

## Analysis of Electrocardiographic Parameters in the Conscious Common Pheasants (*Phasianus colchicus*)

Mehmet KAYA <sup>1</sup>  Sadettin Mehmet SOYLU <sup>1</sup>

<sup>1</sup> Department of Physiology, Faculty of Veterinary Medicine, Ondokuz Mayıs University, TR-55139 Samsun - TURKEY

Makale Kodu (Article Code): KVFD-2013-9413

### Summary

The aim of this study was to establish normal electrocardiographic values and patterns in pheasants (*Phasianus colchicus*). The electrocardiograms were recorded in 24 conscious pheasants from both genders. All electrocardiograms were standardized at 1 mV=20 mm, with a paper speed of 50 mm/sec. Morphological patterns of P, QRS and T deflections were evaluated in the six limb leads (I, II, III, aVR, aVL, aVF). The amplitude and duration of waves and intervals were determined by using lead II. A regular sinus rhythm was observed in all birds. There was no significant difference between male and female pheasants except for amplitudes of P and T waves and duration of T wave. In all leads P waves were mainly positive in both sexes except for lead aVR. The dominant waveforms of the QRS complexes were rS in lead II, III and aVF, and qR in lead aVR and aVL in both sexes. Generally, T waves were positive in lead I, II, III and aVF, and negative in aVL, aVF. The majority of birds showed a slightly elevated ST segment in lead II. Heart rates were 193.5±45.8 and 235.7±59.9 beats per minute and mean electrical axes were -91±10° and -92±18° in male and female birds, respectively. This study provides electrocardiographic data for pheasants, which can be used for clinical purposes.

**Keywords:** Electrocardiography, Pheasant, *Phasianus colchicus*, Heart rate, Mean electrical axis

## Uyanık Haldeki Adi Sülünlerde (*Phasianus colchicus*) Elektrokardiyografik Parametrelerin Analizi

### Özet

Bu çalışmanın amacı adi sülünlere (*Phasianus colchicus*) ait elektrokardiyografik parametrelerin belirlenmesiydi. Bu amaçla her iki cinsiyetten 24 adet uyanık sülünün elektrokardiyogramları 50 mm/sn hızda ve 20 mV/mm amplitüdde kaydedildi. Bipolar ve unipolar ekstremite derivasyonlarında (I, II, III, aVR, aVL, aVF) P, QRS ve T dalga morfolojileri değerlendirildi. Dalgaların süre, yükseklik ve aralıklarının hesaplanmasında derivasyon II kullanıldı. Çalışmada tüm kuşlarda düzenli sinüs ritmi izlendi. Erkek ve dişi sülünler arasında P ve T dalgalarının amplitüdü ve T dalgalarının süresi dışında önemli fark saptanmadı. P dalgası aVR dışında tüm derivasyonlarda her iki cinsiyette de pozitif. Her iki cinsiyette de QRS kompleksi II, III ve aVF derivasyonlarında rS formunda, aVR ve aVL derivasyonlarında qR formunda gözlemlendi. T dalgası I, II, III ve aVF derivasyonlarında pozitif iken aVL ve aVF derivasyonlarında negatif olarak belirlendi. Derivasyon II'de ST segmentinde hafif bir yükselme saptandı. Kalp atım sayısı erkeklerde 193.5±45.8 atım/dk ve dişilerde 235.7±59.9 atım/dk olarak hesaplanırken, ortalama elektriksel eksen erkeklerde -91±10° ve dişilerde -92±18° olarak hesaplandı. Bu çalışma ile klinik amaçlar için kullanılabilecek sülünlere ait elektrokardiyografik veriler elde edilmiştir.

**Anahtar sözcükler:** Elektrokardiyografi, Sülün, *Phasianus colchicus*, Kalp hızı, Ortalama elektriksel eksen

### INTRODUCTION

An electrocardiogram is the record of the electrical activity generated by the heart. Electrocardiography (ECG) has been extensively used for diagnostic or research purposes in both human and animal species for more than a century. The first avian ECG study is dating back to

the beginning of 20<sup>th</sup> century <sup>[1]</sup>. Despite this early start in avian ECG studies, it is not possible to find published reference values for some of the common avian species (e.g. pheasants). With the increasing popularity of bird species as a pet animal, the veterinarians more often



İletişim (Correspondence)



+90 362 3121919



kayam@omu.edu.tr

are confronted with cardiology cases in these species. The findings of ECG are commonly used in the accurate cardiac diagnosis in various bird species such as chicken [2-5], turkey [6-8], quail [4,9,10], duck [2,11], pigeon [2,12,13], parrot [14], and other species [15-17]. Electrocardiography is also used in monitoring cardiac and vital status during the anesthesia in birds [18-21]. However, ECGs obtained from anesthetized birds may not be applicable in un-anesthetized birds [8,22]. Therefore, obtaining the reference ECG patterns and values of unanesthetized birds would be useful.

