Airflow Mechanics, Upper Respiratory Diagnostics, and Performance-Limiting Pharyngeal Disorders

John C. Janicek, DVM, MS, DACVS[a]
Karissa M. Ketzner, DVM
University of Missouri

ABSTRACT: Performance-limiting upper respiratory disorders in horses are frequently encountered throughout all equestrian disciplines. Most upper respiratory disorders alter airflow mechanics and respiratory physiology, resulting in audible respiratory noises, poor performance, or exercise intolerance. Affected horses in some equestrian disciplines may not exhibit poor performance or exercise intolerance but can be disqualified from competition because of audible upper respiratory noises. Diagnosis of upper respiratory disorders requires endoscopy with the patient at rest, high-speed treadmill videoendoscopy, radiography, sound spectrum analysis, or a combination of diagnostic modalities. In affected horses, the pharynx (which is unsupported by bone or cartilage) commonly requires either medical or surgical intervention to reestablish airway patency and allow the horse to maintain an active performance status.

The upper airway is the primary conduit of airflow between the nasal passage and the lungs, allowing sufficient gas exchange between the air and the pulmonary circulation.[1] The equine upper airway (Figures 1 and 2) is a high-resistance, low-capacity ventilatory passage, and airway obstruction causes increased respiratory effort and poor performance. Exercise demands a ventilation rate of approximately 1,500 L/min, resulting in delivery of a high volume of oxygen and elimination of a large quantity of carbon dioxide. During inspiration, negative alveolar pressure creates a force that causes environmental air movement into the lungs, whereas positive pressure drives air out of the lungs against atmospheric pressure during expiration. During high-intensity exercise, peak pressure in the trachea is approximately –30 cm H_2O during inspiration and 15 cm H_2O during expiration.[2] The greater the exercise intensity, the greater is the airflow rate and the larger the pressure change.

[a]Dr. Janicek is currently affiliated with Weems and Stephens Equine Hospital in Aubrey, Texas.

AIRFLOW MECHANICS

Airway resistance (the pressure:flow ratio) is greatly affected by airway diameter. Cylindric tube resistance (R) can be calculated using the

