The prognostic importance of physiological and biochemical parameters in horses afflicted with colic

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ABSTRACT

Background: Colic, a primary cause of illness and death in horses, necessitates the development of improved prognostic tools.

Aim: The aim of this study was to investigate the prognostic significance of physiological and biochemical parameters in horses suffering from colic.

Methods: A comprehensive clinical evaluation of 117 horses included assessment of heart rate, mucous membranes, capillary refill time, rectal temperature, respiratory rate, gut motility, reflux, and limb pulse strength.

Results: Stomach reflux, absence of gut noises, and increased heart rate (mean increase of 12 bpm) strongly correlate with a poor prognosis. Prolonged capillary refill time (mean increase of 3 seconds), rectal temperature (over 38.5°C), elevated packed cell volume (mean increase of 4%), and blood lactate levels (mean increase of 5 mmol/l) underscore the significance of these markers. Notably, blood lactate ($p < 0.001$), gut noises ($p < 0.05$), and heart rate ($p < 0.001$) demonstrate the highest predictive significance based on statistical analysis.

Conclusion: Future research should investigate the prognostic potential of additional parameters and assess the impact of recommended treatments on colic prognosis. This data-driven study emphasizes the critical role of early recognition and thorough assessment in colic cases, offering vital insights into improving equine healthcare and mitigating mortality rates.

Keywords: Colic, Equine, Prognostic, Survival, Parameters.

Introduction

The abdominal pain symptoms known as colic are the leading cause of illness and death in horses. Consequently, they represent the most significant health concern in equines. Excessive consumption of carbohydrates, bloating, and changes in both food and environment may disrupt the delicate equilibrium of the microbiota in the hindgut. Dysbiosis may lead to physiological disruptions in the gastrointestinal system and impact the overall health of the horse, resulting in colic symptoms. There are several additional factors that can cause a horse to experience colic, such as dental issues, internal parasite infections, dehydration, prolonged use of nonsteroidal anti-inflammatory drugs and antibiotics, stress, torsion of the intestines, and stomach ulcers (Bland, 2016). Based on available records, it has been demonstrated that the mortality rate among horses affected by colic might vary within the range of 21% (Leblond *et al*., 2000) to 28% (Tinker *et al*., 1997; Egenvall *et al*., 2008).

The assessment of patient signalment, anamnesis, and basic physical examination can provide valuable insights into the severity of colic conditions in equines (Cook and Hassel, 2014). The following are important components of the colic physical examination: heart rate, mucous membrane appearance and moisture, skin turgor and capillary refill time, as well as rectal temperature, respiratory rate, auscultation of gastrointestinal motility, rectal palpation, presence of gastric reflux, and digital pulsation (Cook and Hassel, 2014).

Modifications in clinical indicators, including heightened heart rate, presence of cyanotic mucous membrane, prolonged capillary refill time, elevated rectal temperature, escalated breathing rate, and decreased gastrointestinal motility, indicate an unfavorable prognosis, and an increased risk of death in horses suffering from colic (Bland, 2016; Bihonegn and Bekele, 2018). When making treatment decisions and forecasting illness prognosis, it is advisable to consider supplementary diagnostic tests for packed cell volume (PCV) and blood lactate concentration (Cook and Hassel, 2014; Kos *et al*., 2022). Therefore, this study aimed to determine the predictive significance of physiological parameters in horses suffering from colic.

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Materials and Methods

Case selection

This study included a total of 117 horses brought to the Large Animal Clinic of Lithuanian University of Health Sciences between the years 2013 and 2020, specifically for the purpose of receiving therapy for colic symptoms. The medical history and physical condition of the horses were recorded upon their arrival. During the physical examination, various physiological factors were measured, including rectal temperature, respiratory rate, gut sounds, presence of spontaneous gastric reflux, digital pulse, heart rate, capillary refill time, and color of the mucous membrane. Blood samples were collected to assess the levels of PCV and blood lactate in horses with colic. Horses with colic exhibited clinical signs such as pawing, rolling on the ground, staring at the abdomen, sweating, and restlessness. Clinical examination was performed by experienced clinicians in the Large Animal Clinic of the Lithuanian University of Health Sciences.

In our study, we categorized the age of horses into four groups: foals (under 1-year-old), youngsters (1–4 years old), adult horses (5–17 years old), and senior horses (18 years and beyond). Additionally, there were a total of 27 different horse breeds, including the English Thoroughbred, the Trakehner, Lithuanian equestrians, Latvian equestrians, and other breeds.

