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GENERAL ARTICLE

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A bitless bridle does not limit or prevent dynamic laryngeal collapse

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Abstract

Background: Bits have often been incriminated as a cause of upper respiratory tract obstruction in horses; however, no scientific studies are available to confirm or refute these allegations. Clinical signs of dynamic laryngeal collapse associated with poll flexion (DLC) are induced when susceptible horses are ridden or driven into the bit.

Objective: To determine whether use of Dr Cook's™ Bitless Bridle, instead of a conventional snaffle bit bridle, would reduce the severity of DLC in affected horses measured objectively using inspiratory tracheal pressures.

Study design: Intervention study using each horse as its own control in a block randomised order.

Methods: Nine Norwegian Swedish Coldblooded trotters previously diagnosed with DLC were exercised on two consecutive days using a standardised high-speed treadmill protocol with either a conventional bridle with a snaffle bit, or Dr Cook's™ Bitless Bridle. Head and neck position, rein tension, inspiratory tracheal pressure measurements, and laryngeal videoendoscopy recordings were obtained. A heart rate greater than 200 bpm, and similar degrees of poll flexion/head height, had to be achieved in both bridles for the individual horse's data to be included for comparison.

Results: Seven horses' data met the inclusion criteria. The change in mean inspiratory tracheal pressure between free and flexion phases in the bitless bridle (−15.2 ± 12.3 cmH_2O) was significantly greater ($P < .001$) than in the snaffle bit bridle (−9.8 ± 7.9 cmH_2O). Mean inspiratory pressure during the free phase was significantly ($P < .001$) more negative with the snaffle bit bridle (−32.3 ± 6.3 cmH_2O), vs the bitless bridle (−28.5 ± 6.9 cmH_2O). Mean pressures in flexion phase, snaffle bridle (−42.1 ± 10.8 cmH_2O), vs bitless bridle (−43.7 ± 15.6 cmH_2O) where not significantly different between bridles ($P = .2$).

Main limitation: Small sample size due to difficulty recruiting suitable clinical cases.

Conclusions: This study could not provide any clear evidence that the effect of a snaffle bit in a horse's mouth influences the development or severity of DLC. Instead,

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head and neck angles induced by rein tension seem to be the key event in provoking DLC in susceptible horses.

KEYWORDS
horse, dynamic laryngeal collapse, upper respiratory tract, bit, bitless bridle, tracheal pressure measurement

1 | INTRODUCTION

Upper respiratory tract (URT) obstruction is a common cause of poor performance in racehorses[1-3] and a major cause of lost earnings and wastage from training.[1,4] Bits have been blamed for directly causing or worsening the severity of URT collapse,[5-7] and, since there are no studies to confirm or refute these allegations, bits have become a controversial welfare issue in horses.[7] Dr. Cook's™ cross-under Bitless Bridle (The Bitless Bridle Inc.) was developed to address these purported airway issues but has not been objectively tested in horses with different forms of URT collapse.

Dynamic laryngeal collapse (DLC) associated with poll flexion is a form of URT collapse that is only evident when affected horses are exercised "on the bit."[8] It is characterised by bilaterally symmetric vocal fold collapse, with some degree of concurrent arytenoid cartilage collapse that can result in moderate to severe inspiratory obstruction.[8,9] Horses have been documented to collapse physically during racing due to this form of airway obstruction. The disorder quickly resolves when horses go off the bit and exercise with a more extended head and neck carriage. Dynamic laryngeal collapse is the most frequently diagnosed dynamic URT obstruction in Norwegian Swedish Coldblooded Trotters (NSCT),[10] but has also been documented in other breeds, and in disciplines that require horses to exercise in high poll flexion.[11,12]

The jointed snaffle, a bit commonly used in harness racing, acts by exerting pressure on the bars of the horse's mouth and the tongue.[13,14] The jointed snaffle has a squeezing action on the mouth with little pressure being applied to the tongue with the head in a neutral position. However, with progressive poll flexion the snaffle acts increasingly on the lower jaw and tongue.[15] Dynamic laryngeal collapse occurs in poll flexion and it could be considered that the bits' changing action on the tongue in this position induces the disorder via direct interactions between the tongue, hyoid apparatus and larynx.

