Arytenoid Cartilage Retention of Laryngoplasty in Horses—In Vitro Assessment of Effect of Age, Placement Site, and Implantation Technique

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The results of this study question the idea that failure of the muscular process is more frequent in one- and two-year-old horses because of the presumably softer (more immature) arytenoid cartilage of their larynges. From a surgical point of view, it is quite appropriate to operate on horses with idiopathic laryngeal hemiplegia when they are yearlings or two-year-olds. Author’s addresses: Chirurgische Veterinärklinik, Universität Gießen, Frankfurter Str. 108, 35392 Gießen, Germany (Herde); Tierärztliche Klinik Telgte, Telgte, Germany (Boening); Klinik für Innere Krankheiten des Pferdes, Universität Gießen, Frankfurter Str. 126, 35392 Gießen, Germany (Sasse). © 2001 AAEP.

1. Introduction

Idiopathic laryngeal hemiplegia has been well documented as a significant and relatively common laryngeal disease of horses. Inspiratory stridor, audible as “whistling” or “roaring,” and exercise intolerance are the most common clinical signs. Neuropathy of the left recurrent laryngeal nerve leads to dysfunction of the intrinsic musculature of the left side of the larynx. Functional loss of the dorsal cricoarytenoid muscle results in medial displacement of the ipsilateral arytenoid cartilage and vocal fold. The consequence of medial displacement of the arytenoid cartilage during inspiration is a functional obstruction of the upper airway. During exercise, higher inspiratory flow rates and increased subatmospheric pressures within the airway lead to further collapse of the affected arytenoid cartilage and associated vocal fold. Increased air turbulence is created, producing the classic “roaring” noise.

Several surgical techniques for correcting laryngeal hemiplegia have been described. According to Marks et al., laryngoplasty effectively reverses upper airway obstruction in exercising horses with experimentally induced left laryngeal hemiplegia. Reported clinical success rates of laryngoplasty in horses with idiopathic left laryngeal hemiplegia (ILH) are highly variable, depending on the criteria used for evaluation. Surgical complications attributed to wound infection and improper prosthesis placement are the reasons for some clinical failures.

Reasons for laryngoplasty failure, which is specifically defined as initial arytenoid abduction followed by complete or partial collapse of the fixation, are not well documented or well understood. Insufficiency of the cartilage—of the muscular process in particular—to retain prosthetic devices has been suggested as a cause of this failure. It has been suggested that the cartilage of one- and two-year-old...
horses is softer (more immature) than that of older animals and that pulling the prosthesis out of the cartilage of younger horses is thus facilitated.3

Measurable biomechanical factors that affect cartilage retention of prostheses include cartilage strength, prosthesis tension, and prosthetic material variables. The amount of prosthesis tension required to cause arytenoid cartilage failure is unknown. Approximately 2 kg of load was originally recommended for arytenoid abduction.1 Other descriptions of the procedure suggest that the prosthesis should be tightened as much as possible.6 Additionally, it is recommended that young horses receive smaller tensile loads than do older horses.7 Boswell et al.5 and Dean et al.8 showed in their in vitro studies that the muscular process of arytenoid cartilage is the part of the laryngoplasty fixation most likely to fail.

The purpose of the study reported here was to determine the amount of load required to cause a suture in the muscular process of the arytenoid cartilage to fail. The principles of fixation failure also were examined. Specimen age and site were evaluated to determine if normal one- and two-year-old horses have reduced cartilage retention strength when compared with three- to 30-year-old horses and if there is a difference in cartilage retention strength between the left and the right muscular processes. The study also sought to determine if a modified implantation technique would increase holding strength and dynamic elasticity.

2. Materials and Methods

Specimen
Forty fresh, clinically normal larynges from one- to 30-year-old warmblood horses were harvested at an abattoir (Fig. 1). The left and right arytenoid cartilages of each larynx were isolated and the intrinsic musculature was removed to facilitate accurate, comparable placement of the prosthesis at the side of the muscular process. Specimens were immediately vacuum packed, stored at −20°C, and defrosted at room temperature 24 hours before testing.

