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Thermography as an early predictive measurement for evaluating epidural and femoral–sciatic block success in dogs

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1 **Time-related changes in post-operative equine morbidity; a**
2 **single-centre study**

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17

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27 **Abstract**

28 **Objective**

29 To test the hypothesis that the prevalence and type of post-operative equine morbidity
30 (POEM) at a single centre does not change over time.

31 **Study Design**

32 Retrospective and prospective observational study.

33 **Animals**

34 The post-operative case records of 92 (of 96) horses undergoing non-abdominal
35 procedures, and surviving to discharge, were compared with previous data from the
36 same centre (Senior et al., 2007).

37 **Methods**

38 Pre-defined morbidities were recorded from horses undergoing surgery between August
39 2013 and July 2014. This was compared with data collected from the same institute
40 from April 2004 to June 2005 and published in a previous study (Senior et al., 2007).

41 **Results**

42 The overall prevalence of morbidities increased from 13.4% to 25%. The prevalence of
43 post-anaesthetic colic, thrombophlebitis, pyrexia, lameness, neuropathy and myopathy
44 increased while the proportion of incidence of diarrhoea, respiratory distress and
45 wounds sustained in recovery decreased.

46 *Analysis* - There was a statistically significant association ($p = 0.045$) between the
47 duration of surgery and the prevalence of PAC (post-anaesthetic colic). Geldings were

48 less likely (OR 0.12, CI 0.02, 0.84) to develop swelling at the catheter site and the
49 likelihood of thrombophlebitis increased by 1.20 (CI 1.01, 1.41) for every year of life.

50 **Conclusions and clinical relevance**

51 Tracking morbidities and changes in their prevalence may elucidate their possible
52 causation and allow prophylactic measures to be taken.

53

54 **Keywords:** Anaesthesia; Equine; Horse; Morbidity; Post-operative

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89 **Introduction**

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91 Postoperative morbidities in horses prolong convalescence and increase hospitalisation
92 costs (Bennett-Guerrero et al., 1999). Mild complications may resolve spontaneously
93 and inconsequentially; severe morbidities may cause permanent lesions, precipitate
94 natural death, or necessitate euthanasia on medical, humane or economic grounds.

95

96 Critical incident reporting and identification of factors influencing post-operative
97 morbidities have been recognised as essential in human medicine (Bolsin et al., 2010,
98 Smith and Mahajan, 2009, Tewari and Sinha, 2013) and the recording of postoperative
99 morbidities is a requirement of the Royal College of Veterinary Surgeons (RCVS).

100

101 The prevalence of post-operative equine morbidities (POEMs) is sparsely described.
102 Young and Taylor included information on anaesthetic-related problems in 19/1314
103 horses following general anaesthesia for non-abdominal procedures, almost all of whom
104 suffered from myopathy (Young and Taylor, 1993). The third confidential enquiry into
105 postoperative equine fatalities (CEPEF) described non-fatal complications but did not
106 classify these beyond myopathies (Johnston, 2005).

107

108 A previous multicentre study (Senior et al., 2007) examined the prevalence of several
109 morbidities affecting horses undergoing non-abdominal surgery, between April 2004
110 and June 2005, in four equine hospitals including the Royal (Dick) School of Veterinary
111 Studies (R(D)SVS), which provided data from 194 anaesthetics. The principal
112 problems identified in this study, in the first 72 hours after recovery from anaesthesia,
113 were: post-anaesthetic colic (PAC) and prolonged recovery (7.7% and 3% respectively).

114

115 In the course of time, putative risk factors may change (e.g. yard and clinical staff, horse
116 population characteristics) producing corresponding changes in the prevalence of
117 morbidities. There is an expectation that morbidity rates should decrease over time with
118 ongoing improvements in clinical practice. The purpose of the current study was to test
119 the (null) hypothesis that the prevalence and type of morbidity at a single centre do not
120 change over time.

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135 **Materials and Methods**

136 After approval from the Veterinary Ethical Review Committee of the R(D)SVS (2014)
137 the proportion of horses suffering from pre-defined morbidities (Table 1), arising
138 between recovery from anaesthesia and hospital discharge, were recorded from horses
139 undergoing non-abdominal surgery between August 2013 and July 2014. This data was
140 then compared with data collected at the same institute from April 2004 and June 2005,
141 and which had been incorporated into the multi-centre study of Senior et. al. (2007).

