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Changes in electrocardiographic indices during the first two days of life in lambs and goat kids

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Abstract In the current study, we aimed to establish reference values for most of the important electrocardiographic (ECG) indices during the first two days of life in lambs and goat kids. A total of 40 animals (20 lambs and 20 goat kids) were enrolled in the study from birth to two days of age. The neonates were born to Kermani ewes and Cashmere (Raini) does of 3 years of age weighing 42 ± 1 and 30 ± 2 kg, respectively. Heart rate (HR) was significantly decreased within the first 48 and 24 hours after birth, respectively ($P < 0.01$). Amplitudes and durations of P, QRS, and T waves were not significantly changed from baseline during the first two days of life. The lengths of PR and RR intervals were significantly prolonged during the first 48 hours after birth ($P < 0.01$). There were significant differences ($P < 0.05$) in the prevalence of cardiac arrhythmias during the entire course of the experiment. It is concluded that ECG indices showed age-related differences in newborn lambs and goat kids during the 48-hour study period. The author suggested that the changes in ECG indices are normal and could be attributed to both colostrum absorption and the physiological development of a newborn.

Introduction

Parturition does considerably affect normal physiology and results in increased adrenocortical activity, decreased immunity, and increased morbidity and mortality due to infectious diseases [1, 2]. In all animal species, the interval between birth and 30 days of age, the so-called neonatal period, represents a delicate phase during which the metabolic profile and serum biochemical characteristics undergo differential changes [3-5]. The metabolic responses occurring during the transition from fetal to neonatal life represent a transition phase from an unstable to a more stable status [3].

Determination of changes in electrocardiographic (ECG) indices in neonates helps veterinarians to make differential diagnoses, evaluate the severity of disease, and administer the appropriate therapeutic strategy [6-8]. Furthermore, a lack of documented studies for changes in ECG indices in lambs and goat kids may lead to failure in generating a differential and exclusive diagnosis of diseases.

The structure of ruminants' placenta prevents the passage of protective antibodies from the dam to the fetus during gestation. Neonates are therefore born without immune protection against environmental pathogens [9, 10] and to survive until immunocompetency, a neonate relies entirely on the passive transfer of maternal antibodies via the ingestion of immunoglobulin (Ig)-rich colostrum [11-13]. Failure of passive transfer (FPT) is not a disease or condition itself but predisposes the calf to develop diseases [11, 14]. Closure of the intestinal permeability to colostral Ig is on average complete by 24 h postpartum [10, 15]. Healthy newborn animals need to absorb Ig following ingestion of colostrum, in a process referred to as passive transfer of Ig, during the first 24 h of life [11, 12, 16-18].

Age-related changes in most physiological, hematobiochemical, and cardiovascular profiles have been emphasized in ruminants [4, 5, 19- 21]. Several studies investigated ECG variables of lambs and goat kids in comparison to adult sheep and goats [19, 20], but they did not include the first two days of life so, the effect of colostrum absorption was not monitored by sequential measurements. It has been found that colostrum intake has essential effects on concentrations of several serum biochemical parameters and macrominerals and ECG indices thereafter [5, 19, 20].

The circulatory physiology of neonates and young animals differs from that of adults; thus, it is important to evaluate the cardiovascular system to develop knowledge about structural and functional differences that occur in young animals, such as lambs and goat kids, within the period following birth [22]. During the first month of life, an acute phase of circulatory and respiratory adaptation occurs in the neonates of different species. There is more variation in clinical and ECG indices in neonates, compared to adults, particularly during the period immediately after birth, which is due to the rapid but varied hemodynamic changes [22, 23]. Parturition, as a stress for both mother and neonate, has considerable physiological effects such as increased adrenocortical activity, decreased immunity, increased morbidity and mortality due to infectious diseases [1, 2]. Measurement of ECG variables in newborns reflects the hemodynamic status, with changes arising during the fetus's transition to neonatal life [23, 24].

We found no published study documenting the changes in ECG indices in small ruminant neonates. In the current study, we aimed to establish reference values for most of the important ECG indices in lambs and goat kids from birth to two days of age. We hypothesized that these indices in small ruminant neonates would be different during aging and after colostrum absorption.

