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Original Article

Electrocardiographic evaluation in pregnant mares and neonate foals of Paint Horse breed

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For the interpretation and evaluation of electrocardiography, it is necessary to know the species' electrocardiographic patterns, as well as the breed and age of the animal. The objective of this study was to describe the electrocardiographic characteristics in neonate foals of Paint Horse breed and in clinically normal pregnant mares. We evaluated 20 animals of each category. The maternal electrocardiographic examinations were performed at 15 and 7 days preterm; the neonatal echocardiographic examinations were performed at birth up to 48 hours postpartum, and thereafter once a week up to 35 days of age. For each electrocardiographic record, the heart rate (HR), cardiac electrical axis, rhythm alterations, wave lengths and amplitudes, and electrocardiographic intervals were analyzed. During the first 48 hours of life of the equine neonate, sinus tachycardia and ventricular arrhythmias were observed. In foals during the first month of age, a predominance of sinus rhythm was observed, with a decrease in HR and R-wave amplitude, and an increase in PR, QT, and RR intervals over the course of days. In pregnant mares, no significant changes were found in the electrocardiographic tracings when compared to that of healthy adult horses. The results of this study demonstrated the influence of age and growth on electrocardiographic parameters.

INTRODUCTION

Among the obstacles of equine production and management, we highlight the neonatal mortality attributed to cardiovascular, pulmonary, thermoregulatory, and metabolic abnormalities (SMITH, 2006). In order to improve equine perinatal care and reduce mortality of newborns, especially animals with high genetic value, electrocardiography (ECG) proves to be an important tool because of its non-invasiveness and easy to be performed in the field (FREGIN, 1982; ROBERTSON, 1992).

The ECG is a complementary exam that allows to detect changes in the electric conduction of the cardiac chambers (arrhythmias) and the axis in the frontal plane (TILLEY, 1992; CAMACHO; MUCHA, 2008). Ventricular repolarization can be caused by the state of myocardial oxygenation, and influences the electrolyte and basic acid imbalance (EDWARDS, 1987; BELERENEAN, MUCHA, CAMACHO, 2003). Currently, there is no universally accepted ECG lead system for use in production animals. However, the most conventional system for ECG in horses are limb shunts (frontal plane) (FERNANDES et al., 2004; YONEZAWA et al., 2009) and base-apex (HALLOWELL, 2008; SAVAGE; FENNELL, 2009).

For the interpretation and evaluation of ECG, it is necessary to know the ECG patterns of the species, race (HILWIG, 1977; FREGIN, 1982), and age (HOLMES; ALPS, 1967). Because the reference values for ECG interpretation in adult horses are variable, little is known about their interpretation in neonatal horses. The difficulties to establish the normal ECG patterns in animals in the neonatal period (LOURENÇO; FERREIRA,

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2003) arise from a series of aspects observed in the cardiocirculatory physiology, which differs from adults in terms of blood pressure, peripheral vascular resistance, cardiac output, discrepancy between left ventricular and right ventricular mass, left ventricular anatomical conformation, and autonomic nervous system innervation (HINES, 2013).

Newborn ECG reflects the hemodynamic repercussions on the right ventricle in intrauterine life, right ventricular overload pattern, and anatomopathological changes resulting from the transition from fetal to neonatal circulation, and may last up to 2 years in humans (ABREU et al., 2004; SOCIEDADE BRASILEIRA DE CARDIOLOGIA, 2003). These changes are due to the physiological development, body size, position of the heart in relation to the body, and the variation in the structural conformation of the cardiac chambers and pulmonary vessels (ANDREA, ATIÉ, MACIEL, 2002; NOGUEIRA, FARIA, SOUSA, 2010).

As in humans and animals, the characteristics of the electrocardiographic tracing should be evaluated according to the age of the patient. In this way, the objective of this study was to describe the electrocardiographic characteristics of amplitude, duration, rhythm, and cardiac axis in the frontal plane and apex base in newborn foals of the Paint Horse breed, and in clinically normal pregnant mares.

MATERIAL AND METHODS

Animals

The experimental procedures of the present study were carried out after approval by the Ethics Committee on Animals Use (ECAU), under protocol number 231/2012. The informed consent form was signed by the owner of the animals, authorizing the scientific study.

A total of 20 Paint Horse foals, euthocytes and non-twins, were evaluated in non-twin births, produced by the embryo transfer technique (ET), in multiparous mestizo recipients (n = 20; mean age, 5–12 years; mean weight, 450 kg). The date of pregnancy was calculated from the date of ovulation, counting from 11 months thereafter.