The aim of the study was to determine whether use of Dr Cook's™ Bitless Bridle, instead of a conventional bridle with snaffle bit in the horse's mouth, would reduce the severity of DLC in affected horses as measured objectively using inspiratory tracheal pressures. Our hypothesis was that in NSCT horses diagnosed with DLC, use of Dr Cook's™ Cross-under Bitless Bridle (The Bitless Bridle Inc.) would result in less negative inspiratory pressures as a sign of decreased airway obstruction in poll flexion compared with a bridle with a jointed snaffle.

2 | MATERIALS AND METHODS

2.1 | Horses

NSCTs diagnosed with DLC using high speed treadmill videoendoscopy (HSTV) that presented to our institution between October 2011 and May 2018 were prospectively included in the study. The horses were racing fit, had no clinical evidence of concurrent disease or lameness, and had not undergone previous surgery for URT obstruction.

2.2 | Standardised exercise protocol

The horses were exercised in regular racing tack (conventional bridle with snaffle bit or Dr Cook's™ Cross-under Bitless Bridle (The Bitless Bridle Inc.), light harness, checkrein and long reins). A standardised treadmill exercise protocol developed for evaluation of the URT in harness racehorses was conducted.[9] Briefly, the exercise protocol consisted of one minute of exercise in free head carriage, followed by a minute in poll flexion, achieved by gathering and driving the horse "into the bit." This was followed by the horse running alternating phases of one minute of free head carriage, and one minute of poll flexion until the horse showed signs of fatigue, failed to engage the bit or completed four phases in total. Treadmill speed was set at 8.5 m/s and at a 1.5% incline for all tests. For inclusion in data analysis the horse had to: achieve and maintain a heart rate of greater than 200 beats per minute; have a similar head position (height) as determined by ratio 1 and degree of poll flexion measured as detailed below; and be subjected to similar rein tension with the bitless bridle during the flexion phase as with the snaffle bit bridle. Horses were allocated by block randomisation to run with either the bitless bridle or the snaffle bit bridle on the first day, and the alternate bridle on the second day.

2.3 | Rein tension

Rein tension was measured by attaching "Super Samson"™ spring balances (Salters, range 0-25 kg, Salters, FKA Brands Ltd.) inline between the reins and leather grips the driver was holding. During free head carriage the driver applied no force to the reins. During the poll flexion phases the force (weight) applied to the left and right rein was recorded at 20, 30 and 40 seconds after the start of the flexion phase. An average of these 3 measurements was used to determine the rein tension applied during each flexion phase.

2.4 | Head position

A digital video camera (Everio HD, JVC, JVK/Kenwood UK Ltd.) was placed on a stand to the left of the treadmill at a consistent measured spot, marked by tapes on the floor, to capture the horses' head, neck and thorax. White self-adhesive markers were placed on the bridle at the base of the left ear, at the level of the bit, and additionally on top of the left withers (Figure 1). Post processing of the film in a media player (VLC, http://www.videoLAN.com) by pausing and taking one still frame shot was used to obtain 3 still images at 20, 30 and 40 seconds from each minute of the exercise test. The still frames were used to determine an average for each minute of the following parameters: The angle between the withers marker, base of ear (poll marker) and bit (α); and the vertical distance from the sidebar to the poll marker divided by the vertical distance from the withers marker to the sidebar (ratio 1) (Figure 1) as reported previously.

2.5 | Videoendoscopic evaluation

Videoendoscopic (Karl Storz, Karl Storz Endoscopes AS) images were digitally recorded. Recordings from the videoendoscopic examination were later reviewed in real-time and slow motion by two blinded Diplomates of the European College of Veterinary Surgeons with more than 10 years of experience in evaluating equine upper respiratory tract disorders. Dynamic laryngeal collapse was graded by consensus as previously described.[17] Grading was by numerical value (0-3) with arytenoid cartilage collapse (ACC) and vocal fold collapse (VFC) being graded separately, where 0 is normal position and 3 is marked collapse of the structure. The grade given for each of the abnormalities was determined by the most severe grade persisting for 10 seconds or more.

