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SHORT CASE SERIES

# Dynamic laryngeal collapse associated with poll flexion as a complication of laryngeal tie-forward surgery in three harness racehorses

Hanna Vermedal DVM | Eric Strand DVM, MSc, PhD, DACVS, DECVS

Faculty of Veterinary Medicine,  
Norwegian University of Life Sciences,  
Oslo, Norway

**Correspondence**

Hanna Vermedal, Veterinary Clinical  
Sciences, School of Veterinary Medicine,  
University College Dublin, Dublin,  
Ireland.  
Email: hannaver@hotmail.com

**Abstract**

**Objective:** To report dynamic laryngeal collapse (DLC) associated with poll flexion as a potential complication of the laryngeal tie-forward procedure (LTFP) in harness racehorses.

**Study design:** Short case series.

**Animals:** Three harness racehorses.

**Methods:** Preoperative and postoperative medical records of all harness racehorses that underwent the LTFP were reviewed, as were high-speed treadmill videoendoscopy recordings of 35 horses that returned for upper airway evaluation postoperatively.

**Results:** One standardbred and two Norwegian coldblooded trotters in which dorsal displacement of the soft palate had been initially diagnosed were found to have bilateral arytenoid cartilage and vocal fold collapse associated with poll flexion after the LTFP. These three horses were otherwise clinically normal when exercised in free head carriage.

**Conclusion:** Dynamic laryngeal collapse associated with poll flexion can occur as a complication after the LTFP in harness racehorses and should be considered as a differential in horses with persistence of airway problems after surgery.

**Clinical significance:** Postoperative DLC may be underdiagnosed in harness racehorses because this complication is obvious only when horses are driven with bit and reins during high speed treadmill or overground videoendoscopy.

## 1 | INTRODUCTION

Dynamic laryngeal collapse (DLC) associated with poll flexion is a dynamic upper airway disorder in horses characterized by bilateral inward collapse of the arytenoid cartilages and vocal folds during head and neck flexion.<sup>1</sup> The disorder is reported most commonly in Norwegian coldblooded trotters (NCT)<sup>2-4</sup> but has also

been documented in other breeds and disciplines.<sup>5-8</sup> It is a serious performance-limiting disorder in harness racehorses,<sup>2</sup> with no current consistently effective treatment option.<sup>2,8,9</sup> The gold standard for diagnosing DLC in horses is considered high-speed treadmill videoendoscopy (HSTV) or overground videoendoscopy with the horse equipped with full racing tack and a driver to induce poll flexion.<sup>1,10</sup>

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Intermittent dorsal displacement of the soft palate (iDDSP) is one of the most commonly reported obstructive dynamic upper respiratory tract (URT) disorders in racehorses.<sup>3,11</sup> The laryngeal tie-forward procedure (LTFP) is currently considered the best surgical treatment for iDDSP in horses<sup>12</sup> and offers a low rate of reported postoperative complications.<sup>12,13</sup> Dynamic laryngeal collapse associated with poll flexion, to the best of the authors' knowledge, has not been reported as a complication after the LTFP in horses. The objective of this report is to document the induction of DLC associated with poll flexion as a complication of the LTFP in three harness racehorses.

## 2 | MATERIALS AND METHODS

### 2.1 | Animals

Medical records of all harness racehorses which were diagnosed with iDDSP, using a standardized HSTV protocol at the Faculty of Veterinary Medicine, Norwegian University of Life Sciences, and surgically treated with the LTFP between 2006 and 2017 were reviewed. High-speed treadmill videoendoscopy recordings of 35 horses that had presented for reevaluation after the LTFP were identified; of these, 18 were Standardbreds (STB) and 17 were NCT. Three of these horses demonstrated DLC associated with poll flexion postoperatively and were included in this case series. None of these horses had signs of DLC associated with poll flexion during the standardized HSTV evaluation before the LTFP. Data reviewed for these cases included breed, sex, age, preoperative history and HSTV findings, racing records, and postoperative history and HSTV findings.

