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Electrocardiogram assessment using the Einthoven and base-apex lead systems in healthy Holstein cows and neonates[1]

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ABSTRACT.- Cedeno D.A., Lourenço M.L.G., Daza C.A.B., Pagnani Filho P. & Chiacchio S.B. 2016. **Electrocardiogram assessment using the Einthoven and base-apex lead systems in healthy Holstein cows and neonates.** *Pesquisa Veterinária Brasileira 36(Supl.1):1-7.* Departamento Clínica Veterinária, Faculdade de Medicina Veterinária e Zootecnia, Universidade Estadual Paulista, Distrito de Rubião Junior, Cx. Postal 560, Botucatu, SP. 18618-970, Brazil. E-mail: mege@fmvz.unesp.br

The objective aimed to describe the electrocardiographic behavior of parameters in Holstein pregnant cows and neonates during the perinatal period. The electrocardiograms were performed using a computerized electrocardiogram. The animals selected for the study were 23 cows and 18 neonates. Maternal electrocardiographic examinations were conducted in the 35, 28, 21, 14, 7 days and one-day pre –partum and the neonates were evaluated in six moments; at the time of birth, 7, 14, 21, 28 and 35 days after delivery. The evaluations were done in pre and post-delivery cows and into the group of neonates between female and male. For each electrocardiographic recording P-wave duration and amplitude, PR interval and the QRS complex duration, R, S-wave amplitude and polarity, QT and RR interval duration were examined. Changes in heart rate, ST segment and T wave polarity were recorded in leads of Einthoven and base-apex planes. The mean electrical axis of the QRS complex was calculated. In cows the results when comparing the two leads system, there are significant changes in the amplitude of the waves P, R, S, and T and the duration of the intervals PR, ST and QRS complex. The difference between primiparous and multiparous dairy cows was in the amplitude of the Twave. It was concluded that the base-apex system is a suitable lead for monitoring heart rhythm in Holstein cows and Einthoven in neonates. During the first month of life, no differences in P, Q, S and T waves, in PR, QRS, and ST intervals and in axis orientation was observed in neonates. There was a significant difference in duration of the QT interval. Among sexes, the difference was in the Q amplitude. This study incorporated the calves and Holstein cows in a single study in search of baseline information regarding the duration and morphology of the ECG parameters. In conclusion, it was proved that, with increasing age, there are changes in ECG components associated with variations in the distance between the recording electrode and the heart. The study contributes by providing Holstein reference values for clinical evaluations.

INDEX TERMS: Neonatology, ECG components, heart rate, cattle.

RESUMO.- [**Avaliação do eletrocardiograma utilizando os sistemas Einthoven e base-ápice em vacas e neonatos saudáveis da raça Holandesa.**] Tem como objetivo descrever o comportamento eletrocardiográfico de parâmetros em vacas da raça Holandesa grávidas e recém-nascidos durante o período perinatal. Os eletrocardiogramas foram realizados utilizando um eletrocardiógrafo computadorizado. Os animais selecionados para o estudo foram 23 vacas e 18 neonatos. Exames eletrocardiográficos maternos foram realizadas em 35, 28, 21, 14, 7 dias e um dia de pré-parto e nos neonatos foram avaliados em seis momentos; no momento do nascimento, 7, 14, 21, 28 e 35 dias após o parto. As avaliações foram realizadas em vacas pré e pós-parto e no grupo de neonatos entre fêmeas e machos. Para cada duração da gravação eletrocardiográfica anali-