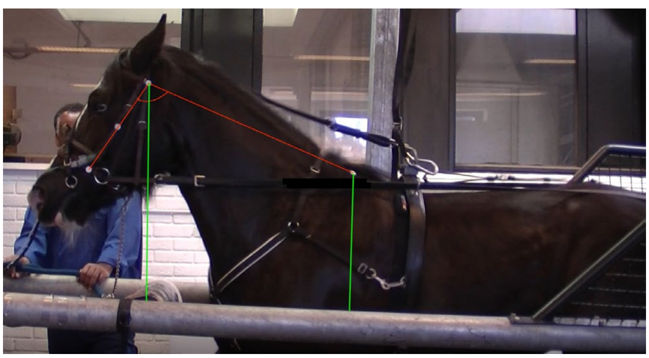

FIGURE 1 A horse on the treadmill showing placement of markers and measurements made. Red lines show "poll flexion angle"; the angle between the two red lines gives the angle of poll flexion in degrees. Green lines show ratio of poll to withers height, calculated by dividing length of poll to treadmill bar height in mm by length of withers to treadmill bar height in mm

2.6 | Tracheal pressure

Tracheal pressure was measured using either "Samba" (Vastra Frolunda, Samba Sensors AS) digital (horse 1-4) or "Millar" (Millar Inc.), analogue (horse 5-9) pressure measurement equipment. The respective pressure sensor was inserted through a 150 cm polyethylene catheter (Baxter Scientific Products) with six side holes in the distal eight cm; the sensor was placed level with the fourth hole from the sealed tip and connected to the control unit. The polyethylene catheter was then placed under videoendoscopic guidance via the right nasal passage so that the catheter tip was 30 cm distal to the larynx in the trachea. The catheter was sutured in place to the external nares. Pressure tracings were continuously recorded in "LabChart Pro version 7" (ADInstruments, ADInstruments Ltd.) on a laptop computer. Peak inspiratory tracheal pressure was determined for each minute of the exercise test by averaging the values for 10 consecutive breaths during the last 15 seconds of each phase of the test.

2.7 | Heart rate

Heart rate was measured by placing a heart rate monitor (Polar, PolarElectro Ltd.) behind the girth at the level of the heart. Data were remotely sent to a pulse watch allowing real time recording of heart rate in beats per minute (bpm). Heart rate was recorded at 20, 30 and 40 seconds into each phase of the exercise test, these 3 values were used to give an average for that phase.

2.8 | Data analysis

Summary statistics of tracheal inspiratory pressure (mean, standard deviation, minimum and maximum values) were calculated for each horse, separated by bridle type (snaffle or bitless) and time period (free or flexion). Linear mixed model analysis with each horse as a random effect and a compound symmetry (exchangeable) correlation structure were fitted to assess the impact of bridle on tracheal inspiratory pressure. Two models were fitted; with bridle as categorical variable (Snaffle free phase [S1], Snaffle flexion phase [S2], Bitless free phase [B1] and Bitless flexion phase [B2]) and with the difference between free and flexion phase for snaffle and bitless as dichotomous variable (S1-S2 vs B1-B2). Intraclass correlation coefficients (ICC) were calculated based on the variance estimates from the models to give an estimate of the level of clustering in the data:

$$\mathrm{ICC} = \sigma^2_{\mathrm{horse}} / \left(\sigma^2 + \sigma^2_{\mathrm{horse}} \right)$$

Models with and without the horse random effect were compared with likelihood ratio tests (LRT). Assumptions for linear mixed models were evaluated. Statistical software (STATA version 16, Stata Corp) was used for all analyses. Significance level was set at $P < .05$.

3 | RESULTS

The horses recruited for the study were between 4 and 7 years of age (mean 5.2 years), and included 4 mares, 4 stallions and one gelding. Tracheal pressure and laryngeal videoendoscopic recordings were obtained for all nine horses; however, only seven horses met all the inclusion criteria for comparisons to be made. One horse was excluded because it did not reach and maintain a heart rate of 200 bpm. Another horse was excluded because it did not achieve a similar degree of poll flexion in the bitless and snaffle bit bridles. The data on poll flexion angles, head height and rein tension are summarised for the seven included horses in Table S1. None of these seven horses had DLC when exercised in free head carriage (Table 1). Some degree of DLC occurred in all individuals when exercised in poll flexion, in both the snaffle bit and the bitless bridle (Table 1).

