Final report

Objektiv måling av øvre luftvegs obstrukskjon i Norsk og Svenske travhester

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Part 1: Detailed summary

Kollaps av øvre luftveier under anstrengelse er en av de mest vanlig årsaker til nedsatt prestasjon hos sports-hester globalt sett. Det finnes en rekke luftveislidelser hos hest, deriblant flere dynamiske øvre luftveislidelser. Dynamiske lidelser viser seg kun under anstrengelse, og er dermed umulig å diagnosere når hesten står i ro. Hesten er unik fordi den kun puster gjennom nesen. Under harde anstrengelse kan volumet luft den puster inn og ut komme opp i hele 2000 liter per minutt. Til å flytte så mye luft inn og ut av øvre luftveier på kort tid under anstrengelse, må stort inspiratorisk og ekspiratorisk lufttrykk skapes. Disse forandringer i lufttrykk over tid kan forårsaker kollaps av forskjellig struktur i øvre luftveiene. Det finnes minst 10 forskjellig former for dynamisk øvre luftveis kollaps på hest.

Hindres luftstrømmen i nesegang, svelg eller larynks da kan det by på betydelige helse-velferds- og prestasjonsproblemer. Opp til nå, evaluering og gradering av kollaps i svelget på hest og mennesker er gjort subjektivt fra videoopptak tatt under endoskopi på tredemølle eller «overground» undersøkelse.

Vårt mål med denne studien var til å kontinuerlig måle lufttrykk i øvre luftveier på aktive travhester med nedsatt prestasjon, samtidig med videoendoskopisk undersøkelse. Dette ble foretatt på tredemølle under anstrengelse. Vår hypotese var at det ville være mulig å få presise objektive tall på grad av obstruksjon på travhester med øvre luftveis kollaps i nesebor, svelg eller larynks. Etter behandling ville disse trykks målinger objektiv kunne vise hvis hesten er

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blitt bedre og validere forskjellig operasjoner eller behandlinger. Med trykk måling det burde også være mulig å friskmelde en hest som hadde normalt forventet lufttrykk i øvre luftveier, uten tegn til inspiratorisk eller ekspiratorisk obstruksjon.

Alle travhester var testet ved Veterinær høgskolen ved NMBU. De var først varmet opp ca. 3000m til å venne seg til tredemøllen. Deretter ble hodelag med sjekk reim, bitt og lange kjøre tømmer satt på hesten. Deretter var et videoendoskop, EKG, og trykk måler utstyrt på hesten (pre-kalibret 250cm lang analogue trykk sensor, Millar Inc, Texas). Trykkmåleren var satt ca. 30cm ned i trakea. Under testen målte trykksensoren kontinuerlig inspiratorisk og ekspiratorisk lufttrykk ved hver respirasjon i Lab Chart Pro V8, samtidig som videoendoskopet tok opptak av det som skjedde i halsen på hver hest. Hestene var kjørt 1,5 grader oppover bakke i 8,5m/sek. fart for kaldblods travere og 9m/sek. for varmblods travere i 4-7 minutter, til de enten var slitne eller en eller flere dynamiske øvre luftveis lidelser ble oppdaget. Hester som var testet for alar fold kollaps hadde trykkmåler plassert i svelget uten endoskop og ble kjørt i 2 minutter med puls over 200/minutt. Deretter var alar foldene suturert oppover, for å stenge de falske neseborene, og hesten var kjørt for 2minuter til med puls på 200 og med trykk måler plassert i svelget for å måle bedring (eller ikke). Etter operasjon ble mange av disse hester testet igjen med trykk måling til å validere behandlingen.

Denne «studien» som ble nylig utført ved NMBU viste at det er mulig å nøyaktig måle inspiratorisk/ ekspiratorisk lufttrykk i trakea og svelget i kliniske kasus i godt under en time, uten komplikasjoner for hesten. Totalt sett har vi testet 300+ aktive kald-og varmblods travere, enkelte på elite nivå. Trykksensoren målte trykket i luftveiene på inn- og utpust, og oppdaget unormale trykkforandringer som følge av vev (som for eksempel falske neseboret) som kollapset. Dette har gjort at vi kan nå kategorisere ulike typer av øvre luftveis kollaps som inspiratorisk/ ekspiratorisk, eller begge deler. Vi kan også gradere ulike alvorlighetsgrader av kollaps som: 1) så vidt målbar (forandring i luft trykk ± 0 til 5 cmH_20); 2) mild (± 5 til10 cmH_20); 3) moderat (± 10 til 20 cmH_20); eller 4) markant (> ± 20 cmH_20). Dette prosjektet har økt vår kunnskap i luftveienes fysiologi, og gitt oss en objektiv måte til å vurdere behov for operasjon og respons på eventuelle inngrep.

Dette forskningsprosjektet burde få stor betydning for travhestenes velferd, helse og løpsprestasjoner. Mange trenere i Norge benytter nå denne type testing ved NMBU på hester de mistenker har øvre luftveis kollaps under løp.