The pheasant, originally native to Georgia, has been introduced all across the world as a game bird. The word pheasant is derived from the ancient river name *Phasis*, which flows from the Caucasus Mountains into the Black Sea [23]. The most well known is the "Common pheasant", which is widespread throughout the world. In the United States and Europe, especially in the United Kingdom, there are many commercial pheasant breeding farms. In some parts of the world where pheasant population has dropped, efforts are being made to reintroduce farm-raised pheasants to wild. At Samsun, Turkey, a city located at the southern part of Black Sea, pheasants are raised at Gelemen Pheasant Production Station and dispatched to nature in an effort to support the pheasant population in this area.

In this study we wanted to create an ECG reference value from healthy conscious pheasants for the first time, to help the veterinarians in evaluating the heart disease profile of these birds.

## MATERIAL and METHODS

### Animals

In this study, a total of 24 mature and healthy pheasants (*Phasianus colchicus*) of both sexes (12 males, 12 females) were used. Body weights (BW) of male and female pheasants were 1257±117 g and 1021±181 g, respectively. Pheasants were 8-12 months old ages and were obtained from the Gelemen Pheasant Production Station, Samsun. Pheasants were brought from the station to the physiology laboratory within plastic transport cages. To acclimate to the laboratory environment, pheasants were kept in semi-darkness zone for 3 days. Pheasants received commercial feed mixtures and water *ad libitum*. This study was approved by the Local Ethics Committee of Samsun Veterinary Control Institute (Approval no: 30). It was not applied any invasive treatment to the animals.

### ECG Recording

ECG recordings were performed at the same time of the day to eliminate changes derived from biorhythms. To minimize stress, all the procedures were carried out in a quiet and dim room and birds' heads was covered with a thin cloth during the manipulation. The pheasants were

gently placed on a rubber surface in a dorsal recumbent position. Throughout the recordings neither sedation nor anesthesia were used. Electrocardiograms were recorded with a portable electrocardiograph (Cardiette, ar600adv, Italy). Blinded alligator clip electrodes were attached after gel application to the skin at the base of the wings and to the skin overlying the stifle on the right and left sides. When optimal immobilization and good electrode contacts were obtained, ECG recordings were started (approximately within 5 min after the electrode placement). If a pheasant showed any movement, ECG recordings was discontinued until the movement ceased. The standard bipolar (I, II and III) and augmented unipolar (aVR, aVL and aVF) limb leads were recorded with a paper speed of 50 mm/sec. The lead II recordings run for at least 60 sec and all the other leads for 30 sec. Lead II was selected for the measurement of amplitude and duration of waves. Because of the small waveforms a double standard was used (20 mm equals to 1 mV). The mean heart rate (HR) was calculated by using the average of 10 consecutive RR intervals. The QRS waveforms were labeled according to the standard nomenclature: the major deflection was indicated by a capital letter and the minor deflections by lower case letters. Mean electrical axis (MEA) was calculated by using lead II and III as described by Edwards [24], since the QRS complex was not represented in Lead I. The morphologic patterns of P, QRS and T waves were evaluated for each lead. Amplitudes and durations of the waves, PQ/PR and QT intervals, and duration of ST segments were determined by the inspection of lead II.

