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Equine Veterinary Education Clinical Commentary

Active or Passive Laryngeal Closure

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The intrinsic laryngeal musculature regulates the size of the glottic opening (or rima glottidis) by controlling the position of the corniculate processes of the arytenoid cartilages and the vocal folds. Contraction of the cricoarytenoideus dorsalis muscle widens the glottic opening by abducting the corniculate process of the arytenoid cartilage and tensing the vocal folds. The thyroarytenoideus, arytenoid transversus and cricoarytenoideus lateralis adduct the corniculate process of the arytenoid cartilage, thereby narrowing the glottic opening. The glottic opening is widened during exercise, to permit the increased ventilation required for exercise and is closed during swallowing to prevent aspiration of food.

The purpose of this clinical commentary is to describe glottic closure that occurs during exercise and which is evident during an exercising endoscopy procedure.

Laryngeal hemiplegia or arytenoid cartilage collapse is well described in the horse, where recurrent laryngeal neuropathy results in progressive atrophy of the cricoarytenoideus dorsalis muscle, and failure of, usually the left, arytenoid cartilage to fully abduct during exercise. Bilateral laryngeal paralysis also occasionally occurs in the horse, most commonly secondary to hepatopathy or toxins, resulting in almost complete obstruction of the rima glottidis. These forms of arytenoid cartilage collapse are a ‘passive’ form of glottic closure, due to failure of the abductor muscles to maintain patency in the face of high pressures during exercise.

Also evident during exercise in some horses, is an ‘active’ closure, i.e. the horse is capable of arytenoid abduction but there are times when the glottis is closed, presumably resulting from contraction of the adductor muscles rather than failure of the abductor muscles. They are often quick closure manoeuvres. These active glottic closures can be seen during swallowing, before snorting, jumping, sprint start and often a change of pace -an example would be a horse doing an extended canter down the long side of the arena. Often a ‘grunting’ sound can be heard at the time of the glottic closure. For activities such as jumping, riders will often associate the 'grunting' noise when the horse is putting in extra effort at take-off. Active glottic closure appears to occur more frequently at lower levels of exercise (walk/ trot) or at the start of a pace, it is uncommon to see it during established high-intensity exercise. It is also interesting to note that active glottic closure (aside from swallowing) is less often seen during treadmill endoscopy and is more commonly seen during overground endoscopy. Whether this difference relates to differences in the exercise being undertaken or whether the presence of the rider is the cause is at yet unknown. However, it has been noted that if a rider kicks the horse during ridden exercise, a glottic closure may be observed, presumably as the horse tries to protect the thorax.

Humans can also develop forms of exercise-induced laryngeal obstruction (EILO). Whereas, currently these forms of obstruction or collapse are considered passive in horses, there is controversy surrounding whether they are active or passive in human patients (Hull et al. 2016). In humans, active adduction is key in activities such as vocalisation, swallowing and coughing. Complete or partial active glottic closure also occurs during breath holds, typical when a person is straining or performing a Valsalva manoeuvre (Mendelsohn and Martin 1993, Orlikoff 2008). In this situation brief glottic closure allows entrapment and subsequent pressurisation of air that helps stabilise the chest wall. Restraining the collapse of the ribcage, this supportive closure allows the muscles of the trunk and limbs to perform with greater effectiveness. The maintenance of alveolar (and thus intra-truncal) pressure during lifting has been shown to not only assist the support of the pectoral girdle but also to alleviate part of the load on the vertebral column. Even moderate levels of physical exertion may be associated with this type of adductory bias (Orlikoff 2008). Laryngeal closure is seen in a variety of activities during maximal effort in humans. One study investigating upper limb power, showed that all the people assessed could achieve greater power when the larynx was closed. There was an average of 20% power loss when the larynx remained patent (Naito and Niimi 2000).