Veterinærhøgskolen ved NMBU samarbeider med leger og forskere ved Haukeland Universitetssykehus i Bergen som nylig har utviklet videoendoskopisk undersøkelser for mennesker som løper på tredemølle og får øvre luftveis kollaps (EILO - exercise induced laryngeal obstruction) under anstrengelse slik hester gjør. Erfaring fra NMBU Veterinærhøgskolens prosjekt på varm-og kaldblods travhester er blitt brukt til å utvikle en metode til å måle inspiratorisk-og ekspiratorisk lufttrykk i øvre luftveier hos mennesker som løper på tredemølle og får øvre luftveiskollaps. Denne metoden er nå publisert i internasjonale medisinske tidsskrifter. Legene er også veldig interessert i denne metoden til å validere fremtidig behandlinger på deres pasienter.

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Part 2: Main report (max. 10 pages)

Introduction

The horse is an obligate nasal breather, incapable of efficient air transport through the oral cavity as most other species. Despite this, sporting horses breathe up to 1800 - 2000 liters of air/ minute during peak exercise intensity, all of which passes through the nostrils, nasal passageways and nasopharynx before entering the larynx and thereafter the lower airways. This rapid transport of large amounts of air during inspiration and expiration results in great pressure fluctuations which places different regions of the upper respiratory tract (URT) under considerable stress. Therefore, URT obstruction, or inward collapse of airway structures, during exercise is one of the most common causes of poor performance in sporting and racing horses in Scandinavia, and worldwide. URT collapse can occur at the level of the nostrils/ alar folds (false nostril), nasopharynx, larynx and proximal trachea, and also involve multiple structures concurrently. Most of these disorders are not diagnosable during resting endoscopy and therefore are ”dynamic” and require endoscopy during exercise for definitive diagnosis.

Evaluation of laryngeal/ pharyngeal collapse during exercise in horses and humans is currently graded “subjectively” by clinicians through visual review of videoendoscopic recordings from treadmill or overground endoscopy (Figure 1). One visualizes endoscopically the anatomic structure(s) which are collapsing inward, but it is difficult to know the degree of abnormal airway obstruction being created. A great number of Equine studies (100+) have been published in the international literature during the past 30 years, assessing racing performance parameters (wins and placings, money earned, racing times, etc.) before URT diagnosis, and after treatment.[1] The purpose of which is an attempt to classify and grade the severity of obstruction caused by the different forms of URT collapse, and thereafter the improvement attained (or not) with different established or new surgical procedures. These methods are also subjective and biased, as racehorses often develop other concurrent performance problems or go down in racing class, which will influence performance parameters and confound results.

This project seeks to develop airway pressure measurement as an ”objective” clinical tool during high speed treadmill videoendoscopy to assess the type and degree of obstruction occurring in the individual horse. It is hypothesized that re-evaluation of the patient after an intervention or treatment with airway pressure measurements, during an identical exercise test, will provide direct objective data readily available for statistical analysis. This will allow for a more critical assessment of specific therapies/ surgeries, and should raise the “level of evidence” in this area of veterinary medicine.

Our research group has recently applied the same airway pressure measurement techniques in human medicine for the first time with a group of physicians in Norway who have pioneered treadmill endoscopy for the diagnosis of ”exercise induced laryngeal obstruction” (EILO).[2] Human medicine is also very interested in this type of technology to validate their specific treatments for EILO in their patients.[3]

This particular project for which we received funding from Stiftelse Hestforskning and the Norwegian Research Council (NFR), will test normal and URT obstruction “affected” harness racehorses (Standardbreds and Coldblooded trotters) competing in Norway and Sweden. The anticipated research results should quickly be of benefit to the racing industry and improve