### 2.2 | Exercise protocol

All horses were exercised according to a previously standardized HSTV protocol<sup>2,3</sup> and driven on the treadmill with full racing tack, including bit, bridle, harness, conventional head-check and long reins. After a warm-up period of approximately 2500 to 3000 m, the horses were exercised for 1-minute phases, alternating between free head carriage (phases 1, 3 and 5) and poll flexion (phases 2, 4 and 6). During the phases with poll flexion, the horses were driven "onto the bit" by an experienced harness racehorse person by applying tension on the reins as if they were being driven on a racetrack. During "free head carriage," the horses were exercised with no tension on the bit and reins. The NCT were exercised at a constant speed of 8.5 m/second, and the STB were exercised at 10 m/second, on a 1.5° treadmill incline. The preoperative examination was reproduced exactly for each horse examined postoperatively. Active

racehorses typically achieve a heart rate over 200 beats per minute after the first minute (phase 1) and reach exhaustion by the fifth or sixth minute.

### 2.3 | Videoendoscopic evaluation

Videoendoscopic evaluation was performed throughout the length of the exercise protocol, and the images were digitally recorded. The endoscope was inserted in the right ventral meatus in all cases. High-speed treadmill videoendoscopy recordings were evaluated in slow motion as well as real time to diagnose all URT abnormalities. Any deviation from normal was identified and graded when applicable. Intermittent dorsal displacement of the soft palate was noted as present or not present. Arytenoid cartilage collapse (ACC) and vocal fold collapse (VFC) were graded mild, moderate or marked, as previously described.<sup>2,3</sup> Axial deviation of the aryepiglottic folds (ADAF) was graded mild, moderate or severe, as previously described.<sup>14</sup> Dorsomedial deviation of the epiglottic margins (DMDEM) was graded mild, moderate, or severe, as previously described.<sup>3</sup>

## 3 | RESULTS

### 3.1 | Case 1

A 3-year-old NCT mare initially presented for intermittent abnormal respiratory noise during training. The mare had not started racing prior to admission. Physical examination was unremarkable, and no signs of inflammation or laryngeal dysfunction were evident at resting endoscopic examination of the upper airway. During HSTV, the mare developed marked palatal instability, immediately followed by repeated episodes of iDDSP of 1- to 2-seconds duration during the third phase of free head carriage (phase 5). When the horse repeatedly displaced its soft palate, it was unable to maintain the trotting gait and demonstrated increasing unwillingness to continue exercise. The HSTV evaluation was discontinued, and surgical treatment with the LTFP was recommended to the handlers. The mare was treated with the LTFP at another clinic within several months.