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sou-se onda P e amplitude, intervalo PR e da duração do complexo QRS, R, S amplitude de onda e polaridade, QT e duração do intervalo RR. Mudanças na frequência cardíaca, segmento ST e polaridade da onda T foram registradas. A média do eixo eléctrico do complexo QRS foi calculada. Em vacas, há mudanças significativas na amplitude das ondas P, R, S, T, e a duração dos complexos QRS e intervalos PR e ST. A diferença entre as vacas leiteiras multíparas e primíparas estava na amplitude da onda T. Concluiu-se que o sistema base-ápice é adequado para monitorar o ritmo cardíaco em vacas da raça Holandesa e o Einthoven em neonatos. Nos neonatos durante o primeiro mês de vida, não houve diferenças nas ondas P, Q, S e T, em intervalos PR, QRS, e ST e na orientação do eixo. Houve diferença significativa na duração do intervalo QT. Entre os sexos, a diferença estava na amplitude Q. O presente estudo incorporou os bezerros e vacas da raça Holandesa em um único estudo, em busca de informações em relação a duração e morfologia dos parâmetros do ECG. Conclui-se portanto que, com o aumento da idade, ocorrem alterações nos componentes do ECG, associadas com as variações na distância entre o elétrodo de registo e o coração. O estudo contribui, fornecendo valores de referência de bovinos da raça Holandesa para avaliações clínicas.

TERMOS DE INDEXAÇÃO: Neonatologia, componentes ECG, frequência cardíaca, bovinos.

INTRODUCTION

To improve a perinatal care of cattle and reducing mortality of newborns, especially of animals with a high genetic value, the electrocardiographic examination is an important tool for determining the heart rate, heart rhythm and conduction disorders. Nowadays, the studies of the ECG in cows and neonates are scarce. Electrocardiography is a noninvasive, inexpensive technique that yields useful information in classification of arrhythmias, diagnosing conduction abnormalities and it is a valuable aid in prognostic and therapeutic considerations (Rezakhani et al. 2004). The electrocardiogram (ECG) provides a record and measure of the time varying potential difference that occurs over the surface of the body as the result of electrical activity within the heart. This is associated with depolarization and repolarization of the myocardium that occurs in a definite pattern and sequence and then the ECG can be used to measure and time these events (Radostits et al. 2007). The technic yields useful information in classification of arrhythmias and diagnosing conduction abnormalities (Fregin 1985). The deep penetration of the Purkinje fibers in the myocardium makes it unsuitable for determination of chamber enlargement.

No single electrocardiographic lead system has been universally accepted for use in large animals. Bipolar leads (I, II, III, base-apex) and unipolar leads (aVF, aVR, aVL, thoracic) have been described, but the amplitude, duration and configuration of the different wave forms vary widely, depending on an animal's breed, size, body type and sex (Shmakov & Roshchevskii 1995). The electrocardiographic configurations and clear separation of the duration of the phases of the waveform facilitate the interpretation of electrocardiogram (ECG). Base apex lead have been used for large animals. It has clear and large waves and complexes and animal movement has a minimum effect on the recording (Deroth 1980).

Electrical axis (EA) determined on QRS is a vector originating at the center of Einthoven's triangle representing the direction of the ventricular activation process as projected in the plane of limb leads. EA provides important clues for derivation of ECG pathological correlation and the degree of deviation refers to either ventricular activities or intermittent conduction disturbances (Amory et al. 1993).

The bovine heart is almost vertical in the thoracic cavity, and its theoretical axis runs from the vicinity of the cervical scapular angle in the *regio prescapularis* to the *regio apices* (Hamlin & Smith 1960).

In young calves, the QRS electrical axis of the heart indicates a left ventricular preponderance, and that during early postnatal growth direction turns from left to right (Alfredson & Sykes 1942). In healthy calves, after a few weeks of life, the time intervals become very stable although the animals are doubling or quadrupling their weight. Hence, as the heart is also growing, there must be a considerable increase of the rate of conduction and of the mass of heart muscle (Van Arsdel 1959). During a study of 24 ambulatory electrocardiogram in 10 calves, Pessoa et al (2014) found that 90% of the calves presented normal sinus rhythm and concluded that arrhythmias in young animals are physiological. Regarding the above arguments, the purpose of this study was conducted to obtain electrocardiographic data regarding the normal electrocardiographic values morphology and duration in dairy cows and neonates in farm conditions, using the standard bipolar limb leads (I, II and III), augmented unipolar limb leads (avL, avR and avF) in Einthoven and standard base apex lead system.