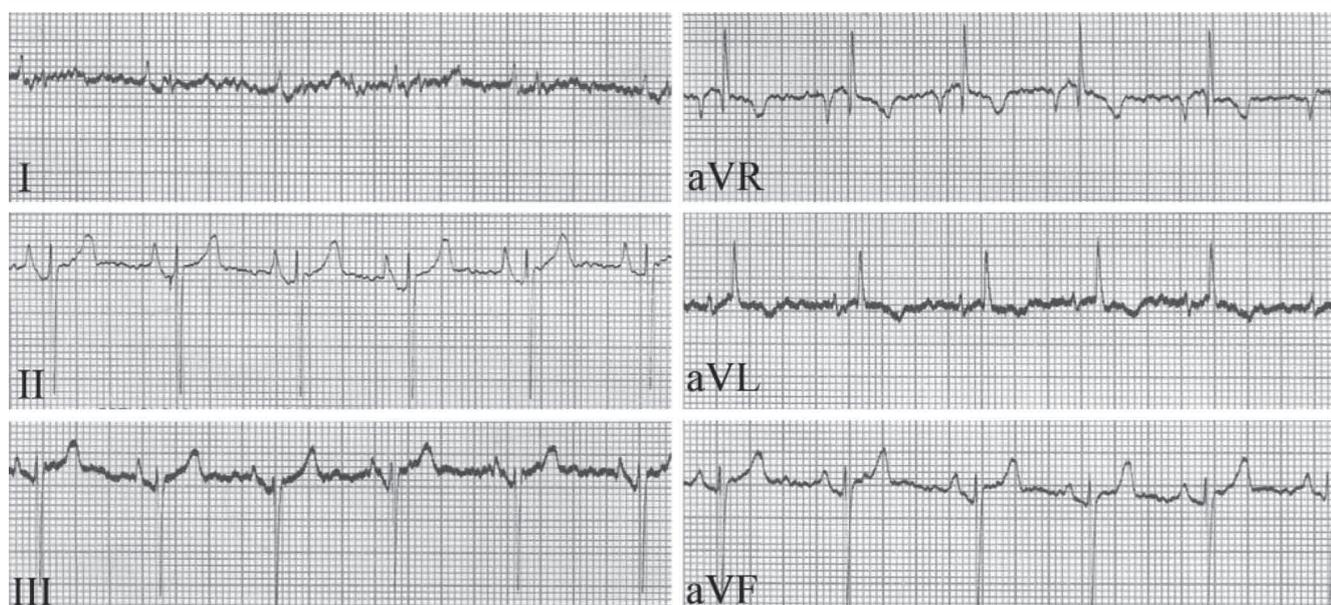
### Statistical Analysis

Mean, standard deviation (SD), minimum and maximum values were calculated by using the MINITAB statistical package (MINITAB Inc., State College, PA, USA). Data are presented as mean±SD. The amplitudes of waves and the duration of intervals, BW, HR and MEA were analyzed by one-way analysis of variance. The relationship BW and amplitudes of waves and, BW and durations of waves were determined by correlation analyses.

## RESULTS

The vast majority of lead recordings were obtained without major artifacts. A regular sinus rhythm was observed in all birds. A representative ECG of a pheasant is shown in Fig. 1. P and T waves could not be evaluated in some leads in both genders because the waves were isoelectric (Table 1). In two female pheasants, the measurement of duration and amplitude of P and T waves in lead I, III, aVL, and in one bird only in lead I were almost impossible because of respiratory artifacts; therefore quantitative data for these leads were not evaluated. The remaining leads were regular and had assessable wave morphologies.

There was a significant difference between male (0.18



**Fig 1.** Representative electrocardiogram of a male pheasant in six leads. Standardization: 20 mm=1 mV; chart speed, 50 mm/sec

**Şekil 1.** Bir erkek sülüne ait altı ekstremite derivasyonunda kaydedilmiş örnek elektrokardiyogram. Standardizasyon: 20 mm=1 mV; kâğıt hızı: 50 mm/sn

**Table 1.** Morphologic patterns of P and T waves and QRS complex in standard bipolar and augmented unipolar limb leads in male (n=12) and female (n=12) pheasants (Values are given number of 12)

**Tablo 1.** Dişi (n=12) ve erkek (n=12) sülünlerde standart bipolar ve artırılmış unipolar ekstremite derivasyonlarında P ve T dalgaları ile QRS kompleksinin morfolojik biçimleri (Değerler 12'de adet olarak verilmiştir)