The mares were vaccinated with Pneumabort-K® + 1b (Equine Rhinopneumonite, Zoetis Animal Health Specials, Canada) at the fifth, seventh, and ninth month of pregnancy. The animals were kept in Tifton 85 (Cynodon dactylon) pasture, with mineral salt *ad libitum* and fed with 17% protein (2.0 kg/animal/day). All mares underwent general clinical examination, and were healthy in the present study. The deliveries occurred without complications and no obstetric intervention was required.

Time points of analysis

The ECG examinations were performed in the mares at two time points during pregnancy, namely at 330 and 338 days (approximately 15 and 7 days before delivery). The ECG examinations were performed in the neonates at birth, at 4, 8, 12, 16, 20, 24, 36, and 48 hours after delivery, and on the 7th, 14th, 21st, 28th, and 35th day of life. During the recordings, the foals remained with their mothers in order to avoid stress and tachycardia.

Electrocardiographic examinations (maternal and neonatal)

The ECG evaluations were performed using the computerized ECG system (TEB®, São Paulo, Brazil), in the leads in the frontal plane (I, II, III, aVR, aVL and aVF) at a velocity of 25 mm/sec and sensitivity adjusted to 1 cm = 1 mV. The leads used in the maternal and neonatal ECG corresponded to the base-apex and frontal plane. In the latter, the commonly used electrodes were alligator clips moistened with alcohol, positive electrode ("left thoracic limb," yellow) positioned in the region above the left humeral radial ulnar joint, negative electrode right, third electrode ("right pelvic limb," black) above the right femur-tibiopatellar joint, and the fourth electrode ("left pelvic limb," green), as described previously (FERNANDES et al., 2004).

In order to register the base-apex derivation, three electrodes were coupled, a negative electrode being attached to the medial portion of the right side of the neck, a positive electrode fixed between the third and fourth left intercostal space, at the height of the olecranon, and the earth electrode fixed at the withers of the animal (PATTESON, 1996).

The ECG records obtained had a duration of 5 min, and were evaluated by taking into account the duration, amplitude, and morphology of the waves, by choosing the free traces of artifacts. The following parameters were calculated: (1) duration of P and T waves, QRS complex and PR and QT intervals in milliseconds (ms); (2) amplitude of P, R, and T in millivoltage (mV); and (3) T polarity, rhythm, HR (bpm), and cardiac electrical axis (based on the behavior of the QRS complex).

The maternal and neonatal records were performed in the morning, in a closed environment (individual stall), free of external stimuli to avoid consequent tachycardia. Neonates were always kept close to their mothers in order to avoid stress and tachycardia. The floor of the bay where the animal examinations were performed was covered with rubber plates in order to avoid interferences with the ECG tracing. The animals were kept in season, without any sedation, tranquilization, or anesthesia. The results of the tracings were not correlated with the individual weight of each animal.

Statistical analysis

To evaluate the ECG parameters during the selected time points, the repeated measures analysis of variance (ANOVA) was performed complemented with the *post-hoc* multiple comparisons test of Bonferroni (version 9.1.3; SAS Institute, Cary, NC, USA, 2006). Friedman's nonparametric analysis complemented with Dunn's multiple comparisons test (version 9.1.3; SAS Institute, Cary, NC, USA, 2006) were used for variables not adherent to the normal probability distribution. The verification of data normality was performed according to the Shapiro Wilk test followed by the Pearson or Spearman correlation tests for nonparametric data (version 3.10; Sigma Stat Software, USA, 2005). The results were expressed as mean and standard deviation at the 5% level of significance.

RESULTS

The ECG evaluations performed in neonates, after statistical analysis, showed significant differences between the P, R, S, T, and P wave lengths, PR interval, QRS complex, and T wave amplitudes. The duration (ms) and amplitude (mV) of the waves and intervals in base-apex and lead II of frontal plane are shown in Table 1.

Table 1 – Comparison of electrocardiographic parameters (mean, standard deviation, maximum and minimum) in lead II of frontal plane and base-apex in neonate foals of Paint Horse breed, from birth to 35 days of age.

