

Laryngeal hemiplegia in the horse: an update

Laryngeale hemiplegie bij het paard: een update

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ABSTRACT

Laryngeal hemiplegia is a progressive upper airway dysfunction in the horse. It is not only seen in thoroughbred racehorses but also in warmblood horses, draft horses and in ponies. The condition is most frequently seen on the left side. The left laryngeal recurrent nerve gradually loses function and the function of the left cricoarythenoideus dorsalis muscle is compromised. This condition is most often idiopathic. It possibly leads to exercise intolerance but a respiratory noise is often the primary complaint of the owner. Right sided laryngeal hemiplegia is almost always related to other pathologies causing the nerve to malfunction. The diagnosis is not always easy because of the restricted availability of endoscopy in the field. A better understanding of laryngeal ultrasound examination might offer a new possibility in diagnosing laryngeal hemiplegia. If abnormal inspiratory sound is the only problem, laser treatment alone can be satisfactory. If the horse shows clear signs of exercise intolerance, further treatment is needed. If correctly executed, the outcome of laryngoplasty is good. Other techniques, like nerve grafting and pacemakers, are being explored and might even be regarded as better alternative treatments in the future, as these are more physiologic compared to laryngoplasty. In sporthorses presented with idiopathic laryngeal neuropathy without postoperative complications, the prognosis is good.

SAMENVATTING

Laryngeale hemiplegie is een bekende aandoening van de bovenste luchtwegen bij het paard. Het komt niet alleen voor bij volbloeden maar eveneens bij warmbloedpaarden, koudbloeden en pony's. Deze aandoening wordt voornamelijk aan de linkerzijde gezien. De functie van de linker nervus laryngeus recurrens wordt geïnhibeerd, waardoor een verlamming van de linker cricoarythenoïdeus dorsalis-spier optreedt. Laryngeale hemiplegie aan de rechterzijde heeft bijna altijd een onderliggende oorzaak in tegenstelling tot laryngeale hemiplegie aan de linkerzijde. Deze aandoening geeft mogelijk aanleiding tot een vermindering van het prestatievermogen van het paard, maar vaak is de primaire klacht die de eigenaar waarneemt de aanwezigheid van een inspiratoir geluid. De diagnose is niet altijd simpel, voornamelijk omdat de meeste praktijkdierenartsen geen endoscoop ter beschikking hebben. Recente studies wijzen uit dat echografisch onderzoek van de larynx kan helpen bij de diagnose van deze aandoening. Dit is een goed en beter beschikbaar alternatief. Indien de enige klacht die de eigenaar waarneemt het geluid is dat het paard maakt tijdens de arbeid, dan is een laserbehandeling de beste keuze. Ondervindt het paard problemen met de intensiteit van het werk dan is verdere chirurgische interventie nodig. Laryngoplastie of "tie-back" krijgt tegenwoordig nog steeds de voorkeur van de meeste chirurgen. Er zijn echter nieuwe behandelingen in ontwikkeling, waarbij gebruik wordt gemaakt van zenuwgreffes en pacemakers om reïnnervatie mogelijk te maken. Deze laatste vernieuwingen zorgen voor een sterke reductie van de complicaties die wel vaker gezien worden bij laryngoplastie. Niettegenstaande is de prognose voor sportpaarden met idiopathische linker laryngeale hemiplegie die een laryngoplastie ondergaan zonder postoperatieve complicaties, goed.

INTRODUCTION

Paresis or paralysis of one or two arytenoid cartilages, also called laryngeal hemiplegia, is an important condition of the larynx in the horse (Davenport-Goodall and Parente, 2003; Dixon et al., 2001). In normal horses at rest, about 67 liters of air pass the larynx each minute. When the horse is exercised, this flow rises to approximately 1800 L/min (Butler et al. 1993; Franklin and Allen, 2017). Malfunctioning of the arytenoid cartilage causes a reduction of the cross sectional area of the entrance to the larynx resulting in insufficient air passage through the larynx (Dixon et al., 2001). The already negative pressure in the upper airway tract drops even more, which might lead to aspiration of the non-functional arytenoid cartilage and/or the aryepiglottic fold(s). Additionally, vibration of the vocal cord(s) is seen (Franklin, 2008; Williams et al., 1990). The most common clinical signs observed by the owner are exercise intolerance and an abnormal inspiratory noise (Franklin and Allen, 2017; Martin et al., 2000; McCann, 2000; Witte et al., 2011).

ANATOMY

The equine larynx consists of five cartilages: the epiglottic cartilage, two arytenoid cartilages, the thyroid cartilage and cricoid cartilage (Figure 1). The extrinsic muscles ensure movement of the complete larynx relative to the soft palate. The movement of the cartilages relative to each other are coordinated by the intrinsic muscles: the cricoarythenoideus dorsalis muscle, the cricoarythenoideus lateralis muscle, the thyroarythenoideus muscle, arythenoideus transversus muscle and cricothyroideus muscle (Fulton et al., 2012; König and Liebich, 2004; McCarrel and Woodie, 2015) (Figure 2). These muscles are all innervated by the laryngeal recurrent nerve except for

the cricothyroideus muscle, which is innervated by the cranial laryngeal nerve (Cheetham et al., 2008; Reesink et al., 2013). The cricoarythenoideus dorsalis muscle is responsible for the abduction of the arytenoid cartilages (Figure 3A). The cricoarythenoideus lateralis muscle, the thyroarythenoideus muscle, the arythenoideus transversus muscle are adductors, and the cricothyroideus muscle is responsible for vocalization (Figure 3B). The functioning of these different structures is important for respiration, deglutition and phonation (Cheetham et al., 2008; Fulton et al., 2012).

