Title Page

Running head:
Outcomes of horses treated with removal of a laryngoplasty prosthesis

Article Title:
Outcomes of horses treated with removal of a laryngoplasty prosthesis

Author Names:
Laura E Fitzharris1 BVSc CertESM DipACVSMR MRCVS
J. Geoffrey Lane2 BVetMed DESTS FRCVS
Kate J Allen1 BVSc PhD CertEM(IntMed) DipACVSMR MRCVS

Institutional Affiliation:
1 = University of Bristol, UK.
2 = Cedars Surgical Services, Somerset, UK.

Grant/Financial Support:
The primary author, Laura Fitzharris, conducted the research during a residency training position funded by the Horserace Betting Levy Board (HBLB).

Conflict of Interest:
The authors declare no conflict of interest related to this report.
Presentation:

The results have not been published or presented however, an abstract has been accepted for combined podium and poster presentation at the International Conference of Equine Exercise Physiology in Lorne, Australia in November 2018.

Corresponding Author:

Laura Fitzharris

Equine Sports Medicine Centre,

University of Bristol,

Langford House,

Langford,

Bristol,

BS40 5DU

UK

LE.Fitzharris@gmail.com
Abstract:

Objectives: (i) To determine the proportion of horses treated by laryngoplasty prosthesis removal (LPR) for complications associated with prosthetic laryngoplasty (LP), (ii) to determine the reason for LPR, and (iii) to determine the outcome of horses undergoing LPR to manage iatrogenic coughing / dysphagia.

Study design: Retrospective study

Sample Population: Client-owned horses treated with LP (n=1202) and LPR (n=58)

Methods: Clinical case records were reviewed to determine the number of horses treated with LP and LPR by the same surgeon. Historical, clinical, endoscopic and surgical data were extracted for those horses undergoing LPR. Long term outcome was assessed by questionnaire.

Results: The proportion of horses treated with LP subsequently treated with LPR by the same surgeon was 3.5% (42/1202). Coughing / dysphagia was the reason for LPR in 90% (52/58) of horses. Sufficient follow-up to determine outcome in horses undergoing LPR for coughing / dysphagia was available in 32 horses. Arytenoid abduction grade at the time of LPR did not significantly influence clinical response (p=0.416). Presenting clinical signs resolved following LPR in 21/32 (66%) horses and 24/32 (75%) horses returned to exercise.

Conclusions: Coughing / dysphagia was the most common reason for LPR. Clinical signs improved in the majority of horses following LPR.

Clinical significance: Laryngoplasty prosthesis removal can be a useful treatment option for horses affected with unmanageable coughing / dysphagia caused by LP.
Prosthetic laryngoplasty (LP) is the mainstay of treatment for horses with recurrent laryngeal neuropathy, but it is recognized to have a high rate of post-operative complications in comparison with other surgeries performed to treat dynamic upper airway obstructions. Short term complications include prosthesis failure, loss of abduction, seroma formation, incisional dehiscence and coughing. In the longer term there may be loss of abduction, chronic coughing, dysphagia, with or without the nasal reflux of ingesta, aspiration pneumonia, inflammatory airway disease, exercise induced pulmonary haemorrhage, esophageal incompetence, dysfunction of the soft palate and other forms of dynamic airway obstruction.

Coughing resulting from dysphagia is the most common complication following LP, with studies reporting 5-57% of horses affected. Several mechanisms to explain the dysphagia following LP have been proposed: (i) reduced protection of the rima glottidis during swallowing due to inability to adduct the arytenoid cartilage and removal of the vocal cords; (ii) damage to the muscles of the upper esophagus, their innervation or the peri-esophageal fascia and adventitia; (iii) development of adhesions lateral to the larynx, between the arytenoid and thyroid cartilages, and to the cranial esophagus or esophageal diverticulum. Many horses with complications following LP can be managed conservatively. However, persistent or severe coughing / dysphagia, which affects the ability to be ridden, quality of life, or results in an increased risk of developing respiratory infection or aspiration pneumonia, may be an indication for laryngoplasty prosthesis removal (LPR). Laryngoplasty prosthesis removal may lead to...
an improvement in clinical signs with reduction of coughing / dysphagia where over-
abduction is present or where rima glottidis protection is reduced. More recently
alternative treatments to LPR are being investigated for the treatment of dysphagia
following LP, including laryngeal tie forward surgery and vocal cord bulking.²⁰ The
proportion of LP horses in which LPR is subsequently performed is not known.