Sex	P Wave					QRS Complex							T Wave		
	Leads	Pos	Neg	Iso	Bip	Iso	rS	qR	Rs	QS	Qr	R	Pos	Neg	Iso
Male	I	7	1	4	0	7	2	1	0	1	1	0	7	1	4
	II	10	0	0	2	0	12	0	0	0	0	0	12	0	0
	III	12	0	0	0	0	12	0	0	0	0	0	12	0	0
	aVR	0	10	1	1	0	0	11	1	0	0	0	0	11	1
	aVL	1	3	0	8	0	0	12	0	0	0	0	0	12	0
	aVF	12	0	0	0	0	12	0	0	0	0	0	0	12	0
Female	I	6	1	3	0	5	3	0	2	1	0	0	6	1	3
	II	9	1	0	2	0	9	0	0	3	0	0	11	0	1
	III	6	1	2	2	1	7	0	0	3	0	1	8	2	1
	aVR	1	9	2	0	1	0	9	0	0	0	2	1	9	2
	aVL	4	2	4	1	1	0	5	1	1	1	0	3	4	4
	aVF	7	0	2	3	2	6	1	0	3	0	0	8	2	2

Pos: positive, Neg: negative, Iso: isoelectric, Bip: biphasic (+/- or -/+)

mV) and female pheasants (0.10 mV) in amplitudes of P waves ( $P=0.01$ ) but durations were similar (Table 2). As shown in the Table 1, there were a total of five isoelectric P waves in the male pheasants and thirteen isoelectric P waves in the female pheasants. In all leads, P waves were mainly positive in both sexes except for lead aVR in which P waves were negative. The majority of P waves were biphasic in lead aVL in male pheasants at ratio of 8:12. There were four notched P waves in male (two waves in each lead II and III) and four waves in female birds (three waves in lead II and one wave in lead aVF). P waves were tall and

pointed in shape in one male pheasant in lead II, III and aVF, and in another one in lead I and aVF.

The duration of PQ/PR and QT intervals were similar in both sexes (Table 2).

There was no significant difference between male and female birds in amplitude and duration of QRS complexes although both parameters were high in males than females (Table 2). The dominant waveforms of the QRS complexes were rS in lead II, III and aVF, and qR in lead aVR and aVL in both sexes. However, Rs, QS, Qr and R forms of

**Table 2.** Amplitudes and durations of P, QRS and T waves and durations of P-Q/P-R, Q-T intervals and S-T segment, and heart rates and electrical axis in male and female pheasants**Tablo 2.** Dişi ve erkek sülünlerde P, QRS ve T dalgalarına ait amplitüd ve süreler ile P-Q/P-R, Q-T aralıklarına ve S-T segmentine ait süreler ile kalp atım sayıları ve elektriksel eksen değerleri

Sex	Variation	P wave		P-Q/P-R Interval	QRS Complex		T Wave		Q-T Interval	S-T Segment	BPM	MEA
		Amp	Dur		Amp	Dur	Amp	Dur				
Male	Mean	0.183	0.033	0.071	-0.600	0.033	0.276	0.072	0.140	0.037	193.5	-91
	SD	0.101	0.008	0.012	0.247	0.006	0.113	0.017	0.016	0.008	45.8	10
	Min	0.000	0.020	0.050	-1.100	0.020	0.080	0.040	0.120	0.020	100.0	-104
	Max	0.330	0.040	0.090	-0.250	0.040	0.450	0.100	0.180	0.050	254.0	-68
Female	Mean	0.096	0.030	0.063	-0.450	0.028	0.137	0.051	0.134	0.046	235.7	-92
	SD	0.037	0.013	0.011	0.171	0.010	0.058	0.014	0.019	0.014	59.9	18
	Min	0.000	0.010	0.050	-0.700	0.020	0.050	0.020	0.100	0.020	160.0	-127
	Max	0.150	0.060	0.080	-0.250	0.050	0.250	0.060	0.160	0.060	341.0	-60
P value		0.010	NS	NS	NS	NS	0.002	0.004	NS	NS	NS	NS

The amplitudes and durations are given in millivolt and second, respectively, *SD*: standard deviation, *Min*: minimum value, *Max*: maximum value, *Amp*: amplitude, *Dur*: duration, *BPM*: beats per minute, *MEA*: mean electrical axis (°), *NS*: no significance

QRS complexes were observed in a small number of male and female pheasants in various leads (Table 1).

Both amplitude ( $P=0.002$ ) and duration ( $P=0.004$ ) of T waves were higher in male pheasants than females (Table 2). There were a total of five isoelectric T waves in male and 13 isoelectric T waves in female pheasants. Generally, T waves were positive in lead I, II, III, aVF and negative aVR and aVL in both sexes (Table 1). In five male pheasants T waves were notched in lead II and aVF, while in one male bird all the leads had notched T waves. In females, notched T waves were observed in only one bird on lead II and aVF.