MATERIALS AND METHODS

Study area and climate. The electrocardiograms were registered during the period May 2014 to October 2014. The farm is located at latitude 22°53'09"S and 48°26'42"W, 20 km southeast of the city of Botucatu, São Paulo, Brazil. The region has a humid subtropical climate, with a temperature and humidity environmental during the trial period from 5.3 to 34.5°C and 62.3% and 85.5% respectively.

This project had the approval of the Ethics Committee on Animal Use (CEUA, no. 89-2014) and signing the informed consent by the owner of the farm.

Animals. The animals selected were 23. The cows were pregnant clinically healthy animals. From the beginning of the dry period (non-lactating), the animals remained in a maternity paddock, where they received corn silage three times a day. All the cows were brought into an enclosed barn, where the sampling took place per week, for two weeks prior to the start of the trial to acclimatize them to the facility, handling and the electrocardiogram procedures.

The cows and neonates stood on a rubber mat for insulation during the recording sessions. The electrocardiogram was only recorded when the heart rate was in the resting range and when the neonate was standing in a square position. The animals were not sedated.

Following birth, the neonates underwent a clinical examination. Female calves were removed from their mothers and transferred to individual pens. They received colostrum for the first 2 days and then fed according to a regular schedule for rearing neonates based on provision of whole milk and gradually supplemented with concentrates. Males were removed from their mothers and housed together in a big pen, fed with the same quantity of colostrum and *ad libitum* roughage (maize silage).

Experimental design. For each method over a two-minute trace ECG was obtained. The record was scanned and three to four complexes P-QRS-T were selected without artifacts, per method, per animal. They were analyzed manually and the average for each measured within the same animal was calculated. From these values, it was obtained a statistical average, and its standard deviation. In addition, the results were analyzed to evaluate the existence, or not, significant differences between genders in neonates and in cows. The electrocardiographic examinations followed a pattern of repetitions over time at pre-defined times. The examinations were performed from 8:00 to 12:00 am at the following moments:

Maternal electrocardiograms: were conducted in the 35, 28, 21, 14, 7 days and one-day pre-partum;

Neonatal electrocardiograms: at birth, 7, 14 , 21 , 28 and 35 days; neonates were studied six times from the first day of life until 35 days as they grew, producing 108 electrocardiograms for each system.

Maternal and neonatal ECG. Cows were contained in a chute with a rubber mat to prevent interference in the electrocardiographic tracing. The electrocardiograms were performed using the computerized electrocardiogram TEB® (TEB, São Paulo, Brazil), consisting of an electronic circuit coupled to a notebook. For electrocardiographic monitoring, electrodes were placed directly on the skin of the animal according to the Einthoven plane and base--apex. The electrodes were fixed to the skin by means of clips, applying alcohol at the attachment points for the better propagation of the electrical signal. The track was recorded and standardized with sensitivity set to 1cm = 1mV over two minutes and speed of 50mm/s.

To record the leads of the frontal plane and base apex bipolar limbs leads (I, II, III) and augmented unipolar member (AVL, AVR and AVF), the electrodes were fixed to the skin of the animal in the olecranon region, the forelimbs and the patella, the hind limbs. To record the derivation base-apex, three electrodes were attached, and a negative electrode placed in the medial portion of the board on right neck, a positive electrode placed between the third and fourth left intercostal space, at the time of the olecranon, and finally, the electrode land set at the withers.

For each electrocardiographic recording duration and P-wave amplitude (mV ms P and P, respectively) were analyzed, the duration of PR (PR ms) interval, QRS duration (QRS sec) and morphology of complex, the wave amplitude R (R mV), the amplitude of the S wave, the duration of the QT (QT ms) interval and the RR interval. Changes in heart rate, ST segment and T wave polarity are also recorded.

