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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

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The authors declare no conflict of interest related to this report.

Presentation:

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1 **Abstract:**

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

6 **Study design:** Retrospective study

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

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

12 **Results:** The proportion of horses treated with LP subsequently treated with LPR by the
13 same surgeon was 3.5% (42/1202). Coughing / dysphagia was the reason for LPR in 90%
14 (52/58) of horses. Sufficient follow-up to determine outcome in horses undergoing LPR
15 for coughing / dysphagia was available in 32 horses. Arytenoid abduction grade at the
16 time of LPR did not significantly influence clinical response (p=0.416). Presenting
17 clinical signs resolved following LPR in 21/32 (66%) horses and 24/32 (75%) horses
18 returned to exercise.

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

21 **Clinical significance:** Laryngoplasty prosthesis removal can be a useful treatment option
22 for horses affected with unmanageable coughing / dysphagia caused by LP.

23 **Introduction:**

24 Prosthetic laryngoplasty (LP) is the mainstay of treatment for horses with recurrent
25 laryngeal neuropathy,¹⁻⁴ but it is recognized to have a high rate of post-operative
26 complications in comparison with other surgeries performed to treat dynamic upper
27 airway obstructions. Short term complications include prosthesis failure, loss of
28 abduction, seroma formation, incisional dehiscence and coughing.^{5, 6} In the longer term
29 there may be loss of abduction^{4, 7}, chronic coughing⁴⁻⁷, dysphagia⁷, with or without the
30 nasal reflux of ingesta⁴, aspiration pneumonia^{3, 8}, inflammatory airway disease, exercise
31 induced pulmonary haemorrhage⁹, esophageal incompetence¹⁰, dysfunction of the soft
32 palate¹¹ and other forms of dynamic airway obstruction.^{12, 13}

33

34 Coughing resulting from dysphagia is the most common complication following LP, with
35 studies reporting 5-57% of horses affected.^{1-3, 5-8, 14-17} Several mechanisms to explain the
36 dysphagia following LP have been proposed: (i) reduced protection of the rima glottidis
37 during swallowing due to inability to adduct the arytenoid cartilage⁷ and removal of the
38 vocal cords^{1, 7}; (ii) damage to the muscles of the upper esophagus, their innervation or the
39 peri-esophageal fascia and adventitia^{10, 14, 18}; (iii) development of adhesions lateral to the
40 larynx¹¹, between the arytenoid and thyroid cartilages, and to the cranial esophagus or
41 esophageal diverticulum. Many horses with complications following LP can be managed
42 conservatively. However, persistent or severe coughing / dysphagia, which affects the
43 ability to be ridden, quality of life, or results in an increased risk of developing
44 respiratory infection or aspiration pneumonia, may be an indication for laryngoplasty
45 prosthesis removal (LPR).^{3, 5, 6, 10, 15, 17, 19} Laryngoplasty prosthesis removal may lead to

46 an improvement in clinical signs with reduction of coughing / dysphagia where over-
47 abduction is present or where rima glottidis protection is reduced. More recently
48 alternative treatments to LPR are being investigated for the treatment of dysphagia
49 following LP, including laryngeal tie forward surgery and vocal cord bulking.²⁰ The
50 proportion of LP horses in which LPR is subsequently performed is not known.

51

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

63 **Materials and Methods**

64 Animals:

65 A retrospective case study reviewing clinical case records, with either a telephone or
66 paper questionnaire follow up, was undertaken. The study was approved by the
67 University of Bristol animal welfare and ethical review board. All horses, for which
68 records were available, that had undergone LP or LPR between September 2003 and June
69 2017 were included in the initial part of the study to determine the proportion of LP
70 horses subsequently requiring LPR by the same surgeon. The horses that underwent LPR
71 were included in the latter parts of the study to determine the reasons for LPR and to
72 determine the outcome of horses undergoing LPR for coughing / dysphagia. Detailed
73 information from case records was only extracted for LPR horses.

74

75 Laryngoplasty Prosthesis Removal Procedure:

76 All LPR were performed by a single surgeon [JGL] at multiple equine hospitals. The
77 original LP records were reviewed (if available) to establish the nature and number of
78 prosthesis(es) used, to aid LPR surgical planning. Food was withheld from the horses for
79 >9 hours before surgery and preoperative antimicrobial were administered. The surgical
80 approach for LPR was the same as for LP.¹⁵ The knot of the prosthesis(es) were most
81 commonly located between the caudal border of the cricopharyngeus muscle and the
82 caudal border of the cricoid cartilage. The course of the prosthesis was followed caudally
83 and rostrally, and the prosthesis was transected and subsequently withdrawn through the
84 arytenoid and cricoid cartilages. This process was repeated for removal of a second

85 prosthesis, if present. Care was taken to minimize disruption to the fibrous tissue
86 surrounding the prostheses.

