSITY OF SYDNEY (a), Centre for Veterinary Education.  
[http://vetbook.org/wiki/horse/index.php?title=Epiglottic\\_retroversion](http://vetbook.org/wiki/horse/index.php?title=Epiglottic_retroversion) Assessed April 2015.
131. UNIVERSITY OF SYDNEY (b), Centre for Veterinary Education.  
[http://vetbook.org/wiki/horse/index.php/Axial\\_deviation\\_of\\_the\\_aryepiglottic\\_fold#cite\\_note-0](http://vetbook.org/wiki/horse/index.php/Axial_deviation_of_the_aryepiglottic_fold#cite_note-0) Assessed April 2015.
132. VAN ERCK, E., FRIPPIAT, T., DUPUIS, M.-C., RICHARD, E. and ART, T. (2009) Upper airway dynamic endoscopy: are track and treadmill observations comparable? In: *Proceedings of the 4th World Equine Airways Symposium*. Berne, Switzerland. p 254.
133. VAN ERCK, E. (2011) Dynamic respiratory videoendoscopy in ridden sport horses: Effect of head flexion, riding and airway inflammation in 129 cases. *Equine Veterinary Journal* 43: 18-24.
134. VISSER, E. K., VAN REENEN, C. G., VAN DER WERF, J. T. N., SCHILDER, M. B. H., KNAAP, J. H., BARNEVELD, A., BLOKHUIS, H. J. (2002) Heart rate and heart rate variability during a novel object test and a handling test in young horses. In: *Physiology and Behaviour*, Elsevier volume 76, issue 2, pages 289-296.
135. VON BORELL, E., LANGBEIN, J., DESPRÉS, G., HANSEN, S., LETERRIER, C., MARCHANT-FORDE, J., MARCHANT-FORDE, R., MINERO, M., MOHR, E., PRUNIER, A., VALANCE, D., VEISSIER, I. (2007) Heart rate variability as a measure of autonomic regulation of cardiac activity for assessing stress and welfare in farm animals – a review. In: *Physiology and Behaviour*, Elsevier volume 92, issue 3, pages 293-316.

136. WEISS, D. J., SMITH, C. M. (1998) Haemorrhological alterations associated with competitive racing activity in horses: implications for exercise-induced pulmonary haemorrhage (EIPH). *Equine Veterinary Journal* 30, 7-12.
137. WEST, J. B., MATHIEU-COSTELLO, O., JONES, J. H., BIRKS, E. K., LOGEMANN, R. B., PASCOE, J. R., TYLER, W. S. (1993) Stress failure of pulmonary capillaries in racehorses with exercise-induced pulmonary haemorrhage. *Journal of Applied Physiology* 75, 1097-1109.
138. WEST, J.B., MATHIEU-COSTELLO, O. (1994) Stress failure of pulmonary capillaries as a mechanism for exercise-induced pulmonary haemorrhage in the horse. *Equine Veterinary Journal* 26, 441-447.
139. WITTE, S.H., WITTE, T.H., HARRISS, F., KELLY, G. & POLLOCK, P. (2011) Association of owner-reported noise with findings during dynamic respiratory endoscopy in Thoroughbred racehorses. *Equine Veterinary Journal* 43, 9–17.
140. WOODIE, J. B., DUCHARME, N. G., KANTER, P., HACKETT, R. P., ERB, H. N. (2005) Surgical advancement of the larynx (laryngeal tie forward) as a treatment for dorsal displacement of the soft palate in horses: a prospective study 2001-2004. *Equine Veterinary Journal* 37, 418-423.
141. WOODIE, J. B. (2012) Dynamic Endoscopy.  
<http://www.roodandriddle.com/images/files/DYNAMIC%20ENDOSCOPY-Winter%202012.pdf> Assessed April 2015.

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