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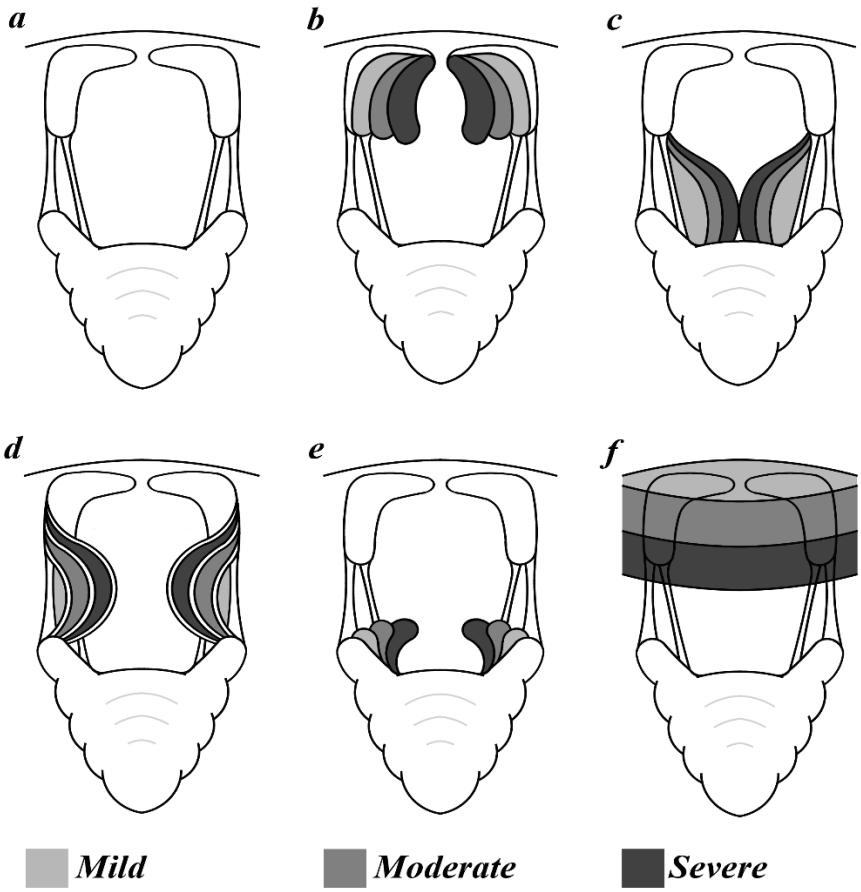
Equine welfare and health. Additionally, this project represents use of new technology, which could benefit both veterinary and human medicine.

Figure 1: Subjective grading scheme of upper respiratory tract (URT) collapse during exercise developed at NMBU. (Strand E, Fjordbakk CT, et al. Relative prevalence of upper respiratory tract obstructive disorders in 2 breeds of harness racehorses (185 cases: 1998-2006) ***Equine Vet J*** 2012.)



a) Normal fully abducted larynx *b*) arytenoid cartilage collapse *c*) vocal fold collapse *d)* aryepiglottic fold collapse *e*) collapse of the margins of the epiglottis *f*) collapse of the roof of the nasopharynx

PROJECT BACKGROUND

Airway pressure measurements in horses were first performed in North America in the 1990's and have been to date mainly employed in scientific studies. Our group at NMBU has approximately 16 years experience in measuring airway pressures from our own scientific studies.[4,5] A recent "pilot study" in Equine clinical cases performed at NMBU revealed that it is possible to measure URT obstruction objectively and non-invasively with pressure transducers in either the trachea or nasopharynx during treadmill endoscopy on an out-patient basis.

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SPECIFIC AIMS OF THE PROJECT

The overall aim of this project was to develop and refine the use of airway pressure measurements in harness racehorses for the first time in clinical cases presenting on an outpatient basis. These horses presented to our university (NMBU) teaching hospital for poor performance workup or fitness evaluation during high speed treadmill videoendoscopy. We wished to: define normal range limits for inspiratory/ expiratory tracheal pressures in harness racehorses exercising maximally; assess the percentage of horses tested with this technique for which we acquired reliable airway pressure readings; and to quantify the degree (mild, moderate, severe) and type of airway obstruction (inspiratory/ expiratory/ both) for common Equine upper respiratory tract disorders. Finally we wished to demonstrate the usefulness of airway pressure measurements with a particular form of URT obstruction occuring at the level of the nares – alar fold collapse. Diagnosis of this disorder, at this point in time, is very subjective. We wished to develop and validate a definitive test for assessing whether a horse has alar fold collapse, based upon nasopharyngeal airway pressure measurement, and definitely assess the improvement in airway pressure acheived after appropriate surgical treatment.

1) ***Manuscript 1***- To determine normal range of baseline values for peak inspiratory and expiratory tracheal pressures during maximal exercise in healthy, successful Standardbreds and Coldblooded trotters.

2) ***Manuscript 2***- To objectively determine and rank the severity of inspiratory and/or expiratory airway obstruction occurring with a number of common dynamic URT disorders using simultaneous treadmill videoendoscopy and tracheal pressure measurements. These abnormalities include *palatal instability, dorsal displacement of the soft palate, collapse of the nasopharynx, laryngeal neuropathy, dynamic arytenoid and vocal fold collapse, inward collapse of the aryepiglottic folds and margins of the epiglottis, epiglottic entrapment*, etc.

3) ***Manuscript 3***- To validate an objective test recently developed by us for definitively diagnosing *alar fold collapse* using nasopharyngeal airway pressure measurements. Airway pressures will be measured in strenuously exercising horses – baseline status and after tying up the alar folds - in normal and alar fold collapse affected horses. This will establish “cut-off” pressure values for normal vs. affected individuals. Thereby providing an objective method of assessing need for surgery. Presently this disorder is diagnosed by subjectively assessing improvement in abnormal respiratory noise after tying the alar folds up, thereby closing the entrance to the false nostril. Improvement attained after surgery will also be determined.