Parameters		Base-Apex				Frontal Plane (Lead II)			
	n	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
HR (bpm)	280	111.57	19.83	63.00	179.00	111.11	20.23	60.00	186.00
P (ms)	280	87.17[a]	14.66	40.00	133.00	69.07[b]	17.20	30.00	163.00
P (mV)	280	0.23[a]	0.09	0.00	0.50	0.20[b]	0.06	0.060	0.42
PR (ms)	280	152.36[a]	21.04	93.00	223.00	136.41[b]	23.19	83.00	230.00
QRS (ms)	280	72.16[a]	8.43	50.00	110.00	61.35[b]	9.75	23.00	90.00
R (mV)	280	0.03[a]	0.04	0.00	0.26	0.49[b]	0.34	0.00	1.47
S (mV)	280	0.98[a]	0.34	0.20	2.80	0.01[b]	0.02	0.00	0.14
QT (ms)	280	281.92	29.47	183.00	367.00	278.72	34.21	53.00	367.00
T (ms)	280	91.55[a]	18.65	53.00	160.00	103.41[b]	21.80	33.00	180.00
T (mV)	280	−0.15[a]	1.27	−21.00	0.73	−0.42[b]	0.33	−1.45	0.63
RR (ms)	280	554.90	102.67	337.00	947.00	552.69	102.39	323.00	967.00

Different overlapping letters (a, b) present on the same line, indicate significant difference (a ≠ b: $p < 0.05$). bpm: beats per minute; HR: heart rate; ms: milliseconds; mV: millivolts; n: number; S.D.: standard deviation.

The neonatal HR suffered a reduction from birth until 36 hours of life, but without significant differences. The HR at birth was significantly reduced when compared with HR at days 28 and 35. The results of this parameter are described in Figure 1 and Table 2.

Figure 1 – Variation of heart rate from birth to 35 days of age in neonate foals of Paint Horse breed.

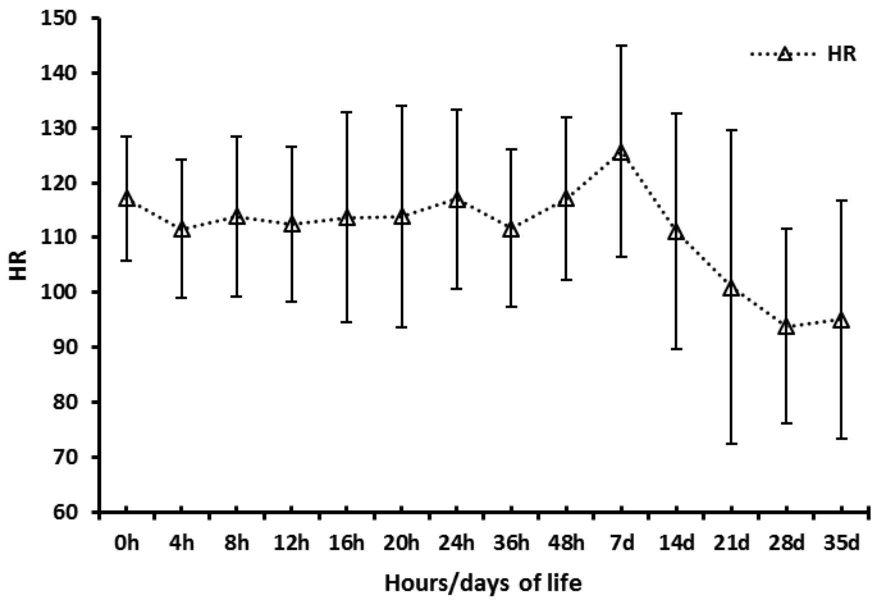

Table 2 – Variation of HR, PR, QT, RR intervals, and R wave between birth and 35 days of age, in neonate foals of Paint Horse breed in lead II of frontal plane.

	HR (bpm)		PR Interval (ms)		QT Interval (ms)		RR Interval (ms)		R Wave (mV)	
Time points	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Birth	117.1[cd]	14.6	121.3[a]	16.6	284.2[b]	30.0	521.6[ab]	68.5	0.74[b]	0.28
4 hours	111.6[bcd]	14.1	127.6[abc]	18.7	296.5[b]	23.1	541.3[ab]	73.8	0.76[b]	0.25
8 hours	113.9[cd]	19.1	129.1[abc]	18.1	291.6[b]	30.6	540.9[ab]	87.5	0.77[b]	0.25
12 hours	112.5[bcd]	20.2	134.1[abcd]	18.5	290.3[b]	23.1	545.8[ab]	84.9	0.69[b]	0.37
16 hours	113.7[cd]	16.4	132.0[abcd]	19.9	282.7[b]	24.2	539.8[ab]	70.2	0.66[b]	0.30
20 hours	113.9[cd]	14.4	127.9[abc]	18.3	275.6[ab]	23.1	536.3[ab]	70.8	0.64[b]	0.34
24 hours	117.0[cd]	14.7	129.1[abc]	10.1	275.0[ab]	20.9	513.4[a]	62.3	0.63[b]	0.28
36 hours	111.7[bcd]	19.2	131.3[abcd]	17.3	274.8[ab]	29.5	555.7[ab]	80.2	0.50[b]	0.24
48 hours	117.1[cd]	21.5	124.8[ab]	19.1	270.5[ab]	29.8	523.0[ab]	89.5	0.53[b]	0.22
7 days	125.7[d]	28.5	148.6[dc]	27.5	247.2[a]	56.0	495.2[a]	113.0	0.19[a]	0.19
14 days	111.1[bcd]	17.7	144.5[cde]	26.4	265.7[ab]	28.9	542.6[ab]	86.2	0.21[a]	0.20
21 days	101.0[abc]	21.7	142.0[bcde]	21.4	281.4[b]	40.7	607.6[bc]	121.3	0.19[a]	0.20
28 days	93.8[a]	18.3	160.0[e]	25.1	285.7[b]	36.0	659.0[c]	97.2	0.23[a]	0.27
35 days	95.1[ab]	18.0	157.0[e]	23.3	280.7[b]	44.1	649.1[c]	137.9	0.24[a]	0.24