The mean electrical axis of the QRS complex was calculated from the hexaxial reference system on the frontal plane (Tilley 1992) based on the behavior of the QRS complex, observing the derivations in the front plane by the sum of the positive and negative deviations in derivations I and III. Heart rate was calculated from ECG tracing by R-R

Statistical analysis. The results of the heart rate, amplitude and duration of the complexes were analyzed by comparison of means (ANOVA and Kruskal-Wallis and Bonferroni), using the computer program SPSS 19, considering $P<0.05$.

RESULTS

The mean values and their standard deviation for heart rate and the amplitude and duration of ECG parameters analyzed for the frontal plane and base-apex method are shown in the table 1 for neonates and for cows on Table 2.

In the Einthoven method, cows had a HR of 81±11.7 beats per minute. All the cows had a normal sinus rhythm. At a normal heart rate, the complete cardiac cycle (RR interval) lasted for cows 0.75±0.11 seconds (Table 1) and for neonates 0.48±0.08 seconds in the Einthoven method (Table 2). In the same method, the mean heart rate in the neonates studied was 131±19.4 beats per minute (bpm).

The amplitude of lead II Q wave was 0.03±0.06mV. The amplitude of lead II R wave was 0.20±0.15. The range of T wave duration (Ventricular repolarization) was 0.08±0.02 sec and amplitude 0.18±0.09mV for positive T wave con-

Table 1. Comparison of heart rate and ECG components in Holstein cows in bipolar derivation of lead II (mean, standard deviation, minimum, maximum) in Einthoven and base apex method

Variable		Einthoven				Base-apex			
	n	Mean	S.D.	Mín	Máx	Mean	S.D.	Mín	Máx
HR (b/min)	136	81	11.7	56	112	79	12.9	55	170
P (sec)	136	0.01	0.007	0.00	0.017	0.07	0.004	0.00	0.013
P (mV)	136	0.10[a]	0.03	0.05	0.24	0.18b	0.06	0.05	0.62
PR Interval (sec)	136	0.19[a]	0.07	0.05	0.70	0.21b	0.04	0.08	0.50
QRS Complex(sec)	136	0.08[a]	0.02	0.04	0.16	0.10b	0.02	0.05	0.18
Q (mV)	136	0.03	0.06	0.00	0.31	0.02	0.12	0.00	0.90
R (mV)	134	0.20[a]	0.15	0.00	0.59	0.14[b]	0.15	0.00	0.99
S (mV)	136	0.08[a]	0.15	0.00	0.80	0.45[b]	0.24	0.00	0.97
QT Interval (sec)	136	0.35[a]	0.05	0.09	0.49	0.38[b]	0.04	0.21	0.54
T (sec)	136	0.08	0.02	0.04	0.13	0.08	0.01	0.05	0.12
T (mV)	136	0.18[a]	0.09	0.02	0.59	0.22[b]	0.10	0.04	0.56
RR Interval	136	0.75	0.11	0.54	1.07	0.77	0.11	0.35	1.09

Within line, different superscripts letters (a,b) denotes a significant difference (A≠B: $p<0.05$).

figuration on lead II. The configuration of the T wave was 73.4% positive and 26.5% negative.

In the cows, the lead II, the P wave (atrial depolarization) duration was 0.01±0.007 sec and ranged between 0.00 and 0.017 sec. The P wave was oriented in the positive direction. The P wave amplitude was 0.1±0.03mV and ranged from 0.05 to 0.24mV on lead II (Table 1). The lead II R wave was present in all the tracings. Most of the animals presented a lead II Q wave (54. 4%) while the S wave was found in 45. 6% of the lead II.

Between multiparous and primiparous cows, the significant difference was in the amplitude of the T wave (Table 3). In cows during the six moments prior to calving, there were no significant difference in heart rate and electrocardiogram components.

