Evaluation of the upper respiratory tract in the horse during treadmill exercise - A review. 1. Endoscopy

Kästner, S B; Weishaupt, M A; Townsend, H G G
Evaluation of the upper respiratory tract in the horse during treadmill exercise - A review. 1. Endoscopy

Abstract

Literature pertaining to the evaluation of the upper respiratory tract of the horse during exercise was reviewed. Articles were found by searching two databases. Videoendoscopy, upper airway pressure measurement and airflow measurements are used for assessing upper airway function. Treadmill accommodation and exercise protocols, examination protocols, the endoscopy technique, indications for the examination during exercise and normal and abnormal functions of the upper airways are described in pari I of this review. The most frequently observed dysfunctions are dorsal displacement of the soft palate with an incidence of 21 to 52 % and laryngeal hemiplegia with an incidence of 9 to 25 % of all upper airway obstructions. Videoendoscopy during treadmill exercise as a subjective technique can already accomplish a good evaluation of the upper airway function. But a final assessment of the presence of a respiratory limitation can only be made by the quantitative determination of upper airway flow mechanics (airway pressure and flow-volume measurement) which are presented in part II of this review
Evaluation of the upper respiratory tract in the horse during treadmill exercise – A review
Part I: Endoscopy

Sabina B. R. Kästner1, M. A. Weihaupt1 and H.G.G Townsend2

1 Veterinär-Chirurgische Klinik der Universität Zürich, Zürich, Schweiz
2 Department of Veterinary Internal Medicine, Western College of Veterinary Medicine, University of Saskatchewan, Canada

Summary

Literature pertaining to the evaluation of the upper respiratory tract of the horse during exercise was reviewed. Articles were found by searching two databases. Videoendoscopy, upper airway pressure measurement and airflow measurements are used for assessing upper airway function. Treadmill accommodation and exercise protocols, examination protocols, the endoscopy technique, indications for the examination during exercise and normal and abnormal functions of the upper airways are described in part I of this review. The most frequently observed dysfunctions are dorsal displacement of the soft palate with an incidence of 21 to 52 % and laryngeal hemiplegia with an incidence of 9 to 25 % of all upper airway obstructions. Videoendoscopy during treadmill exercise as a subjective technique can already accomplish a good evaluation of the upper airway function. But a final assessment of the presence of a respiratory limitation can only be made by the quantitative determination of upper airway flow mechanics (airway pressure and flow-volume measurement) which are presented in part II of this review.

keywords: horse, endoscopy, upper airway, treadmill, exercise

Beurteilung der oberen Luftwege des Pferdes während der Belastung auf einem Laufband – Eine Literaturstudie

Teil I: Endoskopie


Die Anforderungen an das Laufband, Voruntersuchungsprotokolle und Indikationen für die Untersuchung unter Belastung werden beschrieben. Desweiteren werden der Angewöhnungsprozess des Pferdes an das Laufband, die verschiedenen Belastungsprotokolle und die Technik der Belastungsendoskopie dargestellt.


Schlüsselwörter: Pferd, Endoskopie, Obere Luftwege, Laufband, Belastung

Introduction

The use of treadmills in equine research and training is not new. Horses were exercised on mechanical treadmills during the long sailboat trips from Europe to North America. In the latter part of the 19th century Hagemann
and Zuntz already used a steam driven treadmill to investigate the oxygen consumption of working draught horses. The first modern, motor driven treadmill in equine research was used at the Royal Swedish Veterinary School in Stockholm during the 1960s. But the evaluation of upper respiratory tract dysfunctions in horses during exercise on high-speed treadmills is a relatively new method (Derk森 et al., 1986; Stick and Derksen, 1989; Belknap et al., 1990; Morris and Seeherman, 1990). Its importance lies in the fact that many functional disorders (i.e. dorsal displacement of the soft palate, pharyngeal collapse) are not apparent at rest. On the other hand abnormal findings at rest do not necessarily mean a functional limitation during exercise (Williams et al., 1990, Morris and Seeherman, 1991). In addition, some methods are not sensitive enough to diagnose mild disease stages at rest.

There are different methods of assessing upper respiratory function in horses during exercise. These include endoscopy, upper airway pressure measurement and airflow measurement (pneumotachography). Recently there have been many advances in the techniques and the knowledge about the diagnostic value of these tests. The purpose of this review is to describe the techniques of the evaluation of the upper respiratory tract in the horse during exercise, list the indications, and discuss the usefulness and value of the different methods. Part I of the review deals with endoscopy during exercise.

Material and Methods (Literature Reviewed)

Publications on the evaluation of the upper respiratory tract function during exercise were found by consulting two databases. The Index Medicus (Medline) and the Commonwealth Agricultural Bureaux (CAB) were searched for the terms "horse" or "equine" and "treadmill". Reports pertaining to the upper respiratory tract were then selected manually. The search was carried out for the period from 1966 to the current date. Articles in the Proceedings of the American Association of Equine Practitioners, the American College of Veterinary Internal Medicine, the American College of Veterinary Surgeons and the Proceedings of the Geneva Congress of Equine Medicine and Surgery were included as original, if the methods were clearly stated. This review encompasses all the original articles and reviews on the evaluation of the equine upper respiratory tract on a treadmill found by the above stated searching method. In addition selected references on basic principles of different measurement techniques and specific airway disorders are included.

Results

Ventilation seems to be an important limiting factor of performance in strenuously exercising horses (Petsche et al., 1995). In addition, respiratory tract disorders are the second most cause for poor performance in horses (Morris and Seeherman, 1991). The introduction of the flexible fiberoptic endoscope in equine medicine has been helpful in the description and diagnosis of several upper respiratory tract disorders (Cook, 1974, 1981a, 1981b; Raphel, 1982). Recognized causes of upper airway obstruction at rest are laryngeal hemiplegia (LH), dorsal displacement of the soft palate (DDSP), epiglottic entrapment (EE), arytenoid chondropathy, rostral displacement of the palatopharyngeal arch, subepiglottic cysts, and pharyngeal cicatrizes (Cook, 1974, 1981a, 1981b; Raphel, 1982; Lumsden et al., 1995). During exercise large pressure changes occur in the upper respiratory tract (Derk森 et al., 1986). Studies of upper airway flow mechanics in exercising horses have made it clear that identification of an upper airway function abnormality does not necessarily mean a functional airway obstruction when the horse is exercising (Stick and Derksen, 1989; Williams et al., 1990). On the other hand, the absence of an upper airway abnormality at rest does not rule out a functional obstruction during strenuous exercise (Morris and Seeherman, 1990). Attempts to mimic airflows and pressure changes during exercise include endoscopy immediately after exercise, during naso occlusion (Holcombe et al., 1996) and chemically induced hyperventilation with doxapram (Dopram®) (Archer et al., 1991) or lobelinum hydrochloride (Lobelin®) (Art et al., 1991; Reutter, 1993).