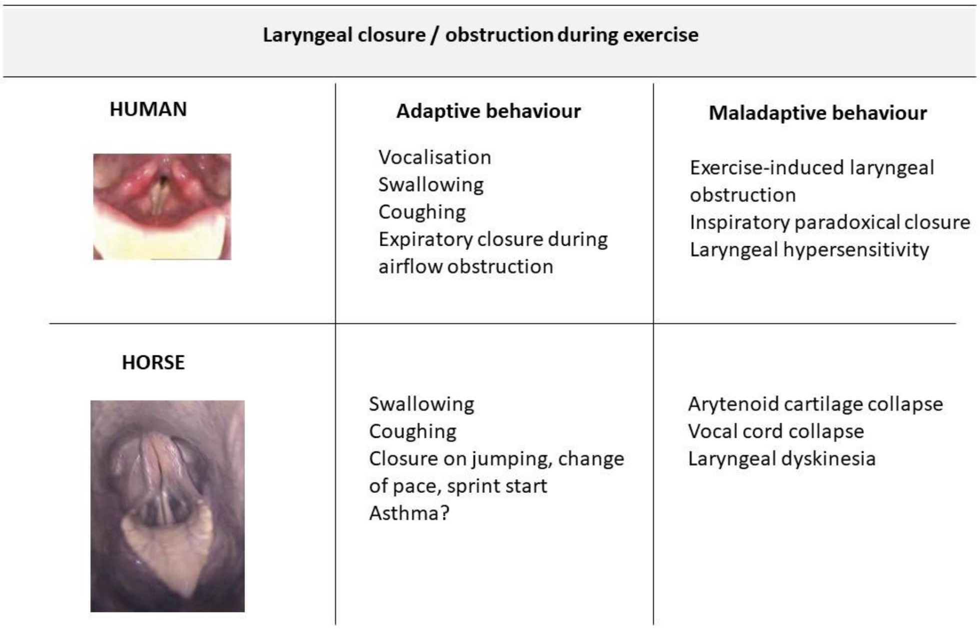
It seems likely that active glottic closure, as is observed in the horse during sprint starts, jumping and pace change could also be an adaptive process; acting to generate force +/- to provide a stabilising mechanism to create intrathoracic pressure and support during these movements. Accordingly, the data from humans, raises the question as to whether laryngeal surgery (e.g. in the form of tie-back and hobday, which prevents complete glottic closure) could be detrimental for some activities, most likely those requiring generation of explosive power such as jumping.

A further example, of how laryngeal closure may be functionally helpful or 'adaptive' is provided in human studies evaluating expiratory phase laryngeal closure. Specifically, in addition to breath-hold manoeuvres, active contraction of the adductor muscles during expiration is thought to provide expiratory ‘braking’. There is close neurophysiological coupling between the larynx and diaphragm, and vocal fold adduction is thought to play a role in regulating the time constraints of lung emptying and thus controlling end-expiratory lung volume (Brancatisano et al. 1985). This strategy appears to be prominent in conditions such as chronic obstructive pulmonary disease (COPD). In the later, a chronic relatively fixed impairment in expiratory airflow often leads patients to utilize a ‘pursed-lip’ expiratory breathing pattern. It is assumed that this acts to generate a degree of auto positive end-expiratory pressure (PEEP) and thus to optimize intra-thoracic pressure and provide flow generation. It is now apparent that this process also occurs at the level of the laryngeal inlet, with the degree of active glottic narrowing directly relating to the severity of COPD (Baz et al. 2015, Hull et al. 2019). Intervention to increase laryngeal patency, in this setting, has been shown to be associated with a deleterious outcome (Lillie and Fowler 2013).

Likewise, in severe asthma excessive laryngeal closure was apparent in the expiratory phase in 40% of patients, the inspiratory phase in 47% and in both phases in 13% (Hull et al. 2019). Laryngeal closure during expiration is proposed to modulate intra-thoracic pressure, however excessive closure particularly during inspiration is considered maladaptive and likely to increase work of breathing (Hull et al. 2019). Certainly, these and other studies appear to show that, in humans, closure of the laryngeal inlet during exertion can involve different anatomical structures / levels of the larynx. It is thus apparent that the most common form of EILO in humans involves inspiratory closure of the supra-glottic / arytenoid structures (>80% of cases) whereas in inducible laryngeal obstruction or vocal cord-dysfunction the closure almost exclusively occurs at the glottic level.

An emerging concept in human respiratory medicine is that laryngeal hyperresponsiveness or hypersensitivity may play a role in the development of exercise–induced laryngeal obstruction in some people (Hull et al. 2016, Nordang et al. 2018). As the glottic closure reflex serves to protect the lower airways against aspiration, laryngeal hypersensitivity could lead to an exaggerated tendency to inappropriate reflex closure, that becomes amplified / prominent during exercise. It seems likely that the hyperpnoea of exercise and the heightened upper airway flow may trigger a defensive closure reflex.

In summary, in the exercising horse, laryngeal closure can be passive or active, physiologic or pathologic. Brief episodes of apparent active glottic closure are not uncommon during light ridden exercise. They are less commonly seen during high-intensity exercise. When they occur frequently during ridden exercise the significance is less clear. It is important not to assume that adaptive processes that are amplified are necessarily deleterious. The associated case report is an unusual presentation as the findings were also associated with an obvious respiratory distress. When observed during an overground endoscopy procedure the veterinary surgeon can at that time, work with the rider to understand whether alterations in how the horse is ridden influences their occurrence. Veterinary surgeons must also be cautious reviewing exercising endoscopy recordings as interpretation of their significance is likely to be harder without information obtained when observing the horse – such as the actions of the rider, change in pace etc. Like humans, an association with equine asthma is also a potential explanation and further investigations of the lower airways should always be considered and evaluated.



Schematic outlining proposed adaptive and maladaptive responses resulting in laryngeal closure

Supplementary item: Endoscopic recording during exercise of a horse with left-side arytenoid cartilage collapse. Also evident during the recording are multiple ‘active’ glottic closures.

Author's declaration of interests

No conflicts of interest have been declared

Ethical animal research

Not applicable to this clinical commentary which represents a review of the literature and personal clinical experience.

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