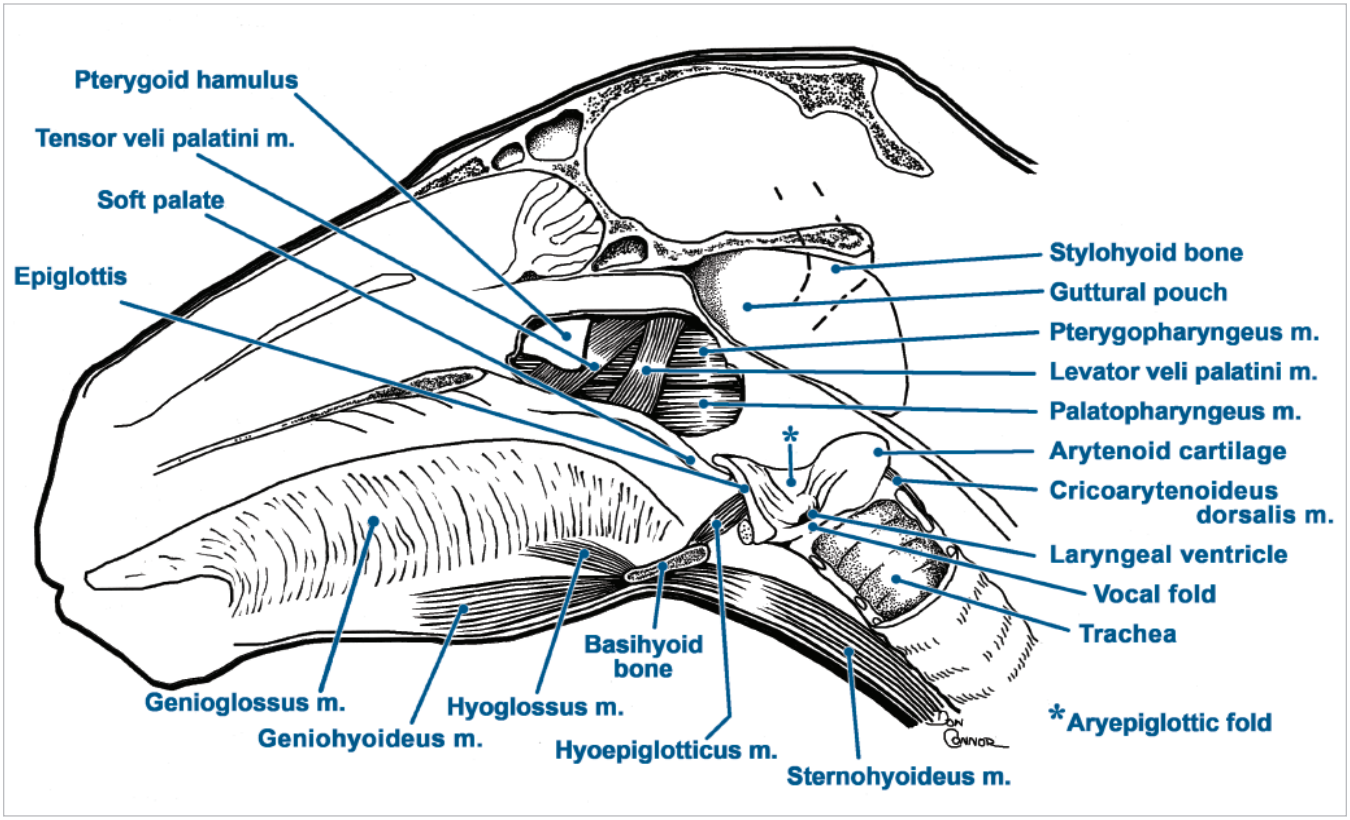

Figure 1. Illustration of the equine upper airway anatomy from a midline sagittal view. (Illustration by Don L. Connor, University of Missouri)

following formula (n = gas viscosity; L = length of trachea; r = radius of trachea):

$$R = (8 \times nL) \div r^4$$

Gas viscosity, which affects the pressure:flow relationship, is constant.[3] Because the radius is to the fourth power, a small difference in airway radius has a major impact on airway resistance. A 20% decrease in the airway radius doubles airflow resistance.[1] In resting horses, two-thirds of the total airflow resistance during inspiration and expiration is in the upper airway.[4] During inspiration, negative pressure causes unsupported tissue to be drawn into the airway, resulting in upper airway narrowing; thus upper airway resistance during exercise becomes more than 80% of the total airflow resistance.[4] During expiration while a horse exercises, upper airway resistance accounts for approximately 50% of the total airflow resistance because the airway diameter is enlarged by positive pressure.[4]

Most mammals can breathe by mouth during exercise, providing a low-resistance pathway to accommodate the greater airflow requirement and thereby minimizing the work of breathing. However, the anatomic relationship of the larynx and caudal soft palate makes horses obligate nasal breathers. During exercise, the 20-fold increase in airflow while breathing must occur through the nose.[4]

Other factors affecting upper airway function include head position and vascular engorgement. In resting horses, air entering the upper airway turns approximately 90 degrees to flow from the nasal passage into the trachea. During normal exercise, most horses straighten their head and neck, increasing the angle of the pharynx through which air flows and thereby reducing the work of breathing.[3] Straightening of the airway not only allows a more direct route to the lungs but also tends to stretch upper airway tissue, making it more resistant to collapse.[1] In some equestrian disciplines, horses carry their heads and necks in extended or flexed positions. For example, Thoroughbreds are raced with their head and neck extended, whereas the head and neck are often flexed in Standardbreds and in sporting events such as show jumping and dressage. Clini-

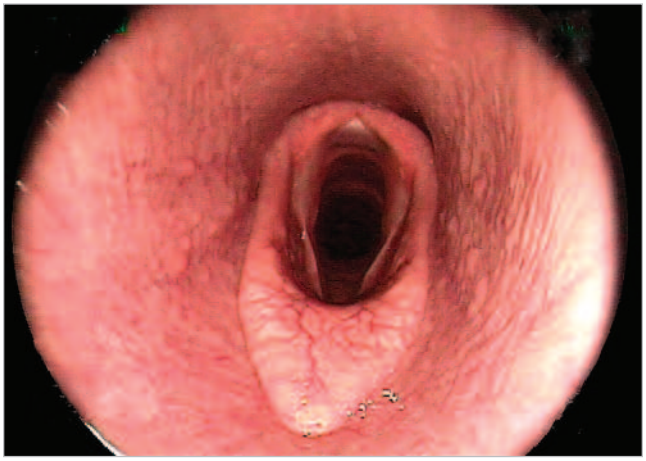

Figure 2. Normal endoscopic appearance of the equine upper airway.

Figure 3. High-speed treadmill videoendoscopy. This diagnostic method allows visualization of dynamic airway disturbances that cannot be visualized during endoscopy with the patient at rest.

cal signs of obstructive airway disease are often more evident when a horse's head and neck are flexed. It has been demonstrated that when a horse's head and neck are flexed, upper airway impedance is twice that of a horse exercising with its head extended.[3] Head and neck flexion not only increases the work of breathing but also makes the upper airway tissue more prone to dynamic collapse.[1]

DIAGNOSTIC TECHNIQUES

Most performance-limiting upper airway disorders are diagnosed using endoscopy with the patient at rest, videoendoscopy during high-speed treadmill exercise, radiography, and sound spectrum analysis. These diagnostic tools permit a clinician to differentiate between inspiratory and expiratory upper airway disorders. Endoscopy allows the observation of commonly diagnosed mechanical airway obstructions such as severe laryngeal hemiplegia, arytenoid chondritis, persistent dorsal displacement of the soft palate (DDSP), epiglottic entrapment, and subepiglottic cysts. The primary limitations of endoscopy of the upper respiratory system include the inability to (1) observe dynamic airway disorders, (2) confirm that an observed abnormality is impeding athletic performance, (3) observe multiple disorders that may occur simultaneously (complex disorders), and (4) evaluate the efficacy of treatments for performance-limiting upper respiratory disorders.