The Treadmill

Until the late 1980s most treadmills only reached speeds of 3 to 6 m/s and therefore could only be used for studying horses during low intensity exercise. On the modern high-speed treadmills horses can be tested at high intensity exercise at speeds up to 18m/s which is necessary for the assessment of upper airway function. Treadmills used for clinical exercise testing should have sufficient tread length and width. This requires a length of at least 3.4 meters and a width of at least 0.8 meters (Rose and King, 1993). Optimal is a length of 4 to 5 meters and a width of 1 to 1.5 meters (Seeherman, 1991). The additional length and width gives the horse sufficient room for momentary changes in position on the belt without excessive contact with the side rails or premature termination of the exercise test in case the horse is carried back. For exercise at high speed it is also important to have safety devices as an emergency stop and a gantry with a safety belt.

Most of the commercially available large motorized treadmills meet these criteria: Mustang 2200 (Kagra AG, Fahrwangen, Switzerland); Säto II (Uppsala, Sweden; Equispeed Technologies, Raymore, Missouri, USA); Classic Walmank (Walmank International Corp., Freedom PA, USA). An extensive description of dimensions and housing conditions for treadmill installations is given elsewhere (Seeherman, 1991; Seeherman et al., 1992).
Methodology of the Evaluation of the Upper Airways during Treadmill Exercise

Preexamination

A complete history and physical examination with emphasis on the respiratory tract always precedes examination during strenuous exercise. (Morris, 1991). This will include external palpation of the laryngeal and pharyngeal area to identify any swelling or atrophy of the cricoarytenoideus dorsalis muscle, and a standing endoscopic evaluation of the respiratory tract including the cervico-laryngeal reflex (slap-test) (Greta et al., 1980). Endoscopy at rest should be attempted without sedation, because it is reported that xylazine alters the arytenoid abduction (Archer et al., 1991, Valdes-Vasquez et al., 1997). If indicated such as with suspected arytenoid chondritis, pharyngeal abscessation, DDSP and guttural pouch infection radiographs can be taken. Any abnormalities should be recorded to be able to compare it with observed dysfunction during exercise.

In addition, a thorough lameness examination should precede treadmill exercise to rule out an orthopedic problem as a cause of poor performance and to ensure that the horse is able to work on a treadmill at high speeds without being harmed.

Indications

An overview of indications for exercise endoscopy is given in Table 1.

Tab. 1: Indications for exercise endoscopy.
Indikationen der Belastungsendoskopie.

<table>
<thead>
<tr>
<th>History</th>
<th>Endoscopy at rest</th>
<th>Endoscopy during exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abnormal inspiratory noise with/without PP</td>
<td>LH grade II</td>
<td>Indicated in connection with PP</td>
</tr>
<tr>
<td></td>
<td>LH grade III</td>
<td>Indicated</td>
</tr>
<tr>
<td></td>
<td>LH grade IV</td>
<td>Not necessary</td>
</tr>
<tr>
<td>Abnormal inspiratory and/or expiratory noise with/without PP</td>
<td>Ulceration or hemorrhage of any structure of the larynx or pharynx</td>
<td>Indicated</td>
</tr>
<tr>
<td>Abnormal respiratory noises with/without PP</td>
<td>No abnormalities</td>
<td>Indicated</td>
</tr>
<tr>
<td>PP of unknown origin musculoskeletal abnormal</td>
<td>No abnormalities</td>
<td>Indicated</td>
</tr>
<tr>
<td>After surgical correction of upper airway disorders especially if no improvement of respiratory noise or performance is observed</td>
<td>Inconclusive findings</td>
<td>Indicated</td>
</tr>
</tbody>
</table>

LH = laryngeal hemiplegia; PP = poor performance

Dorsal Displacement of the Soft Palate (DDSP)

Recent studies by Derksen and Coworkers (1997) indicate that DDSP might be caused by damage to the pharyngeal branches of the vagal nerve which travel with the pharyngeal plexus close to the retropharyngeal lymphnodes. DDSP causes clinical signs during strenuous exercise but not at rest. The displacement can be associated with an inspiratory and expiratory or mainly expiratory noise and often a sudden slowing down of the horses during exercise. Certain endoscopic observations at rest are suggestive for the presence of intermittent DDSP. DDSP is easily induced by nasal occlusion or withdrawal of the endoscope from the trachea. Normally the soft palate is returned into the normal position after swallowing. Persistence of the induced displacement over repeated swallowing manoeuvres, mucosal ulceration or bleeding of the free border of the soft palate, the dorsal pharynx or the tip of the epiglottis, and a small or faccid appearing epiglottis are suggestive for intermittent DDSP (Morris , 1991; Lumsden et al., 1995; Kannegieter and Dore, 1995). However, there are also horses with intermittent DDSP which do not show any signs at resting endoscopy (Lumsden et al., 1995; Kannegieter and Dore, 1995).

Laryngeal Hemiplegia (LH)

LH describes asynchronous, asymmetric arytenoid cartilage movement caused by degeneration or damage most times of the left recurrent nerve. For the description of the various degrees of asynchronous/asymmetric movement of the arytenoid cartilages at rest different grading systems have been developed (Baker, 1983; Rakestraw et al., 1991; Lane, 1993). This review will use the grading system by Rakestraw and Coworkers (1991) (Table 2).

Tab. 2: Subjective Laryngeal Grades for Resting Horses (Rakestraw et al., 1991).
Einteilung der Kehlkopffunktion am stehenden Pferd (Rakestraw et al., 1991).