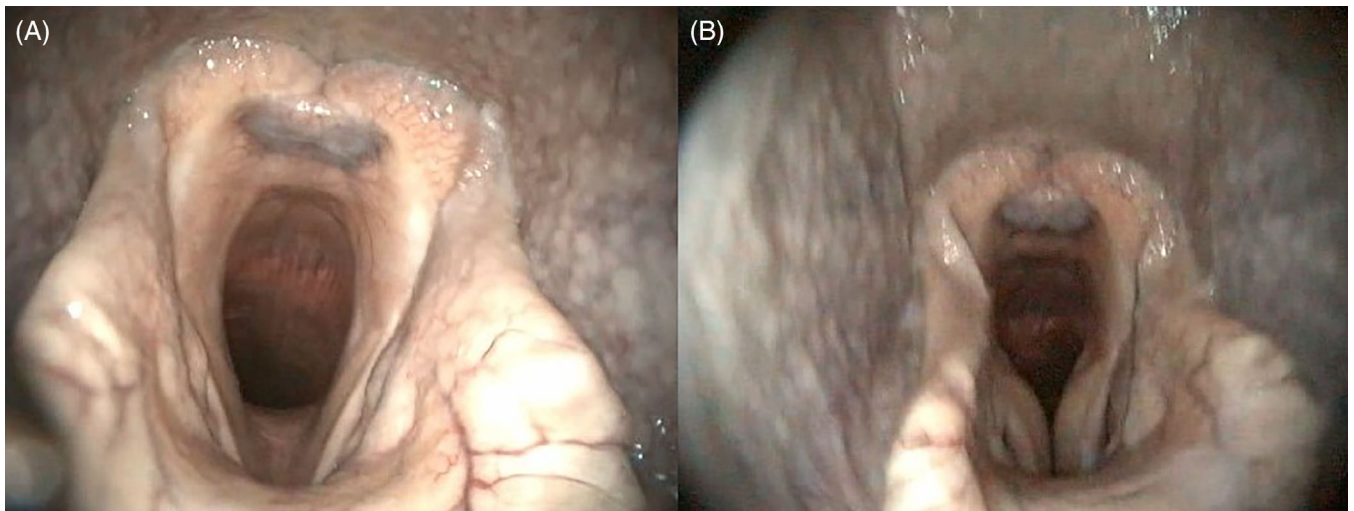
Twenty-one months after the initial HSTV examination, the mare re-presented to our hospital with complaints of being difficult to drive during exercise and racing, associated with poor performance and abnormal respiratory noise. The mare had started racing 10 months after the LTFP and raced with mediocre results until 3 months before readmission. No upper airway abnormalities were noted at resting endoscopic examination. At HSTV evaluation postoperatively, the mare developed

mild DLC associated with poll flexion during the first phase of poll flexion (phase 2), which resolved completely after releasing tension on the reins. During the second phase of poll flexion (phase 4), DLC associated with poll flexion developed immediately with mild to moderate bilateral ACC and marked VFC as well as mild ADAF and DMDEM (Figure 1).

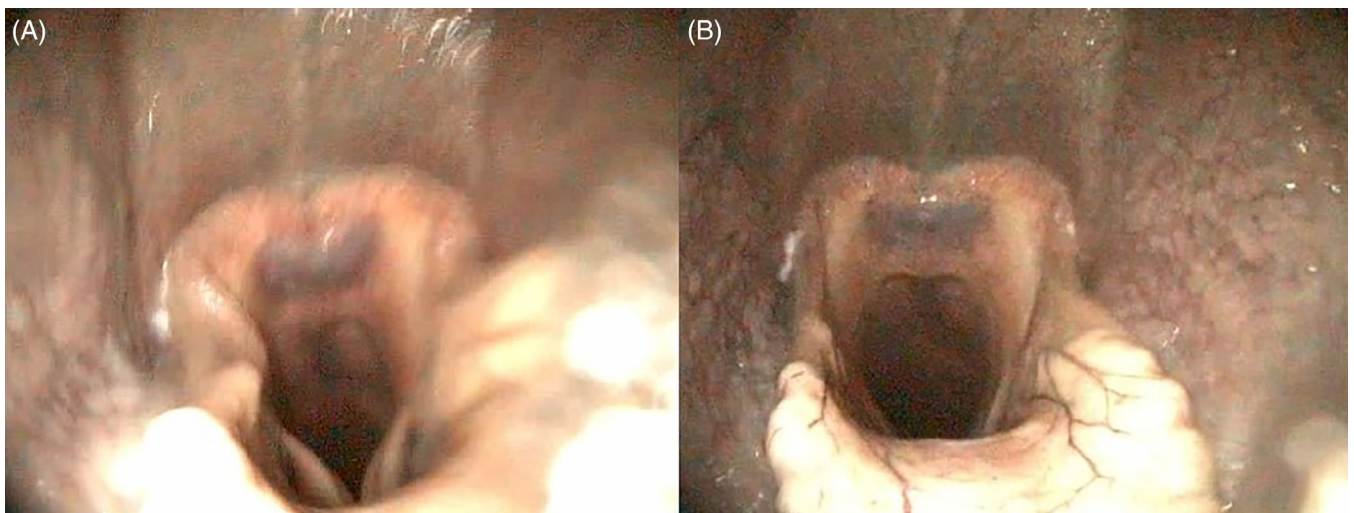
### 3.2 | Case 2

A 3-year-old STB mare first presented to our hospital for upper airway evaluation because of abnormal respiratory