In this investigation, the equine subjects were classified into two distinct cohorts: those who survived and those who did not. Our study did not include any horses that were euthanized. The assessment of all indicators was conducted in two groups using distinct criteria. The classification of rectal temperature was based on two categories: high, defined as ≥38.5°C, and low, as <38.5°C. The assessment of respiratory rate was categorized as either high, defined as greater than 16 breaths per minute, or low, defined as 16 breaths per minute or fewer. The auscultation of the dorsal and ventral abdomen was performed, and the gastrointestinal sounds were categorized as either present (heard in more than two abdominal areas) or diminished and nonexistent (heard in two abdominal areas or fewer) for each quadrant of the abdomen. The presence or absence of spontaneous gastric reflux and digital pulsation were determined. The assessment of heart rate was conducted, categorizing it as either high (more than 44 beats per minute) or normal (ranging from 24 to 44 beats per minute). Capillary refill time was categorized into two groups: greater than 2 seconds and 2 seconds or less. The hue of the mucosal membrane was characterized as either vividly pink or exhibiting signs of cyanosis and pallor. The clinicopathological variable known as PCV was categorized as either large (>50%) or low (≤50%). The measurement of PCV was performed using an EKF Diagnostics' HemataStat II microhematocrit centrifuge (USA). The blood lactate concentration ($[La^-]_b$) was evaluated using an express analyzer Arkray Lactate Pro 2 (Japan) to ascertain whether it fell within the high range (≥2 mmol/l) or the low range (<2 mmol/l).

Statistical analysis

Statistical analysis to assess survival was performed using IBM SPSS Statistics version 29.0. The present study aimed to evaluate the predictive value of 10 physiological indicators in determining horse survival through a comparative analysis between colic survivors and non-survivors. A total of ten variables were included in the Cox proportional hazard model. The odds ratio (OR) and Fisher's exact test were calculated. The statistical significance of the results was determined based on the criteria of $p < 0.01$ and $p < 0.05$. The research utilized Microsoft Office Word 2010 and Microsoft Office Excel 2010 for data analysis and documentation purposes.

Ethical approval

Not needed for this study, as this research is based on retrospective analysis.

Results

The overall survival rate measured in this research was 84.6% (99 out of 117). The research group consisted of 117 individuals, with 53% (62/117) being mares, 42% (49/117) being castrated males, and 5% (6/117) being stallions. The findings of our research reveal that 55% of all mares, survived, while 45% did not. Similarly, 42% of all the castrates survived, while 39% did not. On the other hand, only 3% of the stallions out of all 117 horses made it through, while 17% did not. The sex of the horse did not have a substantial impact on its survival ($p = 0.084$).

The results of our study indicate that 68% of the horses were within the age range of 5–17 years old. Senior horses accounted for 15% of the total, while younger horses made up 14%. Only 3% of the horses were less than 1 year old. The mean age of the horse was 11 ± 6,457 years. Our study found that the percentages of survivors and non-survivors among horses aged 5–17 years were comparable (68% and 67%, respectively); 15% of senior horses survived, while 17% did not; 15% of younger horses survived, while 11% did not; and only 2% of horses under the age of one survived, while 6% did not. Upon examining the influence of age on horse survival, no statistically significant findings were observed ($p = 0.692$).

The distribution of horse breeds was as follows: English thoroughbreds and Trakehners each represented 11% of the total, while Lithuanian equestrians and Latvian equestrians each accounted for 8.6%. Half-breeds constituted 8% of the total. Trakehners exhibited the highest mortality rate among horses, accounting for 17% of the overall total. Hanoverians, half-breeds, and Žemaitukas were less likely to survive among the horses, with each breed accounting for 11% of the non-surviving horses. According to the findings of our research, the breed did not have a major impact on the survivability of horses ($p = 0.324$).

The colic syndrome was most often caused by large colon obstruction (25%), large colon dislocation (9%), meteorism, first-degree stomach distension, and gastrointestinal spasms (6% each). Concerning the horses' ability to survive, the clinical diagnoses had a substantial impact ($p = 0.001$, $p < 0.001$). Our study found that 1% of the horses identified with incarcerated inguinal hernia survived, while 22% did not. Horses suffering from meteorism exhibited a survival rate of 4%, whereas 17% did not survive. Patients diagnosed with first-degree stomach distension, intestinal strangulation, and peritonitis had a survival rate of 5%, while the non-survival rate was 11%, respectively.