142

143 During both periods, animal characteristics (body weight, age, breed and sex) and
144 pertinent case information (duration of hospitalisation, surgical categorisation e.g.
145 orthopaedic *versus* soft tissue) of animals surviving surgery was entered into a database.
146 The surgery performed was briefly noted e.g. arthroscopy, laryngoplasty. Details of
147 POEMs were gleaned from each animal's clinical case notes and the anaesthetic record.
148 Further details were collected during post-operative rounds when the cases were
149 discussed.

150

151 Two populations were defined for analysis: 2013-14 and 2004-2005 (Senior et al.,
152 2007). Data from horses experiencing prolonged recoveries (recumbency lasting > 30
153 minutes per hour of anaesthesia time) were not analysed in the current study unless
154 extraordinary interventions, e.g. slinging, were required (Senior et al., 2007).

155

158 Statistical analyses were performed using Minitab® (version 16.0 for Windows).
159 Comparisons were made to detect differences between groups for age, body weight, sex,
160 elective or emergency status and anaesthesia time. Anaesthesia time was defined as the
161 time from induction of anaesthesia until the horse was moved into the recovery box. A
162 value of $p < 0.05$ was considered statistically significant. Each of the categories were
163 examined for normality of distribution using a probability plot of the data. Body
164 weight, time for hospitalisation and age were not normally distributed in comparison to
165 anaesthesia time. A Mann-Whitney test was used to examine the non-parametric data
166 (age and body weight) while a 2 sample t-test was used to compare anaesthesia time
167 between groups. A χ^2 test was used to analyse sex and elective-emergency status
168 differences. Statistical analysis of changes in morbidity prevalence were carried out
169 using a χ^2 test.

170

171 The prevalence of morbidities was analysed using binary logistic regression to
172 determine if signalment or procedure status i.e. emergency/elective, duration of surgery,
173 age, body weight or time in the hospital, had any significant association with the
174 individual morbidities. A two stage process was adopted. First, univariate analyses of
175 individual variables was carried out. Second, multivariable analyses were conducted to
176 establish if combined factors e.g. sex and age, bore significant relationships with
177 specified morbidities. For this, those univariate terms where $p < 0.2$ were entered into
178 initial multivariable binary logistic analyses (Hosmer and Lemeshow 2000) and terms
179 were excluded until a final model of statistical significant terms was achieved.

180

182 **Results**

183 A total of 96 cases were recorded between 1st August 2013 and 31st July 2014. Of these
184 92/96 survived to discharge. Two of the anaesthetics were repeated. The previous data
185 (Senior et al., 2007) reported a total of 194 anaesthetics for non-abdominal procedures
186 of which full data were available for 101 cases.

187

188 The results are presented in Table 2. Information regarding age, body weight,
189 emergency status, time in hospital and anaesthetic time only pertained to the subset of
190 data provided by M. Senior (101 of 194 anaesthetics) while the prevalence of
191 morbidities relate to the short communication (Senior et al., 2007).

192

193 *Signalment*

194 Horses did not differ in age (median 6.0 years in the 2004-5 and 2013-14 groups, $p =$
195 0.564). Hospitalisation time was statistically significantly longer in 2013-14 (median of
196 9 days vs 6 days, $p < 0.01$). Both data sets were incomplete with respect to sex: 2 and 4
197 horses were missing from the 2013-14 and 2004-2005 data sets, respectively. Geldings
198 made up 63% of group 2013-14 compared with 49% of horses from Senior's dataset
199 from 2004-2005 ($p < 0.001$). The average anaesthetic time was statistically significantly
200 longer in procedures conducted in the most recent time period (103, compared to 87
201 minutes in 2004-5, $p = 0.003$) and the number of emergency cases was statistically
202 significantly greater in the more recent data set (29%, compared with 21%; $p < 0.001$).

203 Orthopaedic surgery was carried out in the majority of cases (54/92, 59% in 2013-14
204 and 58/101, 57%). The majority of the orthopaedic cases involved arthroscopy with
205 lavage while soft tissue cases largely comprised upper airway surgery and castration.