   In addition to these 3 broader manuscripts (studies) we wished to complete a study (manuscript) comparing *use of a bitless bridle to a conventional ”bitted” bridle* in inducing the disorder ”dynamic laryngeal collapse associated with poll flexion” using tracheal airway measurements as the major outcome measurement. This dynamic

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disorder is especially common in the Scandinavian Coldblodded trotter which is known to trot very aggressively into the bit during training and especially racing. Additionally we wished to perform a conventional study using racing data before and after diagnosing/ treating *intermittent dorsal displacement of the soft palate* at our hospital. This study will be the first part of a future PhD Thesis illustrating the convention method of assessing a URT disorder versus the new method developed here using airway pressure measurements as the definitive outcome measure. Finally, we wished to publish a manuscript with a series of Standardbreds and Coldblooded Trotters undergoing our testing protocol which were diagnosed with *compression of the epiglottis during poll flexion*. This conditon has not been described before in the veterinary literature. The tracheal pressure readings witnessed with this ”new” URT disorder will be presented in ***Manuscript 2.***

Material and methods

High-speed treadmill examinations took place in our original treadmill facility in Oslo until November 30 2020; and thereafter at the new Veterinary Teaching Hospital on Campus Ås (ca 30minutes outside Oslo) from December 1, 2020 to completion of the project. Both campuses housed a “Sato” high-speed treadmill (manufactured in Sweden) and advanced endoscopy equipment, EKG monitors and other necessary equipment. All horse were driven by experienced harness racehorse trainers employed at our teaching hospital.

Population: Typically, 60-90 harness racehorses present each year to our facility as clinical cases for dynamic upper respiratory tract evaluation, poor performance evaluation or fitness evaluation prior to the upcoming season. Tracheal pressure measurements were taken concurrently and continuously with the videoendoscopic examination in most horses.

Exercise protocol: All horses were exercised using a previously standardized HSTV protocol (used on all our previous projects and publications) 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 2500-3000 meters, the horses were exercised for 1-minute phases, alternating between free head carriage (phases 1, 3, 5) and poll flexion (phases 2, 4, 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 Coldblooded trotters were exercised at a constant speed of 8.5 m/s, and the Standardbreds at 9 m/s, at the trot on a 1.5° treadmill incline until full fatigue.

Tracheal / nasopharyngeal pressure readings were performed using a pre-calibrated 250cm long analogue pressure sensor (Millar Inc, Texas). The pressure sensor was inserted through a 150cm long 4mm outer diameter polyethylene catheter, with 6 side holes in the distal 8 cm. The sensor was then positioned at the end of the protective catheter, level with the fourth hole from the sealed tip, and connected to a digital control unit v8 (AD Instruments Ltd. UK). The polyethylene catheter is then placed under videoendoscopic guidance via the right nasal passageway so that the catheter tip is 30cm distal to the larynx in the trachea. If testing

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nasopharyngeal pressure (for alar fold collapse) the same equipment was positioned at the level of the guttural pouch openings, rostral to the apex of the epiglottis. The catheter is fastened to the endoscope holding strap, at the level of the nostril, with one suture. Pressure tracings were continuously viewed/ recorded in "Lab Chart Pro v8" on a laptop computer. Mean peak inspiratory / expiratory nasopharyngeal/ tracheal pressure were determined for each 1-minute phase of the exercise test by averaging the values for 10 consecutive breaths during the last 15 seconds of each phase (minute) of the exercise test. Abnormalities, if present, were graded visually as in Figure 1 and the mean (+ SD) inspiratory/ expiratory pressures were determined from 10 consecutive breathes when the abnormality was present.

Statistical analysis:

- ***Manuscript 1*** A repeated measures ANOVA with Tukey's post hoc test for pairwise comparisons was performed to analyze and compare the mean peak inspiratory and expiratory tracheal pressures in each consecutive phase for each horse.

- ***Manuscript 2*** A two-way repeated measures ANOVA with Tukey's post hoc test for pairwise comparisons was performed to analyze the mean peak inspiratory and expiratory tracheal pressures for different laryngeal/pharyngeal disorders in different phases of the exercise protocol and to compare affected phases to baseline values of unaffected horses for respective phases.

- ***Manuscript 3*** A two-way repeated measures ANOVA with Tukey's post hoc test for pairwise comparisons was performed to analyse the effect of *suturing up the alar folds* on inspiratory and expiratory nasopharyngeal pressures versus baseline values. Horses available for post operative nasopharyngeal pressure testing also were evaluated with two-way repeated measures ANOVA with Tukey's post hoc test for pairwise comparisons with regard to baseline, *suturing up the alar folds* and attained *post-operative values*.