<table>
<thead>
<tr>
<th>Grade</th>
<th>Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Symmetrical, synchronous abduction and adduction of the left and right arytenoid cartilages.</td>
</tr>
<tr>
<td>II</td>
<td>Some asynchronous movement (hesitation, flutter, or abductor weakness) of the left arytenoid cartilage during any phase of respiration. Full abduction of the left arytenoid cartilage can be maintained by swallowing or nasal occlusion.</td>
</tr>
<tr>
<td>III</td>
<td>Asynchronous movement (hesitation, flutter, or abductor weakness) of the left arytenoid cartilage during any phase of respiration. Full abduction of the left arytenoid cartilage cannot be induced and maintained by swallowing or nasal occlusion.</td>
</tr>
<tr>
<td>IV</td>
<td>There is no substantial movement of the left arytenoid cartilage during any phase of respiration.</td>
</tr>
</tbody>
</table>
LH is associated with an inspiratory stertor during exercise. A clinical examination should include exercise with the horse in normal head position during performance and endoscopic evaluation of the arytenoïd excursions during nasal occlusion, during and after an induced swallowing reflex or during induced hyperventilation by Lobelina® (Reutter, 1993). Morris and Seeherman (1990) and Kannegieter and Dore (1995) discuss the possibility of a progressive dynamic collapse with extended exercise in horses with laryngeal function grade I and II. But an extensive study comparing arytenoid cartilage movement at rest and during exercise has shown that horses with laryngeal function grade I and II were all able to fully abduct the arytenoid cartilages during exercise (Rakestraw et al., 1991). Also Lumsden and co-workers (1995) do not consider laryngeal function grade I and II an indication for evaluation on the treadmill. LH grade III seems to be the laryngeal function in question. There are different studies which suggest that between 20 and 70% of horses have laryngeal function grade III at rest experience a pronounced central displacement of the left arytenoid cartilage ("dynamic collapse") and occasional collapse of the rima glottidis during exercise (Rakestraw et al., 1991, Lumsden et al., 1995). Based on calculated left to right ratios during exercise racehorses with resting LH grade III were divided into 3 subgroups: IIIa-the horse is able to obtain and maintain full abduction of both arytenoids during exercise [maximal abduction ratio of 0.80, maximal collapse ratio of 0.79], IIIb-the affected arytenoid is incompletely abducted, but this degree of abduction is maintained during exercise [maximal abduction ratio of 0.69, maximal collapse ratio of 0.57] and IIIc-progressive and severe collapse of the affected arytenoid and the vocal cords [maximal abduction ratio of 0.61, maximal collapse ratio of 0.18] (Hammer et al., 1995) suggesting that horses with grade IIIa do not require surgical intervention because they are able to maintain full abduction during exercise. However, approximately 95% of the horses with LH grade III fall into category IIIb and IIIc. The same studies have shown that laryngeal function grade IV at rest make an evaluation during exercise unnecessary because of total paralysis of the arytenoid cartilage (Morris and Seeherman, 1990, 1991, Rakestraw et al., 1991, Lumsden et al., 1995).

Epiglottic Entrapment (EE)

EE presents mainly as a permanent disorder. It is defined as permanent when it is observed throughout the endoscopic examination, during swallowing and when observed on consecutive examinations at rest (Lumsden et al., 1995). Evaluation of persistent EE on the treadmill seems to be warranted to document the severity of airway obstruction, because airway pressure measurements have indicated that thick membranes (aryepiglottic fold) might cause a more severe airway obstruction than thin membranes (Williams et al., 1990). Intermittent EE has first been diagnosed during treadmill exercise endoscopy (Morris and Seeherman, 1991). Horses with intermittent EE do not have abnor-

Other Indications

Treadmill endoscopy has allowed the diagnosis of some rare functional disorders like epiglottic retroflexion (Parente et al., 1994; Lumsden et al., 1995; Derksen et al., 1997), vocal cord prolapse without additional arytenoid cartilage dysfunctions (Hackett et al., 1994; Kannegieter and Dore, 1995) and collapse of the pharynx (Strand and Staempfli, 1993; Hackett et al., 1994) which were not apparent at resting endoscopy. Currently there is no knowledge about the clinical significance of these rare disorders. Evaluation of the upper respiratory tract during treadmill exercise can also be indicated after surgical correction of upper airway disorders (Stick and Derksen, 1989; Kannegieter and Dore, 1995) to control the result, especially if there is no improvement in performance or respiratory stertor.

Treadmill Accommodation and Exercise Protocols

Protocols for the dynamic evaluation of the upper airway function should simulate a horse's usual performance conditions as close as possible (Morris and Seeherman, 1990). During the examination the horse should wear its own tack as bridle, bit, hobbles or overcheck. Side reins can be used if it is necessary to achieve a flexed head and neck position during performance (Lumsden et al., 1995). Before examination during exercise the horse has to be familiarized with the treadmill. There are different protocols used for acclimatization of the horse to run comfortably on a treadmill. Morris and Seeherman (1990) use a protocol that is designed to minimize disruption of the training schedule. The whole evaluation of the respiratory tract, including two resting endoscopies can be performed in 1 1/2 to 2 hours. These authors report that it takes typically only 20 to 30 minutes to get the horses (Thoroughbreds, Standardbreds) running on the treadmill at high speeds. The group at Michigan State University (Stick et al., 1991; Derksen, 1993; Lumsden et al., 1995) use a protocol that will take 2 or 3 days for training and endoscopy. The horse has two training runs which can be performed in one or two days. Other investigators report on average one to two training runs to acclimatize the horses to the treadmill (Strand and Staempfli, 1993; Kannegieter and Dore, 1995). Horses not trained for high performance running (Wambooths, draught horses, ponies) tend to need a longer accomodation time for exercising at gallop speeds needed for the upper respiratory tract evaluation than Thoroughbreds and Standardbreds (personal observation).

During exercise on the treadmill the horse is encouraged to maintain its position on the treadmill. The speed is adjusted to accommodate the use and fitness level of the horse. Prior to the evaluation the horse has a warm up period. Pub
lished protocols use 4.5 m/s for 6 minutes trotting (Morris and Seeherman, 1990) or 5–7 m/s for 5 minutes and 12–14 m/s for 1 minute at the gallop (Stick et al. 1991; Derksen, 1993; Lumsden et al., 1995). The treadmill is usually inclined at 3% for trotting horses (Standardbreds) and at 6% for galloping horses (Thoroughbreds, endurance horses and 3-day eventers) (Morris, 1991). Parente and Martin (1995) use three degrees of inclination for Thoroughbreds and no inclination for Standardbreds. In human exercise physiology as well as in equine sports medicine it is well known that exercise on a treadmill at level causes less energy expenditure than exercise on the track (Barney et al., 1993). The same authors determined 1.7 – 2.1 degrees as the optimal inclination for saddle horses (3 day eventers) to get the same heart rate response on the treadmill at certain speeds as during exercise over ground. The inclination is necessary to obtain the same workload than over ground, to simulate the load of the rider or the sulky (Morris, 1991). In addition, the inclination makes exercise on the treadmill safer, because lower speeds can be used. The lower inclination for Standardbreds is necessary to enable these horses to maintain stride (Morris, 1991). Early protocols measured the horses during submaximal exercise (Sheppell et al., 1988). Results indicated that the evaluation methods are more sensitive near maximal exercise (Lumsden et al., 1994) and that the fastest possible speed for the individual horse are necessary to reproduce a similar stress on the upper respiratory tract as under competition conditions (Ducharme et al., 1994). The individual horses maximal heart rate is determined by an incremental exercise test. Then the horses are tested at the treadmill speed corresponding to their 75% of maximal heart rate (HR75 max) and at maximal heart rate (HRmax) for 2 minutes (Lumsden et al., 1994). Often several trials are necessary to fatigue the horse and induce certain dysfunctions.