Different overlapping letters (a, b, c, d, e) indicate significant differences between the time points (a ≠ b ≠ c ≠ d ≠ e: $p < 0.05$). bpm: beats per minute; HR: heart rate; ms: milliseconds; mV: millivolts; S.D.: standard deviation.

The duration of PR, QT, and RR intervals did not differ significantly in the first 48 hours. In general, a significant increase in QT, PR, and RR intervals was observed from the first 48 hours of life until the 35th day. The R wave amplitude values from birth to 48 hours differed from the 7th to the 35th days of life, with a significant decrease in this period (Table 2).

In neonates, there was a negative correlation between HR and HR interval (r = –0.5540, P < 0.0001), HR and QT interval (r = –0.7146; P < 0.0001), and HR and RR interval (r = –0.9414, P < 0.0001) during the assessed period.

Among the parameters analyzed in the frontal and base-apex shunt II in recipient mares, a significant reduction in the mean QRS complex in the frontal plane (111.53 ± 10.03 ms) was observed when compared to the base-apex mode (99.72 ± 25.15 ms). Significant reductions were also observed in the R-wave amplitude in the frontal plane mode (0.52 ± 0.30 mV) compared to the base-apex mode (0.06 ± 0.04 mV), and in the S-wave amplitude in the base-apex mode (1.19 ± 0.20 mV) compared to the frontal plane (0.01 ± 0.02 mV). It was also observed in maternal values, negative correlations between HR and RR interval (r = –0.9653, P < 0.0001), HR and PR interval (r = –0.5390, P < 0.0003), HR and QT interval (r = –0.6840; P < 0.0001).

The comparison between the ECG of the mares and neonates in lead II from frontal plane revealed that only the amplitude of the S and R waves were not significantly different. The neonates presented higher HR values and amplitudes of the P, Q, and T waves, whereas the mares had higher values in relation to the axis, durations of the P and T waves, and PR, QRS, QT, and RR intervals. The results are described in Table 3.

The mares had a mean cardiac axis of 86.52 ± 54.74 degrees, median of 90°, maximum value of 150°, and minimum value of –150°. For this parameter, the neonates presented a mean of 39.92 ± 74.29, median of 30°, maximum value of 180°, and minimum value of –173°.

When comparing the ECG parameters of the neonates according to sex, the females presented significantly lower amplitudes of the P, Q, and T waves (0.18 ± 0.05 mV, 0.15 ± 0.12 mV, and –0, 36 ± 0.29 mV, respectively) when compared to males (0.21 ± 0.06 mV, 0.24 ± 0.26 mV, –0.45 ± 0.34 mV, respectively). Only the amplitude of the S wave was higher in the filly (0.01 ± 0.003 mV).

In relation to the heart rhythms, we observed a predominance of the sinus rhythm (85%; 17/20) in neonates from birth to 48 hours of age, with an average HR of 114 ± 17 bpm. Sinus tachycardia corresponded to 45% (9/20) of the rhythms analyzed, with an average HR of 147.86 ± 8.2 bpm. Unsustained ventricular tachycardia was found in 15% (3/20) of the animals, and isolated ventricular premature contractions (VPC) of the right ventricle in 10% (2/20) in the first 48 hours of life.

Table 3 – Comparison of electrocardiographic parameters (mean, standard deviation, maximum and minimum) between mares and neonates foals of Paint Horse breed in lead II of frontal plane.