Results and discussion

Overall findings

During this project period, we have acquired tracheal and/or nasopharyngeal airway pressure measurement in 300+ active Standardbreds or Coldblooded trotters presenting for dynamic URT evaluation and/ or fitness evaluation. Equipping/ tacking the horses, warming them up on the treadmill for 2000 to 3000meters, and then performing the actual videoendoscopy/ pressure measurement test took typically 30-40 minutes for each individual. None of these horses experienced any complication of the pressure measurement protocol/ equipment that required veterinary attention. We obtained excellent quality continuous pressure tracings in 95% of the tested horses for the exercise test period which varied from 4 to 8 minutes. The main reason for not acquiring good data was due to mucous from the trachea clogging the catheter holes near the sensor causing drift in the pressure readings. This situation is easily

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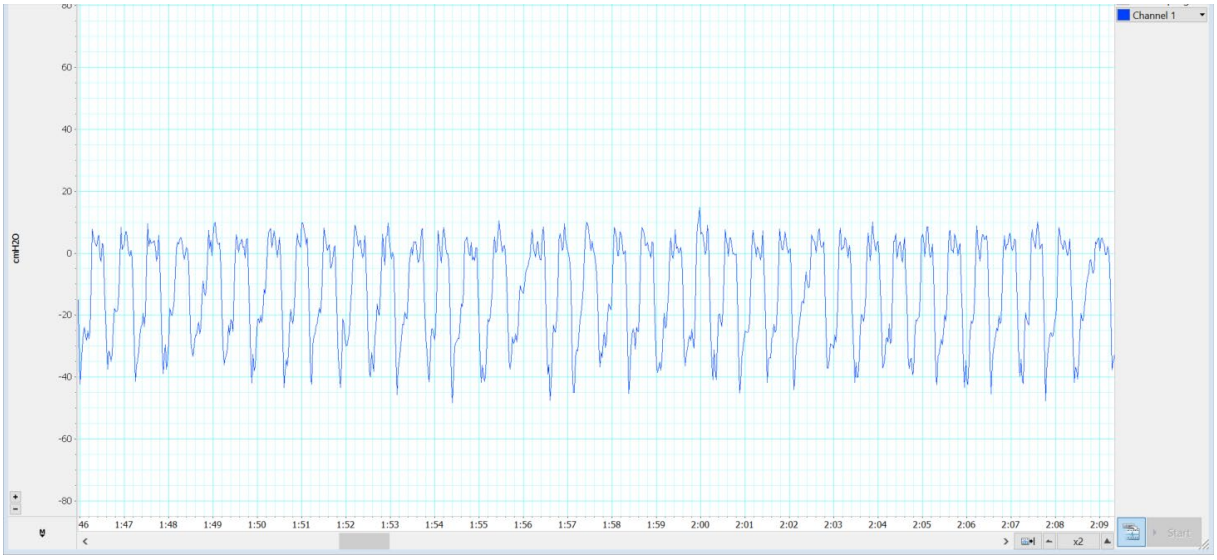
recognized for the individual horse and such data was disgarded. On rare occasion, a horse protested having the pressure measuring catheter placed along side the endoscope in the nasal passageway. If a horse was especially uncooperative the pressure measuring part of the examination was terminated.

Manuscript 1

Inspiratory and expiratory tracheal pressure values (mean and SD of 10 consecutive breathes) were established during the end of each 1 minute period (phase) of the 5 to 7 minute long treadmill test using a total of 76 ”clinically normal” Standardbreds and Coldblooded trotters.

The figure (#2) below shows a typical pressure tracing of a ”normal” harness racehorse exercising maximally. The peak inspiratory pressure is ca. -40 cm H_20; the peak expiratory pressure is ca +9 cm H_20. Note the consistency of the readings for 35 consecutive breathes over 23 seconds taken inbetween phase 2 and 3 of the exercise test.

Figure 2 – example of inspiratory and expiratory pressure tracing for a normal racehorse. The positive spikes are peak expiration and the negative spikes represent peak inspiratory pressure. Airway pressure is measured in cmH_2O.



Most horses tested in this study reached peak inspiratory and expiratory pressures by phases 4 (poll flexion) and 5 (free head carriage). In both breeds of horses poll flexion phases (2,4,6) had greater (more negative) inspiratory pressure peaks than ”free head carraige” phases of a magnitude of 3.5 cm H_20. This represents a change in the conformation of the airways during poll flexion (horse on the bit) which creates a mild inspiratory obstruction in itself.

Statistical analysis revealed no significant differences between breeds for inspiratory and expiratory pressures during high intensity exercise. Neither was there a significant difference across different levels of racing performance and experience among the horses as a group. However there is some variabilty in the inspiratory and expiratory pressures measured at the end of each 1 minute phase of the test, which reflects the horses as individuals and how their respective respiratory tracts are dimensioned and function.

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Manuscript 2

The airway pressure measurements have allowed us to accurately categorize different forms of URT obstruction as ***inspiratory/ expiratory, or combined***. It has also allowed us to grade obstructions as: 1) ***barely measurable*** (change in pressure ± 0 to 5 cmH_2O); 2) ***mild*** (± 5 to 10 cmH_2O); 3**)** ***moderate*** (± 10 to 20 cmH_2O); or 4) ***severe*** (> ±20 cmH_2O).