Implantation Technique
Both the left and the right muscular processes were transversely predrilled with a 16-gauge hypodermic needle. The location of this drilling hole was always 1 cm distal to the muscle insertion of the dorsal cricoarytenoid muscle. The needle was withdrawn and a crochet hook was used to insert the prosthesis. In this study, a metric 6 Mersilene® thread served as a prosthetic implant. In all cases, the total length of the predrilled tunnel was 1 cm (Fig. 2).

Mechanical Testing
With the specimen oriented horizontally, the suture arms were secured to the fixed and moving heads of a Zwick® material testing machine.9 Progressive tensile forces in a proximal direction were applied to the implanted prosthesis until this caused the thread to pull out of the muscular process. In all specimens, tension load was applied to the cartilage in the same way as in the in-vivo situation (direction parallel to the cricoarytenoid articulation, i.e., rostromedial–caudolateral). The sutures were distracted to failure at a displacement rate of 25 mm/s.

Applied force and displacement were measured. Graphs of load vs. displacement were generated and the following values were measured:

1. The force (N) and tension (%) necessary to cause partial failure of the left and right muscular processes.
2. The force (N) and tension (%) necessary to cause complete failure of the left and right muscular processes.

Statistical Analysis
Statistical analysis was carried out with the statistical program package BMDP.9,c The effect of a horse’s age on cartilage retention strength was tested by using the BMDP6D program to perform correlation and regression analyses. To describe the data, correlation coefficient (r) and regression line (y = m · x + b) were given. A logistic regression was performed to analyze the dependency between the occurrence of load displacement graphs showing a first partial muscular process failure and the age of the horse. Age was logarithmically transformed because its distribution was skewed to the right. The matched pairs t-test was used to compare the retention strengths of the left and the right cartilages. p values ≤ 0.05 indicate statistical significance. p values were given exactly.

3. Results
In 27 specimens, a load displacement graph of each muscular process showed uniform displacement during loading, followed by complete muscular process failure (Fig. 3). The force causing complete cartilage failure was, on average, 131.32 N (SD...
$35.81 \) for the left muscular process and $113.13 \text{ N (SD 26.00)}$ for the right muscular process. These forces were approximately five to six times higher than the 2 kg tensile force recommended for manual fixation during surgery.

For 53 specimens, the load displacement graph showed an initial partial muscular process failure followed by increased cartilage retention strength before complete muscular process failure. These findings were characterized by peak(s) ≥1 in the load-displacement curves (Fig. 4). Average force at the first partial failure was 77.50 N (SD 26.65) for the left muscular process and 75.65 N (SD 28.63) for the right one.

Partial muscular process failure occasionally occurred at loads that were approximately half of the ultimate cartilage retention strength. This type of failure could occur similarly in clinical cases by acute mechanical cartilage failure, which would result in endoscopic evidence of arytenoid relaxation without complete cartilage failure. With regard to the force required for complete cartilage failure, the left muscular process showed a significantly higher

\[ \text{Fig. 2. Specimen prepared for testing.} \]

\[ \text{Fig. 3. Load displacement graph showing uniform displacement during loading followed by complete muscular process failure.} \]

\[ \text{Fig. 4. Load displacement graph showing partial muscular process failure at the first peak (1) followed by increased cartilage retention strength before complete muscular process failure (2).} \]
stability than did the right one. Also, tension for complete failure of the left muscular process was significantly higher ($p = 0.0039$) than it was for the right muscular process.

Age did not significantly influence the force required for complete cartilage failure of the left muscular process. For the right muscular process, however, it was established that age was a significant influence ($p = 0.002$). The slope of the regression line prepared for the right cartilage was negative ($m = -1.6560$) and characterized the average decline of the force required for complete cartilage failure per year of life (Fig. 5). This influence could not be established for the left muscular process (Fig. 6).