Parameters	Mares				Neonates			
	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max
HR (bpm)	59.32[a]	8.88	45.00	85.00	111.11[b]	20.23	60.00	186.00
P (ms)	103.10[a]	27.47	67.00	167.00	69.07[b]	17.20	30.00	163.00
P (mV)	0.17[a]	0.04	0.06	0.26	0.20[b]	0.06	0.06	0.42
PR (ms)	224.88[a]	38.68	163.00	340.00	136.41[b]	23.19	83.00	230.00
QRS (ms)	99.72[a]	25.15	47.00	167.00	61.35[b]	9.75	23.00	90.00
Q (mV)	0.08[a]	0.07	0.00	0.32	0.21[b]	0.23	0.00	2.08
R (mV)	0.52	0.30	0.00	1.18	0.49	0.34	0.00	1.47
S (mV)	0.01	0.02	0.00	0.07	0.01	0.02	0.00	0.14
QT (ms)	427.48[a]	30.37	370.0	493.00	278.72[b]	34.21	53.00	367.00
T (ms)	119.35[a]	26.31	60.00	170.00	103.41[b]	21.80	33.00	180.00
T (mV)	0.01[a]	0.23	–0.50	0.42	–0.42[b]	0.33	–1.45	0.63
RR (ms)	1028.8[a]	136.56	699.00	1310.0	552.69[b]	102.39	323.00	967.00
E. Axis (degrees)	86.52[a]	54.74	–150.00	150.00	39.92[b]	74.29	–173.00	180.00

Different overlapping letters (a, b) indicate significant differences (a ≠ b: $p < 0.05$). bpm: beats per minute; E. Axis: cardiac electrical axis; HR: heart rate; ms: milliseconds; mV: millivolts; S.D.: standard deviation.

On the 7th day, 65% (13/20) of the animals presented a sinus rhythm, and 35% (7/20) had sinus tachycardia, evolving at day 14 of life to 80% (16/20; i.e., sinus) and 20% (4/20; i.e., sinus tachycardia). On the 21st and 28th days, only 5% (1/20) of the foals had sinus tachycardia; thus, on the 35th day, 100% (20/20) of the rhythms analyzed corresponded to the sinus. A total of 5% (1/20) of junctional tachycardia at the 7th day of life was observed.

In the maternal analyzes, 95% (19/20) of the pregnant females had a predominantly sinus rhythm. Among the conduction disorders detected in this category, the second-degree atrioventricular block was present in 25% (5/20) of the animals, while the left bundle branch block was present in 5% (1/20).

DISCUSSION

The neonatal HR presented a progressive and significant decrease from birth to the 35th day of life, and the RR interval, which is inversely correlated with HR, presented a significant increase in this period. Madigan et al. (2013) reported a similar decrease in HR with advancing age, whereby it was elevated at birth and decreased at the age of 30 days. The heart has autonomic control and does not require the central nervous system to act. However, it may be influenced by the sympathetic and parasympathetic systems, which are represented by the adrenergic fibers and the vagus nerve, respectively (VAN LOON, PATTESON, 2010). High HR values in the neonatal period can be explained in part by the immaturity of the autonomic nervous system, with parasympathetic innervation acting in later stages, resulting in a predominantly adrenergic neural control in neonates (BEUCHÉE et al., 2012; FERRER, 1985, SELIG et al., 2011).

The increase in the RR interval and the decreased HR observed on the 35th day may be related to the maturation of the parasympathetic tone, indicating the beginning of the balance between the branches of the autonomic nervous system in the equine neonate. In humans, development is complete at 2 years of age (LANDROT et al., 2007). In dogs, the parasympathetic system is active only after the eighth week of life (BRIGHT, 1995).

The duration of the PR interval increased from birth to 35th day, which is in line with previous findings in neonatal foals (120 to 180 ms) (LOMBARD, 1990), but is below that of adult mares in this study and previous studies (FERNANDES et al., 2004). However, the results demonstrated the immaturity of the parasympathetic system and the sympathetic performance in the sinoatrial and atrioventricular nodes, since they are influenced by both systems. The atrioventricular node is sensitive to changes in sympathetic activity leading to tachycardia and increased electrical conduction velocity (VAN LOON, PATTENSON, 2010). Another factor that explains the increase in atrial conduction velocity is the lower myocardial mass of the neonates compared with adults (LOMBARD et al., 1984; STEWART, ROSE, BARKO, 1984).

The ventricular depolarization, which was represented by the amplitude of the R wave, decreased between birth and the 35th day of life. This decrease may be explained by the maturation of the His bundle and the Purkinje cells, which results in synchronized depolarization of the cardiac muscle (TILLEY et al., 1992).

The present study demonstrated a progressive increase in the QT intervals together with decreasing HR with age, thus indicating a negative correlation between QT interval and HR. Therefore, QT interval provides a direct measurement of the duration of ventricular systole, whereby the QT interval is representative of the ventricular muscular mass (HAMID; BARHAM, 2010). Thus, when HR decreases, the QT interval duration increases.

