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The effect of potassium levels on electrocardiographic data in calves with neonatal diarrhea

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ABSTRACT

Objective: The objective of the current study was to assess the potassium levels and electrocardiographic (ECG) data in calves that diagnosed with newborn diarrhea.

Materials and Methods: This study was conducted on a dairy farm located in Ankara, involving a population of 500 dairy animals. The calves were divided into two groups: one group with normal potassium levels (NKg, n=24) and another group with hyperkalemia (HKg, n=16) due to neonatal diarrhea. After the initial clinical examination was conducted on the farm, electrocardiographic investigations were carried out utilizing an ECG equipment. A biochemical analysis was conducted on electrolytes Na^+, K^+, and Cl^- extracted from blood samples collected in red plain tubes, utilizing an automated analysis system

Results: The findings indicate that there were no statistically significant differences observed across all ECG variables between the two groups.

Conclusion: Acidemia and metabolic acidosis are commonly observed in calves suffering from hyperkalemic diarrhea, as documented in previous investigations, often accompanied by heart rhythm problems. In contrast, the current investigation revealed that neonatal calves with diarrhea and hyperkalemia had just a deepening of the T wave, without any additional abnormalities. Nevertheless, it is important to note that acidemia and metabolic acidosis were not of a severe nature. The implementation of Holter monitoring is indicated for calves experiencing hyperkalemia in conjunction with diarrhea.

Keywords: *Calf, Diarrhea, Electrocardiography*

INTRODUCTION

Hyperkalemia, characterized by an increased concentration of potassium in the bloodstream, has the potential to induce significant cardiac rhythm disturbances, particularly in neonatal calves affected by diarrhea (Constable et al., 2005; Trefz et al., 2015). Potassium is an essential electrolyte that serves a crucial purpose in preserving optimal electrical conductivity in the cardiac system and facilitating regular muscle operation. Nevertheless, in the event that the quantities of this substance exceed a certain threshold, it has the potential to interfere with the heart's regular rhythm and overall operation (Elliott and Braun, 2017).

The presence of hyperkalemia in individuals can be identified through various electrocardiographic (ECG) manifestations. These include the observation of tall and symmetric T waves, widening of the QRS complex, progressive flattening and eventual disappearance of P waves, as well as the occurrence of life-threatening dysrhythmias and bradycardia. These distinct patterns can be utilized to diagnose hyperkalemia and assess its severity (Mattu et al., 2000; Diercks et al., 2004). Comparable results are observed in calves

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who have been subjected to experimental hyperkalemia, as well as those that have had either experimentally generated or naturally occurring diarrhea (Bergman and Sellers, 1954; Lewis and Phillips, 1973; Weldon et al., 1992; Constable, 1999; Özkan et al., 2011; Başoğlu and Aydoğdu, 2013). However, it has been demonstrated through retrospective studies that, ECG may exhibit a relatively low sensitivity in the diagnosis of hyperkalemia (Wrenn et al., 1991; Montague et al., 2008).

The objective of the current study was to assess the potassium levels and electrocardiographic (ECG) data in a cohort of 40 calves (age<30 days) diagnosed with newborn diarrhea, originating from dairy farms located in Ankara, Türkiye.

MATERIALS and METHODS

This study was conducted on a dairy farm located in Ankara involving a population of 500 dairy animals. A total of 40 Holstein calves were selected as participants for the study. The calves were divided into two groups: one group with normal potassium levels (NKg, n=24) and another group with hyperkalemia (HKg, n=16) due to neonatal diarrhea. Calves were excluded from the study if diarrhea wasn't considered to be the primary problem. The investigation carried out during this study received approval from the Ankara University Animal Experiments Local Ethics Committee, under permit number 2023-4-29.

After the initial clinical examination was conducted on the farm, electrocardiographic investigations were carried out utilizing an ECG equipment (Carewell 1103 L Vet, China) The electrocardiograms were acquired when the calves were in a standing position. The application of electrocardiography electrodes involved the utilization of alligator clips. These clips were affixed to the skin in specific locations: the olecranon on the caudal aspect of the forelimbs, the cranial aspect of the hindlimbs over the patellar ligament, and the 8th intercostal space of the left thorax near the costochondral junction. Additionally, a neutral electrode was positioned over the right patellar ligament. All recordings were standardized at 10 mm/mV and 50 mm/s. Calves that underwent monitoring following the recording of an ECG that lasted for at least five minutes, with the aim of identifying any arrhythmias that may have been present. There was no application of digital filters.

A biochemical analysis was conducted on electrolytes Na^+, K^+, and Cl^- extracted from blood samples collected in red plain tubes, utilizing an automated analysis system (Fujifilm Dri-Chem 4000i, Fujifilm, Japan).