ETIOLOGY

Left laryngeal hemiplegia

Left laryngeal hemiplegia is by far the most prevalent condition and in most cases, the cause is unknown. This idiopathic form is characterized by a distal axonopathy with resulting demyelination of the nerve (Cahill and Goulden, 1987; Dixon et al., 2001; Duncan et al., 1991). The condition is progressive in nature, and a malfunction of the arytenoid may turn into complete paralysis over a period of three to four months. Some authors suggest that the left laryngeal recurrent nerve is more sensitive to this pathology because of its length and because the left recurrent laryngeal nerve makes a loop around the aorta (Duncan et al., 1991; König and Liebich, 2004). This might be the reason why big warmblood horses and draft horses are more frequently effected by left laryngeal hemiplegia than ponies. Up to 40 % of these big horse breeds present laryngeal asymmetries (Cahill and Goulden, 1987; Davenport-Goodall and Parente, 2003; Dixon et al., 2001; Brakenhoff et al., 2006; Kraus et al., 2003; McCann, 2000). It has been suggested that there is a hereditary component. In thoroughbred racehorse populations for instance, the con-

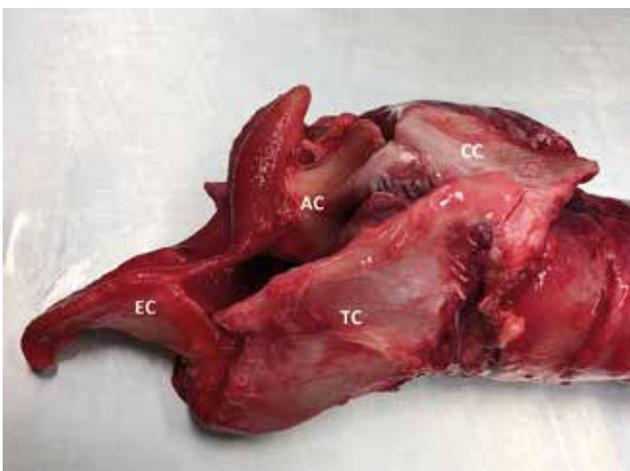


Figure 1. Cartilages: the epiglottic cartilage (EC), the arytenoid cartilage (AC), the thyroid cartilage (TC) and the cricoid cartilage (CC).

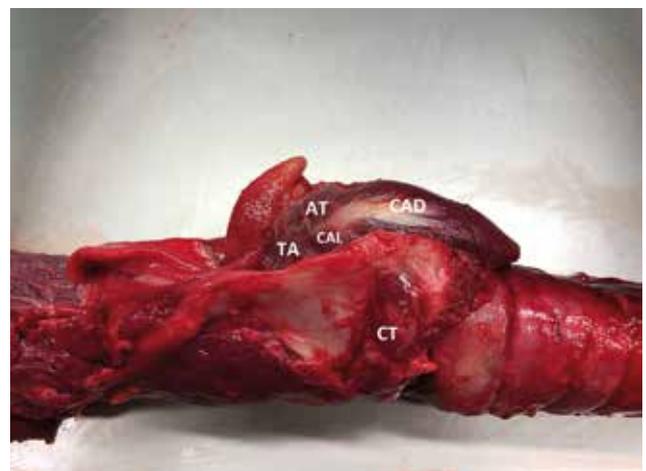


Figure 2. Intrinsic muscles: the cricoarythenoideus dorsalis muscle (CAD), the cricoarythenoideus lateralis muscle (CAL), the thyroarythenoideus muscle (TA), arythenoideus transversus muscle (AT) and cricothyroideus muscle (CT).



Figure 3A. The left cricoarytenoideus dorsalis muscle has been removed revealing the cricoid cartilage.

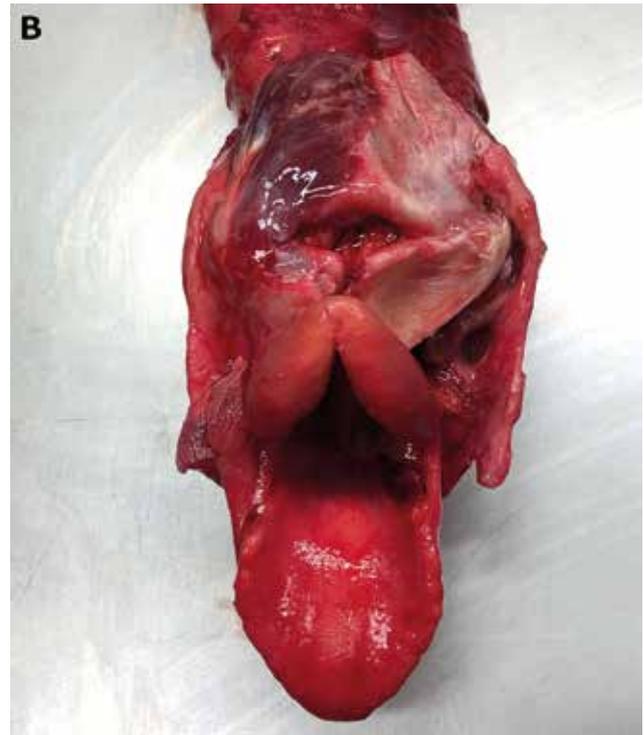


Figure 3B. Following the removal of the left cricoarytenoideus dorsalis muscle, the left arytenoideus transversus muscle is removed revealing the arytenoid cartilage.

dition is often diagnosed (Cahill and Goulden, 1987; Brakenhoff et al., 2006; Dixon et al., 2001). This is probably also related to the strenuous exercise these horses are exposed to and to the awareness amongst trainers. Some horses, which are not exposed to this high intensity work, show less symptoms (Franklin, 2008; McCarrel and Woodie, 2015).

Other pathologies that could result in damage or malfunction of the left recurrent laryngeal nerve are periphlebitis, perivascular injections, left guttural pouch mycosis, chondritis, abscesses or other masses, trauma and cervical surgery (Cahill and Goulden, 1987; Franklin, 2008; McCarrel and Woodie, 2015). However, they are much less common than the idiopathic form of left laryngeal hemiplegia (Dixon et al., 2001).