Durations of ST segments were similar in both sexes. It ranged from 0.02 to 0.05 sec and 0.02 to 0.06 sec in male and females, respectively (Table 2). In the majority of the birds a slightly elevated ST segment was observed in lead II.

Average heart rate and MEA values were similar in male and female pheasants (Table 2).

## DISCUSSION

This study was conducted at the Faculty of Veterinary Medicine in Samsun, Turkey (latitude 41° 13' N, longitude 36° 29' E). Anesthetics can alter ECG values by changing heart rate and QT interval [14,25]; hence no anesthetic or tranquilizing agents were applied in this study. Instead, ECGs were recorded in conscious pheasants by covering birds' heads with a thin and dark-colored cloth. The recordings were performed approximately 5 min after the attachment of clips. This calming period allowed us to obtain considerably proper ECG wave patterns in pheasants.

ECG values were similar in both sexes except for

amplitudes of P and T waves, and duration of T waves. The amplitudes of P and T in male birds were higher than those of females ( $P=0.01$  and  $P=0.002$ , respectively). Similar to our findings, Lopez-Murcia et al. [13] reported sex related differences in amplitudes of P, R and T waves in competition pigeon with the males having higher amplitudes than females. The author explains these differences with higher cardiac tissue mass of males than females due to the competition. But in our study, we could not attribute these differences to heart weight directly since the hearts of the birds were not weighed. However, in previous studies [26,27] a positive correlation between BW and heart weight were reported. From this point of view it can be expected that the heart weights of males would be greater than those of females since in this study, the BWs of males were significantly (1257 vs. 1020,  $P=0.001$ ) higher than those of females. Therefore, the explanation of Lopez-Murcia et al. [13] about the amplitude differences in male and female pigeons could be applied to our result. However, there was no relationship between BW and amplitudes of P and T wave in correlation analysis ( $P=0.831$  and  $P=0.299$ , respectively). Similar findings were reported in raptors [17] and in macaws [15] earlier by other authors. They pointed out that there is no significant relationship between BW and wave amplitudes in conscious raptors and macaws.

In this study, a total of 18 isoelectric P waves were observed in different leads and derivations, looking at the ECGs of all the pheasants. Uzun et al. [28] reported a similar finding where they detected five and eleven silent P waves in rock and chukar partridges, respectively. The P waves were dominantly positive in all leads except for lead aVR and only in male pheasants it was biphasic in lead aVL. In this respect, there is compatibility between our results and those findings reported by many authors [16,17,28-30]. On the other hand, Hassanpour et al. found that the P waves were mainly positive in all leads in green peafowl [31]

and in helmeted guinea fowl [32]. Machida and Aohagi [33] reported that the P waves are generally biphasic in lead I and III, and positive in lead II. The amplitude of P wave in our study was higher than the value described by Uzun et al. [28] and Hassanpour et al. [31]; lower than the value notified by Casares et al. [15] and Lopez-Murcia et al. [13] and, similar to the value reported by Espino et al. [30] and Talavera et al. [17]. The mean P wave durations in lead II were 0.03 and 0.03 sec in male and female pheasants, respectively, which was fairly similar to the values reported by many authors [13,15,17,28,30]. We observed a total of eight notched P waves in birds. According to author's knowledge, there was not any report on this phenomenon in avian species.

In this study, the QRS polarity was always negative in lead II, III and aVF, and positive in lead aVR and aVL. The QRS complex in lead I was either very low or isoelectric, and both negative and positive deflections were observed. The deflection of QRS complex in leads II, III and aVF was dominantly identified as the rS type. Likewise, in lead aVR and aVL the most frequent morphologies were qR. Our findings were almost similar to results obtained in many studies [15-17,28,30-32].

There was no Q wave in lead II and III, whereas Q wave was present in lead aVR and aVL in 22 of 24 pheasants. These results are confirmed by other ECG studies in birds [16,17,28,31-33]. The mean values of duration and amplitude of QRS complexes were similar to those reported previously in buzzards [30] but higher than those reported in pigeons [13].

T waves were always positive in lead I, II, III and aVF, and always negative in the other two leads. These findings of T wave morphology were similar to those reported previously in various birds [16,17,28-31,33].