**Endoscopy Technique**

The first reports on the use of endoscopy during exercise on a high-speed treadmill were published in 1988 (Morris and Seeherman) and 1989 (Stick and Derksen). Although it is possible to use a fiberoptic endoscope, the advent of videoendoscopes in veterinary medicine made it possible to obtain clearer images during exercise, because they have better luminous intensity than fiberoptic endoscopes and can be equipped with electronic shutters [i.e. Videendoscope CF 100 HL, Olympus; Video Gastroscope for Horses, Karl Storz GmbH]. An endoscope length of 180 cm is desirable to be able to fix it properly to the bridge and have enough length available to correct for momentary position changes of the horse during exercise.

After the warm-up period the treadmill is stopped and an endoscope is inserted after superficial anesthesia with 2% lidocain into the ventral meatus of the right or left nostril and positioned to allow visualization of the pharynx and larynx without touching any of the laryngeal structures. The endoscope is fastened to the bridge by adhesive tape (Fig. 1), penrose drains or Velcro® straps (Morris, 1991; Stick et al. 1991; Derksen, 1993). The Velcro® straps allow a quick removal of the device in case of an accident or uncooperative horse (Morris, 1991). To allow easy visualization, as well as permanent recording the endoscope is coupled with a videotape recorder (Morris and Seeherman, 1990). Additionally a microphone can be attached to the endoscope 5 to 10 cm from the nostrils to allow recording of the abnormal respiratory noises (Morris and Seeherman, 1990). A minimum of three (Lumsden et al., 1995) to four (personal observation) handlers is needed to safely perform an endoscopy at speed. One person has to adjust the monitor-image continuously. Two/three other operators handle the horse and operate the treadmill. After insertion of the endoscope the treadmill is started again and the exercise protocol completed (Stick et al. 1991, Derksen, 1993, Lumsden et al., 1995). Treadmill speed and inclination are adapted to the horse’s fitness level or horses are exercised at their usual racing gait (9 m/s to 13.5 m/s) to reach a heart rate in excess of 220 beats/minute (Morris and Seeherman, 1990; Morris, 1991; Parente and Martin, 1995). It has been observed that disturbing the horse by sudden slowing down can help to induce the displacement of the soft palate (Lumsden et al., 1995).

**Fig. 1:** Horse prepared for exercise endoscopy on a treadmill. The endoscope is fixed to the bridge with adhesive tape. Für eine Belastungsendoskopie vorbereitetes Pferd. Das Endoskop ist mit Klebeband am Zaum fixiert.

30 minutes after exercise a second endoscopy at rest is performed (Morris, 1991; Lumsden et al., 1995). Afterwards the video recording is evaluated in slow motion or freeze frame mode, sequence by sequence.

**Observations during Exercise**

**Normal Function of the Upper Airways**

In the resting horse the arytenoid cartilages are slightly abducted during expiration and slightly abducted during inspiration. The swallow reflex includes the complete adduction of the laryngeal cartilages, dorsal displacement of the epiglottis and ventral movement of the root of the pharynx and dorsal movement of the soft palate (closure of the
nasopharyngeal sphincter) to prevent the passage of food or saliva into the trachea. This is followed by complete, bilateral abduction of the arytenoid cartilages. Then the cartilages return into resting position (Morris, 1991). Displacement of the soft palate can be induced in normal horses by insertion of the endoscope into the trachea and withdrawing it again or by touching the laryngeal structures. The displacement than occurs after a swallowing reflex. ‘Normal’ horses return the soft palate into normal position after an other swallowing reflex (Morriss, 1991).

During a transitional time at the beginning of exercise frequent full symmetrical abduction and adduction of the arytenoid cartilages can be observed before full abduction is achieved (personal observation). During exercise the ‘normal’ horse fully abducts the arytenoid cartilages as ventilation increases (Morris, 1991). The larynx stays open during strenuous exercise until ventilation returns to resting levels. The horse is able to swallow during strenuous exercise; the reflex is intact with full adduction of the arytenoid cartilages, which then return to the fully abducted position. Horses may swallow several times during exercise, but repeated swallowing indicates an irritation or hypersecretion as in COPD affected horses (Morris, 1991).

Abnormal Function of the Upper Airways
Obstructing functional abnormalities observed during exercise are intermittent DDSP (Morriss and Seeherman, 1990; Stick et al., 1991; Parente et al., 1994; Hackett et al., 1994; Parente and Martin, 1995; Lumsden et al., 1995; Kannegieter and Dore, 1995) [Figs 2a-b], LH or dynamic arytenoid cartilage collapse (Morris and Seeherman, 1990; Stick et al., 1991; Morris and Seeherman, 1991; Rekestraw et al., 1991; Parente et al., 1994; Parente and Martin, 1995; Kannegieter and Dore, 1995; Lumsden et al., 1995) [Figs.2c-d], intermittent EE (Morris and Seeherman, 1991; Hackett et al., 1994; Kannegieter and Dore, 1995; Lumsden et al., 1995; Weishaupl et al., 1997), permanent EE with obstructing aryepiglottic folds (Morris and Seeherman, 1990), aryepiglottic fold collapse (Hackett et al., 1994; Kannegieter and Dore, 1995; Parente and Martin, 1995), aryepiglottic fold lutter (Kannegieter and Dore, 1995) vocal fold prolapse (Hackett et al., 1994; Lumsden et al., 1995), vocal cord lutter (Kannegieter and Dore, 1995), epiglottic retroversion (Parente and Martin, 1995; Derksen et al., 1997), epiglottic lutter (Kannegieter and Dore, 1995), collapse of the roof of the nasopharynx (Strand and Staempfli, 1993; Hackett et al., 1994), prolapse of the cranial part of the soft palate (Holcombe et al., 1997), rostral displacement of the palatoaryngeal arch (Lumsden et al., 1995) and a combinatin of several disorders (Kannegieter and Dore, 1995; Lumsden et al., 1995). The most frequently observed dysfunctions are DDSP and LH with a range of 21 to 52 % and 9 to 25 % of all upper airway obstructions, respectively (Stick et al., 1991; Morris and Seeherman, 1991; Rekestraw et al., 1991; Hackett, et al., 1994; Parente and Martin, 1995; Kannegieter and Dore, 1995; Lumsden et al., 1995).
The limitation of endoscopy during exercise is that it requires subjective interpretation of airway function. Upper airway function can be evaluated objectively by quantitative methods like upper airway pressure and airflow measurements (pneumotachography).