Right laryngeal hemiplegia

Right laryngeal hemiplegia is more rare than left laryngeal hemiplegia and is almost never idiopathic. The most common causes are a fourth branchial arch defect or chondritis of the laryngeal cartilage(s). The fourth branchial arch defect is characterized by dysplasia of one or more of the laryngeal cartilages (Davenport-Goodall and Parente, 2003; Garrett et al., 2008; Garrett et al., 2013). As seen on the left side, all factors compromising the function of the laryngeal nerve, such as phlebitis, are possible reasons of malfunctioning. A correct diagnosis of these underlying

pathologies is important because they may seriously influence the treatment of these specific cases. The prognosis is more guarded as right sided hemiplegia is more often non-idiopathic (Davenport-Goodall and Parente, 2003; Dixon et al., 2001; Franklin, 2008).

Bilateral laryngeal paralysis

Bilateral laryngeal paralysis is rare and may be caused by central nervous system pathology, intoxications, general anesthesia or encephalopathy after liver failure. It can easily become a life threatening situation and the prognosis is very guarded (Cahill and Goulden, 1987; Davenport-Goodall and Parente, 2003; Dixon et al., 2001).

DIAGNOSIS

Clinical examination

Horses suspected of laryngeal hemiplegia should be carefully inspected and a general clinical examination should be performed with emphasis on the upper airway. The neck should be inspected and palpated for masses, phlebitis or other abnormalities (McCarrel and Woodie, 2015). The presence of scars in the area of the linguofacial vein or ventral to the larynx should be noticed (Davidson and Martin, 2003; McCarrel and Woodie, 2015). Palpation may confirm asymmetries at the level of the larynx musculature or cartilages.



Figure 4. A resting endoscopic image of the left arytenoid cartilage, which is clearly paralyzed. The amount of abduction is clearly less than on the right side (courtesy of Fabrice Rossignol).

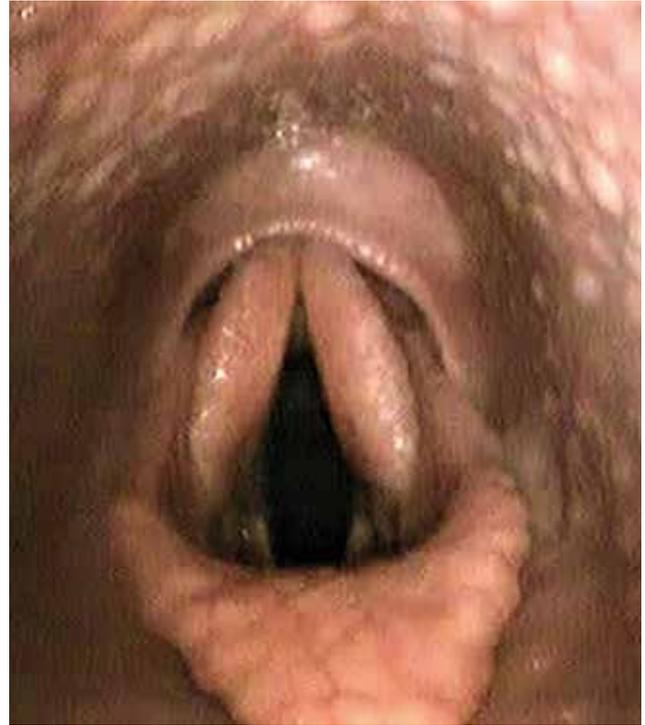


Figure 5. The palatopharyngeal arch is often more prominent at resting endoscopy in horses with a fourth branchial arch defect (courtesy of Fabrice Rossignol).

This is not conclusive but should be remarked during the examination (Franklin, 2008). Adduction of the arytenoid is triggered by a ‘slaptest’, i.e. by slapping on the contralateral side of the thorax at expiration. If present, this movement can be palpated at the level of the larynx. The slaptest should be done in the non-sedated, calm horse. However, this test alone is not conclusive (Franklin, 2008; McCann, 2000;).

Resting endoscopy

If possible, a complete endoscopy should be performed on the non-sedated horse in order not to interfere with laryngeal mobility. The larynx has to be examined when the horse is breathing normally, when the nostrils are occluded and when the horse is swallowing. The anatomy of the cartilages should be evaluated with special attention to abnormal shape, size or presence of a mass. The epiglottis should be dorsal to the soft palate. A previous laser treatment at the level of the vocal cords should be remarked. The larynx should be symmetrical (Davidson and Martin, 2003; Williams et al., 1990) and if not, the grade of asymmetry should be noted (McCann, 2000) (Figure 4). Asymmetry of the arytenoids is scaled by the Hagemeyer grading system, which is most commonly used (Barakzai and Dixon, 2011; Fulton et al., 2012) (Table 1). The degree of abduction of a horse may change over time as the disease is progressive (Davidson et al., 2011; Franklin, 2008; McCarrel and Woodie, 2015).

Although most cases of left laryngeal hemiplegia are idiopathic, all possible causes should be excluded. Horses with a fourth branchial arch defect have a more prominent palatopharyngeal arch, which partially covers the dorsal apices of the arytenoids (Figure 5). Chondritis cannot always be seen via endoscopy, but lesions at the level of the arytenoid mucosa may be present (Davenport-Goodall and Parente, 2003). The nose, guttural pouches and trachea should also be checked for abnormalities, such as guttural pouch mycosis, mucus or food in the trachea, which might indicate other airway pathologies or deglutition problems (Davenport-Goodall and Parente, 2003; Davidson and Martin, 2003).