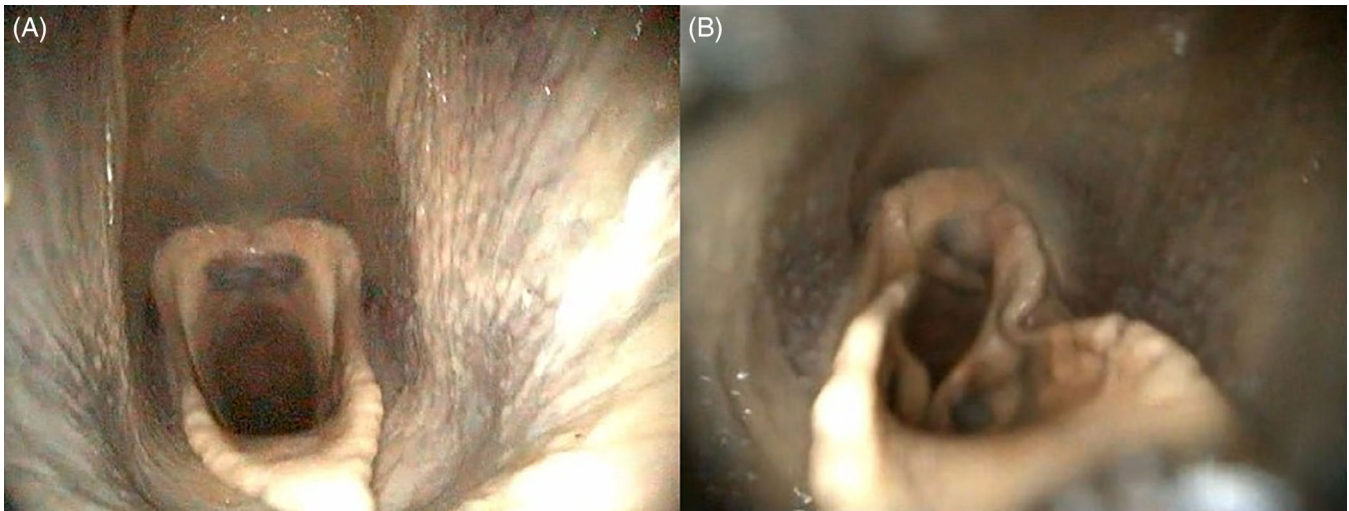
noise and excessive salivation during racing. During HSTV, the mare displayed palatal instability in the first phase of poll flexion (phase 2), then repeatedly displayed iDDSP in the second phase of free head carriage (phase 3), followed by prolonged displacement in the consecutive phases. No other abnormalities were noted at endoscopic evaluation. Surgical treatment was advised, and the mare was treated with the LTFP on the following day. During surgery, the distance from the caudal aspect of the basioid bone to the cranial aspect of the cricoid cartilage (BC distance)<sup>13</sup> was reduced from 85 mm to 45 mm (net rostral advancement 40 mm) as measured intraoperatively.



**FIGURE 1** Case 1 in second phase of poll flexion (phase 4) before the LTFP (A) and after the LTFP (B) illustrating mild to moderate bilateral ACC and marked VFC also associated with mild ADAF and DMDEM. ACC, arytenoid cartilage collapse; ADAF, axial deviation of the aryepiglottic fold; DMDEM, dorsomedial deviation of the epiglottic margin; LTFP, laryngeal tie-forward procedure; VFC, vocal fold collapse



