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Article

Prognostic Significance of Physiological and Biochemical Parameters in Colic-Afflicted Equine

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Simple Summary: In the context of equine health, colic is a leading cause of illness and death, with mortality rates ranging from 21% to 28%. This study is based on a retrospective analysis of patient registry data (containing 117 colic patients) collected from 2013 to 2020 that evaluates the predictive value of physiological parameters in colic prognosis. By retrospectively analyzing this dataset, we identify key predictors of poor outcomes in horses suffering from colic. The study underscores the importance of early recognition and thorough assessment in colic cases. Our findings indicate that stomach reflux, the absence of gut noises, increased heart rate, prolonged capillary refill, cyanotic mucosa, elevated packed cell volume and blood lactate levels are strong predictors of fatal outcomes in colic-affected horses. Notably, blood lactate, gut noises, and heart rate demonstrate the highest predictive significance. Further research is needed to assess the predictive value of other parameters, including respiratory rate, digital pulse, and rectal temperature, in colic equine survival. Additionally, the impact of recommended treatments on colic prognosis requires investigation. This study provides valuable insights for equine healthcare, emphasizing the importance of early recognition and thorough assessment in colic cases to enhance care and reduce mortality rates.

Abstract: Colic, a primary cause of illness and death in horses, necessitates improved prognostic tools. We assessed the predictive value of physiological parameters in colic prognosis. A comprehensive clinical evaluation encompassed heart rate, mucous membranes, capillary refill time, rectal temperature, respiratory rate, gut motility, reflux, and limb pulse strength. Results reveal key predictors of fatal outcomes in colic-affected horses. Stomach reflux, absence of gut noises, and increased heart rate (mean increase of 12 bpm) strongly correlate with a poor prognosis. Prolonged capillary refill (mean increase of 3 seconds), 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 ($p < 0.001$) exhibit the highest predictive significance based on statistical analysis. Future research should explore 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 syndrome; equine; prognostic; survival; outcome; physiological; parameters; biochemical

1. Introduction

The abdominal pain symptoms known as colic is the leading cause of illness and death in horses. Consequently, it represents the most significant health concern in equines. [1]. Based on available records, it has been shown that the death rate among horses affected by colic might vary within the range of 21% [2] to 28% [3,4].

The assessment of patient signalment, anamnesis, and basic physical examination can yield valuable insights into the severity of colic conditions in equines. [5]. 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, gastrointestinal motility auscultation, rectal palpation, presence of gastric reflux, and digital pulsation [5].

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, are indicative of an unfavorable prognosis and an enhanced death risk in horses suffering from colic [1,6]. When making treatment decisions and forecasting illness prognosis, it is advisable to consider supplementary diagnostic tests for packed cell volume (PCV) and blood lactate (LAC) [5,7]. Therefore, the objective of this research is to ascertain the predictive significance of physiological parameters in equines afflicted with colic.

2. Materials and Methods

2.1. Case selection

This study comprised a total of 117 horses who were brought to the Large Animal Clinic of Lithuanian University of Health Science (LUHS) between the years 2013 and 2020, specifically for the purpose of receiving therapy for colic syndrome. The medical history and physical state of the horses were recorded upon their arrival. During the physical exam, many physiological factors were measured, such as the temperature of the rectal area, the rate of breathing, the sounds coming from the intestines, the presence of gastric reflux, the digital pulse, the heart rate, the time it takes for the capillaries to refill, and the color of the mucous membrane. Blood samples were collected in order to assess the levels of packed cell volume and blood lactate in horses suffering from colic.

In this investigation, the equine subjects were classified into two distinct cohorts: those who exhibited survival and those who did not. The assessment of all indicators was conducted in two groups using distinct norms. The classification of rectal temperature was based on two categories: high, defined as above 39 °C, and low, defined as 39 °C or less. 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 less. The auscultation of the dorsal and ventral abdomens was performed, and the gastrointestinal sounds were categorized as either present (more than two spots) or diminished and nonexistent (two spots or less) for each quadrant of the abdomen. The presence or absence of 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 packed cell volume (PCV) was categorized as either large (>50%) or low (≤50%). The measurement of packed cell volume was performed with a hemocytometer. The blood lactate concentration (LAC) was evaluated using an express analyzer to ascertain whether it fell within the high range (≥2 mmol/L) or the low range (<2 mmol/L).

2.2. Statistical analysis

Survival analysis 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 its related 95% confidence interval were obtained. 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.

3. Results

The overall survival rate observed 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. Colic syndrome was most often caused by problems with the large colon (34%), the large colon dislocating (9%), meteorism, stomach distension, and gastrointestinal spasms (6% each). **Table 1** presents the distribution of gender percentages according to the intervals of the measured indicators' values.

Table 1. Gender-based distribution of horses according to a variety of physiological parameter standards.