Despite frequent reports of complications following LP, the authors are not aware of any
published studies describing the outcomes following LPR although such information
would assist decision-making for veterinary surgeons confronted with intractable
complications of LP. The specific objectives of this study were: (i) to determine the
proportion of horses that had previously undergone LP subsequently requiring LPR by
the same surgeon; (ii) to determine the main reasons for LPR; and (iii) to determine the
outcome of horses undergoing LPR for coughing / dysphagia. Secondary objectives were
to determine the prevalence of arytenoid over-abduction in horses treated with LPR; to
determine whether delay in performing LPR influenced outcome; and to determine
whether arytenoid abduction grade at the time of LPR influenced outcome. We
hypothesize that removal of the prosthesis can lead to resolution of coughing / dysphagia.
Materials and Methods

Animals:
A retrospective case study reviewing clinical case records, with either a telephone or paper questionnaire follow up, was undertaken. The study was approved by the University of Bristol animal welfare and ethical review board. All horses, for which records were available, that had undergone LP or LPR between September 2003 and June 2017 were included in the initial part of the study to determine the proportion of LP horses subsequently requiring LPR by the same surgeon. The horses that underwent LPR were included in the latter parts of the study to determine the reasons for LPR and to determine the outcome of horses undergoing LPR for coughing / dysphagia. Detailed information from case records was only extracted for LPR horses.

Laryngoplasty Prosthesis Removal Procedure:
All LPR were performed by a single surgeon [JGL] at multiple equine hospitals. The original LP records were reviewed (if available) to establish the nature and number of prosthesis(es) used, to aid LPR surgical planning. Food was withheld from the horses for >9 hours before surgery and preoperative antimicrobial were administered. The surgical approach for LPR was the same as for LP. The knot of the prosthesis(es) were most commonly located between the caudal border of the cricopharyngeus muscle and the caudal border of the cricoid cartilage. The course of the prosthesis was followed caudally and rostrally, and the prosthesis was transected and subsequently withdrawn through the arytenoid and cricoid cartilages. This process was repeated for removal of a second
prosthesis, if present. Care was taken to minimize disruption to the fibrous tissue surrounding the prostheses.

**Data Collection:**

The clinical case records for LP and LPR were used to determine the proportion of LP horses subsequently requiring LPR by the same surgeon. The clinical case records for all horses treated with LPR were reviewed to determine the reason for LPR. The case records for horses treated with LPR for the primary complaint of coughing/dysphagia had the following information extracted: age, breed, sex, use, date of LP, arytenoid abduction grade at time of LP, surgeon who performed LP, prosthesis material, whether ventriculocordectomy (VC) was performed, date of LPR, arytenoid abduction grade and endoscopic findings at time of LPR, and complications that occurred during the LPR surgery or hospitalization period.