These airway pressure readings also allowed us to determine whether a horse was "free" from any form of upper respiratory tract obstruction. By having the pressure sensor in the nasopharynx, we could evaluate the region from the nostrils to the rostral nasopharynx for evidence of obstruction, such as alar fold collapse. When the pressure sensor was located in the trachea, we evaluated the total region of the URT from nares to the rostral trachea. The most severe airway obstruction measurements we recorded were associated with unilateral or bilateral arytenoid cartilage collapse. These were cases presenting with *idiopathic laryngeal neuropathy* or *dynamic laryngeal collapse associated with poll flexion.* Interestingly, several endoscopically visual obstructive disorders such as *palatal instability, medial deviation of the aryepiglottic folds and epiglottic entrapment* created none to only very mild changes in the airway pressure profiles in tested horses. This indicates that surgical treatment may be unnecessary, at least in the short term, for certain diagnoses. Once the statistical analysis is completed for this study, a ranking of the degree of severity of airway obstruction during strenuous exercise for different nasopharyngeal and laryngeal disorders will be established. It is expected that some of the findings will surprise veterinary clinicians who deal with URT obstructive disorders in horses.

**This manuscript is being readied for peer review submission to *Equine Veterinary Journal* Autumn 2025/ Winter 2026.

Manuscript 3

Twenty-one alar fold collapse affected individuals, and 6 "normal" controls were tested with nasopharyngeal airway pressure measurement before (baseline) and after suturing up the alar folds bilaterally. Simple main effects analysis showed that *suturing up the alar folds* had a significant effect on expiratory tracheal pressures **(p<0.001),** but not on inspiratory tracheal pressures (Figure 3). Expiratory tracheal pressures decreased from (mean ± SD) **35.8 ± 8.81** cmH_2O before *suturing up the alar folds* to **20.1 ± 7.04** cmH_2O after in 21 affected horses. This validates suturing up the alar folds and closing the entrance to the false nostril as a diagnostic test for this condition.

Thirteen of the 21 horses were available for post-operative nasopharyngeal airway pressure measurement once they had returned to racing. A further decrease (improvement) in expiratory pressure **13.3 ± 2.29** was witnessed relative to baseline affected values **(p<0.0001)** and to alar folds sutured up **(p=0.0030)**. Six "normal" horses without any clinical evidence of alar fold collapse had nasopharyngeal pressures of **7.8 ± 1.89** (mean ± SD) indicating that

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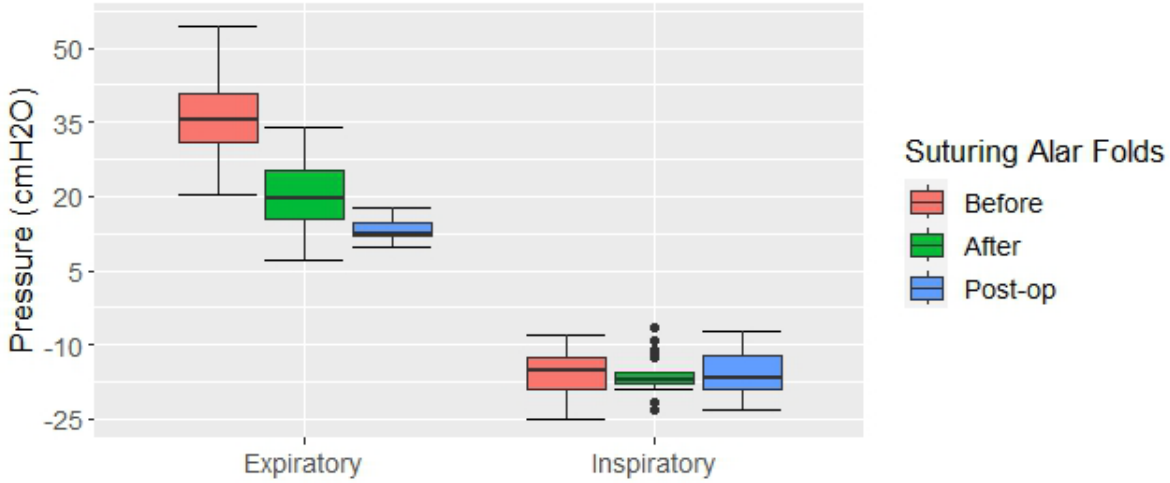
complete alar fold resection surgery almost restored nasopharyngeal airway pressures to the expected “normal” range.

No significant change was noted regarding inspiratory nasopharyngeal pressures between these 3 phases indicating that alar fold collapse is a dynamic form of URT obstruction which affects expiration only (Figure 3).

Figure 3. Expiratory and inspiratory nasopharyngeal airway pressures measured in 21 Standardsbred racehorses baseline (before) and after suturing up the alar folds. Thirteen of these 21 horses additionally had pressures measured again after corrective surgery (post-op) and return to racing.