Only inspiratory pressure data recorded during the first (free) and second (flexion) exercise phase were analysed as inclusion criteria were met by only two horses in the third (free) and forth (flexion) phase due to horses fatiguing during the test. The linear mixed model (Table 2), considering all horses and controlling for repeated measurements, demonstrated that there was a difference between the inspiratory pressure means in the free phase, when DLC was not present, with the snaffle bit bridle causing greater obstruction −32.3 cmH_2O than the bitless bridle −28.5 cmH_2O ($P < 001$). In the flexion phase, DLC was present in all horses, and the difference in inspiratory pressure between the snaffle bit bridle − 42.1 cmH_2O and the bitless bridle −43.7 cmH_2O was not significant ($P = .2$). Examination of the difference in mean inspiratory pressure between the free and flexion phase in each type of bridle demonstrated that the bitless bridle was associated with greater head position-induced change in airway pressures than the snaffle bit bridle, with free to flexion differences of −15.2 and −9.8 cmH_2O respectively ($P < .001$).

Assumptions for linear mixed models were considered met. Results from the LRT gave $P < .001$, indicating that the random effect of horse was significant. ICC from the models were high (65% and 51%) indicating that there was larger variation between horses than within each individual horse.

Nasopharyngeal collapse and dorsal displacement of the soft palate were not observed in any of the included horses regardless of bridle type or whether tension was applied to the reins.

4 | DISCUSSION

This study did not provide any clear evidence that the action of a snaffle bit in a horse's mouth influences the development or severity of DLC. Instead, changes in head and neck angles induced by applying rein tension seem to be the key event in provoking DLC in susceptible horses. Poll flexion produces conformational changes especially regarding the relative positioning of the larynx and hyoid apparatus within the intermandibular space.[18]

As with previous investigations, we found that poll flexion increases peak inspiratory pressures in most horses relative to inspiratory pressures documented when exercised in free head carriage with the head and neck extended.[9,16] Head and neck position have been shown to have an effect on a number of dynamic URT obstructions including palatal instability, intermittent dorsal displacement of the soft palate, epiglottic retroversion, medial deviation of the aryepiglottic folds, DLC and dynamic nasopharyngeal collapse.[10,17,19,20] Exercise in poll flexion increases the severity of collapse in these URT disorders.[10,19,21]

It has been hypothesised that tack may play a role in the aetiology of dynamic airway collapse or can be used to prevent dynamic airway collapse. Woodie et al[22] demonstrated that an external device "the laryngohyoid support" could prevent dorsal displacement of the soft palate in experimentally induced cases. A modified check rein that prevents poll flexion has been shown to limit DLC in the research environment.[16] Thus, it was hypothesised that forms of tack that affect laryngeal position may play a role in the aetiology of DLC or help prevent it. The mechanism by which the snaffle bit was hypothesised to play a role in the development of DLC was by causing the tongue to be moved from its normal anatomical position, to alleviate the discomfort caused by the pressure of the bit on the tongue, and thus via the tongue's muscular attachments to the hyoid apparatus have an effect on laryngeal position.[7,23-26] For example, protraction of the tongue by the genioglossus muscle will also result in the basihyoid bone being pulled rostrally.[27] A more rostral larynx position has been associated with increased risk of DLC.[18] In addition, tongue position effects overall laryngeal and pharyngeal stability, so displacement from its normal anatomical position may have more generalised

Horse		1	2	3	4	5	6	7
Free phase	S	0/0	0/0	0/0	0/0	0/0	0/0	0/0
ACC/VFC	B	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Flexion phase	S	2/3	2/1	1/1	1.5/3	1/1	1/0	1/2
ACC/VFC	B	2/2	1/0	1/2	2/2	1/0	1/0	2/2

Abbreviations: 0, normal; 1, mild; 2, moderate; 3, severe; B, bitless bridle; S, snaffle bit.