Ultrasound examination

Laryngeal ultrasonography has a proven sensitivity of 90% and a specificity of 98% in the detection of abnormal movement of the arytenoid cartilage during exercise. This is higher than the sensitivity and specificity of resting endoscopy (Garrett et al., 2011). The ultrasonography is preferably performed on a horse that is clipped on both sides of the neck at the level of the larynx. The head is placed in extension for easy access with the probe. The probes used are a linear transducer (12.5MHz) and a convex transducer (8.5MHz) (Chalmers et al., 2006). Both left and right sides of the larynx are scanned. The anatomy of the cartilages, the cricothyroid articulation and muscles can be imaged. Mineralization of the cartilages is of-

Table 1. By means of the Havemeyer grading system, the grade of asymmetry of the arytenoid cartilages can be described.

Grade	Findings	Subgrade	Findings
I	All arytenoid cartilage movements are synchronous and symmetrical. Full arytenoid cartilage abduction can be achieved and maintained.	/	
II	Arytenoid cartilage movements are asynchronous and/or asymmetrical but full arytenoid cartilage abduction can be achieved and maintained.	A	Transient asynchrony, flutter or delayed movements is seen.
		B	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.
III	Arytenoid cartilage movements are asynchronous and/or asymmetrical but full arytenoid cartilage abduction cannot be achieved and maintained.	A	There is asymmetry of the rima glottis much of the time owing to reduced mobility of the affected arytenoid cartilage and vocal fold, but there are occasions, typically after swallowing or nasal occlusion, when full symmetrical abduction is achieved but not maintained.
		B	There is obvious arytenoid abductor muscle deficit and arytenoid cartilage asymmetry. Full abduction is never achieved.
		C	There is marked but not total arytenoid abductor muscle deficit and arytenoid cartilage asymmetry with little arytenoid cartilage movement. Full abduction is never achieved.
IV	Complete immobility of the arytenoid cartilage and vocal fold.	/	

ten seen, which is normal as the horse ages. The cricoarythenoideus lateralis muscle can be evaluated for fibrosis and atrophy (Figure 6). The ultrasonographic appearance of this muscle is representative for the appearance of the cricoarythenoideus dorsalis muscle, which is more difficult to image. In horses with a longstanding history of laryngeal hemiplegia, obvious fibrosis and atrophy of the cricoarythenoideus lateralis muscle are typically present. Once the veterinarian is trained in performing this examination, other abnormalities, such as a fourth branchial arch defect (Figures 7A and 7B) or chondritis, are easily spotted (Chalmers et al., 2006; Garrett et al., 2008; Garrett et al., 2013). Ultrasonographic examination is thus a valuable diagnostic tool for laryngeal hemiplegia and important in determining the best treatment option for each specific patient (Chalmers et al., 2006; Davidson and Martin, 2003; Garrett et al., 2011).

Treadmill or overground endoscopy

With the help of specialized equipment, a treadmill or overground endoscopy may be realized (Da-

vidson and Martin, 2003). The objective is to be able to recreate training and/or competition circumstances, in which the horse presents with difficulties. Laryngeal hemiplegia is most often diagnosed during resting endoscopy, but some subtle asymmetries that are not or barely observed in resting conditions may become evident during treadmill or overground endoscopy (Barakzai and Dixon, 2011; Dart et al., 2001; Franklin et al., 2006; Fulton et al., 2012). These and additional pathologies, such as a flaccid throat or retroversion of the epiglottis, may be diagnosed. When discussing the treatment options with the owner, a more precise diagnosis, treatment plan and prognosis can thus be made (Dart et al., 2001; Davidson and Martin, 2003; Davidson et al., 2011; Franklin et al., 2006; Parente et al., 1998). When comparing treadmill and overground endoscopy, some authors claim that overground endoscopy is better to recreate 1. the exact circumstances in which the horse presents difficulties and 2. the rider's influence on the horse; for example: in a dressage horse, the amount of flexion of the neck may be adjusted. The examination may also be performed where the horse is stabled or at a competition area. An

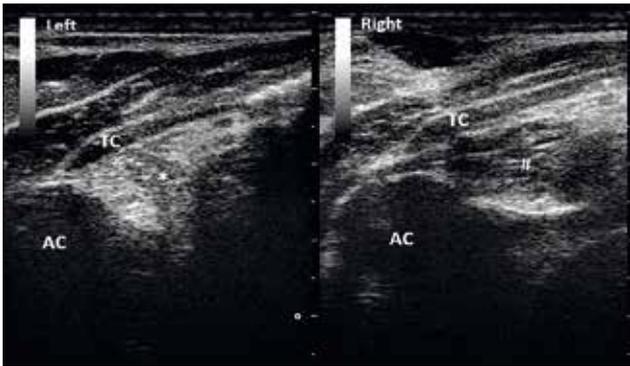


Figure 6. Transverse view of a larynx. Fibrosis of the left crycoarytenoideus lateralis muscle (CAL) is clearly visible when compared to the right CAL, as the left CAL is more echogenic.

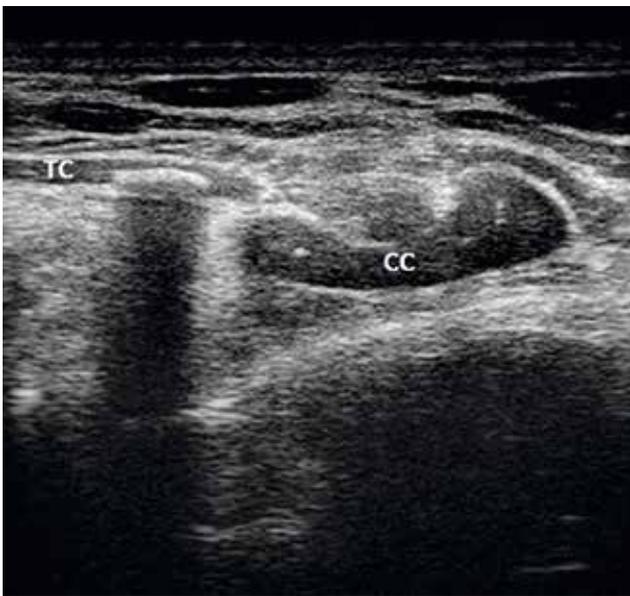


Figure 7A. Longitudinal view of a normal thyroid and cricoid cartilage. There are no signs of dysplasia.