Gender (%)	Gastrointestinal sounds		Gastric reflux		Heart rate		Capillary refill time		Mucous membrane color		PCV		LAC		Respiratory rate		Rectal temperature		Digital pulse	
	≤ 2 spots	> 2 spots	+	-	>44 bmp	24 - 44 bmp	> 2 sec	≤ 2 sec	cyanotic/pale	pink	> 50%	≤ 50%	≥ 2 mmol/L	< 2 mmol/L	> 16 bmp	≤ 16 bmp	> 39°C	≤ 39°C	+	-
Mare	24	76	6	94	52	48	32	68	12	86	4	96	20	80	53	47	2	98	12	88
Castrate	35	65	6	94	52	48	41	59	19	81	15	85	23	77	64	36	9	91	8	92
Stallion	40	60	33	67	100	0	60	40	40	60	100	0	80	20	100	0	50	50	20	80

The variability in horse populations can be attributed to the lack of defined physiological markers among different horses. As a comparison, the study recorded heart rate measurements in 111 out of 117 horses, accounting for 95% of the total sample. Gastric reflux was seen 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 2**). Gastrointestinal sounds ($p<0.001$), gastric reflux ($p=0.037$, $p<0.05$), heart rate ($p=0.005$, $p<0.01$), capillary refill time ($p=0.028$, $p<0.05$), and mucous membrane color ($p=0.043$, $p<0.05$) demonstrated statistical significance in relation to equine survival. The results indicate that both packed cell volume (PCV) ($p=0.008$, $p<0.01$) and blood lactate concentration (LAC) ($p<0.001$) exhibited statistical significance. The survival of patients was shown to be independent of variables such as respiratory rate, rectal temperature, and digital pulse.

Table 2. Clinical and laboratory variables pertaining to the proportion of non-survivor and survivor horses with colic.

Variable	Intervals	Non - survivors (%)	Survivors (%)	P	OR*	95% CI
Gastrointestinal sounds (n=113; 97%)	≤ 2 spots	69	23	<0,001	7.5	2,353-23,901
	> 2 spots	31	77			
Gastric reflux (n=90; 77%)	is	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 sec	67	33	0.028	4.1	1,153-14,821
	≤ 2 sec	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%)	PCV > 50%	36	7	0.008	7.7	1,851-31,748
	PCV ≤ 50%	64	93			
LAC (n=89; 76%)	LAC ≥ 2 mmol/L	87	12	<0,001	46.9	9,072-242,934

	LAC < 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%)	> 39°C	20	4	0.063	5.7	1,021-31,454
	≤ 39°C	80	96			
Digital pulse (n=99; 85%)	is	8	12	1	0.6	0,074-5,404
	none	92	88			

*Probability of death rises with the odds ratio.

This study found that horses lacking intestinal sounds had a much-increased probability of mortality, about 7.5 times greater than horses with observable gut movement (69% versus 31%, respectively; $p < 0,001$).

The analysis found that colic patients with gastric reflux had a significantly higher death rate compared to horses without reflux. Specifically, the non-survival rate for colic patients with gastric reflux was 7.4 times greater than those without reflux (23% versus 77%, respectively; $p=0.037$, $p < 0.05$).

A horse experiencing colic and exhibiting a heart rate over 40 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. Specifically, 87% of non-surviving horses had an elevated heart rate, whereas only 13% of non-surviving horses had a normal heart rate. This association was found to be statistically significant, with a p-value of 0.005, indicating a strong correlation. Additionally, the p-value was less than 0.01, further supporting the significance of the relationship.

A patient's risk of death was four times higher if their capillary refill time was longer than two seconds (67% of non-survivors had a capillary refill time above two seconds compared to 33% with a refill time less than two seconds; $p=0.028$, $p < 0.05$).

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. This association was statistically significant, with a p-value of 0.043, indicating a significant difference between the two groups. In the meantime, 13% of survivors and 36% of non-survivors had cyanotic or pale mucosa.

Colic horses with a higher packed cell volume demonstrate a 7.7-fold greater likelihood of mortality compared to those with a lower PCV (36% with an increased PCV versus 64% with a low PCV; $p=0.008$, $p < 0,01$). In the present study, it was shown that patients exhibiting elevated packed cell volume constituted 36% of the non-surviving horses, while comprising just 7% of the surviving equine.

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 LAC ($p < 0,001$). Of the 15 non-survivors, 87% were horses with a high LAC, and 13% were horses with a low LAC. Meanwhile, 12% of the 74 horses who survived had blood lactate concentrations above 2 mmol/L, whereas 88% had low LAC.

Comparable hazard ratios were seen for physiological measures, specifically heart rate and gastrointestinal sounds, with odds ratios of 7.5 each. Out of all the evaluated parameter ratios, the blood lactate concentration hazard ratio exhibited the highest magnitude, with an odds ratio 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 ($p=0.096$), rectal temperature ($p=0.063$), and digital pulse ($p=1.000$).