When the limitations of endoscopy with the patient at rest prevent a diagnosis, videoendoscopy during high-speed treadmill exercise (Figure 3) may be necessary to understand the source(s) of a horse's performance-limiting upper respiratory disorder(s).[5] High-speed treadmill videoendoscopy permits detection of dynamic upper respiratory disorders such as intermittent DDSP, laryngeal hemiplegia, dynamic collapse of the arytenoid cartilage, pharyngeal collapse, intermittent epiglottic entrapment, epiglottic retroversion, and axial deviation of the aryepiglottic folds. Multiple forms of dynamic collapse occur in 30% of horses with upper respiratory disorders; therefore, treatments that address solitary disorders may often be unsuccessful.[6] Together, DDSP and palatal instability (instability of the caudal edge of the soft palate), along with axial deviation of the aryepiglottic fold, accounted for 50% of the multiple forms of dynamic collapse that occurred during high-speed

Physical examination, radiography, and resting endoscopy may reveal obvious upper respiratory disorders; however, high-speed treadmill videoendoscopy and/or sound spectrum analysis may be required to evaluate subtle performance-limiting upper respiratory disorders.

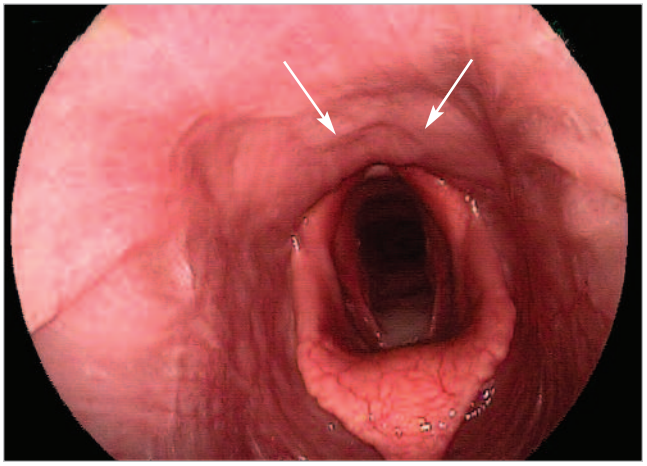

Figure 4. Dorsal pharyngeal collapse. In this case, mild dorsal pharyngeal collapse (*arrows*) is occurring during endoscopy with the patient at rest. Stylopharyngeus caudalis muscle dysfunction results in nasopharyngeal collapse and, ultimately, occlusion of the rima glottidis.

treadmill videoendoscopy in one study.[6] In the same study, laryngeal hemiplegia in combination with another upper respiratory disorder accounted for 31% of the multiple forms of dynamic collapse during high-speed treadmill videoendoscopy.[6]

In conjunction with endoscopy, radiography can be used to identify subepiglottic cysts, DDSP, epiglottic entrapment, and calcification of the arytenoid cartilage associated with arytenoid chondritis.

Sound spectrum analysis is not widely used outside of academia but has proven to be useful in analyzing respiratory noises during exercise.[7,8] Spectrograms that analyze recurrent laryngeal neuropathy and DDSP are available.[9] In the future, individual upper respiratory noises will likely have a specific "voiceprint," allowing sound spectrum analysis to be used in the field.

SURGERY

Most patients with performance-limiting upper airway disorders can be surgically managed and have a favorable prognosis for return to athletic performance. The main objectives of surgical intervention in all upper respiratory disorders are stabilization of the upper airway and prevention of its collapse.

THE PHARYNX

The pharynx is a musculomembranous tubular structure that is unsupported by bone or cartilage, extends from the caudal end of the nasal cavity to the larynx, and is equally divided by the soft palate to form the nasopharynx dorsally and the oropharynx ventrally.[10] The intrinsic muscles of the pharynx include the tensor veli palatini, which is innervated by the mandibular branch of the trigeminal nerve; the levator veli palatini, palatinus, and palatopharyngeus, which are innervated by the pharyngeal branch of the vagus nerve; and the stylopharyngeus, which is innervated by the glossopharyngeal nerve.[10] All of these muscles contribute to nasopharyngeal stability by means of timely muscular contractions that tense and dilate the pharyngeal wall.[10] The extrinsic muscles of the pharynx include the hyoepiglotticus, genioglossus, and geniohyoideus, which are innervated by the hypoglossal nerve; the sternohyoideus and sternothyroideus, which are innervated by the ventral branches of the first and second cervical nerves; and the thyrohyoideus, which is innervated by the pharyngeal branch of the vagus nerve.[10] All of these muscles of the larynx and hyoid apparatus permit an increase in the pharyngeal diameter or increase the stability of the soft palate.[10]

Pharyngeal disorders that are recognizable only during strenuous exercise can be difficult to diagnose and have been treated with limited success. For example, the etiologies of intermittent DDSP and persistent DDSP appear to be different and should, therefore, be addressed accordingly.[11] Furthermore, pharyngeal abnormalities in horses are not always single entities and can be associated with multiple forms of upper respiratory dynamic collapse.[6,12]