Alar fold collapse has traditionally been thought of as a form of inspiratory airway obstruction, which creates abnormal respiratory noise, and has an uncertain effect on racing performance. Utilizing airway pressure technology we have demonstrated that alar fold collapse causes an expiratory obstruction in all cases, which is of such a magnitude that it must impair racing performance since the horse is an obligate nasal breather. Using our scale of airway obstruction on the 21 horses diagnosed with alar fold collapse: 5 horse were diagnosed with mild obstruction (increase pressure +5 to 10 cmH_2O); 9 horses had moderate obstruction (increase +10 to +20 cmH_2O); and 7 horses had severe obstruction (> 20 cmH_2O). This study demonstrates that alar fold obstruction can be a serious obstructive disorder in Standardbreds and should be treated based upon animal welfare concerns.

**This manuscript was accepted for publication in *Equine Veterinary Journal* June 13, 2025 (DOI: 10.1111/evj.14556).

This overall project seeks to broaden our understanding of Equine airway physiology, and provide an objective tool to assess the need for surgical treatment and assess the response thereafter. It is anticipated that this will benefit the health and welfare of horses in Scandinavia and beyond.

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Airway measurements hold the potential to provide objective, continuous, numerical and verifiable data to describe URT function during exercise. If the pharynx/larynx is viewed as the entrance valve to the airway tree, future access to such data can become as important to respiratory medicine as transvalvular pressure gradients are in today's cardiology.

Finally, the findings of this study will thereafter be applied in human medicine with a group of physicians we collaborate with at Haukeland (Human) University Hospital, who have pioneered treadmill endoscopy in children and adults during the past decade. Our collaborative research team has just published the first ever translaryngeal airway pressure measurements taken during treadmill endoscopy in exercising humans.[6]

Conclusions

It is possible to accurately measure airway pressures, simultaneously with high-speed treadmill videoendoscopy, in Equine clinical cases presenting on an outpatient basis. Accurate inspiratory and expiratory pressure profiles were generated in 95% of over 300 active harness racehorses tested. These profiles allowed for accurate categorization of inspiratory/ expiratory obstruction as none, mild, moderate, and severe for the different upper respiratory tract disorders commonly diagnosed in harness racehorses. These airway pressure readings also allowed us to determine whether a horse was "free from" all forms of upper respiratory tract obstruction. The most severe airway obstruction measurements were associated with arytenoid cartilage collapse. These were cases presenting with *idiopathic laryngeal neuropathy* or *dynamic laryngeal collapse associated with poll flexion.*

Alar fold collapse, which up to now has been a very subjective diagnosis in veterinary medicine, can be definitely diagnosed with nasopharyngeal airway pressure measurements. In all cases the obstruction to airflow was witnessed during the expiratory phase. Either tying-up the alar folds, thereby preventing the false nostril from filling with air during inspiration which creates an obstruction to expiration, or surgically resecting these structures restores airway pressures to near normal levels. Airway pressure measurements provide direct continuous objective data during an exercise test which readily can be used for statistical analysis thereby elevating the level of evidence over previously employed before and after (diagnosis/ intervention) racing performance analysis. Airway pressure measurements hold the promise of one day becoming as important to respiratory tract medicine, as blood pressure measurements have become in cardiology.

Relevance for the practical horse sector including recommendations.

Airway pressure measuring has become a permanent part of our upper respiratory tract obstruction evaluation protocol for Standardbreds and Cold-Blooded Trotters. This is a unique clinical test provided only by our university (NMBU) in Norway, and presently nowhere else in the world.

Results of this project are already incorporated in student teaching at NMBU, in the area of Equine upper respiratory tract obstruction, and the results have been conveyed to referring veterinarians in Norway. There is growing awareness among major harness racing trainers in

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Norway that this technique is available at NMBU for horses with poor performance or in need of fitness evaluation. Trainers and owners are encouraged to be present during the examination so that they witness the examination themselves and advertise this form of testing by word of mouth to the "trotting" community. Due to increased popularity, in 2023 we tested nearly 100 cases for upper airway obstruction. The results of this study have been presented at major international veterinary congresses to colleagues, specialists, and researchers. Two of the 3 manuscripts are accepted to *Equine Veterinary Journal*, a leading manuscript for Equine veterinary research.

The same equipment and procedures have been applied at Haukeland (Human) University Hospital in Bergen, Norway in humans for the first time after cooperation with our research team at NMBU.[2,6] They hope to develop a clinical test similar to our Equine test for outpatient testing of children and adults with exercise induced laryngeal obstruction (EILO).

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5) Fjordbakk CT, Holcombe SJ, Fintl C, Chalmers H, and Strand E. A novel treatment for dynamic laryngeal collapse associated with poll flexion – the modified air-check. ***Equine Vet J*** 2012, 44 (2) 207-213. ***Combined Norwegian/ Swedish Foundation for Equine Research # H0947078. Norges forskningsråd # 202983.***
6) Fretheim-Kelly Z, Engan M, Clemm H, Andersen T, Heimdal JH, Strand E, Halvorsen T, Røksund O, Vollsæter, M. Reliability of trans-laryngeal resistance measurements during maximal exercise. ***European Respiratory Journal (ERJ) Open Research.*** 2022; 08: 00581-2021. DOI: 10.1183/23120541.00581-2021.