**FIGURE 2** Case 2 in second phase of poll flexion (phase 4) after the LTFP (A) illustrating mild bilateral ACC and moderate VFC along with mild ADAF and DMDEM and immediately afterwards in phase 5 with free head carriage (B) and resolution of laryngeal collapse. ACC, arytenoid cartilage collapse; ADAF, axial deviation of the aryepiglottic fold; DMDEM, dorsomedial deviation of the epiglottic margin; LTFP, laryngeal tie-forward procedure; VFC, vocal fold collapse



**FIGURE 3** Case 3 in second phase of poll flexion (phase 4) before the LTFP (A) and after the LTFP (B) illustrating moderate bilateral ACC and marked VFC along with mild ADAF and moderate DMDEM. ACC, arytenoid cartilage collapse; ADAF, axial deviation of the aryepiglottic fold; DMDEM, dorsomedial deviation of the epiglottic margin; LTFP, laryngeal tie-forward procedure; VFC, vocal fold collapse

Seven months later, the mare re-presented because of poor performance. The mare had mediocre racing results prior to the LTFP, and racing results were poor prior to readmission. During HSTV evaluation at readmission, the mare displayed mild bilateral ACC and moderate VFC associated with poll flexion in all phases with tension applied on the reins (Figure 2). Mild ADAF and DMDEM were also evident during poll flexion. The collapse of laryngeal structures resolved immediately when tension on the reins was released.

### 3.3 | Case 3

A 3-year-old NCT mare presented initially for evaluation of abnormal respiratory noise during exercise, suspected to be due to iDDSP. At HSTV evaluation, the mare displayed iDDSP for 7 seconds on two separate occasions during the first phase of poll flexion (phase 2). Displacement resolved after release of tension on the reins; however, marked palatal instability continued throughout the examination. Surgical treatment for iDDSP with the LTFP was advised, and the mare underwent surgery 2 days later. During surgery, the BC distance was reduced from 100 mm to 55 mm (net rostral advancement 45 mm) as measured intraoperatively.

Thirteen months later, the mare re-presented to our hospital with complaints of return of abnormal respiratory noise during exercise and racing. Prior to the LTFP, the mare placed only once in five races. After the LTFP, the mare improved and placed six times in 12 races before developing poor performance. At presentation, the mare was fit and in normal physical condition. During

HSTV evaluation, the mare demonstrated DLC associated with poll flexion during the first phase of poll flexion (phase 2), characterized by mild bilateral ACC and moderate VFC. The collapse of laryngeal structures resolved immediately after tension on the reins was relieved and returned progressively worse during the second phase of poll flexion (phase 4), as moderate bilateral ACC and marked VFC accompanied by mild ADAF and moderate DMDEM (Figure 3).

## 4 | DISCUSSION

We describe three harness racehorses that developed DLC associated with poll flexion as a complication after the LTFP. These horses were all assessed with HSTV and identical exercise protocols before and after the LTFP, showing no signs of DLC prior to the LTFP. Bilateral arytenoid cartilage and vocal fold collapse associated with poll flexion was first described in 2004<sup>1</sup> and was later renamed *dynamic laryngeal collapse associated with poll flexion* because of frequent concurrent collapse of additional laryngeal structures.<sup>2</sup> The disorder is characterized by bilateral collapse of the arytenoid cartilages and vocal folds occurring only during periods of exercise in “high” poll flexion.<sup>1,2</sup> For harness racehorses, this occurs when the horse is on the bit during training/racing or restrained to prevent premature exhaustion during racing. A decrease in the angle between the mandible and ventral neck of only 12° has been shown to induce DLC in predisposed harness racehorses.<sup>9</sup> Dynamic inward collapse of other laryngeal structures such as the aryepiglottic folds and epiglottic margins is also common,<sup>1,2</sup> as evidenced by the cases in this report. The LTFP in the

three horses included in this study induced a perfect replication of DLC associated with poll flexion identical to naturally occurring cases not subject to previous URT surgery.