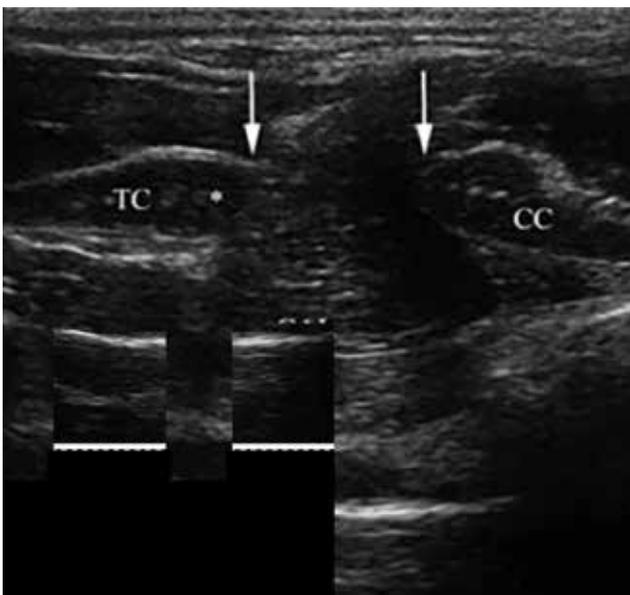


Figure 7B. The dysplasia is clearly visible as there is a gap between the thyroid cartilage (TC) and the cricoid cartilage (CC) (courtesy of Fabrice Rossignol).

advantage of the treadmill is the possibility to perform other examinations more easily when standing next to the exercising horse; for example: blood samples for PO₂ measurements can be taken. A pitfall however is that horses need to get accustomed to the treadmill, which takes time and multiple training sessions. It may cause problems in horses which present anxiety. (Davenport-Goodall and Parente, 2003; Davidson et al., 2011; Franklin and Allen, 2017; McCarrel and Woodie, 2015).

Other

If there is any suspicion of other pathologies of the airway system, other tests, like PO₂ measurement on arterial blood and a bronchoalveolar lavage, may be performed. When there is suspicion of fourth branchial arch defect or chondritis, radiographic examination can be performed. The diagnosis of these pathologies, which possibly contribute to the condition of the horse, is important to decide on the prognosis of each specific case (Davidson and Martin, 2003; Dixon et al., 2001).