Standing endoscopy was performed in all horses by the surgeon before LPR to allow assessment of arytenoid abduction and food contamination of the nasal passages, pharynx, larynx and trachea as an indication of the degree of dysphagia. Arytenoid abduction was graded using a 5-point system\(^1\) whereby the greater the abduction, the greater the grade (table 1). Grade 5/5 was considered over-abduction, grades 3/5 and 4/5 were considered good abduction and grades 1/5 and 2/5 were considered no or poor abduction respectively. Post-operative endoscopy was typically performed by the referring veterinary surgeon.
Follow up information was obtained from questionnaires completed by either the referring veterinary surgeon, owner or trainer. All questionnaires were completed between May 2015 and June 2017. Cases were considered lost to follow up if the referring veterinary surgeons, owner or trainer of the horse were unable to provide sufficient horse details or following at least 5 failed attempts to contact. The questionnaire consisted of 13 questions, of which 11 were open- and 2 close-ended, with the opportunity to provide additional information. Information obtained from the questionnaire included: the reasons for LPR, when the clinical signs were first reported following LP, clinical response to LPR, change in respiratory noise during exercise, subsequent performance and the owner’s overall perception of the success of the surgery (Appendix 1).

Three categories were developed to classify the outcome following LPR: ‘no response’ if there was no or minimal change in the clinical signs exhibited following LPR; ‘partial response’ if a beneficial change in the clinical signs was reported, such that the amount of coughing / dysphagia appeared reduced, but on-going dysfunctions remained; ‘resolution’ if the presenting clinical signs were no longer exhibited.

Data Analysis:

Data were entered into Microsoft Excel and descriptive information was derived from this database. Statistical analyses were performed using SPSS Statistics version 24 (IBM Corp, Armonk, NY). Numerical variables (age and time between LP and LPR) were
assessed for normality graphically and by use of the Shapiro-Wilk test. A Kruskal-Wallis test was used to assess whether time span between LP and LPR varied depending on outcome, and whether arytenoid abduction grade at the time of LPR was associated with outcome. Statistical significance was set at p<0.05.
Results:

Demographics:

During the study period 1,202 horses had LP performed by JGL to treat the presenting signs of recurrent laryngeal neuropathy. A total of 58 horses underwent LPR (figure 1) in the same period. For 42/58 (72%) of the removal procedures the same surgeon had performed the original LP with different surgeons performing the original surgery in the other 16 horses. The proportion of LP horses subsequently treated with LPR by the same surgeon was 3.5% (42/1202). Surgeons elsewhere may have removed a laryngoplasty prosthesis from others in the group of 1,202 horses, however that information was not available as part of the existing clinical records.

The primary reason for LPR was coughing and/or dysphagia in 52/58 (90%) horses, discharging tract from prosthesis infection in 3/58 (5%) horses and abnormal respiratory noise in the remaining 3/58 (5%) horses. The focus of this paper is to report the outcomes of horses subjected to LPR that presented with signs of coughing and/or nasal discharge containing food material, both indicative of dysphagia, and only these horses will be discussed hereafter. Fifty-two horses presented for LPR due to signs of coughing / dysphagia, questionnaires were completed for 36 horses however; the useable response rate was 32/52 (62%) (figure 1).

The final population of 32 horses included 27 geldings, 1 entire male and 4 mares. There were 13 Thoroughbreds (11 racehorses and 2 eventers), 13 mixed breeds (4 eventers, 8 hunters and 1 hacking), 4 Warmbloods (2 dressage, 1 showjumper, and 1 eventer) and 2
horses for which both the breed and use were unknown. Of the 32 horses the median age at the time of LPR was 7 years (range 2 to 12 years). The exact date of the original surgery was unknown for 6/32 (19%) horses, for the remainder the median time between LP and LPR was 8 months (range 3 months to 5 years).

Original Laryngoplasty:

All horses, bar one, had left sided LP, and all LP surgeries were performed under general anesthesia. All horses had a VC procedure performed either at the time of, or before, LP. For the 20/32 (63%) horses in which surgery was performed by the author, 9 had unilateral (left sided) vocal-cordectomy and bilateral ventriculectomy and 11 had bilateral VC. All VC were performed using a surgical approach via a laryngotomy incision. A range of prosthesis material were used including; monofilament polyamide [Ethilon®]A (n=14), combination of monofilament polyamide [Ethilon®]A and braided polyethylene and polyester [Fibrewire®]B (n=8), polyethylene terephthalate [Ethibond®]A (n=4), combination of monofilament polyamide [Ethilon®]A and polyethylene terephthalate [Ethibond®]A (n=1), and stainless steel (n=1). The prosthesis material was not recorded in 4 cases. The abduction grade during LP, assessed by intra-operative endoscopy, was grade 4/5 in all 20/32 (63%) cases for which JGL was the surgeon.