The influence of a horse’s age on the first partial muscular process failure was not significant for the left side (Fig. 7) but was significant ($p = 0.034$) for the right one. The slope of the regression line prepared for the right cartilage was negative ($m = -1.2705$) and characterized the average decline of the force required for the first partial failure per year of life (Fig. 8). For the left muscular process, it could be established that, with increasing age, there is a tendency for load-displacement graphs showing a first partial muscular process failure to occur more frequently. This frequency was, however, barely significant ($p = 0.067$).

These results question the hypothesis that cutting into the muscular process is facilitated in one- or two-year-old horses because of the presumably softer (more immature) condition of their arytenoid cartilages. The right muscular process shows a tendency to lose its stability with advancing years. This tendency could not, however, be established for the left cartilage. For the left muscular process, increased occurrence of first partial cartilage failure with advancing years became apparent. This first partial cartilage failure may postoperatively lead to endoscopic evidence of arytenoid relaxation.

4. Discussion

Possible modes of clinical laryngoplasty failure include acute mechanical cartilage failure, cyclic cartilage failure, cartilage fracture, and improper

![Fig. 5](image5.png)

Fig. 5. The slope of the regression line prepared for the right cartilage was negative and characterized the average decline of the force required until complete cartilage failure per year of life.

![Fig. 7](image7.png)

Fig. 7. Regression line prepared for the left muscular process. There was no significant influence of age on the first partial muscular process failure.

![Fig. 6](image6.png)

Fig. 6. Regression line prepared for the left muscular process. There was no significant influence of age on the force required until complete cartilage failure.

![Fig. 8](image8.png)

Fig. 8. The slope of the regression line prepared for the right cartilage was negative and characterized the average decline of the force required until the first partial failure per year of life.
prosthesis placement. In the study reported here, complete cartilage disruption occurred because of acute mechanical failure. Considering the cartilage retention strengths (approximately five to six times the recommended placement load), this type of complete cartilage failure is unlikely to occur in clinical cases. Local muscular contractions and changing luminal barometric pressures, which act on the prosthesis and the cartilage, are presumably small loads when compared with the tension load.

Load-displacement curves in 53 specimens showed an initial partial muscular process failure at the first peak. Partial cartilage failure occasionally occurred at loads that were approximately half of the ultimate cartilage retention strength. This principle of failure could occur similarly in clinical cases, which would result in endoscopic evidence of arytenoid relaxation. Individual and age-related differences in cell, fiber, and matrix structures presumably are reasons for first partial muscular cartilage failure, particularly concerning implantation sites and superficial cartilage structures. This is supported by the study of Orsini et al., which describes increasing mineralization of the muscular process exclusively with advancing years.

Comparing the left and right muscular processes intra-individually, it was found that in almost all cases the left cartilage was characterized by stronger retention strength. The reason for this significant left-to-right difference is not easy to define. One possible reason could be phylogenetically defined size differences. Additional data to establish phylogenetical hypoplasia of the right muscular process are required. With the present number of cases, significant age-related decreasing retention strength can be demonstrated only on the right muscular process. For the left muscular process only, it could be established that there is a tendency for first partial cartilage failure to occur more frequently with increasing age. On the other hand, the percentage of complete cartilage failure was less in young horses. This leads to the conclusion that laryngoplasty can be performed in yearlings and two-year-olds.

By using a modified implantation technique called double-loop implantation (Fig. 9), which is used in a small number of cases, we achieved increased cartilage elasticity not only in the phase of complete failure but especially at first partial muscular process failure. By using this double-loop implantation technique, the elastic phase of cartilage deformation is extended and final complete failure is delayed. This method preferably will be used on older horses when proceeding cartilage mineralization causes a lower degree of retention strength.

No in-vivo studies have yet been performed, but in-vivo use of the technique seems to be possible.

References and Footnotes


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