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Part 3: Result dissemination

State all result dissemination from the financed project into the appropriate section, including information as indicated in each section. Additional rows can be added to the table.

Scientific publications	**Manuscript 1:** Vermedal H, Risnes I, Fretheim-Kelly Z, Olsen HMB, Fintl C, and Strand E. Inspiratory and expiratory tracheal airway pressures during high-intensity exercise in harness racehorses. Accepted to ***Equine Veterinary Journal*** June 22, 2025 (DOI:10.1111/ejv.14557). **Manuscript 3** Strand E, Vermedal H, Olsen HMB, Fjordbakk CT and Fretheim Kelly Z. Objective diagnosis of alar fold collapse in active Standardbred trotting racehorses using nasopharyngeal airway pressure measurements. Accepted to ***Equine Veterinary Journal*** June 13, 2025. (DOI:10.1111/evj.14556). **Manuscript 2** Vermedal H, Risnes I, Fretheim-Kelly Z, Fintl C, and Strand E. Ranking the severity of commonly encountered upper respiratory tract obstructive disorders utilizing inspiratory and expiratory tracheal airway pressure measurements in active harness racehorses. To be submitted to ***Equine Veterinary Journal*** Autumn 2025/ Winter 2026.

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	Bonus manuscripts associated with this project:
	Fretheim-Kelly Z, Fjordbakk CT, Fintl C & Strand E. A bitless bridle does not limit or prevent dynamic laryngeal collapse. ***Equine Vet J.*** 2020; 00: 1-7. DOI: 10.1111/evj.13287.
	Vermedal H, O'Leary JM, Fjordbakk CT, McAloon C, Løkslett H, Stadsnes B, Fretheim-Kelly Z and Strand E. Outcome analysis of 95 harness racehorses with confirmed dorsal displacement of the soft palate treated with laryngeal tie-forward surgery. ***Equine Vet J***. 2021. DOI: 10.1111/EVJ.13479
	Vermedal H, O'Leary JM, Klemsdal AE, Roen GM, Fretheim-Kelly Z, and Strand E. Unilateral and bilateral compression of the epiglottis during poll flexion in harness racehorses. ***Equine Veterinary Education*** 2023. DOI: 10.1111/eve.13925. Olsen HMB, Sørby R, and Strand E. Progressive sequential development of left and right sided idiopathic recurrent laryngeal neuropathy in a standardbred racehorse. Accepted ***Equine Veterinary Education*** Nov.14, 2024. **DOI:** 10.1111/eve.14089
Conference publications/ presentations	Vermedal H, O'Leary JM, Fjordbakk CT, McAloon C, Løkslett H, Stadsnes B, Fretheim-Kelly Z and Strand E. Outcome analysis of 95 harness racehorses with confirmed dorsal displacement of the soft palate treated with laryngeal tie-forward surgery. Awarded 2nd place of top 10 Abstract Presentations at 2021 ***European College of Veterinary Surgeons (ECVS) "Virtual" Resident Forum***. July 8, 2021.
	Vermedal H, O'Leary JM, Klemsdal AE, Roen GM, Fretheim-Kelly Z, and Strand E. Unilateral and bilateral compression of the epiglottis during poll flexion in harness racehorses. Presented by Sigrid Lykkjen at ***European College of Veterinary Surgeons (ECVS) Annual Scientific Meeting,*** Cracow, Poland. July 7, 2023.
	Strand E, Vermedal H, Fjordbakk CT and Fretheim-Kelly Z. Objective diagnosis of alar fold obstruction in Standardbreds. ***Annual Scientific Meeting of American College of Veterinary Surgeons,*** Louisville, Kentucky October 16, 2023. Online abstract ***Veterinary Surgery*** 2023.

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Other publications, *media etc.*	"Luftveistest for travhester kan hjelpe mennesker – Hest og mennesker kan ha lignende pusteproblemer. Norges Miljo-og Biovitenskapelige Universitet (NMBU) Internet publication. October 2021.
	«Alene i verden om å bruke denne teknologien på aktive travhester: - På dette feltet ligger hestemedisin langt foran human medisin» Skrivet av Maren Gahrmaker Kalleberg, **Hest.no**. November 2023.
Oral communication, *to horse sector, students etc.*	The findings of this study have been incorporated in my teaching lectures and practical demonstrations at NMBU to our veterinary students and have been conveyed to our referring veterinarians in the field.
Student theses	Emma Sofia Sundstrom and Kristine Solberg. Objective measurement of upper respiratory tract function in racehorses – minute volume, airflow, and airway pressure measurements (a review). Student MSc. Thesis Project completed Dec 3. 2020.
Other	Hanna Vermedal, DVM will complete a **PhD Thesis** titled "Objective measurement of upper respiratory tract obstruction in harness racehorses." which will include a number of these manuscripts -Thesis defense Autumn 2026.

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