Rostral Pharyngeal Collapse

Rostral pharyngeal collapse is the fluttering of the rostral aspect of the soft palate and may be a precursor to DDSP. This condition has been reproduced experimentally by bilaterally transecting the tendon of the tensor veli palatini muscle.[13] Affected horses make an upper respiratory expiratory noise because of rostral soft palate billowing, which can be diagnosed only during high-speed treadmill videoendoscopy.[10] The clinical significance of this condition as it relates to athletic performance is unknown; however, this condition may interfere with inspiration. A specific surgical treatment has not been objectively proven, but oral thermal or tension palatoplasty or rostral nasal laser thermoplasty may be useful.[10,14,15] Also, if significant inflammation is present, antiinflammatory treatment may be indicated. This condition should not be confused with palatal instability, which is defined as progressive dorsoventral movements of the caudal portion of the soft palate with

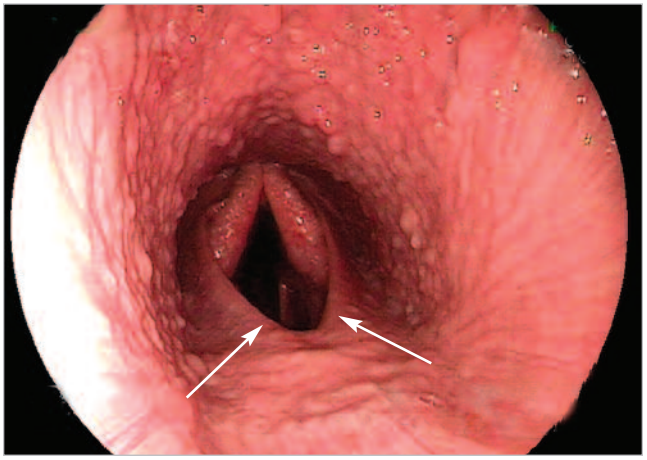

Figure 5. Dorsal displacement of the soft palate. As the soft palate displaces dorsally (*arrows*), the epiglottis can no longer be visualized in the nasopharynx. Consequently, an expiratory disturbance occurs because the caudal border of the soft palate billows and vibrates throughout expiration.

flattening of the ventral surface of the epiglottis against the dorsal surface of the soft palate.[6]

Dorsal Pharyngeal Collapse

Dorsal pharyngeal collapse is an inspiratory upper airway disturbance that causes respiratory noise and exercise intolerance. This condition can be observed as (1) unilateral or bilateral ventral displacement of the nasopharyngeal roof or (2) axial displacement of the lateral nasopharyngeal walls.[16] In exercising horses, a certain degree of nasopharyngeal collapse is normal at the end of expiration; however, if the nasopharynx collapses to occlude the rima glottidis, exercise intolerance results (Figure 4). A diagnosis can be made using endoscopy with nasal occlusion or during high-speed treadmill exercise. Stylopharyngeus caudalis muscle dysfunction causes collapse of the pharyngeal roof.[17] It is presumed that palatopharyngeus muscle dysfunction results in collapse of the lateral pharyngeal walls. The etiology is unknown but may be attributable to inflammation or neuritis of the glossopharyngeal nerve or the pharyngeal branch of the vagus nerve.[10] The prognosis for a return to high-speed performance is guarded. Either systemic or topical pharyngeal antiinflammatory treatment should be instituted if inflammation is the suspected cause.[10] Surgical treatment options are limited; however, I (JCJ) have successfully managed some cases of dorsal pharyngeal collapse by using focal laser-facilitated nasopharyngeal cauterization to induce dorsal pharyngeal fibrosis.

Dorsal Displacement of the Soft Palate

DDSP is an expiratory upper airway disturbance that occurs most frequently during intense exercise, although it can be diagnosed at rest. The noise made during expiration may be described as "choking down or swallowing the tongue." Permanent DDSP can be diagnosed using videoendoscopy with the patient at rest; however, high-speed treadmill videoendoscopy may be required to diagnose intermittent DDSP. A study that evaluated the occurrence of DDSP during high-speed treadmill exercise in racehorses determined that 38% of the horses had no previous history of abnormal upper respiratory noise and that 80% had normal results of endoscopic examinations while at rest.[12] When the soft palate displaces dorsally, the epiglottis cannot be observed within the nasopharynx and is positioned within the oropharynx (Figure 5). In horses with DDSP, the caudal free margin of the soft palate billows and vibrates across the rima glottidis throughout expiration.[18] Consequently, an airway obstruction is created, resulting in increased tracheal expiratory pressure and impedance and reduced minute ventilation.[19] Permanent DDSP is uncommon and results from damage to the efferent motor innervation of the soft palate muscles and the dorsal pharyngeal constrictor muscles.[20] Intermittent DDSP during exercise is one of the more common performance-limiting conditions in athletic horses, and its etiology is currently unknown. It has been suggested that this condition is associated with elongated soft palates, subepiglottic cysts, epiglottic malformation or hypoplasia, caudal larynx retraction, caudal tongue retraction and mouth

Dorsal displacement of the soft palate is the most commonly treated pharyngeal performance-limiting upper respiratory disturbance; however, the etiology has not been completely elucidated, resulting in multiple treatment options and varying results.