A commercially accessible software package (GraphPad Prism, version 7.01, GraphPad Software, La Jolla) was used to perform the statistical analysis of the obtained data. Statistical significance was determined by considering p values of <0.05. The normal distribution of data was assessed using the D'Agostino & Pearson, Shapiro-Wilk, and Kolmogorov-Smirnov tests. The ROUT (Q=1%) method was utilized to identify and flag outliers. A series of t-tests were performed to compare 15 variables between the two groups.

RESULTS

The age of the cases was represented by the median value of 14 days, with an interquartile range of 10.25–15 days. Given that the study was carried out within the facilities of a dairy farm, it was observed that a majority of 95% (n=38) of the calves belonged to the Holstein breed.

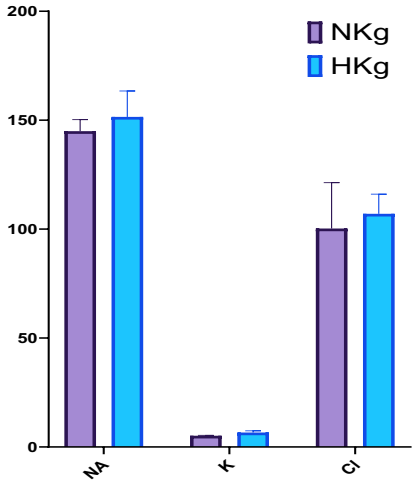

Figure 1. Electrolyte status in 40 neonatal diarrheic calves.

Table 1. Serum biochemistry variables between groups.

	NKg (n:24)		HKg (n:16)		p value
	Mean	SD	Mean	SD	
Na^+ mmol/L	145	5.29	151.50	11.91	0.0225
K^+ mmol/L	5.14	0.19	6.61	0.79	<0.0001
Cl^- mmol/L	100.30	21.04	107.00	9.04	0.2343
Na^+/K^+-ratio	0.035	0.001	0.044	0.007	<0.0001

Table 2. The ECG findings of Lead II of 40 neonatal calves with diarrhea

	NKg (n:24)		HKg (n:16)		*p* value
	Mean	SD	Mean	SD	
Heart Rate (beats/min)	174.30	49.45	173.90	38.95	0.9809
PR ınt (ms)	89.42	27.73	98.00	31.97	0.3726
P wave duration (ms)	44.25	15.20	42.63	21.92	0.783
QRS duration (ms)	126.30	89.48	118.60	58.09	0.7641
T wave duration (ms)	36.58	10.27	42.06	17.51	0.2193
QT interval(ms)	242.60	45.36	250.30	46.72	0.6078
QTc interval(ms)	403.40	56.53	418.60	62.29	0.4285
P Axis (°)	76.83	90.89	59.00	98.24	0.5595
QRS Axis (°)	116.90	106.91	90.38	108.30	0.4489
T Axis (°)	62.29	88.33	106.60	125.58	0.1971
II/ST amplitude (mV)	0.05	0.18	-0.01	0.11	0.2795
P amplitude (mV)	-0.02	0.26	-0.04	0.37	0.617
Q amplitude (mV)	-0.32	0.43	-0.25	0.37	0.5795
R amplitude (mV)	0.35	0.37	0.35	0.27	0.4573
S amplitude (mV)	-0.22	0.43	-0.18	0.36	0.7364
T amplitude (mV)	0.08	0.46	0.02	0.38	0.0569

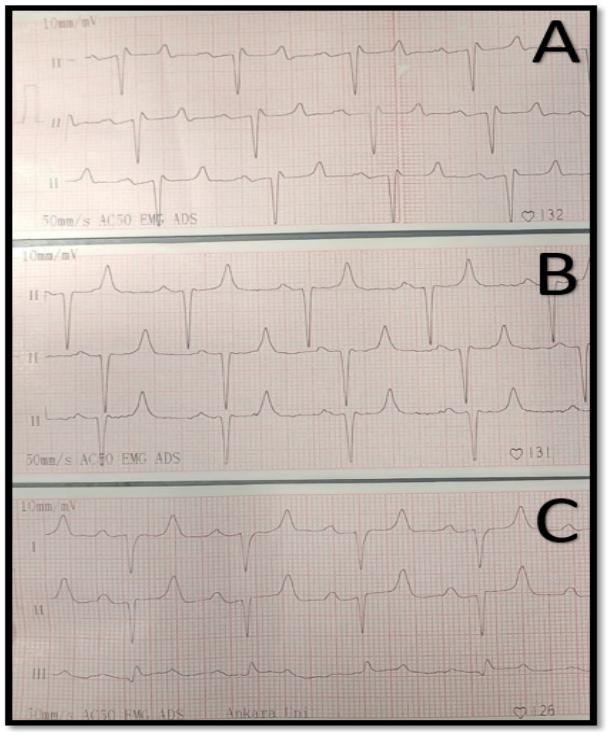

Figure 2. A: ECG findings of a calf with neonatal diarrhea in the hyperkalemia group with a serum potassium level of 8,12 mmol/L. B: ECG findings of a calf with neonatal diarrhea in the hyperkalemia group with a serum potassium level of 8,33 mmol/L. C: ECG findings of a calf with neonatal diarrhea in the normokalemia group with a serum potassium level of 4.77 mmol/L.