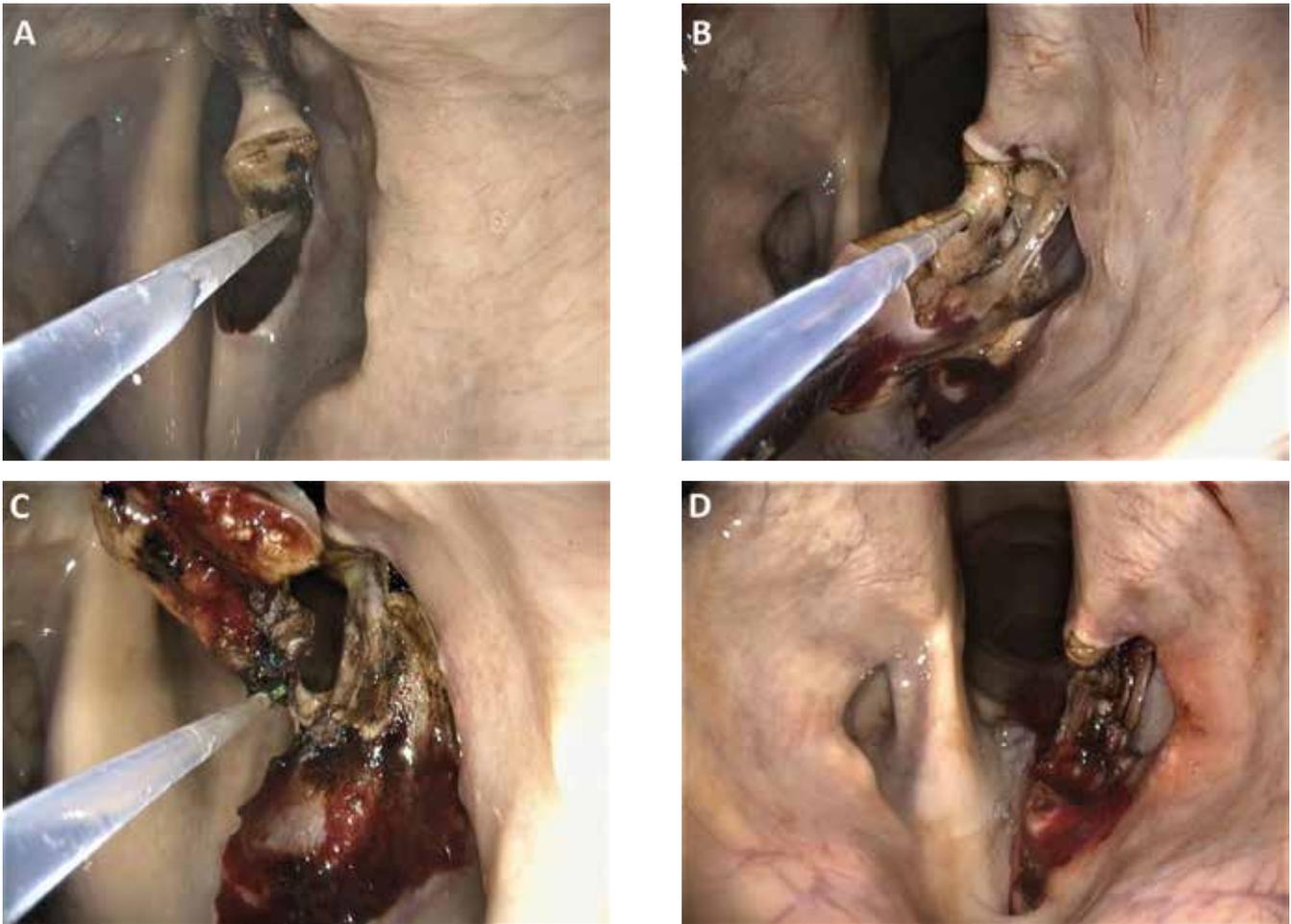
TREATMENT

Treatment of laryngeal hemiplegia should be considered carefully. If the horse only presents a respiratory noise without other difficulties with its workload, surgery is not always necessary (McCann, 2000). Indeed, the risk of complications after treatment should always be considered and some have severe consequences for the horse. Discussing the different treatment options, possible outcome and complications, with the future purpose of the horse in mind, is therefore very important. Owners should also be informed that symptoms may disappear after treatment but that the horse will not 'cure' from this condition; moreover, it will be noticed during a pre-purchase sale (Davenport-Goodall and Parente, 2003).

Laser treatment

Ventriculocordectomy (i.e. excision of a ventricle and excision of a vocal cord), cordectomy (i.e. excision of a vocal cord) or cordotomy (i.e. horizontal transection of a vocal cord) are part of today's standard treatment of laryngeal hemiplegia (Figures 8A, 8B, 8C, 8D). In cases where the horse only makes noise during work but does not show signs of exercise intolerance, laser treatment is considered the best option (Brown et al., 2003; Brown et al., 2004; McCann, 2000).

Currently, mostly, a diode laser is transendoscopically used to perform this procedure on the standing sedated horse after local anesthesia of the vocal cords, larynx and nose. Before the use of a diode laser, a laryngotomy was performed to grant access to the larynx. In case of left laryngeal hemiplegia, mostly,



Figures 8 A, B, C, D. Cordectomy of the left vocal cord with a diode laser in the standing horse (courtesy of Fabrice Rossignol).

ventriculocordectomy is performed on the left side only. An additional cordotomy or cordectomy of the right side is sometimes performed (McCann, 2000). When the laser is used, care should be taken when cutting. The energy used during laser treatment should be limited and the cartilage should not be touched by the laser to avoid severe inflammation at the level of the larynx and specifically, the cartilage, which could lead to suffocation (Davenport-Goodall and Parente, 2003). Other complications of bilateral laser treatment are ‘webbing’ at the level of the vocal cords, i.e. the formation of fibrous strands attaching the left and right vocal cord to each other (Dixon et al., 2003a). Postoperatively, adequate use of anti-inflammatory drugs is advised. After laser treatment, the horse will no longer produce or will produce only a minimal amount of abnormal noise; additionally, sound reduction may be noticed until up to 90 days after surgery (Brown et al., 2003). However, the effect on respiration itself is minimal, making laser treatment as a stand-alone procedure insufficient for horses with exercise intolerance (Davenport et al., 2001; Fulton et al., 2012; Hawkins et al., 1997; Henderson et al., 2007; Kidd and Slone, 2002; McCarrel and Woodie, 2015; Tate et al., 1993).

Laryngoplasty

In cases where the horse presents exercise intolerance, laryngoplasty or ‘tie-back’ can be performed. With this technique, permanent abduction of the arytenoid cartilage is achieved using one or two prosthesis (Brown et al., 2004; Davenport-Goodall and Parente, 2003; Marks et al., 1970; McCann, 2000; Williams et al., 1990). The prosthesis replaces the dysfunctional cricoarytenoideus dorsalis muscle and attaches the arytenoid to the cricoid cartilage resulting in a permanent abduction of the arytenoid cartilage. The prosthesis may consist of non-absorbable sutures alone or in combination with metallic anchoring materials, based on the surgeons preference (Brandenberger et al., 2017; Lechartier et al., 2015; Schumacher et al., 2000). Once the prosthesis is in place, it is tightened under endoscopic control, in a way that an ideal abduction of the arytenoid is achieved. The amount of abduction needed should be related to the workload intensity of the horse (Figures 9A and 9B). It is often expressed in ‘Dixon grades’. Especially sport and leisure horses do not necessarily need maximal abduction (Barnett et al., 2003). A study by Rakesh et al. (2008) showed that 88% of the maximal cross-

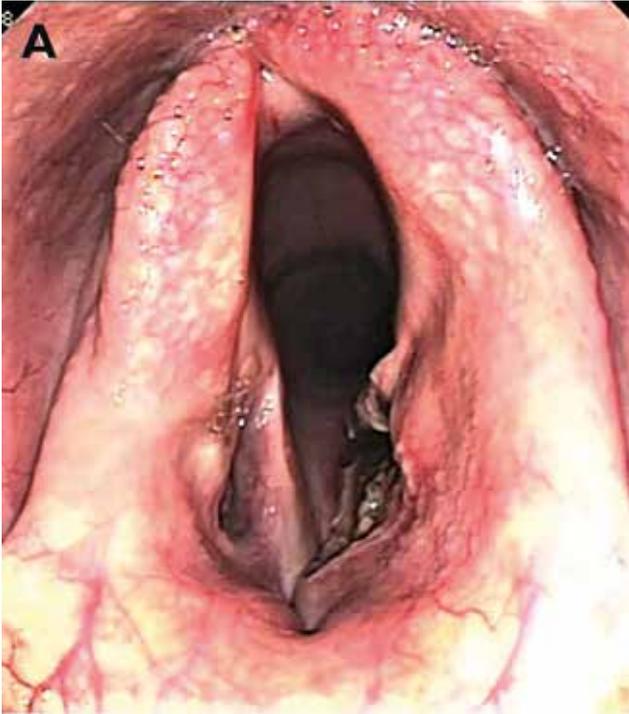


Figure 9A. Postoperative endoscopic image of a thoroughbred racehorse that was treated by laryngoplasty and laser (Dixon grade 1) (courtesy of Fabrice Rossignol).