In neonates, different types of QRS complexes were found in lead II. The most frequent configuration was Qr (25.3%), QS (11.0%), Rs (13. 2%), R (19. 8%), and qr (9. 9%), less evident RS, rS, rR, qs and r. The QRS complex (ventricular depolarization) length range was from 0.05 to 0.12 sec having duration of 0.07±0.01 sec on lead II tracings during the first month of life (Table 2).

In neonates, there were no significant difference in wave amplitude or duration during the six moments of electrocardiographic measurements (Table 4 and 5). In the cows during the six moments pre partum there were no significant difference in heart rate and electrocardiogram components.

The results of neonate PR and QT intervals, and ST segment for lead II ECG records observed throughout the experiment are given in Table 6. The PR interval duration range in lead II was from 0.11±0.02 sec. The QT interval with a significant difference had duration range was between 0.24s to 0.27 sec. The ST amplitude had no depressed or elevation segment out of the base line.

In table 7 are registered values obtained for ECG components from one and another sex in calves. The Q waves are higher in male neonates (0.33±0.28mV) than in female neonates (0.14±0.24mV). This difference among genders predominated during the six moments of the study.

In Table 8, are listed the values of the ECG components of neonates and cows using the base apex method. The duration and amplitude of waves, intervals, segments and complex are significantly different between animals.

Table 2. Comparison of heart rate and ECG components in Holstein neonates between 1 and 35 days old in bipolar derivation of lead II (mean, standard deviation, minimum and maximum) in Einthoven and base-apex method

ECG Component		Einthoven				Base-Apex			
	N	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max
FC (bpm)	81	131	19.4	91	175	126	20.7	89	186
P (sec)	81	0.02	0.001	0.00	0.07	0.02	0.004	0.00	0.03
P (mV)	81	0.17	0.10	0.06	0.86	0.18	0.08	0.04	0.04
PR Interval (sec)	81	0.11	0.04	0.07	0.40	0.11	0.02	0.03	0.18
QRS Complex (sec)	81	0.07	0.01	0.05	0.12	0.07	0.02	0.04	0.12
Q (mV)	81	0.24	0.30	0.00	1.40	0.25	0.35	0.00	1.41
R (mV)	81	0.19	0.22	0.00	1.15	0.23	0.24	0.00	0.95
S (mV)	81	0.21	0.33	0.00	1.64	0.29	0.44	0.00	1.61
QT Interval (sec)	81	0.25	0.03	0.18	0.32	0.25	0.03	0.17	0.34
T (sec)	81	0.07	0.02	0.04	0.12	0.07	0.02	0.04	0.13
T (mV)	81	0.32	0.19	0.06	1.00	0.34	0.24	0.07	1.20
RR Interval	81	0.48	0.08	0.26	0.67	0.46	0.076	0.29	0.66

No significant difference p<0.05.

Table 3. Comparison of heart rate and ECG components in Holstein multiparous and primiparous cows in bipolar derivation of lead II (mean, standard deviation, minimum, maximum) in d base apex method

Variable	Multiparous					Primiparous				
	n	$\bar{X}$	SD	Mín	Máx	n	$\bar{X}$	SD	Mín	Máx
HR (bpmin)	72	80	14,3	61	170	67	79	11,7	55	102
P (sec)	72	0,02	0,001	0,00	0,00	67	0,03	0,01	0,00	0,3
P (mV)	72	0,18	0,05	0,06	0,27	67	0,18	0,07	0,05	0,62
PR interval (sec)	72	0,21	0,04	0,08	0,49	67	0,20	0,02	0,16	0,26
QRS complex (sec)	72	0,09	0,02	0,05	0,18	67	0,10	0,01	0,06	0,15
Q (mV)	72	0,00	0,03	0,00	0,19	67	0,04	0,17	0,00	0,90
R (mV)	72	0,13	0,19	0,00	0,99	67	0,16	0,10	0,00	0,40
S (mV)	72	0,44	0,26	0,00	0,97	67	0,45	0,22	0,00	0,83
QT interval (sec)	72	0,38	0,03	0,21	0,49	67	0,38	0,03	0,31	0,54
T (sec)	72	0,08	0,01	0,05	0,12	67	0,08	0,01	0,05	0,11
T (mV)	72	0,20 a	0,10	0,04	0,53	67	0,24 b	0,10	0,10	0,56
RR interval (sec)	72	0,76	0,10	0,35	0,98	67	0,77	0,11	0,58	1,00