Materials and Methods

Animals

The present study was carried out in the School of Veterinary Medicine, Shahid Bahonar University of Kerman, southeast of Iran (latitude 30°19'N and longitude 52°07'E). A total of 40 animals (20 lambs and 20 goat kids) born between February and April 2015 were enrolled in the study during the first two days of their lives. The animals were maintained at the animal farm of the Faculty of Veterinary Medicine at Shahid Bahonar University of Kerman, Kerman, Iran. The neonates were born to Kermani ewes and Cashmere (Raini) does of 3 years of age weighing 42 ± 1 and 30 ± 2 kg, respectively, during the breeding season. Mothers of neonates were reared under the same husbandry and management conditions in the same group pen. Mothers received anthelmintic treatment at the two months before parturition. A constant ration containing a mixture of wheat straw (60%) and alfalfa hay (40%) ad libitum, plus 300 g of barley grain head-1 day-1, supplemented with white salt and a trace-mineralized supplement, was offered over the whole course of the study. During pregnancy, the mothers were housed in individual houses. Gestational age was calculated based on the artificial insemination date. Pregnancy scans and single pregnancy confirmation were performed using a transcutaneous ultrasonography technique (V8, EMP, China). Near the expected parturition date, the ewes were kept in a paddock, next to the facilities, where they were supplemented with a commercial ration composed of 16% crude protein (about 300 g animal-1). Right after the parturition, the animals were moved to a shed allowing the ewes and newborns to be protected from either adverse weather or predators. Mothers and newborns were allowed to remain together throughout the study.

On the day of birth, all lambs and goat kids were subjected to physical examination and appeared to be normal and healthy. Lambs and goat kids received colostrum artificially via bottle feeding and were analyzed for the occurrence of FPT. The first feeding occurred at 40 ± 15 (mean ± standard error of mean) minutes after birth and the colostrum was offered again every 30 min to obtain an intake volume equivalent to 10% of the neonate's body weight (BW) [25]. The transitional milk milked at 12, 24, and 36 h after birth was artificially ad libitum offered via bottle.

Experimental procedures: measurement of ECG parameters

ECG tests were initiated immediately after birth (before the ingestion of colostrum) and then were performed within the first and second days after birth. All experimental procedures were performed without sedation. The animals stood on a rubber mat for insulation during the ECG recording sessions next to their mothers (to reduce stress) and the ECG was only recorded when the animals were calm and standing in a square position.

The ECG was obtained from each animal on a bipolar base-apex lead using a one-channel ECG recorder (Cardiocare-2000, Bionet Co., Ltd, Korea) with a paper speed of 25 mm sec-1 and calibration of 10 mm equal to 1 mV [26]. In the base-apex lead system, the positive electrode (left hand) was placed on the fifth intercostal space, just caudal to the olecranon, and the negative electrode (right hand) on the jugular furrow, about the lower one-third of the left side of the neck. The earth electrode was attached to the withers. The electrodes were attached to the skin using alligator clips and after the application of methyl alcohol [27]. The precision of duration was 0.02 sec. and amplitude was 0.05 mV. A magnifier was used for measuring ECG indices. The HR was calculated by measuring the average six RR intervals of each trace. To describe the QRS complex, the first negative deflection was termed Q and the subsequent positive and negative deflections were labeled R and S, respectively. If the QRS complex was a single negative deflection, it was described as the QS pattern [28]. In the case of biphasic P or T waves (-/+ or +/-), the amplitudes of two phases were summed.

Statistical analysis

Data were expressed as mean values ± standard deviation (SD) and were tested for normality using the Kolmogorov-Smirnov test. Repeated-measures ANOVA was used to compare the ECG indices among different sampling times. McNemar's test was implemented for comparison of the prevalence of cardiac arrhythmias. All Statistical analyses were performed using SPSS 20 (SPSS for Windows, SPSS Inc, Chicago, Illinois). Differences were considered statistically significant when the calculated P value was less than 0.05.