The variation in the assessment of physiological indicators to determine predictive significance arises from differences in the number of horses, as not every horse had all its indicators evaluated. For comparison, the study recorded heart rate measurements in 111 out of 117 horses, accounting for 95% of the total sample. Gastric reflux was observed in 90 out of 117 horses, representing 77% of the total number of animals studied. Additionally, rectal temperature was detected in 86 out of 117 horses, or 74% of the group (Table 1). Thus, we ascertain the predictive significance of physiological indicators in relation to the number of

horses they were assessed for. Gastrointestinal sounds ($p = 0.001$, $p < 0.001$), gastric reflux ($p = 0.037$, $p < 0.05$), heart rate ($p = 0.005$, $p < 0.01$), capillary refill time ($p = 0.028$, $p < 0.05$), mucous membrane color ($p = 0.043$, $p < 0.05$), and rectal temperature ($p = 0.019$, $p < 0.05$) demonstrated statistical significance in relation to horse survival. The results indicate that both PCV ($p = 0.008$, $p < 0.01$) and blood lactate concentration ($[La^-]_b$) ($p = 0.001$, $p < 0.001$) exhibited statistical significance. The survival of patients was shown to be independent of variables such as respiratory rate and digital pulse.

This study found that horses lacking intestinal sounds had a significantly increased probability of mortality, about 7.5 times greater than horses with existing gut movement (69% *vs.* 31%, respectively; $p = 0.001$, $p < 0.001$). Research revealed that only 23% of horses who had reduced gastrointestinal sounds in less than two abdominal areas managed to survive ($p = 0.001$, $p < 0.001$).

The analysis found that colic patients with spontaneous gastric reflux had a significantly higher death rate compared to horses without reflux. Specifically, the non-survival rate for colic patients with gastric reflux

Table 1. The percentage distribution of colic horses is based on survival rates at various levels of indicators.

Variable	Intervals	Non—survivors (%)	Survivors (%)	p	OR*	95% CI
Gastrointestinal sounds ($n = 113$; 97%)	≤2 abdominal area	69	23	<0.001	7.5	2.353–23.901
	>2 abdominal area	31	77			
Gastric reflux ($n = 90$; 77%)	Present	23	4	0.037	7.4	1.310–41.791
	None	77	96			
Heart rate ($n = 111$; 95%)	>44 bmp	87	48	0.005	7.5	1.606–34.617
	24—44 bmp	13	52			
Capillary refill time ($n = 104$; 89%)	>2 Seconds	67	33	0.028	4.1	1.153–14.821
	≤2 Seconds	33	67			
Mucous membrane color ($n = 108$; 92%)	Cyanotic/pale	36	13	0.043	3.8	1.088–13.248
	Vividly pink	64	87			
PCV ($n = 88$; 75%)	>50%	36	7	0.008	7.7	1.851–31.748
	≤50%	64	93			
$[La^-]_b$ ($n = 89$; 76%)	≥2 mmol/l	87	12	<0.001	46.9	9.072–242.934
	<2mmol/l	13	88			
Respiratory rate ($n = 112$; 96%)	>16 bmp	81	56	0.096	3.4	0.9–12.6
	≤16 bmp	19	44			
Rectal temperature ($n = 86$; 74%)	≥38.5°C	47	17	0.019	4.3	1.310–14.130
	<38.5°C	53	83			
Digital pulse ($n = 99$; 85%)	Is	8	12	1	0.6	0.074–5.404
	None	92	88			

*Probability of death increases with the odds ratio.

was 7.4 times greater than those who survived (23% *vs.* 4 %, respectively; *p* = 0.037, *p* < 0.05).

A horse experiencing colic and exhibiting a heart rate over 44 beats per minute had a much higher likelihood of mortality, being 7.5 times more likely to die compared to horses with a normal heart rate. This association was found to be statistically significant (*p* = 0.005, *p* < 0.01). Specifically, 48% of the horses that survived had an elevated heart rate, compared to 87% of the horses that did not survive.

A patient's risk of death was four times higher if their capillary refill time was longer than 2 seconds (*p* = 0.028, *p* < 0.05). Sixty-seven percent of those who did not survive have had a capillary refill time greater than 2 seconds, while only 33% of those who did survive had this characteristic.