In conclusion, examination of the upper respiratory tract during exercise on high-speed treadmills can be a useful tool in evaluation of upper respiratory tract disorders. It has been shown that many functional disorders only occur during high intensity exercise. On the other hand some abnormalities observed at rest do not produce a functional disorder during exercise. But the evaluation on the treadmill should not be used as a routine diagnostic tool. A good history, careful physical examination and endoscopic examination at rest are prerequisites before dynamic evaluation can be indicated. Many horses with a functional upper airway obstruction during exercise have a history of an abnormal respiratory noise during exercise or suggestive diagnostic findings at examination at rest. Videolaryngoscopy during treadmill exercise as a subjective technique already can accomplish a good evaluation of the upper airway function. But a final diagnosis of the presence of a respiratory limitation can only be made by quantitative measurement of respiratory mechanics (airway pressure and flow-volume measurement). Videolaryngoscopy coupled with these objective methods is currently considered the optimum method to evaluate upper airway function.

**Literature**


Dr. Sabine Kästner, M Vet Sci
Dr. M. Weishaupt
VETERÄR-CHIRURGISCHE KLINIK DER UNIVERSITÄT ZÜRICH
WINTERTHURERSTRASSE 260.
CH-8057 Zürich, Schweiz
Tel.: ++41-1-635-94-34
Fax: ++41-1-635-89-05
E-mail: skaest@vetchr.unizh.ch

Professor of Large Animal Medicine
Department of Veterinary Internal Medicine
Western College of Veterinary Medicine,
University of Saskatchewan
52 Campus Drive
Saskatoon, SK S7N 5B6,
Canada
Phone: ++1 (306) 966-7097
Fax: ++1 (306) 966-8747
E-mail: townsend@admin3.usask.ca

Pferdeheilkunde 14
Evaluation of the upper respiratory tract in the horse during treadmill exercise – A review
Part II: Measurement of upper airway flow mechanics

Sabine B. R. Kästner1, M. A. Weishaupt1 and H.G.G Townsend2

1 Veterinär-Chirurgische Klinik der Universität Zürich, Zürich, Schweiz
2 Department of Veterinary Internal Medicine, Western College of Veterinary Medicine, University of Saskatchewan SK S7N 5B, Canada

Summary

Literature pertaining to the evaluation of the upper respiratory tract of the horse during exercise was reviewed. Articles were found by searching two databases. Videendoscopy of the upper airways during exercise is presented in part I of this review. Part II describes upper airway pressure and airflow measurements for objective assessment of the presence of a respiratory limitation. Different measurement techniques and definitions of upper airway pressure as well as airflow measurement techniques are described. Upper airway pressures and flow indices increase linearly with increasing exercise. Airflow resistance as caused by laryngeal hemiplegia grade IV increases negative upper airway pressure and limits inspiratory flow. Dorsal displacement of the soft palate alters both inspiratory and expiratory pressures.

Keywords: horse, airflow, upper airway pressure, flow resistance, flow-volume loop

Beurteilung der oberen Luftwege des Pferdes während der Belastung auf dem Laufband – Eine Literaturstudie

Teil II: Messung der Atemmechanik der oberen Luftwege


Die Kombination einer Belastungsendoskopie mit einer der hier beschriebenen Methoden gilt als das derzeitige Optimum zur Beurteilung der Funktion der oberen Atemwege des Pferdes unter Belastung.

Schlüsselwörter: Pferd, Atemstromstärke, Trachealdruck, Atemwegswiderstand, Atemstrom-Volumen Schleife

Introduction

The importance of the evaluation of the upper respiratory tract function during exercise lies in the fact that many functional disorders are not apparent at rest. On the other hand abnormal findings at rest do not necessarily mean a respiratory limitation during exercise (Williams et al., 1990a, 1990b, Morris and Seeherman, 1991). In addition, some methods are not sensitive enough to diagnose mild disease stages at rest.
There are different methods of assessing upper respiratory function in exercising horses. These include endoscopy, upper airway pressure measurement and airflow measurement (pneumotachography). Recently there have been many advances in the techniques and the knowledge about the diagnostic value of these tests. The purpose of this review is to list the different techniques of upper respiratory tract evaluation in the horse during exercise, and describe their indications, usefulness and diagnostic value.

Part I described exercise endoscopy. In Part II the measurement of airflow and upper airway pressures are presented.

Material and Methods

The methods used for localization of the literature pertaining to the evaluation of the upper airways during exercise are given in part I of this review (Kästner et al., 1998).

Results

Upper airway pressure measurements

Techniques

The simplest test of upper airway function is the measurement of the pressure gradient along the upper airway. Several measurement techniques and definitions for upper airway pressure have been used. A catheter (polyethylene, polytetrafluoroethylene, teflon tubing) is placed percutaneously through the wall of the trachea into the cranial part of the trachea (Derkson et al., 1986; Shappell et al., 1988; Funkquist et al., 1988; Williams et al., 1990a; Lumsden et al., 1993; Roethlisberger-Holm, 1993) or nasotracheally (Williams et al., 1990a; Williams et al., 1990b; Ducharme et al., 1994; Rehder et al., 1995) into the pharynx and the cranial part of the trachea. Williams and assistants (1990a) have shown that the pressure recordings via a transnasal catheter are not different from recordings made by a transtracheal catheter but less invasive and therefore more suitable for clinical use. The static pressure is measured by differential pressure transducers and the pressure changes are recorded continuously during the respiratory cycle. Several different definitions for upper airway pressure are reported: Intratracheal pressure (Funkquist et al., 1988; Roethlisberger-Holm, 1993), the pressure difference between the pressure recordings in the trachea and pressure recordings at the horse's mouth (Derkson et al., 1986, Shappell et al., 1988; Lumsden et al., 1993), the difference between tracheal pressure and atmospheric pressure (Williams et al., 1990a), the difference between tracheal and pharyngeal pressure (Ducharme et al., 1994; Rehder et al., 1995) and the difference between pharyngeal and mask pressure (Bayly et al., 1994). Most studies use the measurement of peak static tracheal and pharyngeal pressures to evaluate the function of the upper respiratory tract based on the assumption that peak pressures cause collapse or vibration of the proximal part of the airways. A study on repeatability and normal values for measurements of pharyngeal and tracheal pressures (Ducharme et al., 1994) has shown that mean pressure measurements have better repeatability than peak pressure measurements. At least 96% of all mean pressure measurements were within 5 cmH₂O of the mean value for any horse. At least 96% of all peak pressure measurements were within 10 cmH₂O of the mean peak pressure measurements for any horse.