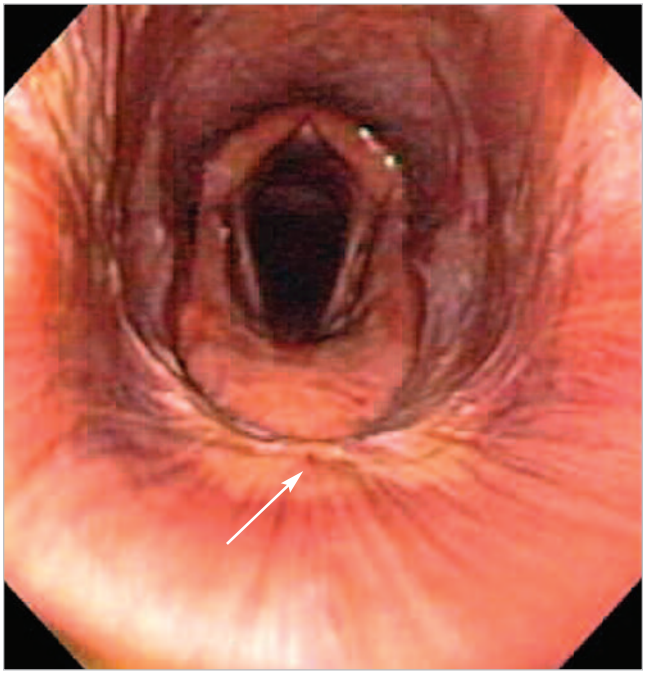

Figure 6. Nasopharyngeal cicatrix. An early case of nasopharyngeal cicatrix (*arrow*) that is characterized by an area of fibrous tissue initiating along the nasopharyngeal floor. This inflammatory process can progress into circumferential occlusion of the upper airway and cause disfigurement of the epiglottic, arytenoid, and medial cartilage of the guttural pouch. (Courtesy of Dr. Peter Rakestraw, Texas A&M University)

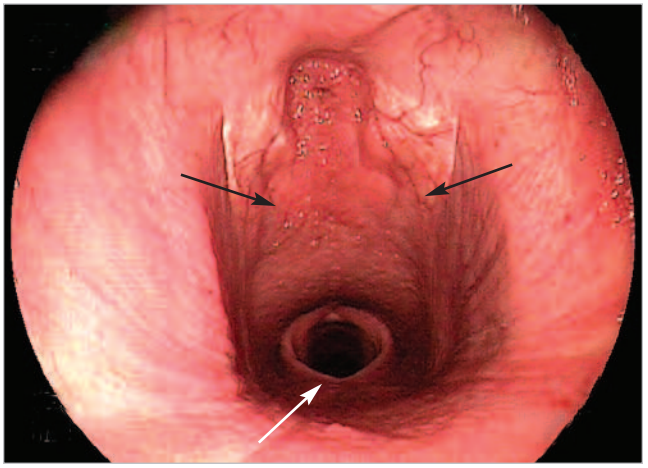

Figure 7. Pharyngeal lymphoid hyperplasia. Severe pharyngeal lymphoid hyperplasia (*black arrows*) is observed in the dorsal pharyngeal recess and dorsal aspect of the nasopharynx. Secondary dorsal displacement (*white arrow*) of the soft palate has occurred, possibly as a consequence of inflammation involving the pharyngeal branch of the vagus nerve. Cases this severe are likely to be performance limiting.

opening, or neuromuscular dysfunction.[12,19–23]

Initially, conservative management, such as administering antiinflammatory medication, changing tack, or using a figure-eight noseband, a tongue tie, or an external laryngohyoid support device, may be helpful in some cases.[24,25] However, it has been shown that a tongue tie does not improve upper airway mechanics in clinically normal horses or in horses that have undergone sternothyrohyoidectomy.[26,27] In addition, computed tomography has not detected a significant difference in pharyngeal diameter or cross-sectional area between horses with or without a tongue tie in place.[28] In one study, an external laryngohyoid support device significantly improved inspiratory and expiratory flow and impedance during exercise after experimental induction of DDSP.[25] This support device improves airflow probably by statically positioning the larynx and the basihyoid bone in a more rostral and dorsal position.[25]

Failure to respond to conservative management of DDSP necessitates surgical intervention if athletic performance is desired. Because no single surgical treatment for DDSP has been established as the gold standard, numerous procedures and modifications of these procedures have been reported in attempts to correct this airway disturbance. Intrinsic procedures, including staphylectomy, epiglottic augmentation, rostral palatoplasty, and caudal palatoplasty, are performed in attempts to stiffen the soft palate and/or epiglottic cartilage. Extrinsic procedures, such as sternohyoideus or sternothyroideus myectomy, are performed to reduce caudal retraction of the larynx. Combinations of intrinsic and extrinsic procedures are often performed in attempts to improve the outcome.