The T wave amplitude of the neonates showed a predominance of negative polarity, and was significantly higher than the amplitude in adult mares. The increase in T wave may indicate myocardial hypoxia or electrolyte changes (BONAGURA; REEF, 1998), situations that may be present during the period of neonatal adaptation (YAMAMOTO, YASUDA, KIMEHIKO, 1991).

Among the maternal parameters analyzed in the frontal and base-apex shunt II, the significant reductions in the QRS complex and S amplitude in the base-apex shunt when compared to the frontal plane, as well as the significant elevation in the R amplitude, may be associated to the positioning of the electrodes in different ECG methods. Indeed, the exact location of the electrodes on the body surface affects the results of the obtained registers (HAMLIN, SMETZER, SMITH, 1964). According to the reference values established by Van Loon and Patteson (2010) for healthy horses, in the base-apex lead, the P wave is less than or equal to 0.16 seconds, the PR interval less than or equal to 0.5 seconds, the QRS complex is 0.14 seconds, and the QT interval less than or equal to 0.6 seconds. The values of the parameters described above in the present study are within the established range.

In the frontal plane in lead II, the ECG characteristics were consistent with those described by Fernandes et al. (2004), except for the T wave amplitudes, which were larger in the present study. Although T wave above 25% of the R wave is indicative of myocardial hypoxia and/or electrolytic disturbances in adult horses (WHITE; RHODE, 1974), there is no citation in the literature suggesting its occurrence in pregnant mares clinically healthy at rest.

In neonates, when the ECG parameters were confronted between the two leads (in the lead II of the frontal plane with the base-apex), significant differences were found between the P, R, S, T, and duration amplitudes of the P waves, PR interval, QRS complex, and T wave. Similar results were obtained in adult horses, justified by differences in the ECG recording methods in relation to electrode positioning.

From birth to 48 hours of life, the predominant heart rhythm was the sinus, which was considered physiological for foals (LOMBARD, 1990; YAMAMOTO, YASUDA, KIMEHIKO, 1991; FERNANDES et al., 2004). Sinus tachycardia and ventricular arrhythmias were also observed in a lower proportion in the present study. Premature ventricular contractions and sinus tachycardia are considered benign in most foals and are indicative of non-specific stress reactions (LOMBARD, 1990). Hypoxemia, hypercapnia, acidemia, high sympathetic tone, and atrial muscle extension play an important role in neonatal arrhythmias (YAMAMOTO, YASUDA, KIMEHIKO, 1991; YAMAMOTO, YASUDA, TOO, 1992). Thus, the importance of knowledge of the ECG species-related characteristics during the period of neonatal adaptation, and at different ages and functional states of the animal, is noted.

The sinus rhythm was predominant after the 7th day in the foals, coinciding with that described by Lombard (1990). In this period, sinus tachycardia (4%), considered benign or physiological (LOMBARD, 1990; FERNANDES et al., 2004), was also observed at a lower percentage. In the mares, sinus rhythm occurred at a higher proportion in the assessed period, and the conduction disorders detected (second degree atrioventricular block and left bundle branch block) demonstrated that cardiac arrhythmias attributed to vagal tonus can be found in healthy animals of the equine species (REEF; MARR, 2010).

The variation of the cardiac electric axis reflects the change in the size and position of the heart in the thorax during growth and as a result of physical maturation of the animal. According to Ayala et al. (1998), foals up to 2 months of age present predominantly negative cardiac electrical axis values. Although the mean observed in the present study was positive, it is believed that there is a considerable variability in the QRS morphology and in the mean electric axis, similarly to adult horses. Although there is some individual tendency for the electric axis to move from right to left over the first few months, this behavior is extremely variable (MADIGAN, 2013).

The cardiac electric axis of the pregnant mares evaluated in the present study is in agreement with the values reported by Fernandes et al. (2004), who evaluated normal purebred blue mares and found that 80.0% of the cardiac axis ranged from 31° to 120°, while 50% ranged from 61° to 120°. A slight deviation to the right was observed, and this may be related to the innervation of the viscera by increased abdominal pressure in the diaphragmatic dome. Vicenzi; Larsson; Fernandes (2000) also found a shift to the right of the cardiac axis in pregnant Mangalarga mares.

To our knowledge, there is no available data on the relationship between sex and cardiac physiology in newborns. In the present study, the males showed significantly higher P (atrial depolarization), Q (ventricular depolarization), and T (ventricular repolarization) amplitudes compared with females.