It was found that horses with cyanotic or pale mucous membranes were 3.8 times more likely to die than horses with brilliant pink mucosa. The non-survival rate was 36% in horses with cyanotic or pale mucosa, whereas the rate was 64% in horses with bright pink mucosa (*p* = 0.043, *p* < 0.05). In the meantime, 13% of survivors and 36% of non-survivors had cyanotic or pale mucosa.

Horses with a rectal temperature over 38.5°C had a considerably increased risk of mortality, almost four times greater than those with a temperature below 38.5°C (47% *vs.* 53%, respectively, *p* = 0.019, *p* < 0.05). An 83% chance of survival was shown in horses with a rectal temperature < 38.5°C, but just 17% in those with a fever.

Colic horses with a higher PCV demonstrate a 7.7-fold greater likelihood of mortality compared to those with a lower PCV (36% with an elevated PCV *vs.* 64% with a low PCV). In the present study, it was shown that patients exhibiting elevated PCV constituted 36% of the non-surviving horses, while comprising just 7% of the surviving equine (*p* = 0.008, *p* < 0.01).

In comparison to horses with a low blood lactate concentration (<2 mmol/l), the risk of mortality was 46.9 times higher for horses with ≥2 mmol/l $[La^-]_b$ (*p* < 0.001). Eighty-seven percent of the horses that did not survive had a high $[La^-]_b$, while only 12% of the horses survived despite having a high $[La^-]_b$. Meanwhile, 13% of the non-survivors had a concentration of less than 2 mmol/l.

Comparable hazard ratios were observed for physiological measures, specifically heart rate and gastrointestinal sounds, each with ORs of 7.5. Out of all the evaluated parameters, the blood lactate concentration hazard ratio exhibited the highest magnitude, with an OR of 46.9. The lowest mortality risk ratio (OR 3.8) was associated with mucous membrane color. The results of our research indicate that there was no significant difference in respiratory rate (*p* = 0.096) and digital pulse (*p* = 1.000).

Discussion

An analysis of the physiological data records of horses hospitalized for colic syndrome was carried out to determine the predictive value of these records regarding the disease outcome. During this examination, a total of 117 horses were identified as diagnosed with colic syndrome. The survival rate observed in the study was 85%, with 99 out of 117 participants surviving. Nevertheless, a considerable proportion of those suffering from colic experienced mortality, amounting to 15% (18 out of 117). The research did not include any horses that were euthanized. The objective of our study was to determine the feasibility of forecasting the prognosis of colic by analyzing deviations from physiological markers.

The present study results indicate that there is a significant connection between decreased gastrointestinal motility and the prognosis of equine colic cases. The results of this study indicate a strong correlation between the prognosis of horse colic sickness and reduced gastrointestinal motility. Colic equine without gut sounds exhibit a mortality rate about 7.5 times higher in comparison to horses with gastrointestinal sounds in all four quadrants. The absence of gastrointestinal sounds, particularly in one or more quadrants, appears to be a strong predictive predictor of poor outcomes, according to a number of studies completed. Furthermore, critical cases have been found to have considerably reduced intestinal sounds when compared to non-critical medical situations (van der Linden *et al*., 2003; Jennings *et al*., 2014; Wormstrand *et al*., 2014; Curtis *et al*., 2015).

The study revealed that colic horses with gastric reflux had a 7.4 times higher risk of mortality, which was statistically significant at *p* < 0.05. According to previous studies conducted by various authors, it has been shown that the occurrence of gastric reflux serves as a dependable indicator for predicting survival outcomes (Freeman, 2018; Straticò *et al*., 2022). The results of these studies support the conclusions of our own analysis, which suggests that stomach reflux may be a significant factor in prognostic matters. On the other hand, Proudman et al. (2006) and colleagues' research has shown that stomach reflux is not a significant predictor of the outcome of horse colic.

According to the findings of the present study, there is a statistically significant correlation (*p* < 0.01) between elevated heart rate and a worsened prognosis in horses exhibiting colic symptoms. The results of this study are largely in line with those of other studies that were carried out in this subject matter (van der Linden *et al*., 2003; Proudman *et al*., 2006; Sutton *et al*., 2009; Wormstrand *et al*., 2014; Curtis *et al*., 2015), (Worku *et al*., 2017; Bowden, *et al*., 2020; Farrell *et al*., 2021). In the study by Jennings *et al*. (2014), data showed a statistically significant increase in heart rate in severe medical patients compared to basic medical cases (*p* < 0.05). Our study's findings are comparable to those of

previous researchers. Based on these findings, the heart rate appears to serve as a clinical prognostic indicator for the condition known as colic in horses.