Results

Various changes in ECG indices in lambs and goat kids during the first two days of their lives are demonstrated in Tables 1 and 2. HR was significantly decreased within the first 48 and 24 hours after birth, respectively ($P < 0.01$). The results of the amplitude and duration of ECG waves and the lengths of PR, QT, and RR intervals in the base-apex lead system in different periods of the study are shown in Table 1. Amplitudes and durations of P, QRS, and T waves were not significantly changed from baseline during the first two days. The lengths of PR and RR intervals were significantly prolonged during the first 48 hours after birth ($P < 0.01$).

There were significant differences ($P < 0.05$) in the prevalence of cardiac arrhythmias during the entire course of the experiment. Sinus tachycardia and arrhythmia were recorded in 40 out of 40 animals in the first and second ECG recordings (Figures 1 and 2). The ECGs were normal at 48 h after birth in 16 animals. However,

Table 1. Electrocardiographic (ECG) indices (Means ± SD) in lambs and goat kids using the base-apex lead system during the first two days of lsife (n=40).

Indices	*Wave*	*Animals*	*Times (hour)* Base line (At birth)	24	48
Heart rate (beats min^{-1}***)***		Total	182 ±3^{a}	141±2^{b}	119±10^{c}
		Kids	184 ±3^{a}	141±2^{b}	127±12^{c}
		Lambs	181±3^{a}	141±3^{b}	113±2^{c}
Amplitude (mV)	P	Total	0.21±0.01	0.21±0.01	0.22±0.01
		Kids	0.21±0.01	0.21±0.01	0.22±0.01
		Lambs	0.21±0.01	0.21±0.01	0.22±0.01
	QRS	Total	0.16±0.01	0.17±0.01	0.17±0.01
		Kids	0.16±0.01	0.17±0.01	0.17±0.01
		Lambs	0.16±0.01	0.17±0.01	0.17±0.01
	T	Total	0.04±0.01	0.04±0.01	0.04±0.01
		Kids	0.04±0.01	0.04±0.01	0.04±0.01
		Lambs	0.04±0.01	0.03±0.01	0.04±0.01
Duration (sec)	P	Total	108.75±6.33	109.35±2.03	109±1.74
		Kids	107.90±3.75	109.70±2.71	109.30±1.63
		Lambs	109.6±8.30	109±1.05	108.7±1.88
	QRS	Total	117.95±1.46	117.90±1.20	117.60±1.75
		Kids	118.20±1.47	117.90±1.19	118±1.05
		Lambs	117.70±1.49	117.90±1.28	117.20±2.25
	T	Total	14.53±0.18	14.60±0.47	14.50±0.2
		Kids	14.54±0.19	14.70±0.62	14.50±0.14
		Lambs	14.52±0.19	14.50±0.25	14.50±0.25
Interval (sec)	PR	Total	113.9±5.39 ^{a}	137.15±7.05 ^{b}	378.9±7.52 ^{c}
		Kids	115.5±5.4 ^{a}	136.90±6 ^{b}	379.20±7.09 ^{c}
		Lambs	116.30±4.42 ^{a}	137.40±8.30 ^{b}	378.6±8.30 ^{c}
	QT	Total	52.91±0.42	53.02±0.88	52.68±1.02
		Kids	52.66±0.39	52.36±0.5	52.39±0.58
		Lambs	53.17±0.29 ^{a}	53.68±0.64 ^{b}	52.97±1.29 ^{a}
	RR	Total	327.85±5.56 ^{a}	422.40±8.58 ^{b}	504.35±40.08 ^{c}
		Kids	326.30±5.57 ^{a}	422±7.97 ^{b}	483.70±48.53 ^{c}
		Lambs	329.4±5.37 ^{a}	422.80±9.57 ^{b}	525±9.41 ^{c}

$^{a, b, c}$: Different superscript letters indicate significant differences within each row. (P < 0.01).