The unique feature of DLC is the immediate resolution of collapse of laryngeal structures when tension on the bit and reins is released and horses are exercised with free head carriage.<sup>1</sup> After it has been induced, the disorder is progressive in nature due to Bernoulli's principle and the Venturi effect and causes severe inspiratory obstruction with peak inspiratory tracheal pressures similar or worse compared to horses with experimentally induced left recurrent laryngeal neuropathy.<sup>4</sup> Although it is apparent only during poll flexion, the disorder limits athletic performance in harness racehorses when they race aggressively onto the bit.<sup>2</sup> Symptoms are absent or reduced when affected horses race with a lower head height and maintain head and neck extension.<sup>9</sup> Predisposed harness racehorses may race successfully early in their careers but can demonstrate progressive bilateral laryngeal collapse if they become sufficiently stressed and difficult to restrain on the bit.<sup>1</sup> This results in greater degrees of poll flexion and increasing airway obstruction. Coldblooded trotters are predisposed to this condition relative to STB,<sup>3</sup> seemingly due to anatomic phenotypes and their aggressive racing temperament. The condition has additionally been reported in an Icelandic horse,<sup>5</sup> a showjumper,<sup>6</sup> a competition draught horse,<sup>7</sup> and several different gaited breeds.<sup>8</sup>

The etiology of DLC associated with poll flexion appears to be due to compression of a rostrally positioned (but otherwise normal) larynx by the hyoid apparatus within the intermandibular space in anatomically predisposed horses. A rostrally positioned larynx, relative to the mandibles, is a trait of certain draught and coldblooded breeds of horses and ponies.<sup>15,16</sup> A recent histopathological study of the intrinsic laryngeal muscles in horses with DLC excludes a neuromuscular pathogenesis such as recurrent neuropathy.<sup>17</sup> This has also been confirmed in a recent genetic study in which researchers identified other potential genes associated with the disorder than those currently known to be potentially associated with recurrent neuropathy. (accepted Equine Veterinary Journal).

Conformational changes during poll flexion in horses with DLC prevent full abduction of the arytenoid cartilages, resulting in secondary collapse of the vocal folds.<sup>2,10</sup> Horses experiencing DLC have a more rostral position of the larynx relative to the hyoid apparatus and a decreased laryngeal lumen width during poll flexion compared with healthy controls.<sup>10</sup> Most horses with DLC also display a narrow intermandibular space and an already more rostral baseline position of the larynx relative to the vertical ramus of the mandible.<sup>2</sup> Therefore, in certain predisposed horses, the LTFP seemingly advances the larynx further rostrally within a narrow intermandibular space, creating

external compression and preventing full abduction of the arytenoid cartilages during poll flexion.<sup>10</sup>

Changes in head and neck position during exercise affect upper airway function in horses,<sup>18</sup> and poll flexion itself causes a mild degree of upper airway obstruction that results in greater inspiratory pressures and increased impedance.<sup>18</sup> Poll flexion causes significantly more negative peak inspiratory tracheal pressure in horses experiencing DLC compared with healthy controls.<sup>4</sup> Head and neck flexion causes the larynx to move more rostrally in relation to the hyoid apparatus<sup>19</sup> as well as inducing a narrowing of the pharyngeal and laryngeal lumen width.<sup>20</sup>

The LTFP was developed to treat horses with DDSP and consists of rostral and dorsal advancement of the larynx by use of suture implants.<sup>13</sup> The horse is positioned in approximately 90° of poll flexion when the suture implants are tightened and knotted. McCluskie et al<sup>19</sup> found that the thyroid cartilage was positioned more rostral in relation to the hyoid apparatus in horses with iDDSP when the head was in a flexed position. This effect disappeared after the LTFP because the larynx is physically moved more rostral by means of suture implants.<sup>19</sup> In a case-controlled study of the LTFP, Cheetham et al<sup>12</sup> demonstrated that a more dorsal and less rostral advancement of the larynx is associated with an increased probability of return to racing postoperatively.