Clinical signs:

The onset of coughing / dysphagia following LP was immediate in 11/23 (48%) horses, and in 12/23 (52%) horses the signs became apparent later. The time delay between LP and onset of coughing / dysphagia ranged from 6 weeks to 3 months in 6/12 (50%)
horses, approximately 12 months in 3/12 (25%) horses, over 3 years after LP in one horse
and was unknown in the remaining 2/12 (17%) horses. No horse was able to undertake
ridden exercise before LPR due to the severity of clinical signs. Coughing was reported in
31/32 (97%) horses and nasal discharge containing food material, indicative of
dysphagia, in 31/32 (97%) horses.

Endoscopic Examination:

During endoscopic examination 26/32 (81%) horses had food material was present at the
nostrils, nasal passages, pharynx or trachea. One horse had no food material observed
during endoscopy despite the presenting complaint by the owner of reflux of both food
and water when eating. The degree of food contamination observed on endoscopy was
not recorded in the remaining 5/32 (16%) horses. The time between last eating and
endoscopy was not recorded for any horse. The median arytenoid abduction grade at the
time of LPR for the 32 horses was grade 3/5 (range 1/5 to 4/5) (table 2). No horse was
over-abducted (grade 5/5).

Laryngoplasty Prosthesis Removal:

All horses had previously been treated with conservative medical management without
success and LPR was considered a last resort. All LPRs were performed under general
anaesthesia with no complications reported during the general anaesthesia or surgery. The
only complication post-surgery was reported in a single horse that developed a seroma
around the incision, which resolved with drainage via needle aspiration.
Outcomes:

Following LPR 8/32 (25%) horses showed no response in clinical signs of coughing / dysphagia, 3/32 (9%) horses had partial response with a reduction in clinical signs, and 21/32 (66%) horses had resolution with elimination of the presenting clinical signs of coughing / dysphagia. The owner’s perception of whether the LPR was successful directly mirrored the results of clinical response outlined above. Arytenoid abduction grade at the time of LPR did not significantly influence clinical response (p=0.416) (table 2). Similarly the interval between LP and LPR did not significantly influence the clinical response to LPR (p=0.655).

Endoscopy was performed by the referring veterinary practice within the first week following LPR and at variable times thereafter. Arytenoid abduction grade and food contamination were not consistently recorded. No horse underwent exercising endoscopy to evaluate arytenoid stability. For 12 horses, the owner was able to provide a subjective comparison of respiratory noise during exercise, and in 6 of 12 (50%) a louder respiratory noise was reported after LPR compared with after LP. All 6 horses had arytenoid abduction grade 3/5 or 4/5 before LPR.

Following LPR 24/32 (75%) horses returned to ridden exercise (figure 2), and 6 of the 24 horses resumed high level athletic performance including: one national hunt racehorse and 5 event horses competing at intermediate or advanced international level (CCI**/CCI***). Overall, 3 of the 8 horses classified as having no response to LPR returned to low level exercise although continued coughing during exercise was reported.
For the 11 racehorses, 7/11 (64%) were able to return to ridden exercise however, only one horse was able to return to racing (national hunt) with the remaining 6 horses retiring to a lower level of exercise including hunting/eventing (n=4) and hacking (n=2).
Discussion:

This is the first study to report the clinical outcomes following LPR for the management of coughing / dysphagia. Although it is recognized that other surgeons may have removed laryngoplasty prostheses from individuals included in the 1202 horses in this study, the results show that the proportion of horses that underwent LPR is not less than 3.5%. Consistent with the existing literature on complications following LP, coughing / dysphagia were confirmed to be the most common reason for LPR. Unmanageable coughing / dysphagia necessitating LPR occurred in horses with both poor and good arytenoid abduction, with no horse classified as being over-abducted. Following LPR 66% of horses had resolution of coughing / dysphagia and 75% were able to resume ridden exercise. The time frame between the original LP and the LPR did not adversely affect the outcome.