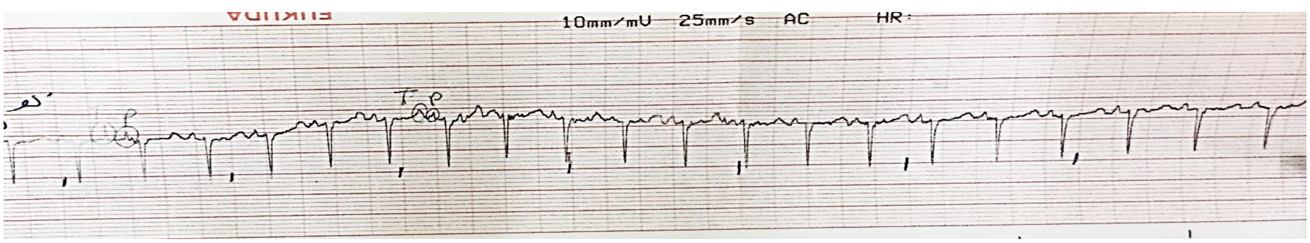

Fig 1. Sinus tachycardia of a lamb at the time of birth (Base-apex lead electrocardiography; 25 mm s^{-1}; 10 mm mv^{-1})

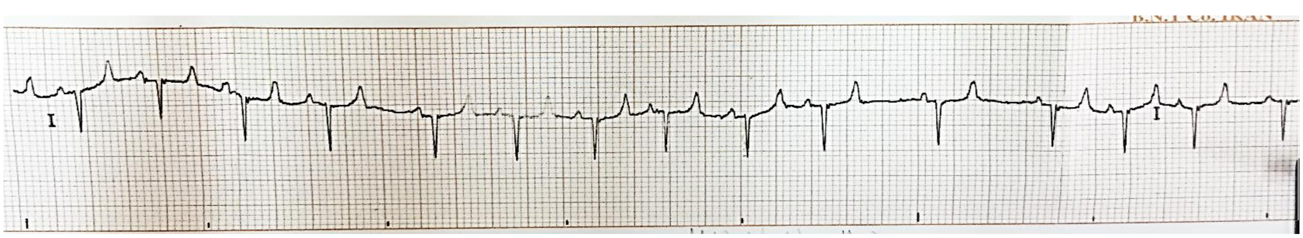

Fig 2. Sinus arrhythmia of a lamb at the time of birth (Base-apex lead electrocardiography; 25 mm s^{-1}; 10 mm mv^{-1})

no clinical signs of cardiac disease or insufficiency were detected in any of the animals. No cardiac arrhythmias, other than sinus arrhythmia and tachycardia were observed.

Discussion

The neonatal period, known as an adaptive period, is a transitional phase during which most organs must adapt to the extra-uterine life to perform their normal functions. In fact, birth and the subsequent 48 hours are the most important for newborn survival because they represent a critical stage for the detection of health problems [5, 19]. Diseases of newborn and neonatal mortality are the major causes of economic loss in the livestock industry [5, 7, 8, 19]. On the other hand, good management techniques and early intervention, diagnosis, and treatment of high-risk conditions in newborns could prevent a substantial proportion of neonatal diseases or deaths [5, 29]. The cardiovascular physiology of neonates and young animals is different from that of adults and therefore, it is important to evaluate ECG indices of young animals, such as lambs and goat kids, in the period following birth [22]. Analysis of changes in ECG indices is a necessary and reliable part of the evaluation of health and nutritional status and differential diagnosis of diseases in neonates [7, 8, 19].

In the present study, the mean HR of neonates in the first postnatal examination was 182.95 ± 3.26 beats min-1. Significant decreases in HR were seen in different animals as they age [23, 30, 31]. Based on our results, the mean HR of the postnatal animals was 182.95 beats min-1 (Table 1), which was similar to the results of Koether et al. (2016) in Bergamasca lambs (191 beats min-1) [23] and higher than those reported by Tajik et al. (2013) in Cashmere goat kids (126 beats min-1), [32] Tajik et al. (2016) in Kermani lambs (146 beats min-1) [33] and Samimi et al. (2015) in Saanen goat kids (125 beats min-1) [34]. Indeed, our result was also higher than the normal ranges reported by Constable et al. (2017) [8] and Smith (2015) [7] for newborn small ruminants. The second examination of this study revealed a mean HR which was similar to the values reported in Cashmere goat kids [32], Kermani lambs [33], and Saanen goat kids [34]. Mendes et al. (2001) [30] and Chalmeh (2015) [31] reported heart rates of 127 and 142 beats min-1, respectively, for one-day-old Holstein calves. After 48 h, the mean HR was near to that of Mendes et al.'s (2001) study [30] and within the normal ranges mentioned by Constable et al. (2017) [8] and Smith (2015) [7]. HR increment is associated with several factors including stress, excitement, pain, and exercise [8]. Stress has been proposed as an important reason for tachycardia [7, 8] and based on the results of our study, higher HR was recorded immediately after parturition compared to other time points ($P < 0.05$). During the neonatal period, stress and elevated HR may arise due to the transition from intrauterine to extrauterine life. This critical phase involves significant physiological adjustments, as most organ functions must adapt to the novel conditions outside the womb. [5, 8, 19, 35].