Staphylectomy can be used to shorten the soft palate; no more than 5 mm of the caudal edge of the soft palate should be resected. When performed alone, staphylectomy has a 60% success rate for treating DDSP.[29] Epiglottic augmentation is used to stiffen a flaccid epiglottis by injecting Teflon paste submucosally into aryepiglottic tissue. Although epiglottic augmentation is not common, it has a 66% success rate.[30] Rostral palatoplasty[15] (thermal or surgical) and caudal thermal palatoplasty[14] performed alone have success rates of 75% and 67%, respectively. Sternohyoideus and sternothyroideus (sternothyrohyoideus) myectomy alone is associated with success rates of 60% to 73%.[12,29,31–33] Numerous modifications of this procedure have produced varied results. When sternothyrohyoideus myectomy is combined with staphylec-

tomy or laser palatoplasty along the caudal edge of the soft palate on the pharyngeal or oral surfaces, success rates of 60% to 92% have been reported.[34–38]

In horses with experimentally created DDSP, a laryngeal tie-forward procedure replaced the function of the thyrohyoideus muscles and prevented DDSP during exercise.[39] By placing a suture prosthesis between the basihyoid bone and thyroid cartilage, this procedure results in approximately 4 cm of rostral laryngeal displacement and reestablishes stability of the laryngopalatal relationship.[39,40] With the use of laryngeal tie-forward, no significant difference in inspiratory and expiratory pharyngeal or tracheal pressures occurs between control and prosthesis-treated horses.[39] More recently, it was determined that 80% to 82% of horses treated with laryngeal tie-forward have a significant improvement in performance and earnings after surgery.[40]

Nasopharyngeal Cicatrix

Nasopharyngeal cicatrix is a stricturing web of fibrous tissue that initiates along the nasopharyngeal floor and can progress to encompass the circumference of the nasopharynx (Figure 6). Consequently, disfigurement of the epiglottic, arytenoid, or medial cartilage of the guttural pouch can occur, resulting in reduction of the rima glottidis diameter and interference with normal respiration.[41] The etiology is thought to be an environmental allergen, primarily associated with the Gulf Coast region, that causes severe inflammation and generalized nasopharyngeal and laryngeal ulceration.[41] Systemic antiinflammatory medication should be initiated and the horse removed from pasture immediately after diagnosis. Transendoscopic laser transection of the cicatrix can be performed if it is causing partial nasopharyngeal obstruction; however, permanent tracheostomy is often required if complete nasopharyngeal obstruction occurs. Partial arytenoidectomy should not be performed in horses with nasopharyngeal cicatrix because the resulting rima glottidis diameter is inadequate for normal respiration.

Pharyngeal Lymphoid Hyperplasia

Pharyngeal lymphoid hyperplasia appears as focal pinpoint areas of edema to coalescing edematous mucosal plaques that commonly involve the nasopharyngeal roof and dorsal pharyngeal recess (Figure 7). This finding is common in young horses and is thought to be the result of a local immune response. Unless pharyngeal lymphoid hyperplasia is severe, it is not usually performance limiting; however, it may predispose a horse to DDSP because of inflammation of the pharyngeal branch of the vagus nerve.[11]

Guttural Pouch Disease

Guttural pouch disease is not a common performance-limiting upper respiratory disorder; however, the cranial nerves that traverse the guttural pouch can become inflamed as a result of guttural pouch disease, causing dysfunction of the muscles they innervate and a secondary upper respiratory disorder. Guttural pouch empyema is the most common guttural pouch disease and can result in pharyngeal and/or laryngeal dysfunction. Distention of the guttural pouch due to chronic empyema or chondroid development may result in dorsal collapse of the pharyngeal wall. Although extensive guttural pouch mycosis is uncommon, it can also result in laryngeal and/or pharyngeal dysfunction; however, most cases of guttural pouch mycosis manifest as life-threatening epistaxis involving the maxillary, internal carotid, or external carotid arteries.

Watch for an upcoming companion article on performance-limiting laryngeal disorders.

Related Content on CompendiumEquine.com
• Recurrent Airway Obstruction (Heaves) (May 2008)