206

207 *Morbidities*

208 The overall prevalence of post-operative morbidities was 13.4% when prolonged
209 recovery was excluded in the 2004-5 data. This compares with 25% in the 2013-14 data
210 meaning that the overall prevalence of morbidities had increased. The prevalence of
211 PAC, thrombophlebitis, pyrexia and neuropathy, myopathy and post-operative lameness
212 increased over time. Post-anaesthetic colic increased in prevalence from 7.7% to 18.5%
213 ($p = 0.01$). In the study by Senior et al no horses experienced post-operative lameness,
214 myopathy or neuropathy in comparison to 3% of horses in the 2013-14 data set ($p =$
215 0.06) and the proportion of horses with thrombophlebitis increased from 1% to 2% ($p =$
216 0.053). Horses classified as pyrexic increased from 0.5% in 2004-5 to 7.6% ($p =$
217 0.002). No horses had a fracture in the post-operative period in either dataset. Fewer
218 horses suffered from diarrhoea in the 2013-14 dataset (2% vs 1%, $p = 0.92$). Similarly,
219 in the 2004-5 dataset 1.5% of horses were described as being in respiratory distress
220 compared to 0% in the 2013-14 dataset ($p = 0.563$). One horse (0.5%) in the 2004-5
221 dataset had wounds in recovery in comparison to 0% in the 2013-14 dataset ($p = 0.490$).
222 Wound infections were not reported in the 2004-5 data set while one horse was reported
223 to have a wound infection in the 2013-14 data.

224

225 *Binary Regression Analysis*

226 Univariate analysis revealed a statistically significant association ($p = 0.045$) between
227 the duration of anaesthesia and the prevalence of PAC in horses. Duration of
228 anaesthesia was not found to be significantly associated with the other morbidities
229 reported. No statistically significant association was found between colic and sex ($p =$

230 0.390), time in hospital ($p= 0.816$), body weight ($p=0.169$), age ($p = 0.403$) or
231 emergency status ($p = 0.075$). Multivariable univariate logistic regression revealed no
232 statistically significant associations between body weight or emergency status, and
233 PAC.

234 Univariate analysis of all horses revealed a statistically significant association ($p=$
235 0.036) between age and thrombophlebitis: the odd's ratio indicated its likelihood
236 increased by 1.20 (CI 1.01, 1.41) for every year of the horse's life. No statistically
237 significant relationships were found for wound infections or pyrexia.

238

239 **Discussion**

240 The purpose of the current study was to test the null hypothesis that the prevalence and
241 type of morbidity at a single centre did not change over time. The null hypothesis was
242 rejected as the overall prevalence of morbidities increased.

243

244 Post-anaesthetic colic, after non-abdominal surgery, increased from 7.7% (2004-5) to
245 18.5% (2013-14) which is statistically significant and clinically important.

246 Additionally, there was a significant association between PAC and the duration of
247 anaesthesia, which has not been identified previously. The prevalence of PAC was
248 greater than that found in other studies, which ranged from 2.8% (Senior et al., 2004,
249 Andersen et al., 2006, Mircica et al., 2003, Senior et al., 2007, Nelson et al., 2013) to
250 10.5% (Jago et al., 2015).

251

252 The reasons for the increase in prevalence are not known. The current study did not
253 investigate post-anaesthetic colic with respect to administration of drugs, personnel or
254 out-of-hours surgery. Emergency status was not associated with an increased risk. In
255 previous studies the risk factors identified included morphine administration and out-of-
256 hours surgery (Senior et al., 2004), decreased faecal output following surgery, the
257 Arabian breed and increasing blood lactate (Nelson et al., 2013). Morphine was found
258 to lead to no increased risk of colic, in contrast to the use of isoflurane and
259 benzylpenicillin or ceftiofur (Andersen et al., 2006). Jago et al found that post-
260 anaesthetic colic following non-abdominal surgery was significantly associated with
261 breed, perioperative microbials and administration of butorphanol (Jago et al., 2015).
262 Senior et al stated that the morbidities reported in the 2004-5 study were believed to be
263 minimums and that 'mild' cases of colic may not have been reported (Senior et al.,
264 2007). Senior et al also found large variations in the post-anaesthetic colic in different
265 centres. The increase in prevalence may have been due to reporting of more 'mild'
266 cases or a different population of horses. In the original data from Senior et al horses
267 were analysed for signs of colic 72 hours following surgery whereas the most recent
268 data included horses that displayed colic until discharge. This may go some way to
269 explain the increase in prevalence. Given the stated risk factors in previous studies,
270 further work investigating drugs used, faecal output and the proportion of surgeries
271 during the out-of-hours period may be useful.