The amplitudes and durations of T waves in males were higher than those of females. The amplitudes in our study were lower than those reported earlier in turkeys [29], macaws [15], in pigeons [13], in kestrels [17] and in peafowl [31], but were similar to those in buzzards [30] and some raptor species [17]. The mean duration of T wave was 0.07 and 0.05 sec in male and female, respectively in our study. The our result for duration of the T wave in males (0.072 sec) was similar to the finding in vultures of Talavera et al. [17] who studied in four raptor species without distinction of sex. Similarly, this parameter in kestrels, owls and eagle owls was consisted with that of females (0.05 sec) in our study. Otherwise, Espino et al. [30] mentioned that T wave durations in buzzards were 0.03 sec which was lower than our values. T wave values obtained in an ECG study in macaws [15] were fairly similar to our results. In a pigeon study, Uzun et al. [28] reported that the duration of T wave was approximately 0.05 sec, which is similar to those of females in our study, and Lopez-Murcia et al. [13], mentioned that this duration was an average of 0.03 sec, which is lower than our

values. The duration of T waves in turkeys was reported by McKenzie et al. [29] as 0.08 sec, which was higher than those of these pheasants.

A normal sinus rhythm was assessed in all pheasants and no remarkable arrhythmia was found in our study in contrast with other studies on anesthetized birds [14,15]. The mean heart rates of male and female pheasants were similar and were 194 bpm and 236 bpm, respectively. The mean HR in this study was much lower than previously studied species: macaws [15]; buzzards [30]; peregrine falcon [16]; partridges [28]; pigeons [13]; Eurasian kestrel, little owl and Eurasian eagle owl [17] and green peafowl [31]. However, our values were fairly similar to those reported for streaked shearwater, night heron, grey heron, little egret, intermediated egret, large egret, Ural owl [33] and were higher than those mentioned for turkeys [29]; whooper swan, mallard, teal, spot-billed duck, great crested grebe [33] and griffon vulture [17].

The MEA was negative in all birds and there was no sex-related difference. The MEA values were reported before for avian species as +95° to -165° for Pekin ducks [34], -95° to -101° for macaws [15], -99.2° for buzzard [30], -64° to -120° for various free-living birds [33], -99.9° for peregrine falcon [16], -95° for rock partridges and -99.5° for chukar partridges [28], -88° for pigeons [13], -78° to -98° for raptors [17] and -96.8° for green peafowl [31]. As can be seen from the [Table 2](#), the average MEA values in this study were negatives and were consistent with those reported in earlier studies mentioned above.

The ST segment represents the end of ventricular depolarization and the beginning of ventricular repolarization. The ST segment extends from the end of the QRS complex to the beginning of the T wave, and it is normally isoelectric. The normal ST segment may be slightly elevated above or depressed below the baseline. The amount of the elevation or depression is considered as abnormal when it is greater than 0.2 mV for dogs and 0.1 mV for cats [24], but there is no reported criterion for ST segment elevation and depression in any avian species. As another abnormal situation, ST segment slurring may be seen when the ST segment goes directly into the T wave without first straightening out even with the baseline, which ST slurring is frequently described with an undetermined cause in healthy birds [13,35]. In our study, the ST segment was almost identifiable in all tracings, and ST slurring was found in only one tracing. In agreement with previous ECG studies on other bird species [14,16,33,35], the ST segment mainly appeared elevated over baseline.

Some authors reported the fusion of P and T waves (P on T phenomenon) in various avian species possibly due to high heart rates [14,25,33]. We did not observe this phenomenon most likely because compared to the birds in the previously mentioned studies the pheasants in this study had lower HRs.

In conclusion, morphology, duration and amplitude of P, QRS and T waves, and heart rates and mean electrical axis of conscious pheasants show similarities and differences with the other avian species studied previously. These variations in avian species explain the need for the specific electrocardiographic patterns and reference values for all wild bird species. Hopefully, The ECG values and patterns derived from these clinically normal pheasants will provide a reference value data to help the diagnosis of cardiovascular abnormalities in this species.

### ACKNOWLEDGMENTS

The authors thank to Dr. Erdem GÜLTİKEN and Beste DEMİRCİ for his help in obtaining birds, and Dr. Serhat ARSLAN for statistical advice.