CONCLUSION

The results of this study demonstrated the influence of age and growth on electrocardiography parameters. The equine neonate presented electrocardiographic abnormalities that may result from the period of neonatal adaptation and the immaturity of its autonomic nervous system. During the first month of life, there was a predominance of sinus rhythms with a decrease in HR, and increased RR, PR, and QT intervals. No significant changes were found in pregnant mares compared with healthy adult horses.

REFERENCES

ABREU, D.C. et al. Elementos significativos do eletrocardiograma nos recém-natos e na primeira infância: suas utilidades clínicas. **Revista da SOCERJ**, v.17, n.4, p.257-261, 2004.

ANDREA, E.M.; ATIÉ, J.; MACIEL, W. Eletrocardiograma na criança e no feto. In: GOLDWASSER, G.P. **Eletrocardiograma orientado para o clínico**. 2.ed. Rio de Janeiro: Revinter, 2002, 327p.

AYALA, I. et al. Modifications of the form and amplitude of the electrocardiographic QRS complex during growth in the Spanish-bred horses. **Zentralblatt für Veterinärmedizin,** v. 45, n. 5, p. 309-317, 1998.

BELERENEAN, G. C.; MUCHA, C. J.; CAMACHO, A. A. **Afecções cardiovasculares em pequenos animais**. São Caetano do Sul: Inter Book. 2003.

BEUCHÉE, A. et al. Influence of hypoxia and hypercapnia on sleep state dependent heart rate variability behavior in newborn lambs. **Sleep**, v.35, n.11, p. 1541-1549, 2012.

BONAGURA, J.D.; REEF, V.B. Cardiovascular Diseases. In: REED, S.M.; BAYLY, W.M. **Equine Internal Medicine.** Philadelphia, Pennsylvania, USA: W.B. Saunders Company, p.290-361, 1998.

BRIGHT, J.M. Chapter 8 - The Cardiovascular System. ln: HOSKINS, J.D. **Veterinary Pediatrics.** Dogs and Cats from birth to six months. 2ed. W.B.Saunders Company: Philadelphia. p.95 - 123. 1995.

CAMACHO, A.A.; MUCHA, C.J. Capítulo 7 -Sistema Circulatório - Seção B: Semiologia do sistema cardiocirculatório de cães e gatos. In: FEITOSA, F.L. **Semiologia veterinária - A arte do diagnóstico**. 3ed. Rocca: São Paulo. 2014. 640 p.

EDWARDS, N. J. **Bolton's hand book of Canine and Feline Electrocardiography**. 2 ed. Philadelphia: W. B. Saunders Company, 1987. 381 p.

FERNANDES, W. R. et al. Características eletrocardiográficas em equinos clinicamente normais da raça Puro Sangue Inglês. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v.56, p.143-149, 2004.

FERRER, M.I. The evolution of the electrocardiogram in the developing heart. **Journal of Insurance Medicine**, v.1, p. 1-6, 1985.

FREGIN, G. F. The equine electrocardiogram with standardized body and limb positions. **Cornell Veterinarian**, v. 72, n.3, p. 304-324, 1982.

HAMID, T.M.; BARHAM, D.N. Electrocardiographic parameters in the Purebred Kurd horse. **Journal of Animal and Veterinary Advances**, v.9, n.21, p.2698-2703, 2010.

HAMLIN, R.L.; SMETZER, D.L.; SMITH, C.R. Analysis of QRS complex recorded through a semi-orthogonal system in the horse. **American Journal of Physiology,** v.207, p.325–333, 1964.

HALLOWELL, G.D. "How to" record a diagnostic ECG. **Proceedings of the 47th British Equine Veterinary Association Congress,** Liverpool, United Kingdom, 2008. Disponível em: <http://www.ivis.org/proceedings/beva/2008/91.pdf>. Acesso em: 18 set.2016.

HILWIG, R. W. Cardiac arrhytmias in the horse. **Journal of the American Veterinary Medical Association**, v.170, n.2, p. 153-163, 1977.

HINES, M.H. Neonatal cardiovascular physiology. **Seminars in Pediatric Surgery**, v.22, n.4, p.174- 178, 2013.

HOLMES, J. R.; ALPS, B. J. Studies into equine electrocardiography and vectorcardiography II. Cardiac vectors distributions in apparently healthy horses. **Canadian Journal of comparative medicine and veterinary science**, v.31, n.6, p. 150-155, 1967.

LANDROT, I.R. et al. Autonomic nervous system activity in premature and full-term infants from theoretical term to 7 years. **Autonomic Neuroscience: Basic and Clinical**, n136, p.105-109, 2007.