Pressure Measurement during Exercise

Normal Function of the Upper Airways

Several experimental studies have shown that pressure along the upper respiratory tract increases with increasing exercise (Table 1). Because of the different definitions for upper airway pressure it is difficult to directly compare the results from the different research groups. Similar pressures in the upper respiratory tract as during exercise can be achieved during nasal occlusion (Holcombe et al., 1996).

Abnormal Function of the Upper Airways

Laryngeal Hemplegia (LH)

Studies on experimentally induced laryngeal hemplegia grade IV (neurectomy or anesthesia of the recurrent nerve) agree on significantly increased (negative) inspiratory upper airway pressures (Derkson et al., 1986; Funkquist et al., 1988; Shappell et al., 1988; Williams et al., 1990a; Lumsden et al., 1994; Ducharme et al., 1994) compared to healthy horses. Williams and assistants (1990a) also observed a significant increase in expiratory pressure. Horses with complete laryngeal hemplegia were readily identified by measurement of tracheal and pharyngeal pressures (Ducharme et al., 1994), but it still needs to be determined how sensitive and useful these measurements are in less severe grades of LH.

Dorsal Displacement of the soft Palate (DDSP)

To correctly identify the occurrence of DDSP in the exercising horse it is necessary to perform endoscopy during exercise. It has been shown that the presence of a 9 mm endoscope in the upper respiratory tract does not interfere with pressure measurements in the trachea and the pharynx (Ducharme et al., 1994). Compared with clinically normal horses, horses with intermittent DDSP did not have excessive negative inspiratory pressures before displacement during exercise (Rehder et al., 1995). Displacement of the soft palate occurred during inspiration, expiration or after swallowing. Some horses displaced the soft palate at the initiation of exercise, some at peak speed and some while slowing down (Rehder et al., 1995). But the same horse
seems to displace consistently at the same time in the breathing cycle when subjected to the exercise test repeatedly. After displacement the airway pressures were significantly altered. Pharyngeal and tracheal inspiratory pressures were decreased, pharyngeal expiratory pressure decreased and tracheal expiratory pressure increased (Rehder et al., 1995), indicating mainly an impairment of expiration.

Tab. 1: Normal values for peak pressures in the upper airways in exercising horses.

<table>
<thead>
<tr>
<th>Inspiratory Tracheal Pressure</th>
<th>Expiratory Tracheal Pressure</th>
<th>Inspiratory Pharyngeal Pressure</th>
<th>Expiratory Pharyngeal Pressure</th>
<th>Speed</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>-12 to -24 mm Hg</td>
<td>6 to 8 mm Hg</td>
<td>-20 to -26 cm H₂O</td>
<td>10 to 24 cm H₂O</td>
<td>7 m/s</td>
<td>Funkquist et al., 1988</td>
</tr>
<tr>
<td>-40 to -50 cm H₂O</td>
<td>15 to 28 cm H₂O</td>
<td>-20 to -26 cm H₂O</td>
<td>10 to 24 cm H₂O</td>
<td>14 m/s</td>
<td>Ducharme et al., 1994</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inspiratory Tracheal Pressure</th>
<th>Expiratory Tracheal Pressure</th>
<th>Speed</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>-29 to -30.6 cm H₂O</td>
<td>11.7 to 12.6 cm H₂O</td>
<td>gallop</td>
<td>Williams et al., 1990</td>
</tr>
<tr>
<td>-29.7 ± 4 cm H₂O</td>
<td>11.9 ± 1.5 cm H₂O</td>
<td>7.2 m/s</td>
<td>Shappell et al., 1988</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inspiratory Tracheal Pressure</th>
<th>Expiratory Tracheal Pressure</th>
<th>Speed</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-) 1.94 ± 0.22 cm H₂O</td>
<td></td>
<td>standing</td>
<td>Lumsden et al., 1994</td>
</tr>
<tr>
<td>(-) 22.29 ± 1.15 cm H₂O</td>
<td></td>
<td>75% HR max</td>
<td></td>
</tr>
<tr>
<td>(-) 38.57 ± 3.93 cm H₂O</td>
<td></td>
<td>HR max.</td>
<td></td>
</tr>
<tr>
<td>(-) 27.49 ± 3.36 cm H₂O</td>
<td>7.85 ± 1.51 cm H₂O</td>
<td>75% HR max.</td>
<td>Petsche et al., 1995</td>
</tr>
<tr>
<td>(-) 40.82 ± 3.92 cm H₂O</td>
<td>8.07 ± 1.90 cm H₂O</td>
<td>HR max.</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: 75% HR max.: 75% of the maximal heart rate; HR max.: Maximal heart rate

Other Abnormalities

Complicated epiglottic entrapment (thick membrane, ulcers) produced modest increases, uncomplicated entrapment and pharyngeal lymphoid hyperplasia grade IV produced slight increases in inspiratory (negative) pressure. Arytenoid chondropathy produced pressure changes similar to LH grade IV (Williams et al., 1990b).

Airflow Measurement

Techniques

Pressure can be affected by changes in flow rate as well as changes in resistance (impedance) of the upper airways. Therefore airflow needs to be measured to correctly assess a respiratory limitation. Upper airway resistance is defined as the ratio of peak upper airway pressure and peak airflow rates for a given inspiration or expiration. Airflow is measured by a pneumotachograph or an ultrasonic flow meter in addition (Robinson, 1992).

Mostly Fleisch pneumotachographs are used to measure airflow in humans and animals. A pneumotachograph measures the pressure difference over a tube with known diameter and resistance and along a laminar flow profile. This pressure difference is directly proportional to the flow. Integration over time equals the ventilated volume. The measurement accuracy of this system depends on the absolute pressure, temperature and humidity of the gas. Derksen and assistants (1986) used in their early experiments two No. 4 Fleisch pneumotachographs (Dynasclines, Blue Bell, Pa, USA) mounted on a facemask. Later a pneumotachograph with a diameter of 15.2 cm was developed for the use in exercising horses (Shappell et al., 1988; Belknap, et al., 1990; Lumsden et al., 1994). A tight fitting fiberglass mask mounted with the pneumotachograph is placed over the horse's nose. The mask allows free movement of the nostrils. A rubber shroud is used to seal the mask against the face. Pressure differences
across the pneumotachograph are measured with a differential pressure transducer (Model DP 45-22,Validyne Sales, Northridge, Ca, USA) and recorded on a physiograph (Model 8188, Gould Inc., Madison Hts., Mich., USA) (Shappell et al., 1988; Belknap et al., 1990; Lumsden et al., 1994).