Reported complications after LTFP are uncommon and include intraoperative hemorrhage, intraoperative and postoperative suture problems, and incisional swelling and dehiscence.<sup>21</sup> Vocal fold collapse after LTFP has been reported in one case and resulted in abnormal respiratory noise when the horse returned to work.<sup>22</sup> After reevaluation, progressive bilateral VFC (worse on the left side) was noted on HSTV. It was postulated that damage to the cricothyroid muscle due to residual fibrous swelling noted after surgery or damage to the innervation of this muscle during surgery caused the VFC seen postoperatively.<sup>22</sup> The cricothyroid muscle tenses and stabilizes the vocal folds.<sup>23</sup> Dysfunction of the cricothyroid muscle has been reported to cause VFC in horses and is a reported complication after laryngoplasty.<sup>23</sup> The proposed pathophysiology for the VFC reported in that case does not suit the cases presented here. We have also seen VFC independent of poll flexion after the LTFP; however, the lack of association with poll flexion makes this a separate entity with a different pathophysiology. The cases presented in this report display both ACC and VFC during phases of poll flexion only, making a static muscle dysfunction or impairment of innervation unlikely. The rostral advancement of the larynx achieved during LTFP is likely the initiating cause for inducing DLC in horses during phases of poll flexion. Unfortunately, preoperative and postoperative radiographs were not taken in these

three horses; this would have allowed for measurement of the relative changes achieved after the LTFP regarding positioning of the larynx relative to the hyoid apparatus and vertical ramus of the mandible. However, the BC distance<sup>13</sup> was measured intraoperatively with a sterile ruler in two of these horses and was 40 mm and 45 mm, indicating substantial rostral advancement of the larynx relative to the basioid bone.

Effective treatment options for DLC associated with poll flexion in the horse are currently limited. A study in which surgical and conservative management of the disorder was compared in 26 harness racehorses provided no evidence of significant improvement in racing performance after surgical management with bilateral ventriculocordectomy.<sup>2</sup> Arytenoid cartilage collapse was still present to the same degree at reevaluation in these horses, and failure of improved racing performance after bilateral ventriculocordectomy provides evidence that ACC has a much greater impact on reduction of airway function relative to VFC.<sup>2</sup> For example, experimental induction of VFC by bilateral cricothyroid myotomy worsens inspiratory pressures by only  $-4.1$  cm H<sub>2</sub>O during maximal exercise, creating only a mild obstruction to air passage.<sup>23</sup> The bilateral ACC occurring with DLC worsens inspiratory pressures by  $-20$  to  $-30$  cm H<sub>2</sub>O, creating in some cases a severe inspiratory obstruction.<sup>4</sup> We still recommend conservative management with tack modifications including figure-8 nose bands, a longer checkrein and throat plates in an attempt to limit poll flexion. It is also important to keep the affected horse's demeanor calm during training/racing so that they do not pull hard on the reins and bit. Prosthetic laryngoplasty with unilateral or bilateral ventriculocordectomy has been attempted in affected non-racing gaited horses in the later years, but the results have not been critically assessed.<sup>8</sup> We have performed ceratohyoidectomy to treat a horse with DLC, with no significant improvement noted (personal clinical experience).

In conclusion, the rostral advancement of the larynx occurring with the LTFP in certain horses induces DLC associated with poll flexion, which is clinically indistinguishable from the naturally occurring disorder. This represents another confirmation that DLC is due to local anatomic phenotypes. The reason that the LTFP does not induce the condition in all horses may be related to the baseline position of the larynx relative to the intermandibular space and/or hyoid apparatus and the degree of narrowness of the intermandibular space. A previous case-controlled study of the LTFP determined that a more dorsal and less rostral position after surgery was associated with an increased probability of racing postoperatively.<sup>12</sup> The reported complication may be underdiagnosed because confirmation of this disorder requires that the horse be examined videoendoscopically at speed in poll flexion. Horses experiencing DLC make an abnormal respiratory noise that some trainers could confuse

with continued iDDSP, and, therefore, be led to believe that the horse had not responded to the LTFP.

## CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

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