Previous research has established that capillary refill time is a noteworthy prognostic indicator for the fatal outcome of colic horses, particularly when there is an observed increase in capillary refill time (van der Linden *et al*. 2003; Sutton *et al*., 2009; Thoefner *et al*., 2000). Confirmation of the importance of capillary refill time as a prognostic factor for colic was provided by the findings of studies conducted by both our study and theirs.

A comparison of abnormal mucosal membrane appearances, particularly cyanotic ones, to normal appearance resulted in a considerable reduction in the likelihood of survival (Ihler *et al*., 2004; Wormstrand *et al*., 2014; Bowden *et al*., 2020). Our study showed that colic horses with pale or cyanotic mucous membranes have a higher likelihood of experiencing a fatal prognosis compared to those with a normal mucous membrane appearance. Meanwhile, the research by van der Linden *et al*. (2003) shows that this particular physiological factor does not have a statistically significant correlation with the outcome of colic in horses.

Thoefner *et al*. (2000) analyzed 357 cases in their research and found a significant correlation between deviations in rectal temperature from 38°C and the outcome. This result aligns with our finding that rectal temperature is an important predictive measure for the outcome of colic in horses. However, further study is required since several studies did not show a significant correlation between temperature and the progression of a horse's disease (Jennings *et al*., 2014; Bihonegn and Bekele, 2018).

In the research by Kadunc Kos *et al*., it was found that PCV can be used to make good predictions about surgical and medical patients (Kos *et al*., 2022). The PCV at admission was shown to be greater in horses that underwent surgical treatment compared to those who received medical treatment. Additionally, the non-surviving horses exhibited larger PCVs than the surviving horses (Kos *et al*., 2022; Spadari *et al*., 2023). A different study found that the presence of PCV was only a significant predictor among patients who had received medical treatment (Ihler *et al*., 2004). In our study, increased PCV was also found to be a significant blood parameter in determining the outcome of colic syndrome. As a result, the assessment of PCV has the potential to be an extremely useful prognostic indicator for a horse with colic.

Our study determined that a higher concentration of blood lactate served as a strong predictive biomarker indicator for the fatal outcome for horses affected by colic. The mortality risk of horses with a blood lactate concentration of ≥2 mmol/l was shown to be 46.9 times higher compared to horses with a lower blood lactate concentration of <2 mmol/l. One of the studies

conducted by Yamout *et al.* (2011) investigated the connection between the levels of plasma D-lactate and the likelihood of survival until discharge. They were unable to identify any relationships that were statistically significant. The measurement of blood lactate concentration has been shown to be an effective predictor of survival, according to subsequent research. The levels of lactate that were found in horses who did not survive were significantly higher than those that did survive (Tennent-Brown *et al*., 2010; Radcliffe *et al*., 2012; Henderson, 2013; Smanik *et al*., 2022; Taschetto *et al*., 2023).

In connection with patients suffering from colic, the variables of respiration rate and digital pulsation did not show any statistical significance. It was also noticed in the data of other studies that there was no significant difference in the respiratory response between the different groups who experienced the outcomes (Jennings *et al*., 2014; Bihonegn and Bekele, 2018). On the other hand, a number of studies have revealed findings that indicate an increased respiratory rate is significantly associated with a reduced likelihood of surviving (Farrell *et al*., 2021).

Conclusion

Significant physiological markers, such as stomach reflux, absence of gut noises, an increased heart rate, capillary refill time, elevated rectal temperature, and higher concentrations of PCV and blood lactate, were found to be good predictors of fatal outcomes for horses with colic. In the present study, the predictive criteria that exhibited the highest degree of significance were the amount of blood lactate, gastrointestinal noises, and heart rate.

However, further investigation is required to determine the predictive significance of physiological markers, such as respiratory rate and digital pulse in relation to the survival of horses with colic. Additionally, it is important to conduct further to determine the potential effects of the proposed treatment on the overall prognosis of horses suffering from colic.

The investigation indicates that a thorough assessment of blood parameters may assist veterinarians in predicting the potential progress of colic, prescribing more suitable therapy, and thereby decreasing fatality rates in horses suffering from colic.

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