LOMBARD, C.W. et al. Blood pressure, electrocardiogram and echocardiogram measurements in the growing pony foal. **Equine Veterinary Journal,** v.16, p.342-347, 1984.

LOMBARD, C. W. Cardiovascular diseases. In: KOTERBA, A.M.; DRUMMOND, W.H.; KOSCH, P.C. (Eds.). **Equine clinical neonatology**. Philadelphia: Lea & Febiger, 1990, 867 p.

LOURENÇO, M.L.G.; FERREIRA, H. Electrocardiographic evolution in cats from birth to the 30 days of age. **Canadian Veterinary Journal**, v.44, p. 914-917, 2003.

MADIGAN, J. E. Electrocardiography. In: **The Manual of Equine Neonatal Medicine,** Internet Publisher: International Veterinary Information Service, Ithaca NY, 2013.

NOGUEIRA, S.S.S.; FARIA, E.G.; SOUSA, M.G. Avaliação do eletrocardiograma em cães e gatos neonatos. **Revista Científica de Medicina Veterinária - Pequenos Animais de Estimação**, v.8, n.4, p.101-107, 2010.

PATTESON, M. **Equine cardiology**. Oxford e Northampton, England: Blackwell Science Ltd, 1996, 264p.

REEF, V.B.; MARR, C.M. Dysrhythmias: assessment and medical management. In: MARR, C.M.; BOWEN, M. **Cardiology of the horse**. 2 nd ed. Philadelphia: W.B. Saunders, 2010, 294 p.

ROBERTSON, S.A. Electrocardiography for the equine practioner. **The Veterinary Annual**, v. 32, p. 192-200, 1992.

SAVAGE, C.J.; FENNELL, L.C. The equine heart: diagnosing disease – physical examination, electrocardiography and echocardiography. **Proceedings of the 11th International Congress of World Equine Veterinary Association**, 2009, Guarujá-SP, Brasil. Disponível em: <http://www.ivis.org/proceedings/weva/2009/410.pdf?LA=1>. Acesso em: 18 set. 2016.

SELIG, F.A. et al. Variabilidade da frequência cardíaca em neonatos prematuros e de termo. **Arquivos Brasileiros de Cardiologia**, v.96, n.6, p. 443-449, 2011.

SMITH, B. P. **Medicina Interna de Grandes Animais**. Davis: Manole, 2006. 1728 p.

SOCIEDADE BRASILEIRA DE CARDIOLOGIA. Diretrizes de Interpretação de eletrocardiograma de Repouso. **Arquivo Brasileiro de Cardiologia.** v.80, supl.II, 2003. Disponível em: <http://publicacoes.cardiol.br/consenso/2003/8002/repouso.pdf> Acesso em: 18 set.2016.

STEWART, J.H.; ROSE, R.J.; BARKO, A.M. Echocardiography in foals from birth to three months old. **Equine Veterinary Journal,** v.16, n.4, p.332-341, 1984.

TILLEY, L. P. **Essentials of canine and feline electrocardiography interpretation and treatment**. 3 ed. Philadelphia: Lea & Febiger, 1992, 470 p.

VAN LOON, G.; PATTESON, M. Electrophysiology and arrhythmogenesis. In: MARR, C.M.; BOWEN, M. **Cardiology of the horse**. 2ª ed. Philadelphia: W.B. Saunders, 2010, 294 p.

VICENZI, R.C.; LARSSON, M.H.M.A.;FERNANDES, W.R. Parâmetros eletrocardiográficos de eqüinos clinicamente normais da raça Mangalarga. Parte II: eixo elétrico médio no plano frontal. **Revista Brasileira de Medicina Veterinária**, v. 22, n.3, p. 111-112, 2000.

WHITE, N.A.; RHODE, E.A. Correlation of electrocardiographic findings to clinical disease in the horse. **Journal of the American Veterinary Medical Association**, v.164, p.46-56, 1974.

YAMAMOTO, K.; YASUDA, J.; KIMEHIKO, T. Electrocardiographic findings during parturition and blood gas tensions immediately after birth in thoroughbred foals. **Japanese Journal of Veterinary Research**, v. 39, n.(2-4), p. 143-157, 1991.

YAMAMOTO, K.; YASUDA, J.; TOO, K. Arrhythmias in newborn Thoroughbred foals. **Equine Veterinary Journal**, v. 24, n. 3, p. 169-173, 1992.

YONEZAWA, L.A. et al. Exame eletrocardiográfico em equinos da raça Puro Sangue Árabe submetidos ao exercício em esteira de alta velocidade e à suplementação com vitamina E. **Archives of Veterinary Science,** v.14, p.134-142, 2009.