Most ECG studies of cardiac arrhythmias have been conducted on adult animals and therefore descriptions of cardiac electrical activity in the neonates have remained limited in the literature [22]. The prevalence of cardiac arrhythmias varied significantly at various time points. In the present study, sinus tachycardia and arrhythmia were the only irregularities observed on the ECG traces and were diagnosed in 100% of the animals at birth and 24 hours postpartum (Figures 1 and 2). Sinus tachycardia is an increased HR that exceeds the normal rate (120 beats min-1) and originates from the sinoatrial (SA) node. Sinus arrhythmia is associated with variations in RR intervals in ECG traces. In a study performed on newborn Thoroughbred foals, 85% of the animals showed various types of cardiac arrhythmias including ventricular premature complex (VPC), paroxysmal atrial fibrillation (AF), and paroxysmal ventricular tachycardia [36]. Mendes et al. (2001) also reported the incidence of cardiac arrhythmias in one-day-old Holstein calves [30]. In studies performed on Iranian fat-tailed lambs younger than 5 days old, Bergamasca lambs, and 15-day-old Najdi goat kids, cardiac arrhythmias were observed in 100% of the cases [23, 35, 37].

Pourjafar et al. (2011; 2012) diagnosed second-degree atrioventricular block (AVB) in Iranian fat-tailed lambs and sinoatrial block (SAB) and VPC in Najdi goat kids [35, 37]. However, we found no evidence of VPC, AF, AVB, and SAB in ECG tracings. Parturients challenge the ruminants' homeostatic mechanisms, especially those controlling the cardiovascular system [7, 8]. ECG tracing of neonates is affected by various parameters including blood pressure (BP) [24], peripheral vascular resistance (PVR) (Koether et al., 2016), cardiac output (CO) [23], ventricular septal defect [23], anatomical conformation [23] and autonomic innervations [24, 22, 23]. Indeed, the development of hypoxemia and acidemia at birth and a great increase in pulmonary blood flow accompanied by a rise in left atrial pressure and distention of the atrial walls due to change in pulmonary vascular resistance (PVR) with the expansion of the lungs after the onset of breathing might be related to the occurrence of cardiac arrhythmias [35, 38]. On the other hand, Belenky et al. (1979) and Pourjafar et al. (2011) mentioned that hypoxia-induced carotid chemoreflex (HCC) has significantly longer response time at parturition compared to times after delivery [35, 39]. Moreover, the central nervous system (CNS) mediating the hypoxic ventilatory response has been demonstrated to be present in newborn animals for at least 12 days postpartum or longer [35, 39]. Since none of the neonates with cardiac arrhythmias showed any clinical signs of cardiac disease at the time of ECG recordings, the observed arrhythmias could be considered physiological ones [35].

Conclusion

It is concluded that ECG indices showed age-related differences in newborn lambs and goat kids during the 48-hour study period. The author suggested that the changes in ECG indices are normal and could be attributed to both colostrum absorption and the physiological development of a newborn; however, more accurate investigations are required to separately evaluate the effects of colostrum and physiological development and determine the key factor/factors.

Conflict of interest

The authors declare that they have no competing interests.

Ethical approval

All ethical considerations including utilizing animals were considered cautiously. Also, the trial convention was affirmed by the animal welfare committee of the Faculty of Veterinary Medicine, Shahid Bahonar University of Kerman, Kerman, Iran. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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