Figure 1 and Table 1 present data pertaining to the levels of electrolytes in venous blood samples collected from calves. A total of 16 calves (40%) exhibited hyperkalemia (cK+:5.84-8.33), while 24 calves (60%) had normokalemia. Figure 2 and Table 2 present a comparative analysis of lead II ECG measurements conducted on two distinct groups of calves. The findings indicate that there were no statistically significant differences observed across all ECG variables between the two groups.

DISCUSSION

According to the results of our research, the ECG variables of calves suffering from diarrhea and having high potassium levels did not significantly differ from one another. While it is acknowledged that previous research has been conducted in this field, we believe that the data we have collected during the decision-making process for diagnosing and treating calf diarrhea on a specific local farm holds significance.

Trefz et al. (2018) performed a study. In their investigation conducted on calves exhibiting

diarrhea and aged less than 21 days, the researchers observed certain outcomes, including elevated voltages of S and T waves, as well as changes in the amplitudes of P and Ta waves, which serve as early indicators of hyperkalemia. This study involved the examination of 130 calves that were admitted to a university animal hospital in Germany over a span of approximately 2 years. The calves were divided into four groups based on their blood pH and potassium levels, taking into account the treatment procedures. There could be multiple factors contributing to the observed disparities between the outcomes of our study and the one just mentioned. The following items can be listed as:

- Calves originating from various locations within the city.
- Calves of the Simental breed selected based on the breeder's preference.
- Admission of the calves to the hospital for medical care and subsequent monitoring of their treatment procedures.
- A total of 130 calves can be systematically divided into four distinct groups, allowing for a more comprehensive examination of each group with a greater level of detailed data analysis.

There are two enantiomeric forms of lactic acid. L-lactic acid is a frequently seen molecule in human metabolism, whereas D-lactic acid is generated by certain strains of microorganisms or by less significant metabolic routes. Although L-lactic acid is a naturally occurring molecule within the body, D-lactic acid is considered a detrimental enantiomer (Pohanka, 2020). Research findings have indicated that D-lactate plays a significant role in the metabolic acidosis commonly observed in calves suffering from diarrhea. The significance of bacterial colonization in the intestinal tract of calves experiencing diarrhea has garnered increased attention following the identification of the involvement of D-lactate in the onset of metabolic acidosis (Ewaschuk et al., 2003; Lorenz, 2004; Ewaschuk et al., 2005; Constable, 2009; Lorenz, 2009; Trefz et al., 2012). In their investigation, Naseri et al. (2019) performed an examination of L-lactate levels and observed a statistically significant elevation in the group of patients with septic shock. Upon assessing the individual blood lactate concentrations of septic calves, it was observed that there was no discernible disparity in mortality rate between hyperlactatemic calves and those with blood lactate concentrations falling within the reference range. In the present study, a comparative analysis of lactate levels between different groups was not carried out. The evaluation of lactate is a crucial criterion that demands consideration in future research endeavors.

In a study conducted by Kızıl et al. (2016) in our country, the potassium values and ECG data of healthy and diarrheic calves were compared. The findings of the ECG indicated the absence of P-waves and the presence of elevated T-wave peaks in hyperkalemic calves exhibiting moderate dehydration. Additionally, a reduction in the amplitude of P-waves, prolonged QRS complex, and, negative T-wave peaks were observed in moderately hyperkalemic calves with mild dehydration. Consequently, calves experiencing diarrhea may exhibit varying degrees of hyperkalemia, a condition that can be clinically diagnosed and potentially detected through electrocardiogram (ECG) analysis. Implementing preventive measures to address hyperkalemia may prove beneficial in devising treatment strategies for diarrheic and dehydrated calves. In the study, the difference between the two groups was not investigated and the findings were evaluated separately for each group. In contrast to the methodology employed in this particular study, the groups in our investigation were formed based on varying quantities of potassium. Therefore, our results reflect the effects of potassium.

CONCLUSION

Consequently, acidemia and metabolic acidosis are commonly observed in calves suffering from hyperkalemic diarrhea, as documented in previous investigations, often accompanied by heart rhythm problems. In contrast, the current investigation revealed that neonatal calves with diarrhea and hyperkalemia had just a deepening of the T wave, without any additional abnormalities. Nevertheless, it is important to note that acidemia and metabolic acidosis were not of a severe nature. The implementation of Holter monitoring is indicated for calves experiencing hyperkalemia in conjunction with diarrhea.

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