Coughing and dysphagia following laryngoplasty:

Due to the nature of LP, some dysphagia in the immediate post-operative period is regarded as inevitable. Previous studies have shown that 22-57% of horses display coughing / dysphagia in the short term, with 5-43% of horses continuing to display signs long term. The causes of coughing / dysphagia following LP are not completely understood, with several mechanisms proposed. Over-abduction of the arytenoid cartilage following LP is proposed to result in reduced protection of the rima glottidis during swallowing, with the incidence of coughing / dysphagia increasing in parallel with greater surgical abduction. However, in the present study unmanageable dysphagia occurred in horses with both ‘good’ abduction (grades 3/5 and 4/5) and no or
poor abduction (grades 1/5 and 2/5) with no horse having over-abduction of the arytenoid (grade 5/5). The clinical improvement in 4/6 (67%) horses with no/poor abduction suggests that the presence of the suture, and not the degree of abduction, was contributory to the coughing / dysphagia.

The prosthesis material most commonly used was monofilament polyamide [Ethilon®] which is considered to be inert, however, it is conjectured that the knot or the cut free ends may cause irritation. Histopathology of local tissues was not performed to evaluate any inflammatory response but in a previous case report fibrosis and thickening of the cricopharyngeus and thyropharyngeus muscles was evident on post mortem examination, supporting this hypothesis. A fibrous tissue response may compromise local innervation and muscle function associated with deglutition. A recent study also reported that the esophageal adventitia adjacent to the muscular process was frequently penetrated during LP, which is an alternative mechanism by which the suture could impede the normal function of the proximal esophagus.

Laryngoplasty Prosthesis Removal:

Many horses with lesser degrees of coughing / dysphagia following LP can be managed successfully with conservative management and medical treatment, and remain useable without LPR. Laryngoplasty prosthesis removal is often regarded as a ‘last resort’ salvage procedure performed in the small number of cases where all other treatment options have failed adequately to resolve the presenting clinical signs and complications following LP. Hawkins (2015) suggested that the prosthesis should not be removed before 60 days
post LP to allow fibrous connective tissue formation around the muscular process to form
and thereby prevent loss of abduction after prosthesis removal. No horse in the present
study had the prosthesis removed within 60 days and the time period between LP and
LPR did not influence outcome. Therefore, veterinary surgeons should fully explore all
medical and conservative options before opting for LPR without there being a detrimental
effect on the outcome.

Adhesions can develop at several locations following LP and there are conflicting views
on the merits of breaking these down at the time of the LPR. On the one hand, minimal
disruption to the adhesions between the arytenoid and thyroid cartilages is thought to help
maintain a degree of abduction and stability of the arytenoid cartilage and reduces
trauma to the soft tissues. On the other hand, adhesions and scar tissue around the
esophageal diverticulum and lateral to the larynx may physically restrict normal
esophageal function and laryngeal advancement - breaking these adhesions down may
aid return to normal mechanical function. During LPR in the cases reported here, an
attempt was made to minimize the breakdown of adhesions in the expectation that this
tissue would contribute to on-going arytenoid abduction.