Ultrasonic flowmeters measure the transmission time of ultrasound signals through a given flow channel. The speed of the gas flow is calculated from the difference of absolute transmission time of ultrasound beams with and against the airstream. With the known diameter of the flow channel the respiratory flow can be calculated. Integration of the flow over time gives the ventilated volume. Several different systems are in use for equine respiratory research like the Spiroson® (Figure 1) [Spiroson Scientific, Isier Bioengineering AG, Zurich, Switzerland (Buess et al., 1986; Weishaupt et al., 1995)], an ultrasonic phase-shift flowmeter [British patent application 8608906 (Woakes et al., 1987)] and a density corrected pneumotachometer [UF202, Novex Instruments Inc. Redmond, WA, USA (Beadle et al., 1995)].

![Horse equipped with a facemask and an ultrasonic flowmeter (Spiroson®) during exercise on a treadmill.](image)

**Fig. 1:** Horse equipped with a facemask and an ultrasonic flowmeter (Spiroson®) during exercise on a treadmill.

Pferd mit Atemmaske und Ultraschallgerät zur Messung der Atemstromstärke (Spiroson®) während der Bewegung auf dem Laufband.

**Upper Airway Flow Mechanics during Exercise**

**Normal Function of the Upper Airways**

Different experimental studies (Derksen et al., 1986; Shappell et al., 1988; Belknap et al., 1990; Lumsden et al., 1993; Lumsden et al., 1994; Connally and Derksen, 1994; Petsche et al., 1994; Guthrie et al., 1995) give normal values for horses without dysfunctions of the upper airway (Table 2). These studies have shown that increasing speed progressively increased respiratory frequency (f), tidal volume (VT), minute ventilation (VE), peak inspiratory flow (PIF), peak expiratory flow (PEF), mean inspiratory flow (MIF), mean expiratory flow (MEF), peak inspiratory pressure (PIP), and peak expiratory pressure (PEP). Inspiratory resistance (Zi) and expiratory resistance (Ze) remained unchanged during exercise (Derksen et al., 1986; Shappell et al., 1988; Belknap et al., 1990).

**Abnormal Function of the Upper Airways**

After surgically induced laryngeal hemiplegia grade 4 (neurectomy) no significant changes were observed at rest. Peak inspiratory pressure (Pip) and inspiratory resistance (Zi) were significantly increased at speeds 4.2 m/s and greater. Peak inspiratory flow was significantly decreased at speed 4.3 m/s (Derksen et al., 1986) or 7.2 m/s and greater (Shappell et al., 1988; Belknap et al., 1990; Weishaupt et al., 1995). This inspiratory limitation leads to an increased inspiratory time reflected in a significantly decreased expiratory time ratio (Te/Ti) at speeds of 4.2 m/s and greater. Weishaupt and assistants (1995) observed additionally a significant decrease in tidal volume, minute ventilation and peak expiratory flow at submaximal exercise levels in a reversible laryngeal hemiplegia model (anesthesia of the left recurrent nerve), reflecting an inspiratory as well as an expiratory limitation.

![Tidal Breathing Flow Volume Loop from a horse with laryngeal hemiplegia grade IV at a heart rate of 200 (V200). Note the early peak flow and the plateau formation during inspiration.](image)

**Fig. 2:** Tidal Breathing Flow Volume Loop von einem Pferd mit Hemiplegia laryngis Grad IV bei einer Herzfrequenz von 200 (V200). Während der Inspiration sind die frühzeitige Spitzenatemstromstärke und die Plateaubildung zu beachten.
Different surgical procedures for the treatment of LH and DDSP have been evaluated with this method. It could be shown that laryngoplasty alleviated the flow limitations of induced LH (Derkson et al., 1986; Shappell et al., 1988). Ventriculocordectomy additionally did not further improve upper airway function (Teters et al., 1996). No improvement could be observed after ventriculocordectomy (Shappell et al., 1988) and subtotal arytenoidecotomy (Beknap et al., 1990). Partial arytenoidecotomy improved respiratory flow limitations at submaximal exercise but at near maximal exercise some inspiratory flow limitations remained (Lumsden et al., 1994).

Tab. 2: Upper airway flow mechanics in normal horses, effect of exercise.

<table>
<thead>
<tr>
<th>At rest</th>
<th>4.2 m/s HR 75 max</th>
<th>11 m/s HR max</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (1/min)</td>
<td>30.8± 1.1 to 50 ± 9</td>
<td>143.6 ± 18.5 to 185 ± 3</td>
</tr>
<tr>
<td>f (1/min)</td>
<td>15.6 ± 3.1 to 33 ± 3</td>
<td>67.2 ± 3.5 to 97.3 ± 9.7</td>
</tr>
<tr>
<td>VT (L)</td>
<td>5.39 ± 0.39 to 6.02 ± 0.92</td>
<td>11.69 ± 0.94 to 13.11 ± 0.8</td>
</tr>
<tr>
<td>VE (L/min)</td>
<td>147 ± 0.08 to 151.41 ± 15.01</td>
<td>950.23 ± 59.02 to 1256 ± 63</td>
</tr>
<tr>
<td>PIF (L/sec)</td>
<td>4.3 ± 0.5 to 7.2 ± 0.8</td>
<td>38 ± 4.7 to 56.3 ± 1.0</td>
</tr>
<tr>
<td>PEF (L/sec)</td>
<td>4.9 ± 1 to 7.9 ± 1.1</td>
<td>40.1 ± 4.2 to 47.5 ± 4.5</td>
</tr>
<tr>
<td>Pui (cm of H2O)</td>
<td>1.94 ± 0.22 to 2.4 ± 0.4</td>
<td>20.9 ± 3.8 to 22.29 ± 1.15</td>
</tr>
<tr>
<td>Pue (cm of H2O)</td>
<td>1.5 ± 0.2 to 1.8 ± 0.4</td>
<td>7.3 ± 0.5 to 9.5 ± 2</td>
</tr>
<tr>
<td>Zi (cm of H2O/L/s)</td>
<td>0.38 ± 0.04 to 0.63 ± 0.08</td>
<td>0.37 ± 0.06 to 0.53 ± 0.06</td>
</tr>
<tr>
<td>Ze (cm of H2O/L/s)</td>
<td>0.14 ± 0.03 to 0.43 ± 0.11</td>
<td>0.16 ± 0.02 to 0.25 ± 0.06</td>
</tr>
<tr>
<td>Ti (sec)</td>
<td>0.74 ± 0.08 to 1.99 ± 0.65</td>
<td>0.32 ± 0.04 to 0.38 ± 0.02</td>
</tr>
<tr>
<td>Te (sec)</td>
<td>0.92 ± 0.11 to 2.23 ± 0.77</td>
<td>0.33 ± 0.04 to 0.39 ± 0.03</td>
</tr>
<tr>
<td>Te/Ti</td>
<td>0.99 ± 0.05</td>
<td>0.94 ± 0.03</td>
</tr>
</tbody>
</table>