272

273 The significant association between increasing anaesthesia time and the prevalence of
274 post-anaesthetic colic highlights the importance of minimising time spent under
275 anaesthesia. The CEPEF study found that the likelihood of death increased as the
276 duration of anaesthesia increased beyond 61 minutes, with the greatest risk being

277 operations lasting longer than 241 minutes (Johnston et al., 1995). Minimising
278 anaesthesia time involves maximising efficiency of surgical preparation, ensuring
279 optimal communication between anaesthesia and surgical teams and provision of
280 sufficient personnel to reduce surgery time. The results presented reinforce the
281 evidence that minimising the time spent by horses under anaesthesia is an important
282 consideration for surgical intervention.

283

284 No cases of neuropathy or myopathy were recorded in horses undergoing non-
285 abdominal procedures during the 2004-5 sampling period in contrast to 3 (out of 92)
286 cases recorded from 2013 – 2014. Previous studies have examined the incidence of
287 post-anaesthetic lameness. Richey et al reported an incidence of post anaesthetic
288 lameness of 6.4%, Franci et al reported this morbidity in 0.98% of horses following
289 surgery and Young and Taylor found that 1.2% of 575 horses developed myopathy
290 following non-orthopaedic procedures (Young and Taylor, 1993, Richey et al., 1990,
291 Franci et al., 2006). Richey et al found a significant association between hypotension
292 and anaesthesia duration with respect to post-anaesthetic lameness while Young and
293 Taylor reported no reduction of incidence when hypotension was treated but did report a
294 decrease in severity (Young and Taylor, 1993, Richey et al., 1990). Bidwell et al
295 reported that three cases with post-anaesthetic myopathy necessitating euthanasia were
296 in horses that had undergone procedures lasting three or more hours (Bidwell et al.,
297 2007). In the current study there was no significant relationship between duration of
298 anaesthesia or body weight and the incidence of myopathy or neuropathy. The presence
299 of hypotension during anaesthesia was not examined but this may be useful in future
300 studies.

301

302 The prevalence of thrombophlebitis doubled in the current study from 1% to 2% and
303 univariate analysis found a significant positive relationship between increasing age and
304 occurrence of thrombophlebitis. Previous studies have reported thrombophlebitis in 8%
305 to 13% horses undergoing colic surgery (Gazzerro et al., 2015, Morton and Blikslager,
306 2002). This may not be an appropriate comparison due to an increased incidence of
307 coagulation abnormalities following abdominal surgery. Previous studies have
308 examined putative risk factors: poor insertion technique, prolonged catheterisation,
309 catheter used for induction of anaesthesia, debilitation of the horse and injection of
310 irritants (Divers, 2003, Lankveld et al., 2001). To our knowledge, links to non-
311 abdominal procedures have not been tested. Gazzerro et al found that geriatric horses
312 were less likely than mature horses to have thrombophlebitis (OR 0.68) which contrasts
313 with our findings (Gazzerro et al., 2015). However, previous studies have found
314 increased co-existing systemic disease with increasing age in horses (Vasto et al., 2006,
315 Fermaglich and Horohov, 2002) which may explain the greater propensity for this
316 complication.

317

318 Wound infection was recorded in 1/92 horses in the most recent data set. This is likely
319 to be an underestimation of the actual rate. In the current study the criteria for
320 identification of wound infections involved a swab being taken for culture and
321 sensitivity and a purulent or seropurulent discharge. In reality, the majority of horses
322 were treated with antibiotics and only if the infection was non-resolving would a swab
323 be taken. Freeman et al previously defined post-operative infection as the persistent (>
324 32 hours) drainage of serous, purulent or serosanguinous fluid from the incision, more
325 than 48 hours after the post-operative period, and local or systemic treatment (Freeman
326 et al., 2012). Further studies using less stringent criteria may yield very different
327 results, highlighting the importance of defining morbidities.

328

329 Pyrexia may arise from inflammation or infection following surgery. In the current
330 study, pyrexia was reported in 7/92 horses compared with 1/194 in the 2004-5 data.
331 The reason for this increase is unknown. No changes in the use of non-steroidal anti-
332 inflammatory use had been implemented. No previous studies have examined the
333 incidence of pyrexia following non-abdominal surgery in horses, but in human patients
334 incidences vary from 9.3% to 18% (Galicier and Richet, 1985, Petretta et al., 2013,
335 Garibaldi et al., 1985). Many of these studies failed to find a cause for the pyrexia and
336 not all patients developed an infection. Likewise, in horses, previous studies have
337 shown that pyrexia is not necessarily associated with infection (Freeman et al., 2012).
338 Further studies may aid identification of contributing factors.