Within column, different superscripts letters (a,b) denotes a significant difference (A≠B: p<0.05); sec = seconds.

Table 4. Variation on heart rate and duration (sec) of waves P and T, between the first day and 35 days of age in neonates in bipolar derivation of lead II (mean, standard deviation) in Einthoven method

Days	Heart Rate (b/min)		P (sec)		T (sec)	
	Mean	SD	Mean	SD	Mean	SD
1	130	24.1	0.05	0.01	0.08	0.01
7	138	21.6	0.04	0.01	0.07	0.02
14	136	27.9	0.04	0.02	0.07	0.02
21	129	23.6	0.04	0.01	0.07	0.02
28	133	15.1	0.06	0.02	0.06	0.01
35	131	15.6	0.05	0.01	0.07	0.02

No significant difference p<0.05.

Table 5. Variation on P, Q, R, S and T wave amplitude (mV), between the first day and 35 days of age in Holstein neonates in bipolar derivation of lead II (mean, standard deviation) in Einthoven method

Days	P (mV)		Q (mV)		R (mV)		S (mV)		T (mV)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	0.20	0.19	0.12	0.11	0.32	0.22	0.14	0.14	0.44	0.27
7	0.16	0.08	0.22	0.21	0.13	0.05	0.39	0.26	0.30	0.17
14	0.16	0.06	0.17	0.15	0.21	0.19	0.42	0.27	0.30	0.18
21	0.17	0.04	0.46	0.24	0.26	0.25	0.21	0.19	0.35	0.26
28	0.15	0.05	0.29	0.18	0.13	0.08	0.17	0.15	0.33	0.23
35	0.17	0.05	0.24	0.16	0.27	0.13	0.24	0.08	0.26	0.16

No significant difference p<0.05.

Table 6. Variation PR, QT intervals, and QRS complex between the first day and 35 days of age in Holstein neonates in bipolar derivation of lead II (mean, standard deviation) in Einthoven method

Days	PR Interval (sec)		QRS Complex (sec)		QT Interval (sec)	
	Mean	SD	Mean	SD	Mean	SD
1	0.11	0.02	0.08	0.01	0.27^{a}	0.03
7	0.12	0.07	0.07	0.01	0.23^{b}	0.03
14	0.10	0.02	0.08	0.01	0.24^{ab}	0.03
21	0.11	0.02	0.07	0.07	0.25^{ab}	0.02
28	0.11	0.03	0.07	0.01	0.25^{ab}	0.01
35	0.11	0.02	0.08	0.01	0.24^{ab}	0.03

Within column, different superscripts letters (a,b) denotes a significant difference (A≠B: p<0.05); sec = seconds.

In Figure 1 are the picture shows the range of electrical axis between cows after and before delivery. The mean electrical axis was 42º ±69 degrees with a range between -45º to +180 degrees in cows before delivery and after calving the mean electrcial axis was 71º ±72º with a range from -27º to 180 degrees.

In Figure 2 the picture shows the range of electrical axis between neonates regarding sex. The mean electrical axis of the heart was +16 degrees for females and -73º for males. The QRS axis showed a wide range (-166º to +180º) in the orientation of the mean electrical axis for females and -153º to +180º for males. There were no significant difference in the neonatal mean cardiac axis in the six moments after calving.