87

88 Data Collection:

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

98

99 Standing endoscopy was performed in all horses by the surgeon before LPR to allow
100 assessment of arytenoid abduction and food contamination of the nasal passages,
101 pharynx, larynx and trachea as an indication of the degree of dysphagia. Arytenoid
102 abduction was graded using a 5-point system¹ whereby the greater the abduction, the
103 greater the grade (table 1). Grade 5/5 was considered over-abduction, grades 3/5 and 4/5
104 were considered good abduction and grades 1/5 and 2/5 were considered no or poor
105 abduction respectively. Post-operative endoscopy was typically performed by the
106 referring veterinary surgeon.

107

108 Questionnaire:

109 Follow up information was obtained from questionnaires completed by either the
110 referring veterinary surgeon, owner or trainer. All questionnaires were completed
111 between May 2015 and June 2017. Cases were considered lost to follow up if the
112 referring veterinary surgeons, owner or trainer of the horse were unable to provide
113 sufficient horse details or following at least 5 failed attempts to contact. The
114 questionnaire consisted of 13 questions, of which 11 were open- and 2 close-ended, with
115 the opportunity to provide additional information. Information obtained from the
116 questionnaire included: the reasons for LPR, when the clinical signs were first reported
117 following LP, clinical response to LPR, change in respiratory noise during exercise,
118 subsequent performance and the owner's overall perception of the success of the surgery
119 (Appendix 1).

120

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

126

127 Data Analysis:

128 Data were entered into Microsoft Excel and descriptive information was derived from
129 this database. Statistical analyses were performed using SPSS Statistics version 24 (IBM
130 Corp, Armonk, NY). Numerical variables (age and time between LP and LPR) were

131 assessed for normality graphically and by use of the Shapiro-Wilk test. A Kruskal-Wallis
132 test was used to assess whether time span between LP and LPR varied depending on
133 outcome, and whether arytenoid abduction grade at the time of LPR was associated with
134 outcome. Statistical significance was set at $p < 0.05$.

135

136 **Results:**

137 Demographics:

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

146

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

155

156 The final population of 32 horses included 27 geldings, 1 entire male and 4 mares. There
157 were 13 Thoroughbreds (11 racehorses and 2 eventers), 13 mixed breeds (4 eventers, 8
158 hunters and 1 hacking), 4 Warmbloods (2 dressage, 1 showjumper, and 1 eventer) and 2

159 horses for which both the breed and use were unknown. Of the 32 horses the median age
160 at the time of LPR was 7 years (range 2 to 12 years). The exact date of the original
161 surgery was unknown for 6/32 (19%) horses, for the remainder the median time between
162 LP and LPR was 8 months (range 3 months to 5 years).

163

164 Original Laryngoplasty:

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

177

178 Clinical signs:

179 The onset of coughing / dysphagia following LP was immediate in 11/23 (48%) horses,
180 and in 12/23 (52%) horses the signs became apparent later. The time delay between LP
181 and onset of coughing / dysphagia ranged from 6 weeks to 3 months in 6/12 (50%)

182 horses, approximately 12 months in 3/12 (25%) horses, over 3 years after LP in one horse
183 and was unknown in the remaining 2/12 (17%) horses. No horse was able to undertake
184 ridden exercise before LPR due to the severity of clinical signs. Coughing was reported in
185 31/32 (97%) horses and nasal discharge containing food material, indicative of
186 dysphagia, in 31/32 (97%) horses.

187

188 Endoscopic Examination:

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

197

198 Laryngoplasty Prosthesis Removal:

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

204

205 Outcomes:

206 Following LPR 8/32 (25%) horses showed no response in clinical signs of coughing /
207 dysphagia, 3/32 (9%) horses had partial response with a reduction in clinical signs, and
208 21/32 (66%) horses had resolution with elimination of the presenting clinical signs of
209 coughing / dysphagia. The owner's perception of whether the LPR was successful
210 directly mirrored the results of clinical response outlined above. Arytenoid abduction
211 grade at the time of LPR did not significantly influence clinical response ($p=0.416$) (table
212 2). Similarly the interval between LP and LPR did not significantly influence the clinical
213 response to LPR ($p=0.655$).