339

340 Previous morbidity studies have investigated risk factors or predictors of survivability
341 with respect to different morbidities. Common factors were; drug use, breed, procedure
342 performed, intra-operative complications, re-laparotomy and personnel. Future studies
343 investigating changes in morbidity with these factors may be useful. However, in order
344 to draw firm conclusions large numbers of horses are required, necessitating a multi-
345 centre study with similar methods of recording post-operative morbidities.

346

347 Several limitations became apparent when analysing the results of this study. In the
348 initial study by Senior et al 194 anaesthetics were examined (Senior et al., 2007). This
349 contrasts with the current study's data in several ways. First, the data from 2013-14 was
350 taken over 12 months compared to 14 months in the 2004-5 data set. Ideally this data
351 would have been matched to the exact time period and the time of year. In addition,
352 many of the records from 2004-5 were incomplete with respect to signalment which led
353 to the inclusion of full data for only 101/194 horses. This introduced bias as the records

354 of animals with significant morbidities are more likely to be complete due to the
355 importance of maintaining legal records when complications occur. It may also be that
356 other morbidities are more likely to be identified if the horse already has a complication,
357 owing to more frequent examination. A further concern was the binary nature of
358 recording, i.e. morbidity present or absent, which does not reflect the subtleties of mild,
359 moderate or severe clinical signs. The decision as to what is included in definitions of
360 morbidity is subjective and disputable (Johnston et al., 1995).

361

362 In conclusion, increases in the prevalence of morbidities were found between 2004-5
363 and 2013-14 following non-abdominal procedures. The expectation was that
364 improvements in clinical practice over time would lead to a decrease in the prevalence
365 of morbidities. Reasons for the overall increase in the prevalence of morbidities are
366 likely to be multifactorial and may include better recording practices, a change in the
367 population of horses or a change in clinical practice. In light of the requirement from
368 the RCVS to audit clinical practice, accurate identification of morbidities is essential.
369 Further studies would be useful to formally define each morbidity with the goal of
370 standardising reporting. Ideally a large scale study would be conducted to identify
371 influencing factors that may have been missed when analysing relatively small numbers
372 of cases.

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379

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449

450

Table 1. Definitions of post-operative equine morbidities identified in previous and current studies. (Tinker et al., 1997, Senior et al., 2007)

Morbidity	Definition
Thrombophlebitis	Inflamed vein with <i>in vivo</i> blood clot formation. Diagnosis on basis of physical signs (venous hardening, redness, warmth and/or pain), or ultrasonography.
Dyspnoea/ respiratory obstruction	Upper airway lesion necessitating intervention e.g. tracheostomy.
Pulmonary oedema	Signs of coughing, wheezing, rales on thoracic auscultation with pink frothy fluid appearing at the nares or mouth, identified on endoscopy or at post-mortem examination.
Lameness, muscle damage, neuropathy	Inability to bear equal weight on all four limbs. Painful, swollen muscles, myoglobinuria, creatinine kinase values >15000 iu/L. Neurological deficits causing lameness or muscle weakness.
Postoperative colic in (previously) non- colic cases	Any recognised sign of abdominal pain, for example, pawing the ground, kicking the abdomen, attempts to lie down (Tinker et al., 1997).
Pyrexia	Rectal temperature > 39 °C
Diarrhoea	Soft or liquid faeces with increased volume and frequency.
Wound Infection	Seropurulent or purulent discharge at surgical site necessitating swabbing for culture and sensitivity.

Table 2. Data comparing horses undergoing non-abdominal procedures in 2013-14 and from Senior et al, 2007. *subset of data used from Senior et al.

	Non-abdominal 2013-14	Senior et al., 2007
Median Age in years (range)*	6 (0 - 21)	6 (1 - 25)
Median Body Weight in kg (range)*	502 (102 – 836)	500 (252, 690)
Median Time in Hospital in days (range)*	9 (0 – 145)	5 (1 – 36)
Mean Anaesthetic time in minutes (SD)*	103 (35.8)	87 (39.5)
Emergencies (%)*	29	21
Post-anaesthetic colic (%)	18.5 (17/92)	7.7
Diarrhoea (%)	1 (1/92)	2
Lameness, Myopathy, Neuropathy (%)	3 (3/92)	0
Fractures (%)	0	0
Wounds in Recovery (%)	0	0.5
Pyrexia	7.6 (7/92)	0.5
Thrombophlebitis (%)	2 (2/92)	1
Wound infection (%)	1 (7/92)	n/a
Respiratory Distress (%)	0	2