TABLE 1 Summary of grade of arytenoid cartilage collapse (ACC) and vocal fold collapse (VFC) during the free head carriage phase and poll flexion phase for each horse

TABLE 2 Inspiratory tracheal pressures (mean ± SD) in cmH_2O recorded in seven horses exercising on a treadmill with head position free and flexed and with two different bridle designs (snaffle bit and bitless)

Horse nr.		1	2	3	4	5	6	7	All horses	*P*-value
Inspiratory pressure free phase	Snaffle bit bridle	−35.5 ± 6.0	−35.8 ± 3.6	−29.9 ± 2.6	−41.7 ± 3.6	−26.1 ± 2.5	−25.7 ± 2.2	−31.6 ± 2.2	**−32.3 ± 6.3**	
	Bitless bridle	−31.6 ± 3.6	−32.2 ± 3.6	−29.0 ± 2.8	−38.4 ± 2.8	−28.3 ± 3.1	−19.1 ± 3.1	−21.0 ± 2.2	**−28.52 ± 6.9**	***P* = .001**
Inspiratory pressure flexion phase	Snaffle bit bridle	−53.8 ± 3.7	−45.7 ± 2.3	−43.3 ± 4.5	−50.9 ± 10.1	−30.0 ± 2.9	−25.8 ± 2.0	−45.3 ± 4.0	−42.1 ± 10.8	
	Bitless bridle	−47.4 ± 2.6	−44.0 ± 4.6	−43.9 ± 4.3	−73.8 ± 9.8	−26.0 ± 3.7	−26.9 ± 2.7	−43.8 ± 2.3	−43.7 ± 15.6	*P* = .2
Difference between inspiratory pressure in free and flexion for each type of bridle	Snaffle bit bridle	−18.3	−9.9	−13.4	−9.2	−3.9	−0.1	−13.7	**−9.8 ± 7.9**	
	Bitless bridle	−15.8	−11.8	−14.9	−35.4	+2.3	−7.8	−22.9	**−15.2 ± 12.3**	***P* < .001***

Bold text denotes values that are significantly different.

*Tracheal inspiratory pressures were compared in mixed linear model analysis.

effects on upper airway stability.[25,26] The jointed snaffle bit has been shown to exert pressure on the tongue when increasing rein tension is applied[13] and the horse is gathered into poll flexion. However, as DLC of similar severity also occurred in the bitless bridle, it seems unlikely that the action of the bit on the tongue plays a role in this disorder. The bit has also been implicated in other URT disorders and has been proposed to affect ventilatory function and thus cause breathlessness;[5-7] however, no other scientific studies directly comparing respiratory responses to bits and bitless bridles have been reported. Since our study demonstrates that the bit has no major effect on the development or severity of DLC, it suggests that a change in the type of bit used is unlikely to provide necessary alleviation of clinical signs for horses affected with this performance limiting URT disorder. Other types of URT disorders such as nasopharyngeal collapse may be more affected by the action of bits and as such should be investigated in future studies in breeds predisposed to these disorders. In our relatively small study using horses preselected as having DLC, nasopharyngeal collapse and dorsal displacement of the soft palate was not observed in any of the horses regardless of bridle type, or whether there was tension applied to the reins.