214

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

222

223 Following LPR 24/32 (75%) horses returned to ridden exercise (figure 2), and 6 of the 24
224 horses resumed high level athletic performance including: one national hunt racehorse
225 and 5 event horses competing at intermediate or advanced international level
226 (CCI**/CCI***). Overall, 3 of the 8 horses classified as having no response to LPR
227 returned to low level exercise although continued coughing during exercise was reported.

228 For the 11 racehorses, 7/11 (64%) were able to return to ridden exercise however, only
229 one horse was able to return to racing (national hunt) with the remaining 6 horses retiring
230 to a lower level of exercise including hunting/eventing (n=4) and hacking (n=2).

231 **Discussion:**

232 This is the first study to report the clinical outcomes following LPR for the management
233 of coughing / dysphagia. Although it is recognized that other surgeons may have removed
234 laryngoplasty prostheses from individuals included in the 1202 horses in this study, the
235 results show that the proportion of horses that underwent LPR is not less than 3.5%.
236 Consistent with the existing literature on complications following LP, coughing /
237 dysphagia were confirmed to be the most common reason for LPR.^{3, 5, 6, 10, 15, 17, 19}
238 Unmanageable coughing / dysphagia necessitating LPR occurred in horses with both poor
239 and good arytenoid abduction, with no horse classified as being over-abducted. Following
240 LPR 66% of horses had resolution of coughing / dysphagia and 75% were able to resume
241 ridden exercise. The time frame between the original LP and the LPR did not adversely
242 affect the outcome.

243

244 **Coughing and dysphagia following laryngoplasty:**

245 Due to the nature of LP, some dysphagia in the immediate post-operative period is
246 regarded as inevitable.¹⁰ Previous studies have shown that 22-57% of horses display
247 coughing / dysphagia in the short term^{3, 14, 16}, with 5-43% of horses continuing to display
248 signs long term.^{1, 3, 7, 16, 17} The causes of coughing / dysphagia following LP are not
249 completely understood, with several mechanisms proposed. Over-abduction of the
250 arytenoid cartilage following LP is proposed to result in reduced protection of the rima
251 glottidis during swallowing, with the incidence of coughing / dysphagia increasing in
252 parallel with greater surgical abduction.⁷ However, in the present study unmanageable
253 dysphagia occurred in horses with both 'good' abduction (grades 3/5 and 4/5) and no or

254 poor abduction (grades 1/5 and 2/5) with no horse having over-abduction of the arytenoid
255 (grade 5/5). The clinical improvement in 4/6 (67%) horses with no/poor abduction
256 suggests that the presence of the suture, and not the degree of abduction, was contributory
257 to the coughing / dysphagia.

258

259 The prosthesis material most commonly used was monofilament polyamide [Ethilon®]^A
260 which is considered to be inert, however, it is conjectured that the knot or the cut free
261 ends may cause irritation. Histopathology of local tissues was not performed to evaluate
262 any inflammatory response but in a previous case report fibrosis and thickening of the
263 cricopharyngeus and thyropharyngeus muscles was evident on post mortem
264 examination¹⁰, supporting this hypothesis. A fibrous tissue response may compromise
265 local innervation and muscle function associated with deglutition. A recent study also
266 reported that the esophageal adventitia adjacent to the muscular process was frequently
267 penetrated during LP,¹⁸ which is an alternative mechanism by which the suture could
268 impede the normal function of the proximal esophagus¹⁴.

269

270 Laryngoplasty Prosthesis Removal:

271 Many horses with lesser degrees of coughing / dysphagia following LP can be managed
272 successfully with conservative management and medical treatment, and remain useable
273 without LPR. Laryngoplasty prosthesis removal is often regarded as a ‘last resort’ salvage
274 procedure performed in the small number of cases where all other treatment options have
275 failed adequately to resolve the presenting clinical signs and complications following LP.
276 Hawkins (2015)¹⁵ suggested that the prosthesis should not be removed before 60 days

277 post LP to allow fibrous connective tissue formation around the muscular process to form
278 and thereby prevent loss of abduction after prosthesis removal. No horse in the present
279 study had the prosthesis removed within 60 days and the time period between LP and
280 LPR did not influence outcome. Therefore, veterinary surgeons should fully explore all
281 medical and conservative options before opting for LPR without there being a detrimental
282 effect on the outcome.