REFERENCES

1. Derksen FJ. Overview of upper airway function. In: Auer JA, Stick JA, eds. *Equine Surgery.* 3rd ed. Philadelphia: WB Saunders; 2006:516-521.
2. Tetens J, Derksen FJ, Stick JA, et al. Efficacy of prosthetic laryngoplasty with and without bilateral ventriculocordectomy as treatments for laryngeal hemiplegia in horses. *Am J Vet Res* 1996;57:1668-1673.
3. Petsche VM, Derksen FJ, Berney CE, et al. Effect of head position on upper airway function in exercising horses. *Equine Vet J Suppl* 1995;18:18-22.
4. Art T, Sertyn D, Lekeux P. Effect of exercise on the partitioning of equine respiratory resistance. *Equine Vet J* 1988;20:268-273.
5. Lane JG, Bladon B, Little DRM, et al. Dynamic obstructions of the equine upper respiratory tract. Part 2: comparison of endoscopic findings at rest and during high-speed treadmill exercise of 600 Thoroughbred racehorses. *Equine Vet J* 2006;38:401-408.
6. Lane JG, Bladon B, Little DRM, et al. Dynamic obstructions of the equine upper respiratory tract. Part 1: observations during high-speed treadmill endoscopy of 600 Thoroughbred racehorses. *Equine Vet J* 2006;38:393-399.
7. Cable CS, Ducharme NG, Hackett, et al. Sound signature for identification and quantification of upper airway disease in horses. *Am J Vet Res* 2002;63:1707-1713.
8. Franklin SH, Usmar SG, Lane JG, et al. Spectral analysis of respiratory noise in horses with upper airway disorders. *Equine Vet J* 2003;35:264-268.
9. Derksen FJ, Holcombe SJ, Hartmann W, et al. Spectrum analysis of respiratory sounds in exercising horses with experimentally induced laryngeal hemiplegia or dorsal displacement of the soft palate. *Am J Vet Res* 2001;62:659-664.
10. Ducharme NG. Pharynx. In: Auer JA, Stick JA, eds. *Equine Surgery.* 3rd ed. Philadelphia: WB Saunders; 2006:544-565.
11. Sullivan EK, Parente EJ. Disorders of the pharynx. *Vet Clin North Am Equine Pract* 2003;19:159-167.
12. Parente EJ, Martin BB, Tulleners EP, et al. Dorsal displacement of the soft palate

in 92 horses during high-speed treadmill examination (1993-1998). *Vet Surg* 2002;31:507-512.

13. Holcombe SJ, Ducharme NG. Effect of bilateral tenectomy of the tensor veli palatini muscle on soft palate function in horses. *Am J Vet Res* 1997;58:317-321.
14. Orddige RM. Thermal cautery of the equine soft palate as a treatment for displacement of the soft palate during exercise. *Proc 7th World Congress* 2001;7:287.
15. Ahren TJ. Oral palatopharyngoplasty: a survey of one hundred post-operative raced horses. *Equine Vet Sci* 1993;13:670-672.
16. Smith CM, Taylor RJ, Dixon PM. Unilateral ventral displacement of the roof of the nasopharynx as a cause of stridor in a pony. *Vet Rec* 1994;134:140-141.
17. Tessier C, Holcombe SJ, Derksen FJ, et al. Effects of stylopharyngeus muscle dysfunction on the nasopharynx in exercising horses. *Equine Vet J* 2004;36:318.
18. Franklin SH, Price C, Burn JF. The displaced equine soft palate as a source of abnormal respiratory noise during expiration. *Equine Vet J* 2004;36:290-294.
19. Rehder RS, Ducharme NG, Hackett RP, et al. Measurement of upper airway pressures in exercising horses with dorsal displacement of the soft palate. *Am J Vet Res* 1995;56:269-274.
20. Holcombe SJ, Derksen FJ, Stick JA, et al. Effect of bilateral blockade of the pharyngeal branch of the vagus nerve on soft palate function in horses. *Am J Vet Res* 1998;59(4):504-508.
21. Haynes PF. Persistent dorsal displacement of the soft palate associated with epiglottic shortening in two horses. *JAVMA* 1981;179:677-681.
22. Linford RL, O'Brien TR, Wheat JD, et al. Radiographic assessment of epiglottic length and pharyngeal and laryngeal diameters in the Thoroughbred. *Am J Vet Res* 1983;44:1660-1666.
23. Blythe LL, Cardinet GH 3rd, Meagher DM, et al. Palatal myositis in horses with dorsal displacement of the soft palate. *JAVMA* 1983;183:781-785.
24. Franklin SH, Naylor JR, Lane JG. The effect of a tongue-tie in horses with dorsal displacement of the soft palate. *Equine Vet J Suppl* 2002;34:430-433.
25. Woodie JB, Ducharme NG, Hackett RP, et al. Can an external device prevent dorsal displacement of the soft palate during strenuous exercise? *Equine Vet J* 2005;37:425-429.
26. Cornelisse CJ, Holcombe SJ, Derksen FJ, et al. Effect of a tongue-tie on upper airway mechanics in horses during exercise. *Am J Vet Res* 2001; 62:775-778.
27. Beard WL, Holcombe SJ, Hinchcliff KW. Effect of a tongue-tie on upper airway mechanics during exercise following sternothyroid myectomy in clinically normal horses. *Am J Vet Res* 2001;62:779-782.
28. Cornelisse CJ, Rosenstein DS, Derksen FJ, et al. Computed tomographic study of the effect of a tongue-tie on hyoid apparatus position and nasopharyngeal dimensions in anesthetized