Obtaining sufficient horses for clinical studies such as this is difficult. First, the horses must have the diagnosis, which should be readily inducible. Racing fitness is a criterion for inclusion due to the vigorous treadmill protocol conducted over two consecutive days. Also, the owners/trainers must be willing to allow their racehorses to participate. Additionally, precise replication of the testing protocol is essential. Therefore, we controlled for a number of parameters such as: heart rate, rein tension, head height and poll flexion angles to ensure similar testing conditions and followed a stringent exercise protocol (Table S1). ICC from the models were high (65% and 51%) indicating that there was a larger variation between horses than within each individual horse, and providing supporting evidence that there was not a large variation in tests for each individual horse, indicating variables were controlled. As there did not appear to be an effect of the jointed snaffle bit on tracheal inspiratory pressure in this small group of horses extending the study to recruit further horses was deemed unnecessary. The difference in mean inspiratory pressure between the two phases, free verses flexion could be interpreted as the bitless bridle caused greater obstruction than the snaffle bit bridle (Table 2). This observation is likely due to the snaffle bit bridle having a more negative baseline inspiratory pressure in the free phase compared with the bitless bridle, but both bits had similar inspiratory pressures during the flexion phase. This resulted in a greater difference in inspiratory pressure between the two phases in the bitless bridle giving the impression that the bitless bridle caused more obstruction. The more negative inspiratory pressure in the snaffle bit bridle during the free phase is an interesting finding and suggests that the presence of a snaffle bit caused mild URT obstruction in these horses. Dr Cook has hypothesised that the airtight lip seal is broken by the presence of a bit and this is an underlying cause in the development of URT pathology.[28] The loss of this seal and the resulting loss of sub-atmospheric pressure in the oropharynx potentially prevents the soft palate from lying firmly against the base of the tongue resulting in a more dorsal positioning of the soft palate and reduction in nasopharyngeal diameter.[28] This reduction in cross-sectional area of the nasopharynx would then result in greater resistance to airflow and more negative inspiratory pressures.[28] No abnormalities were noted on videoendoscopy in any of the horses during the free phase; however, the videoendoscope was positioned such that only the caudal nasopharynx and larynx were visible. The clinical significance of this snaffle-related obstruction is unknown. However, as inspiratory pressures were highly similar for the flexion phase in both bridles, when DLC was present, the snaffle bit does not appear to be associated with DLC pathogenesis. Further studies are needed regarding the snaffle bit´s effect on upper airway dynamics in order to determine its influence on airway mechanics and pathology.

One horse (#5) did not attain the expected drop or worsening of inspiratory pressure with the bitless bridle in poll flexion. Possible explanations for this could be unobserved heterogeneity which can complicate a study of this nature. This would include differences in daily variation in stamina, learning effects on day two to move more efficiently on the treadmill under testing, and in some horses' greater baseline fatigue on day two. By alternating the bridle and bit type used on the first day it was hoped to reduce the impact of these effects on our results.

A final source of error could be the use of the checkrein. We considered whether the bitless bridle test should be conducted without a checkrein; however, we chose to use the checkrein due to its importance in maintaining a similar head height and degree of poll flexion.[16] Had a checkrein not been used with the bitless bridle, it is possible that the horses would have exercised with a greater degree of poll flexion and a lower head carriage than with the checkrein present, causing a bias if the checkrein was used when exercising with the snaffle bit bridle. This would have made comparisons between groups impossible, as both head height and degree of poll flexion seem to be important factors in inducing DLC associated with poll flexion.[16] Thus, it was decided that all tack should be kept constant except for the presence or absence of a jointed snaffle bit. The check bit sits high in the mouth and exerts its pressure on the maxilla limiting the ability of the horse to drop its head and neck, and to potentially break into a gallop during training/racing. It is the action of the snaffle on the tongue and thus hyoid apparatus/larynx that was the theoretical mechanism by which the snaffle bit may induce DLC. The check bit has no action on the tongue and thus should not affect hyoid or larynx position via this mechanism.

The aim of this study was to determine if the jointed snaffle bit's increasing action on the tongue during periods of poll flexion induced or affected the severity of DLC in susceptible horses using objective inspiratory tracheal pressure as the outcome measure. The use of a jointed snaffle bit does not appear to be the inciting event in development of DLC in NSCT, nor does it appear to affect severity of obstruction when DLC is present. Therefore, a change in bit or bridle type will likely not provide improvement of airway function during racing in clinical cases affected with DLC.

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CONFLICT OF INTEREST

None of the authors have competing interests to declare.

AUTHOR CONTRIBUTIONS

All authors contributed to data collection, writing and proofing of the manuscript.

ETHICAL ANIMAL RESEARCH

All procedures were approved by the Faculty of Veterinary Science, Norwegian University of Life Sciences in accordance with national legislation for ethical animal research.

OWNER INFORMED CONSENT

Owners gave consent for their animals' inclusion in the study.

DATA ACCESSIBILITY STATEMENT

The data that supports the findings of this study is available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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