Table 7. Comparison of ECG components and heart rate in Holstein neonates 1-35 days of age between genders in bipolar derivation of lead II (mean, standard deviation, minimum and maximum) in Einthoven method

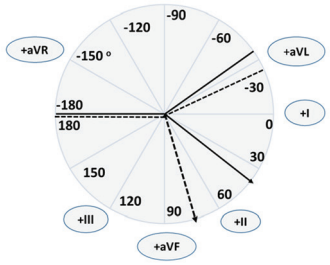
	Female					Male			
	n	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max
HR (bpm)	81	135	20	98	180	128	24	91	202
P (sec)	81	0.07	0.004	0.0	0.003	0.001	0.01	0.0	0.007
P (mV)	81	0.19	0.15	0.06	0.08	0.15	0.04	0.08	0.23
PR Interval (sec)	81	0.11	0.12	0.07	0.40	0.11	0.02	0.07	0.15
QRS complex (sec)	81	0.07	0.04	0.05	0.11	0.08	0.01	0.05	1.12
Q (mV)	81	0.15a	0.01	0.00	1.00	0.37b	0.23	0.00	1.40
R (mV)	81	0.22	0.22	0.00	0.89	0.22	0.21	0.00	1.15
S (mV)	81	0.20	0.27	0.00	0.98	0.15	0.40	0.00	0.64
QT Interval (sec)	81	0.24	0.03	0.19	0.32	0.25	0.03	0.18	0.32
T (sec)	81	0.07	0.02	0.04	0.12	0.07	0.02	0.04	0.10
T (mV)	81	0.33	0.21	0.06	1.00	0.31	0.18	0.07	0.91

Within line, different superscripts letters (a,b) denotes a significant difference (A≠B: p<0.05).

Table 8. Comparison of ECG components between Holstein cows and neonates in bipolar derivation of member II (mean, standard deviation, minimum, maximum) in base-apex method

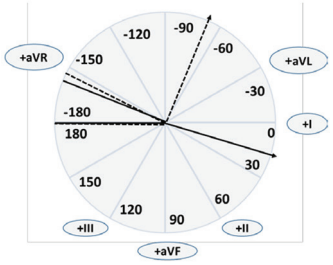
ECGcomponent	Neonates					Cows			
	n	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max
P (sec)	136	0.08	0.48	0.00	3	0.07	0.44	0.00	3
P (mV)	136	0.18	0.08	0.04	0.42	0.18	0.06	0.05	0.62
PR Interval (sec)	136	0.11^{a}	0.024	0.033	0.18	0.2^{b}	0.04	0.08	0.49
QRS complex (sec)	136	0.071^{a}	0.015	0.04	0.12	0.098^{b}	0.019	0.053	0.18
Q (mV)	136	0.25^{a}	0.35	0.00	1.41	0.02^{b}	0.12	0.00	0.9
R (mV)	136	0.23^{a}	0.24	0.00	0.95	0.14^{b}	0.15	0.00	758
S (mV)	136	0.29^{a}	0.44	0.00	1.61	0.45^{b}	0.24	0.00	0.97
QT Interval (sec)	136	0.25^{a}	0.033	0.16	0.34	0.38^{b}	0.38	0.21	0.54
T (sec)	136	0.073^{a}	0.019	0.04	0.12	0.079^{b}	0.01	0.05	0.12
T (mV)	136	0.34^{a}	0.24	0.07	1.2	0.22^{b}	0.1	0.04	0.56
RR Interval	136	0.48^{a}	0.08	0.26	0.67	0.76^{b}	0.1	0.35	1.08

Within line, different superscripts letters (a,b) denotes a significant difference (A≠B: p<0.05).



	n	$\bar{X}$ ± S.D.	Min	Max
Pre	19	42.1 ±69.7	-45	180
Pos	18	71.7 ±72.2	-27	180

Fig.1. Graphic representation of the cardiac axis (degrees) in the frontal plane measured in Holstein cows before and after calving.