Outcome:
Outcome was considered in several ways; change in clinical signs of coughing /
dysphagia, change in respiratory noise and resumption of ridden exercise. Laryngoplasty
prosthesis removal resulted in the resolution of coughing / dysphagia in 66% of horses.
Evaluation of respiratory noise was based on subjective assessment rather than by
objective sound analysis. Assessment of noise required recall of historical information
(from up to 9 years earlier), and as such should be interpreted with some caution. An
increase in respiratory noise following LPR compared with when the prosthesis was in
situ was reported in 50% of horses in which subjective comparison was possible. The
most likely cause is loss of arytenoid stability and abduction following LPR, but this was
not confirmed by exercising endoscopy. Immediately before LPR none of the horses
could fulfil their intended use due to the severity of clinical signs. Following LPR 75% of
horses were able to resume ridden exercise. Although some individuals can undertake a
high level of athletic performance, most racehorses were unable to return to race training.

Study Limitations:
The main limitations of this study are the protracted period over which a retrospective
survey has been applied, historical anamnesis, recall over a prolonged time frame and
using subjective assessments of coughing, dysphagia and respiratory noise made by
multiple people. Information on long term changes in arytenoid abduction, or arytenoid
stability during exercise by overground or treadmill endoscopy was not available. In
addition, the long interval between LPR and questionnaire may lead to some unreliability
over historical information and did result in 20/52 (38%) horses not being suitable for
inclusion through a lack of follow up or poor-quality information on the questionnaires.

Future Investigations:
Diagnostic techniques such as exercising endoscopy and laryngeal ultrasonography that
are widely performed today were not routinely deployed 10-15 years ago. Thus, while
some useful conclusions may be drawn from the findings here, further studies to investigate coughing / dysphagia are required and revisiting older techniques such as fluoroscopy\textsuperscript{19} may also be helpful to discriminate between those cases where LPR would be helpful and those where alternative solutions should be sought. The information presented in this study, along with results of other treatment options such as injection of bulking agents into the vocal cord\textsuperscript{20} will allow the development of a systematic approach to understanding the cause of coughing / dysphagia post LP and deciding upon the most appropriate treatment for each individual.

Conclusions:

In conclusion, a small proportion of horses undergoing LP may require LPR, primarily due to unmanageable coughing / dysphagia. For some horses, the presence of the prosthesis rather than the arytenoid abduction was contributory to the coughing / dysphagia. Laryngoplasty prosthesis removal can resolve coughing / dysphagia induced by LP and should be considered as a potential treatment option for affected horses.

Manufacturer Details:

A = Ethilon\textsuperscript{®} & Ethibond\textsuperscript{®}: Ethicon, Johnson & Johnson Medical N.V., Belgium.

B = Fibrewire\textsuperscript{®}: Arthrex, Inc. Florida, USA.
References:


Table 1 contains schematic drawings and a description of the abduction grading system used to grade arytenoid cartilage abduction following LP, based on the scale first published by Russell and Slone (1994).¹

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
<th>Drawing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The arytenoid cartilage is positioned at the vertical midline</td>
<td><img src="image1" alt="Drawing" /></td>
</tr>
<tr>
<td>2</td>
<td>The arytenoid cartilage is in the normal resting position</td>
<td><img src="image2" alt="Drawing" /></td>
</tr>
<tr>
<td>3</td>
<td>The arytenoid cartilage is abducted past the resting position but not touching the pharyngeal wall</td>
<td><img src="image3" alt="Drawing" /></td>
</tr>
<tr>
<td>4</td>
<td>The arytenoid cartilage is contacting, but does not depress the pharyngeal wall</td>
<td><img src="image4" alt="Drawing" /></td>
</tr>
<tr>
<td>5</td>
<td>The arytenoid cartilage depresses the pharyngeal wall</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
</tbody>
</table>
Table 2 displays the arytenoid abduction grades at the time of LPR for the 32 horses. The primary outcome following LPR was the improvement in clinical signs of coughing / dysphagia which was categorized as resolution, partial response and no response.

<table>
<thead>
<tr>
<th>Abduction Grade</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of horses</td>
<td>3</td>
<td>3</td>
<td>24</td>
<td>2</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>Outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution</td>
<td>2</td>
<td>1</td>
<td>17</td>
<td>1</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>Partial response</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>No response</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>8</td>
</tr>
</tbody>
</table>