283

284 Adhesions can develop at several locations following LP and there are conflicting views
285 on the merits of breaking these down at the time of the LPR. On the one hand, minimal
286 disruption to the adhesions between the arytenoid and thyroid cartilages is thought to help
287 maintain a degree of abduction and stability of the arytenoid cartilage²¹ and reduces
288 trauma to the soft tissues. On the other hand, adhesions and scar tissue around the
289 esophageal diverticulum and lateral to the larynx may physically restrict normal
290 esophageal function and laryngeal advancement¹¹ - breaking these adhesions down may
291 aid return to normal mechanical function. During LPR in the cases reported here, an
292 attempt was made to minimize the breakdown of adhesions in the expectation that this
293 tissue would contribute to on-going arytenoid abduction.

294

295 Outcome:

296 Outcome was considered in several ways; change in clinical signs of coughing /
297 dysphagia, change in respiratory noise and resumption of ridden exercise. Laryngoplasty
298 prosthesis removal resulted in the resolution of coughing / dysphagia in 66% of horses.
299 Evaluation of respiratory noise was based on subjective assessment rather than by

300 objective sound analysis. Assessment of noise required recall of historical information
301 (from up to 9 years earlier), and as such should be interpreted with some caution. An
302 increase in respiratory noise following LPR compared with when the prosthesis was in
303 situ was reported in 50% of horses in which subjective comparison was possible. The
304 most likely cause is loss of arytenoid stability and abduction following LPR, but this was
305 not confirmed by exercising endoscopy.²² Immediately before LPR none of the horses
306 could fulfil their intended use due to the severity of clinical signs. Following LPR 75% of
307 horses were able to resume ridden exercise. Although some individuals can undertake a
308 high level of athletic performance, most racehorses were unable to return to race training.

309

310 Study Limitations:

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

319

320 Future Investigations:

321 Diagnostic techniques such as exercising endoscopy and laryngeal ultrasonography that
322 are widely performed today were not routinely deployed 10-15 years ago. Thus, while

323 some useful conclusions may be drawn from the findings here, further studies to
324 investigate coughing / dysphagia are required and revisiting older techniques such as
325 fluoroscopy¹⁹ may also be helpful to discriminate between those cases where LPR would
326 be helpful and those where alternative solutions should be sought. The information
327 presented in this study, along with results of other treatment options such as injection of
328 bulking agents into the vocal cord²⁰ will allow the development of a systematic approach
329 to understanding the cause of coughing / dysphagia post LP and deciding upon the most
330 appropriate treatment for each individual.

331

332 Conclusions:

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

338

339 Manufacturer Details:

340 A = Ethilon® & Ethibond®: Ethicon, Johnson & Johnson Medical N.V., Belgium.

341 B = Fibrewire®: Arthrex, Inc. Florida, USA.

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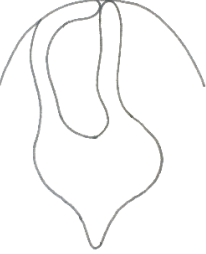

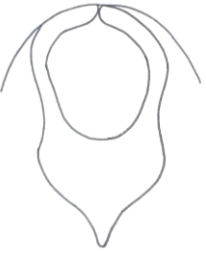
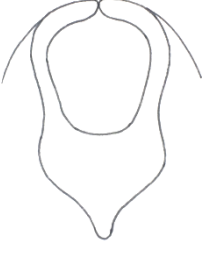
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402 **Table 1**

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

Grade	Description	Drawing
1	The arytenoid cartilage is positioned at the vertical midline	
2	The arytenoid cartilage is in the normal resting position	
3	The arytenoid cartilage is abducted past the resting position but not touching the pharyngeal wall	
4	The arytenoid cartilage is contacting, but does not depress the pharyngeal wall	

5	The arytenoid cartilage depresses the pharyngeal wall	
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407 **TABLE 2**

408 Table 2 displays the arytenoid abduction grades at the time of LPR for the 32 horses. The
409 primary outcome following LPR was the improvement in clinical signs of coughing /
410 dysphagia which was categorized as resolution, partial response and no response.

Abduction Grade	1	2	3	4	5	Total
Number of horses	3	3	24	2	0	32
Outcome						
Resolution	2	1	17	1	0	21
Partial response	0	1	1	1	0	3
No response	1	1	6	0	0	8

411