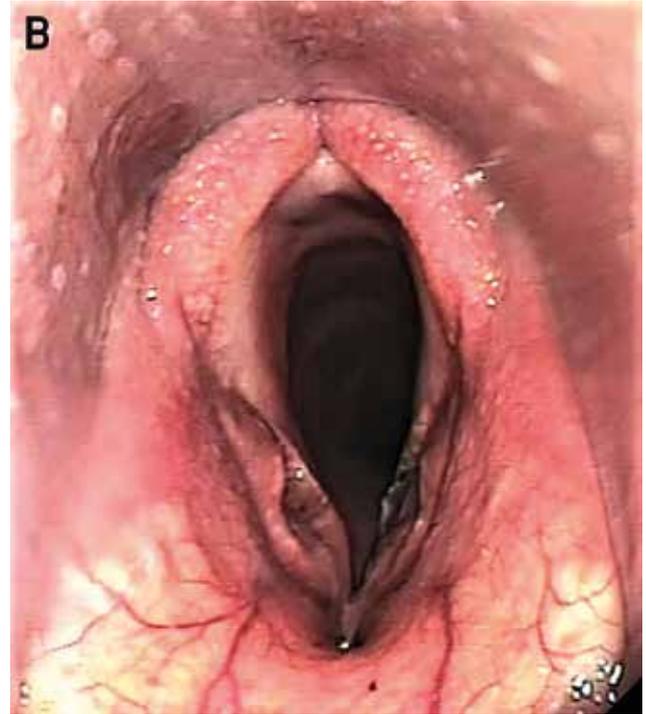


Figure 9B. Postoperative endoscopic image of a sport horse that was treated by laryngoplasty and laser (Dixon grade 3) (courtesy of Fabrice Rossignol).

sectional area of the opening to the larynx is ideal and sufficient to prevent the arytenoid cartilage from being aspirated during work, even in racehorses. It is important to realize that the amount of abduction obtained during surgery will reduce because of regression of the soft tissue swelling after surgery. Barnett et al. (2013) reported that the amount of abduction seen at six weeks postoperatively resembles the long-term amount of abduction when performing dynamic endoscopy. They state that the fibrosis of the arytenoid in its position is completed at that stage.

Laryngoplasty has been performed under general anesthesia for decades but the most recent evolution is to perform the procedure in the standing sedated horse. The advantages of a standing laryngoplasty are the better exposition and visualization of the larynx, a better intraoperative evaluation of the degree of abduction obtained due to the absence of a tracheotube and the absence of complications associated with general anesthesia (Rossignol et al., 2015).

Laryngoplasty is a difficult procedure that must be executed in a precise way. Due to the fragile nature of the cartilages of the larynx, there is no room for error. Seroma formation is frequently observed but often resolves spontaneously the first days after surgery. A first important complication that may occur is that the prosthesis penetrates the lumen of the trachea or the entrance to the esophagus, leading to infection, persistent coughing and/or dysphagia (Figure 10). Next, complete failure of the prosthesis may occur, resulting

in an arytenoid that has returned to its former position (Brandenberger et al., 2016; Brown et al., 2004; Davenport et al., 2001; Dixon et al., 2003a; Froydenlund and Dixon, 2014; Fulton et al., 2012; Greet et al., 1979; Hardcastle et al., 2012). This is related to the cutting of the suture into the cartilage, slipping of the suture of the caudal cricoid edge or failure of suture material. This complication is more often seen in grade III horses, due to the continuous movement made by the not fully paralyzed arytenoid. Up to 20% of these cases present loss of abduction (Brandenberger et al., 2017; Dixon et al., 2003a; Lechartier et al., 2015). To try and avoid this, some surgeons curette or inject the cricoarytenoid joint with polymethylmethacrylate to induce ankyloses, which may result in a better stabilization of the arytenoid position (Barnett et al., 2013a; Leutton and Lumsden, 2015; Parente et al., 2011). Finally, overabduction of the arytenoid may lead to multiple postoperative complications related to the aspiration of food and saliva (Froydenlund and Dixon, 2014; Fulton et al., 2012).

Horses should rest four to six weeks and may recommence training afterwards. Laryngoplasty is often combined with laser ventriculocordectomy or cordectomy. Ideally, this is performed immediately before the laryngoplasty procedure to make intraoperative abduction of the arytenoid cartilage more easy (Barnett et al., 2013a; Barnett et al., 2013b; Davenport et al., 2001; Hawkins et al., 1997; Kidd and Slone, 2002; Kraus et al., 2003).

When nicely executed, laryngoplasty is a technique that offers a quick solution for horses with left laryngeal hemiplegia with up to a 90%-success rate in non-racehorses; in racehorses, the success rate is lower (48–66%) (Cheetham et al., 2008; Davenport et al., 2001; Mason et al., 2013). In a study by Dixon et al. (2003b), 86% of the owners of a mixed breed population was positive about the surgery. Barnett et al. (2013) reported that 93% of the owners of a mixed breed population saw improvement after surgery. However, when these horses had a long-term control endoscopy, 78% still presented upper airway collapse.