### REFERENCES

- Buchanan F:** The frequency of the heart beat and the form of the electrocardiogram in birds. *J Physiol*, 38, 62-66, 1909.
- Kisch B:** The electrocardiogram of birds (chicken, duck, pigeon). *Exp Med Surg*, 9, 103-124, 1957.
- Kadono H, Okada T:** Physiological studies on the electrocardiogram of the chicken I: Bipolar leads. *Res Bull Fac Agric Gifu Univ*, 11, 164-172, 1959.
- Sawazaki H, Hirose H, Matsui K, Yamamori K, Hanyu I:** Comparative electrocardiographical studies on the wave form of QRS complex in vertebrates. *Jpn J Vet Sci*, 38, 235-240, 1976.
- Olkowski AA, Classen HL, Riddell C, Bennett D:** A study of electrocardiographic patterns in a population of commercial broiler chickens. *Vet Res Commun*, 21, 51-62, 1997.
- Krista LM, Jankus EF, Warbel PE, Sautter JH:** Comparison of electrocardiograms of hypertensive and hypotensive male turkeys. *Poult Sci*, 49, 700-703, 1970.
- Yersin AG, Edens FW, Simmons DG:** Effect of *Bordetella avium* infection on electrocardiograms in turkey poults. *Avian Dis*, 35, 668-673, 1991.
- Boulianne M, Hunter DB, Julian RJ, O'Grady MR, Physick-Sheard PW:** Cardiac muscle mass distribution in the domestic turkey and relationship to electrocardiogram. *Avian Dis*, 36, 582-589, 1992.
- Szabuniewicz M, McCrady JD:** The electrocardiogram of the Japanese (*Coturnix coturnix japonica*) and Bobwhite (*Colinus virginianus*) quail. *Zentralbl Veterinarmed A*, 21, 198-207, 1974.
- Onder F, Cenesiz M, Kaya M, Uzun M, Yildiz S:** Effects of the level of copper supplementation in diet on electrocardiogram of Japanese quails (*Coturnix coturnix japonica*). *Rev Med Vet*, 157, 76-79, 2006.
- Andersen HT:** Hyperpotassemia and electrocardiographic changes in the duck during prolonged diving. *Acta Physiol Scand*, 63, 292-295, 1965.
- Lumeij JT, Stokhof AA:** Electrocardiogram of the racing pigeon (*Columba livia domestica*). *Res Vet Sci*, 38, 275-278, 1985.
- Lopez-Murcia MM, Bernal LJ, Montes AM, Garcia Martinez JD, Ayala I:** The normal electrocardiogram of the unanaesthetized competition "Spanish Pouter" pigeon (*Columba livia gutturosa*). *J Vet med A*, 52, 347-349, 2005.
- Nap AMP, Lumeij JT, Stokhof AA:** Electrocardiogram of the African grey (*Psittacus erithacus*) and Amazon (*Amazonas spp.*) parrot. *Avian Pathol*, 21, 45-53, 1992.
- Casares M, Enders F, Montoya A:** Comparative electrocardiography in four species of Macaws (*Genera Anodorhynchus and Ara*). *J Vet Med Ser A*, 47, 277-281, 2000.
- Rodriguez R, Prieto-Montana F, Montes AM, Bernal LJ, Gutierrez-Panizo C, Ayala I:** The normal electrocardiogram of the unanesthetized peregrine falcon (*Falco peregrines brookei*). *Avian Dis*, 48, 405-409, 2004.
- Talavera J, Guzman MJ, Fernandez del Palacio MJ, Albert AP, Bayon A:** The normal electrocardiogram of four species of conscious raptors. *Res Vet Sci*, 84, 119-125, 2008.
- Greenlees KJ, Clutton RE, Larsen CT, Eyre P:** Effect of halothane, isoflurane, and pentobarbital anesthesia on myocardial irritability in chickens. *Am J Vet Res*, 51, 757-758, 1990.
- Machin KL, Caulkett NA:** Cardiopulmonary effects of propofol and a medetomidine-midazolam-ketamine combination in mallard ducks. *Am J Vet Res*, 59, 598-602, 1998.
- Uzun M, Yildiz S, Atalan G, Kaya M, Sulu N:** Effects of medetomidine-ketamine combination anaesthesia on electrocardiographic findings, body temperature, heart and respiratory rates in domestic pigeons. *Turk J Vet Anim Sci*, 27, 377-382, 2003.
- