In vitro comparison of three techniques of prosthesis attachment to the muscular process of the equine arytenoid cartilage

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Abstract

Objectives- To determine the degree and ease of arytenoid abduction achieved with abaxial placement of a FASTak II suture anchor compared to 2 suture patterns with different directions of insertion – caudomedial to craniolateral and medial to lateral)

Study Design- Ex vivo experimental.

Study population- Cadaveric larynges from 10 Standardbred racehorses.

Methods- Each larynx was sequentially instrumented with all 3 arytenoid suture attachment in random order: 1- abaxial placement of a FASTak II suture, 2- caudomedial to craniolateral suture, and 3- medial to lateral suture placement. Each construct was abducted at 5 N increments from 0 to 25 N and the left to right quotient angle ratio (LRQ) measured from digital pictures acquired at each sequential increment.

Results- Arytenoid abduction (higher LRQ) was greater with FASTak II construct than either of the suture patterns. The largest difference occurred at 5N. Approximately 50% less force was required to achieve an LRQ of 1.0 with the FASTak II anchor compared to the suture patterns. No difference was detected between the two suture constructs throughout the study.

Conclusions- Use of the FASTak II suture anchor improved arytenoid abduction compared to 2 suture patterns and minimized the suture loads required to achieve maximum arytenoid abduction.

Clinical Relevance- Use of the FASTak II anchor may decrease the suture load required to achieve arytenoid abduction in clinical cases. This may reduce the load placed on the laryngoplasty, thereby , minimizing postoperative loss of abduction.

Comment [DG1]: Thank you for checking that the scientific content of your abstract has been preserved. I added “abaxial” since it is discussed in your discussion

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INTRODUCTION

Recurrent laryngeal neuropathy (RLN) is a common problem in horses, affecting up to 10% of Thoroughbreds and 42% of draft horses.¹⁻³ The general principle of the laryngoplasty remains largely identical to its original description by Marks et al. in 1970 and is still considered to be the treatment of choice for this condition in athletic horses.⁴ However, complications are common, loss of abduction occurring acutely as a result of construct failure (3-11%) or gradually, as reported in nearly all cases.⁵⁻⁸ This loss of abduction reduces the cross sectional area of the rima glottis and associated airflow, thereby affecting performance.^{9,10}

Research efforts have first focused on improving biomechanical testing techniques, including recent cyclical testing, to identify components of the laryngoplasty construct that could stabilize the degree of rima glottis abduction.¹¹⁻¹⁶ In parallel, multiple techniques for laryngeal prosthesis have been

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developed to reduce suture/cartilage failure.¹⁶⁻²¹ All share similar biomechanical fundamentals, aimed at replacing the function of the cricoarytenoideus dorsalis muscle (CAD).²² The placement of prosthetic material at the caudal aspect of the cricoid cartilage has been tested to determine the configuration or positioning that maximizes arytenoid abduction.^{13,23-25} Suboptimal placement of prosthetic material during laryngoplasty increases the force required to abduct the arytenoid and promote postoperative loss of abduction. Another line of research deals with methods of anchoring the prosthesis to the muscular process, relying mainly on single cycle to failure models.^{13,26-28} Among those, predrilling a hole prior to placing a trocar needle seemed to offer no biomechanical advantage over direct suture placement.¹¹ More recently, single screw fixation (Corkscrew® device, Arthrex) resulted in more stable constructs in cyclical testing than double

or single loops.²⁵ In the same study, the strongest construct in single cycle to failure consisted of a double loop, whereas the weakest included a single loop, screw fixation displaying intermediate properties. The last field of research focuses the influence of prosthetic materials and implantation techniques, on arytenoid abduction, as measured by cross sectional area and or left to right quotient angle ratio (LRQ).^{11,14,29,30}

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Follow this by a brief statement, justifying your study. I.e why will your approach address the limitations / gap in knowledge.

The first objective of this study was to determine which of three laryngoplasty techniques required the least amount of force to achieve clinically relevant arytenoid abduction. Our test group involved a FASTak II® suture anchor with #2 preloaded Fiberwire® (Arthrex). Our positive control group consisted of a caudomedial to craniolateral suture technique, representing the current standard-of-care.^{23,31} Our negative control group consisted of a suture placed in a medial to lateral direction without engaging the arytenoid spine, a suture placement through the muscular process, considered as “suboptimal”. We hypothesized that our test group would achieve greater arytenoid abduction than either control group. We also hypothesized Furthermore, we hypothesized that our positive control group would achieve greater arytenoid abduction than our negative control group.

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MATERIALS AND METHODS

Specimen preparation

Larynges from 10 Standardbred horses aged 3-11 years euthanized for reasons other than respiratory disease were collected and frozen at -20°C. Larynges were

thawed in batches at room temperature (23°C) for 24 hours. All laryngeal cartilages, articulations, and the right cricoarytenoideus dorsalis muscle, the right cricoarytenoideus lateralis muscle and the left cricoarytenoideus lateralis muscle were retained for testing. All other soft tissue (including the left CAD muscle) was removed.

Specimen positioning

Each larynx was positioned in the identically, in a customized cradle positioned 30cm from a digital camera (HC-V250 high definition digital camera, Panasonic, Osaka, Japan) that was controlled remotely using generic wireless technology.^{13,23,24} A 10cm ruler was affixed to the cradle in frame as a reference.

Suture placement

For each larynx, the right arytenoid was maximally abducted to mimic the degree of abduction during maximal exertion. This adduction was achieved with suture material placed according to a standard laryngoplasty and fixed as such for the duration of the testing.³² Subsequently, the left side of each larynx was instrumented with each of the three constructs in a random order. Both suture constructs were placed using #5 Ethibond Excel (7 metric; V-37, Ethicon Inc, NJ)¹² in either a caudomedial to craniolateral (positive control) or horizontal medial to lateral (negative control) direction (not exiting at the arytenoid spine) by an experienced surgeon so that the muscular process was engaged (needle exit 1cm to apex of muscular process). The FASTak®II (Arthrex – 11.7mm from eyelet to tip and 2.8mm diameter) with preloaded #2 Fiberwire suture (AR-1324HF, Arthrex) was placed in the arytenoid 10mm cranial to the insertion of

the CAD muscle, as described previously.²⁵ The free ends of the 6 cm long loops were then attached caudally, immediately adjacent to the cricoid cartilage 1.5cm lateral to the midline, to a hand held tensiometer (Transducer techniques, Temecula, CA) similar to previous reports.^{23,24,33}

Mechanical testing

Each construct was sequentially loaded from 0 to 25N at 5N increments with digital images acquired at each point. The tested construct was then removed and replaced by the next construct and repeated until all were tested.

Left to Right Quotient angle ratio (LRQ)

Arytenoid LRQ was measured and calculated, as described previously, from each photograph by one blinded observer (B.A.) using a soft-ware package (Image J, Bethesda, USA).^{29,34} In brief, a line was drawn from the ventral to the dorsal aspect of the rima glottis and then extended by one third to give a point that was used to measure the left (L^0) and right (R^0) arytenoid angles. The LRQ was calculated by L^0 divided by R^0 .

Statistical analysis

Data were checked for normality and homogeneity of variance using D'Agostino's SK test, '90, and Levene's, '60, Robust test for the equality of variances between groups. Data was modelled using mixed effects regression models with the outcome 'LRQ' and predictor variables 'load' and 'construct'. Wald statistics were used to indicate significant terms in the mixed effects model and a chi-square

test was used to confirm the significance of the random effect. A p-value of 0.05 was used to assign statistical significance throughout.

RESULTS

All constructs were tested with no evidence of cartilage or suture failure. All constructs produced incremental increases in LRQ (Fig 1). At zero load there was no significant difference in LRQ between the three constructs ($p=0.7$) (Fig 2). The FASTak II construct produced significantly more abduction (higher LRQ) compared to both the suture constructs at all loads above zero with the difference being largest at 5N ($p<0.02$). Approximately 50% less force was required to achieve an LRQ of 1.0 for the FASTak II anchor compared to the suture patterns tested. There were no differences between the two suture constructs at any load throughout the study ($p>0.05$).

DISCUSSION

The objective of this study was to determine which of the three suture attachment techniques evaluated produced the greatest degree of arytenoid abduction at certain loads. Based on our results, our first hypothesis can be accepted and our second hypothesis rejected, since the FASTak II anchor produce the highest LRQ, but no difference was detected between our 2 suture groups.

The superior results achieved by our test group may be attributed to the abaxially located anchor point of the FASTak II. This point replicates the point of attachment of the CAD muscle more accurately than our suture techniques, and

therefore required less force to achieve arytenoid abduction. This effect may be caused by the lever arm created by the cricoid, arytenoid and cricoarytenoideus articulation.³⁰ Facilitated abduction via abaxial fixation of the arytenoid is clinically attractive. Indeed, this technique should lessen the force applied to the suture material to achieve the desired degree of arytenoid abduction, concurrently reducing the overall load placed on the construct. This would be expected to improve the ability of the construct to resist in vivo cycling loading, minimizing the loss of abduction due to cartilage or suture failure.

The loads used in this study were similar to those previously reported when evaluating the cricoid cartilage component of the construct.^{23,35} Although the lower loads (5N) reported to achieve abduction in cadaveric larynges may not transfer directly to in vivo application, differences between the anchor and the suture techniques persisted to relatively high in vitro loads of 25N. This value approaches the load of 27.6N reported to achieve clinically relevant arytenoid abduction in vivo.³⁵ The findings of this study prompt us to propose that abaxial fixation with the FASTak II anchor reduce the load required to achieve relevant abduction in clinical cases.

Gradual loss of arytenoid abduction occurs after most laryngoplasty procedures.⁶ Techniques found to decrease postoperative loss of abduction include mechanical arthrodesis of the cricoarytenoid joint,³⁶ and stabilization of the cricoarytenoid joint with laser facilitated surgery or injection of polymethylmethacrylate.^{37,38} These salvage procedures destroy the cricoarytenoid joint and remain possible after the abaxial fixation with an anchor such as the FASTak II. However, the combination of both approaches warrant further evaluation.

The lack of difference between the 2 suture patterns tested here may have been expected; although their direction differed, both sutures were placed through the body of the arytenoid. As a result, distraction forces originate from the centre of the body of the arytenoid in both suture patterns. Based on our results, we infer that, as long as a secure bite is obtained, the direction of the suture would not be important with regards to the load required for abduction in clinical cases. It was interesting to note that, above 10N of load, minimal benefit was gained from applying further load to any of the three constructs tested here. In addition, applying loads beyond those needed to achieve appropriate abduction may contribute to surgical failure due to cartilage or construct failure.

The load applied to the suture to achieve maximum abduction (LRQ=1.0) was 50% lower in the FASTak II anchor group than any of the suture patterns tested. This would imply that the load applied to the construct to achieve a clinically desirable degree of arytenoid abduction may be decreased by half compared to more conventional suture attachment. However, extrapolation of our results warrants caution as removal of soft tissue may influence the overall loads required to achieve abduction. The clinical relevance of the loads measured in this study warrant further evaluation, perhaps using pressure sensors.^{35,39}

In conclusion, laryngoplasty with abaxial placement of a FASTak II anchor resulted in a construct that achieved maximal arytenoid abduction (LRQ 1.0) with approximately 50% of the loads required to achieve this result with a conventional suture technique. Use of suture anchors may facilitate intra-operative arytenoid abduction and reduce post-operative loss of abduction. These encouraging results warrant in vivo evaluation.

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Figure 1. Sequential digital images of LRQ from 0.7, 0.8, 0.9 and 1.0 (left to right).

Figure 2. Load versus resultant LRQ for each construct. Stars denote significant differences between FASTak II and suture constructs ($p<0.05$). (FASTak was the FASTak construct, M->L was the medial to lateral suture placement and CdM->CrL was the caudomedial to craniolateral suture placement)

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249x81mm (300 x 300 DPI)

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Figure 2. Load versus resultant LRQ for each construct. Stars denote significant differences between FASTak II and both suture constructs ($p < 0.05$). (FASTak was the FASTak II construct, M->L was the medial to lateral suture placement and CdM->CrL was the caudomedial to craniolateral suture placement)

361x270mm (300 x 300 DPI)

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