Sex	N	$\bar{X}$ ± S.D.	Min	Max
F	42	16.2 ± 112.6	-166	180
M	53	-73 ± 80.6	-153	180

Fig.2. Graphic representation of the cardiac axis (degrees) in the frontal plane measured in female and male Holstein calves.

DISCUSSION

Electrocardiography is the clinical method of choice to evaluate cardiac problems associated with the production and conduction of electrical stimuli. It is also a useful tool in evaluating electrolyte disturbances. In cows, when comparing the two methods the results indicated significant difference in the amplitude of the waves P, R, S, and T and the duration of the intervals PR, ST and QRS complex. This difference of values in duration and amplitude between the two methods is mainly by the cardiac area enlargement and by the heart rate, associated to variations in the distance between the recording electrode and heart and that the duration of all components ECG. After delivery the amplitude and duration of the ECG components did not had changes.

Electrocardiography is not useful for studying cardiac hypertrophy or myocardial abnormality due to the deep penetration of Purkinjee fibers. The distribution of the Purkinje fibers penetrate the entire thickness of the free walls and the base of the ventricules (Shmakov & Roshchevskii 1995). Due to complete penetration from endocardium to epicardium by the Purkinje fibers, depolarization of both ventricular free walls occurs simultaneously. There are no general fronts of depolarization.

Comparing the values of the neonatal ECG components in the Einthoven and base-apex leads, there are no significant differences in amplitude and duration in six moments of 35 days of age. In the Einthoven method, the QT interval presents a significant change after the first day of life to 35 days of age. Comparing the components of electrocardiograms between both sexes there is a significant change in the Q wave. This difference is present from the first week of life. The Q wave in males was higher than the ones in females ($p<0.05$).

From the above results, it has been proved that with advancing age during the first month of life in six moments in neonates occurs few changes in the amplitude and duration of the ECG components. The values for electrocardiographic parameters in neonates are similar to those reported by Amory et al. (1993) and Mendes et al. (2001).

Between adult and young animals, a significant difference was observed in the morphology and duration of the waves, intervals and segments using the base-apex method. This may be argued because the thickness of the left ventricular wall and the interventricular septum are increased with advancing age. Between cows and heifers, the only significant difference among the electrocardiogram components was in the T wave amplitude. This is most notable in cows due to cardiac activity more intense during milk production (Grupta et al. 1978).

In this study for adult animals, any sinus rhythm lower than 47 and more than 100 beats per minute was taken as sinus bradycardia (SB) and tachycardia (ST), respectively. In this study, no arrhythmia was observed. All the cows had a normal sinus rhythm during the register of the six moments prior to calving from a mean of 83 bpm to 85 bpm. Sinus tachycardia in normal cattle should not be taken as a sign of cardiac disease unless it is persistent or associated with other signs of cardiac disease. In a work done in the University of Sao Paulo, in 30% of calves that presented second-degree atrioventricular block after a second exam six months later, only one animal had the AV block. This is may be related to increase in the vagal tone (Pessoa et al. 2014). Even though that sinus arrhythmia is rare in cattle (Rezakhan et al. 2004), two cows demonstrated ectopic beats. Out of these, one was atrial premature contractions (PAC) and the other a ventricular premature contraction (PVC).

The present study incorporated Holstein calves and adult Holstein cows in a single comprehensive study, in search of baseline information regarding length and morphology of ECG parameters.

CONCLUSIONS

It has been proven that with increasing age, changes occur in length and morphology in the ECG components, associated with variations in the distance between the recording electrode and the heart.

It also confirmed the difference between the male and female, which is determined by physiological, humoral, and the anatomical and histological constitution of each sex (Matsui et al. 1983).

The study contributes to the literature providing reference values of Holstein cattle for clinical evaluation.

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