Nerve grafting

In selected cases, re-innervation of the cricoarytenoideus dorsalis muscle can be achieved with the help of a nerve graft (Davenport-Goodall and Parente, 2003; Ducharm et al., 1989; Rossignol et al., 2018; Fulton et al., 1991; Fulton et al., 2012; McCann, 2000). This technique has been developed in human surgery and modified by veterinary surgeons. The technique as described by Ducharm et al. (1989a) creates an anastomosis between the first cervical nerve (C1) and the abductor branch of the recurrent laryngeal nerve. Ducharm et al. (1989b) and Fulton et al. (1991) described the use of a nerve-muscle pedicle graft. Part of the omohyoideus muscle -with branches of the C1 entering into the muscle- was transplanted into the cricoarytenoideus dorsalis muscle. In a recent study on client owned horses by Rossignol et al. (2018), a novel tunneling technique has been described by which the C1 or C2 nerve branch is directly implanted into the cricoarytenoideus dorsalis muscle. Horses with left laryngeal hemiplegia grade II and III, with a small amount of fibrosis and/or atrophy of the cricoarytenoideus dorsalis muscle were included. Even a grade IV horse was operated successfully. Concurrently, a ventriculocordectomy of the left side was performed in these horses. In 13 out of 14 of these horses, stabilization of the arytenoid cartilage was seen during exercise within four to twelve months after surgery. This is quite a long recovery period when compared to the recovery period after laryngoplasty, which is not preferable in horses with exercise intolerance that should quickly return to work (McCann, 2000). Stimulation of the nerve has recently been described for a more rapid regain of function of the arytenoid cartilage (Mespoulhès-Rivière et al., 2016).

It is important to realize that after a successful nerve graft, the arytenoid abduction will only be achieved in the exercised horse when natural stimulation of the omohyoideus muscle by the C1 or C2 nerve occurs. This means that these horses still show laryngeal hemiplegia at resting endoscopy. The main advantages of the nerve grafting technique is that less complications have been observed compared to laryngoplasty, mainly because there is no permanent abduction of the arytenoid. Moreover, laryngoplasty can

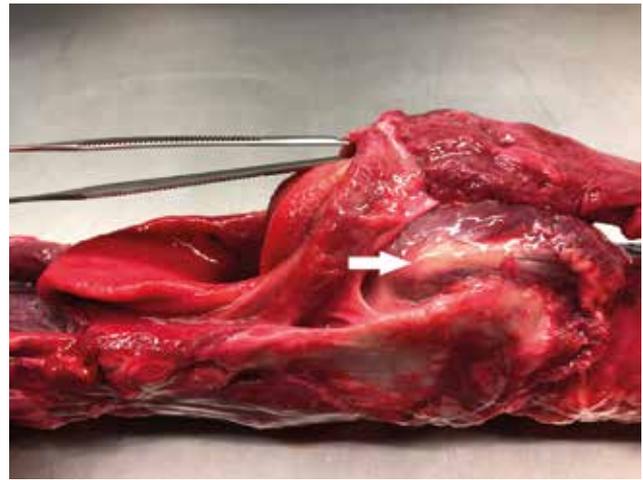


Figure 10. The larynx and its relation to the esophagus are visible (the instrument is placed through the entrance of the esophagus). The muscular process (arrow) is near the entrance. The incorrect placement of the suture through the esophagus may cause chronic deglutition problems.

still be performed if the nerve graft was not successful (Rossignol et al., 2018).

Pacemaker implantation

A new evolution for selected grade II and III left laryngeal hemiplegia cases is to use a pacemaker for controlled stimulation of the cricoarytenoideus dorsalis muscle (Davenport-Goodall and Parente, 2003; Fulton et al., 2012). Several experimental studies have been performed to evaluate this new technology. In some studies, direct stimulation of the cricoarytenoideus dorsalis muscle with a pacemaker was used, while in other studies, the recurrent laryngeal nerve was stimulated (Ducharme et al., 2010; Vanschande-vijl et al., 2010), or a nerve graft was first performed, followed by stimulation of the nerve through a pacemaker to train the muscle (Rossignol et al., 2018). Although these techniques are still in the experimental phase, the results are promising and it is likely that several new evolutions in this domain will form a very valuable treatment alternative in the future (Ducharme et al., 2008; Ducharme et al., 2010).

Arytenoidectomy

Arytenoidectomy is the surgical removal of a part of the paralyzed arytenoid cartilage, either only the muscular process or both the muscular and corniculate process are removed. Although it is no longer considered as the treatment of choice in typical cases of laryngeal hemiplegia, it has been used in cases where laryngoplasty prosthesis has failed, in horses with chondritis or with a fourth branchial arch defect (Davenport-Goodall and Parente, 2003; Fulton et al., 2012; McCarrel and Woodie, 2015). Horses with

an acute form of chondritis can be treated medically first, although this rarely leads to complete regain of function and lesions tend to persist chronically (Garrett et al., 2013). Arytenoidectomy is performed under general anesthesia through a ventral midline laryngotomy. Tracheotomy should be performed to ventilate the horse during surgery and because of the postoperative swelling that often occurs. The mucosal barrier is opened and the laryngotomy wound is left unsutured or partially sutured. The prognosis is quite good and sometimes, even racehorses can perform after arytenoidectomy. However, in cases where arytenoidectomy was performed, a higher remnant instability at the level of the larynx has been seen than in horses that underwent laryngoplasty (Fulton et al., 2012). Radcliffe et al. (2006) claimed that the results after laryngoplasty and arytenoidectomy are equal when a modified technique is used. Reported complications after arytenoidectomy are excessive mucosal tissue or new granulation tissue formation at the entrance to the larynx. This can be resolved with a local laser excision of these tissues. Aspiration of food can also cause respiratory problems at the level of the lungs (Fulton et al., 2012; Radcliffe et al., 2006).

CONCLUSION

Laryngeal hemiplegia is a commonly observed condition resulting in inspiratory noise during exercise, possibly responsible for not reaching a horse's maximal athletic potential. The diagnosis can be simple and precise when a dynamic endoscopy and an ultrasound of the larynx can be performed. Although laryngoplasty has some disadvantages, it is the current golden standard for treating the condition. The technique has recently evolved, and is currently performed under sedation and local anesthesia in order to achieve an ideal abduction of the arytenoid cartilage, reducing the likelihood of complications. Moreover, the rapid development of more physiological techniques such as nerve grafts and the evolving technology regarding the use of pacemakers might replace laryngoplasty in the future.

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