horses. *Am J Vet Res* 2001;62:1865-1869.
29. Anderson JD, Tulleners EP, Johnston JK, et al. Sternothyrohyoideus myectomy or staphylectomy for treatment of intermittent dorsal displacement of the soft palate in racehorses: 209 cases (1986-1991). *JAVMA* 1995;206:1909-1912.
30. Tulleners EP, Stick JA, Leitch M, et al. Epiglottic augmentation for treatment of dorsal displacement of the soft palate in racehorses: 59 cases (1985-1994). *JAVMA* 1997;211:1022-1028.
31. Harrison IW, Raker CW. Sternothyrohyoideus myectomy in horses: 17 cases (1984-1985). *JAVMA* 1988;193:1299-1302.
32. Duncan DW. Retrospective study of 50 thoroughbred racehorses subjected to radical myectomy surgery for treatment of dorsal displacement of the soft palate. *Proc AAEP* 1997;43:237-238.
33. Llewellyn HR, Petrowitz AB. Sternothyroideus myotomy for the treatment of dorsal displacement of the soft palate. *Proc AAEP* 1997;43:239-243.
34. Carter B, Robertson J, Beard W, et al. Sternothyroideus myectomy, tenectomy, and staphylectomy for treatment of dorsal displacement of the soft palate in horses. *Vet Surg* 1993;22:374.
35. Bonenclark G, Bryant J, Hernandez J, et al. Sternothyroideus tenectomy or sternothyroideus tenectomy with staphylectomy for the treatment of soft palate displacement. *Proc AAEP* 1999;45:85-86.
36. Hogan PM, Palmer SE, Congelosi M. Transendoscopic laser cauterization of the soft palate as an adjunctive treatment for dorsal displacement of the soft palate in the racehorse. *Proc AAEP* 2002;48:228-230.
37. Barakzai SZ, Johnson VS, Baird DH, et al. Assessment of the efficacy of composite surgery for the treatment of dorsal displacement of the soft palate in a group of 53 racing Thoroughbreds (1990-1996). *Equine Vet J* 2004;36:175-179.
38. Smith JJ, Embertson RM. Sternothyroideus myotomy, staphylectomy, and oral caudal soft palate photothermoplasty for treatment of dorsal displacement of the soft palate in 102 Thoroughbred racehorses. *Vet Surg* 2005;34:5-10.
39. Ducharme NG, Hackett RP, Woodie JB, et al. Investigations into the role of the thyrohyoid in the pathogenesis of dorsal displacement of the soft palate in horses. *Equine Vet J* 2003;35:258-263.
40. Woodie JB, Ducharme NG, Kanter P, et al. 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 Vet J* 2005;37:418-423.
41. Schumacher J, Hanselka DV. Nasopharyngeal cicatrices in horses: 47 cases (1972-1985). *JAVMA* 1987;191:239-242.

ARTICLE #1 CE TEST

The Auburn University College of Veterinary Medicine approves this article for 2 contact hours of continuing education credit. ***Subscribers may take individual CE tests or sign up for our annual CE program.*** *Those who wish to apply this credit to fulfill state relicensure requirements should consult their respective state authorities regarding the applicability of this program. CE subscribers can take CE tests online and get real-time scores at* ***CompendiumEquine.com****.*

1. In a resting horse, which fraction of the total resistance to airflow is in the upper airway?
a. one-third
b. one-half
c. two-thirds
d. three-fourths

2. Videoendoscopy with the patient at rest allows diagnosis of all the following upper respiratory disturbances except
a. arytenoid chondritis.
b. axial deviation of the aryepiglottic folds.
c. persistent dorsal displacement of the soft palate (DDSP).
d. persistent epiglottic entrapment.

3. The intrinsic musculature of the pharynx includes all of the following except the
a. tensor veli palatini.
b. levator veli palatini.
c. palatopharyngeus.
d. hyoepiglotticus.

4. Which of the following extrinsic muscles of the pharynx is innervated by the pharyngeal branch of the vagus nerve?
a. genioglossus
b. sternohyoideus
c. thyrohyoideus
d. sternothyroideus

5. Rostral pharyngeal collapse has been experimentally reproduced by transecting the tendon of the _____ muscle.
a. tensor veli palatini
b. palatopharyngeus
c. stylopharyngeus
d. palatinus

6. Staphylectomy, epiglottic augmentation, rostral palatoplasty, and sternohyoideus/sternothyroideus myectomy are all treatments for
a. rostral pharyngeal collapse.
b. nasopharyngeal cicatrix.
c. dorsal pharyngeal collapse.
d. DDSP.

7. Dysfunction of the _____ muscle causes collapse of the pharyngeal roof during dorsal pharyngeal collapse.
a. palatopharyngeus
b. stylopharyngeus caudalis
c. palatinus
d. sternohyoideus

8. Which of the following is not an acceptable treatment for nasopharyngeal cicatrix?
a. antiinflammatory medications
b. transendoscopic laser transaction
c. permanent tracheostomy
d. partial arytenoidectomy

9. Which upper respiratory disturbance may predispose a horse to DDSP as a result of inflammation of the pharyngeal branch of the vagus nerve?
a. pharyngeal lymphoid hyperplasia
b. elongated soft palate
c. subepiglottic cyst
d. epiglottic hypoplasia

10. What is the maximal length that should be removed from the soft palate during staphylectomy for correction of DDSP?
a. 2 mm
b. 5 mm
c. 7 mm
d. 10 mm