4. Discussion

An analysis of the physiological data records of horses that were hospitalized for colic syndrome was done in order to find out how useful these records were for predicting the outcome of the disease. In the course of this examination, a total of 117 equine subjects were identified as having been diagnosed with colic syndrome. The survival rate seen 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 objective of our study was to determine if it is possible to forecast the prognosis of colic by analyzing deviations from physiological markers. There were several limitations observed in this investigation. Upon analyzing the data, it was observed that none of the equines had undergone comprehensive measurements of both physiological and blood parameters. Hence, the first constraint of the investigation was the varying quantities of horses in relation to the number of criteria assessed. Another problem is that there is not enough information about horses that have been euthanized, which makes it hard to figure out the exact causes and outcomes of each case. The further limitation of the research is the omission of an investigation into the potential impact of the administered interventions, specifically surgery or medication, on the evaluation of the predictive significance of physiological markers. This feature underscores the necessity for more research, considering the potential impact of the treatment modality.

The present investigation revealed a notable correlation between reduced gastrointestinal motility and the prognosis of equine colic disease. Colic equine without gut sounds exhibits a mortality rate about 7.5 times higher in comparison to horses displaying gastrointestinal sounds in all four quadrants. Multiple studies have documented that the lack of gastrointestinal sounds, especially in one or more quadrants, is a strong prognostic predictor of poor outcomes. Furthermore, critical cases have been found to have considerably reduced intestinal sounds when compared to non-critical medical situations [8–11].

The study found that colic horses with gastric reflux have a 7.4-fold higher chance of dying, with a significance level of $p < 0.05$ reflecting statistical significance. 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 [12,13]. These studies corroborate our own study findings, which suggest that gastric reflux may possess significant prognostic implications. However, Proudman et al.'s research has found that gastric reflux is not a significant predictor of horse colic [14].

Our research revealed a statistically significant correlation ($p < 0.01$) between elevated heart rate and a worse prognosis in horses suffering from colic syndrome. This finding is highly consistent with previous research conducted in the field [8–10], [14–18]. In the study by Jennings et al. data showed a statistically significant increase in heart rate in severe medical patients compared to basic medical cases ($p < 0.05$) [11]. Our findings bear a resemblance to the outcomes of prior studies. This observation suggests that heart rate may serve as a significant prognostic predictor for 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 [8,16,19]. The research findings from both our study and theirs have provided confirmation about the significance of capillary refill time as a prognostic indicator for colic.

The odds of survival were significantly lowered when comparing aberrant mucosal membrane appearances, particularly cyanotic, to the typical look [9,15,20]. In our study, it was shown 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 Linden et al. shows that this particular physiological factor does not have a statistically significant link with the outcome of colic in horses [8].

In the research by Kadunc Kos et al., it was found that the packed cell volume can be used to make good predictions about surgical and medical patients [7]. The packed cell volume at admission was shown to be greater in horses that underwent surgical treatment compared to those that received medicinal treatment. Additionally, the non-surviving horses exhibited larger packed cell volumes than the surviving horses [7,21]. In a separate study, PCV was only a significant predictor among medically treated patients [22]. In our study, increased packed cell volume (PCV) was also found to be a significant blood parameter in determining the outcome of colic syndrome. Consequently, the measurement of packed cell volume (PCV) shows promise as a valuable prognostic indicator for horse colic.

In our investigation, it was discovered 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. In 2011, Yamout et al. did a study that looked at the relationship between plasma D-lactate levels and the chance of survival until discharge [23]. They did not find any statistically significant links. Subsequent studies have indicated that the measurement of blood lactate concentration serves as a valuable predictor of survival, with considerably greater levels observed in horses who did not survive compared to those that did [24–26].

The variables of respiration rate, rectal temperature, and digital pulsation did not demonstrate statistical significance in relation to colic patients. The findings of other studies also observed that there was no significant variation in respiratory response or rectal temperature across the outcome groups [6,11]. In contrast, several studies have yielded findings indicating that an elevated respiratory rate is significantly associated with a reduced likelihood of survival [18,20]. Furthermore, in a 2000 study, rectal temperature variation from 38°C was found to be substantially connected to the outcome of colic horses [19].

5. Conclusions

Significant physiological markers, such as stomach reflux, no gut noises, an increased heart rate, an increased capillary refill time, and higher concentrations of packed cell volume and blood lactate, were found to be good predictors of fatal outcomes for colic horses. In the present investigation, 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, digital pulse, and rectal temperature, in relation to the survival of horses with colic. Additionally, it is important to do further research in order to ascertain the potential effects of the recommended treatment on the overall prognosis of horses suffering from colic.

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