Abbreviations: HR = heart rate, f = respiratory frequency, VT = tidal volume, VE = minute ventilation, PIF = peak inspiratory flow, PEF = peak expiratory flow, MIF = mean inspiratory flow, MEF = mean expiratory flow, Pui = inspiratory pressure (tracheal pressure - mask pressure), Pue = expiratory pressure (tracheal pressure - mask pressure), Zi = inspiratory impedance, Ze = expiratory impedance, Ti = inspiratory time, Te = expiratory time, Te/Ti = ratio expiratory time : inspiratory time.

Myectomy of the sternothyrohyoid muscle is often used as a treatment for DDSP. But in healthy horses myectomy increased the negative inspiratory pressures and inspiratory resistance in the upper respiratory tract (Holcombe et al., 1994).

Tidal Breathing Flow Volume Loops (TBFVL)

The clinical use of upper airway pressure and impedance measurement is limited (Stick and Derksen, 1989; Williams et al., 1990b) because of its invasive nature. Flow-volume analysis is a common test for respiratory function in humans because it is noninvasive and sensitive. But sensitivity, specificity and repeatability of the test depends on patient cooperation for maximal inhalation and exhalation (Lumsden et al., 1993). In human neonates and infants tidal breathing flow volume loops (TBFVL) have been evaluated. This variation of the test lacks sensitivity and has great flow variability compared to maximal breathing (Abramson et al., 1982). Qualitative and quantitative analysis of flow-volume-loops and airflow rates at rest in Standardbreds has shown large intra- and interhorse variations for the TBFVL indices (Lumsden et al., 1993) reflecting different breathing strategies in the individual horse. This limits the clinical usefulness of TBFVLs obtained in resting horses. During high-speed treadmill exercise airflow of horses are near maximal breathing (Beknap et al., 1990). The coefficients of variation for TBFVL indices progressively decreased with increasing exercise level indicating that respiratory patterns became less variable (Lumsden et al., 1993). Evaluation of upper airway function by TBFVLs requires the same equipment and near maximal exercise protocols as airflow measurements described above. Specific computer software allows the analysis of loop shape and quantitative TBFVL indices (Petsche et al., 1994). Loops are usually calculated by the means of 10 breaths, loop closure is accepted as adequate if there is less than 5% difference in expiratory and inspiratory volume.
Normal Function of the Upper Airways

At rest four basic shapes occurred. The inspiratory curve was mono-, bi- or triphasic with PIF early or late in inspiration, the expiratory flow was biphasic with peak flow early in expiration. During exercise inspiratory flow was monophasic, biphasic or a combination of both, predominantly a biphasic inspiratory shape occurred. The expiratory curve was mono- or biphasic. (Lumsden et al., 1993). Representative values for TBFVL indices in healthy horses are given by Lumsden and assistants (1993) and Petsche and assistants, (1994).

Abnormal Function of the Upper Airways

After surgically induced LH grade 4 (LRLN) no changes in loop shape were seen at rest (Lumsden et al., 1993). During submaximal and near maximal exercise loop shapes were markedly altered. The inspiratory limb shows a peak flow early in inspiration followed by a marked reduction in airflow [plateau formation] (Figure 2). The expiratory curve is approximately the same as in normal horses. After induced LH grade IV mainly the inspiratory indices were altered. PEF/PIF, the expiratory flow at 50% of the volume: inspiratory flow at 50% of the volume ratio (EF 50/IF 50) and Ti/Ttot increased and PIF decreased significantly at submaximal and near maximal exercise. IF 50, IF 25 and Te/Ti decreased significantly at near maximal exercise compared to normal horses (Lumsden et al., 1993, Lumsden et al., 1994).

Flow measurements in horses with DDSP are presently difficult to perform because it is almost impossible to determine when the horse displaces the palate without a concurrent videendoscopy (Pehnder et al., 1995). In addition, horses with DDSP tend to start mouth breathing. Mouth breathing produces a high amount of saliva which can interfere with the flow measurement technique. In conclusion, examination of the upper respiratory tract during exercise on high-speed treadmills can be a useful tool in evaluation of upper respiratory tract disorders. It has been shown that many functional disorders only occur during high intensity exercise. On the other hand some abnormalities observed at rest do not produce a functional disorder during exercise. An evaluation on the treadmill should not be used as a routine diagnostic tool. A good history, careful physical examination and endoscopic examination at rest are necessary before dynamic evaluation is indicated. Many horses with a functional upper airway obstruction during exercise have a history of an abnormal respiratory noise during exercise or suggestive diagnostic findings at examination at rest. Videendoscopy during treadmill exercise as a subjective technique already can accomplish a good assessment of the upper airway function. But a final diagnosis of the presence of a respiratory limitation can only be made by the quantitative measurement of respiratory mechanics (airway pressure and flow-volume measurement). Videendoscopy coupled with these objective methods is currently considered the optimum method to evaluate upper airway function.

Literature


---

**Ultraschall beim Pferd**
**Gynäkologie, Andrologie und Orthopädie**
**aktuelle Therapie Fohlenintensivmedizin**

**5. Fortbildungsveranstaltung der Tierklinik Partners**

**28. Februar 1998**

**Referenten:**
Dr. G. Stadtbäumer, Telgte
Dr. Dr. habil. W. Kühn, Kaufungen

**Ort und Veranstalter:**
Tierklinik Partners,
Brummattstr. 10–15, 79684 Wehr, Tel.: 07762-51144
und Gesellschaft für Pferdedie Medizin
Beginn: 9.00 Uhr, Ende 18.00 Uhr

**Teilnahmegebühr:**
DM 250.– + 15% MWST = DM 287,50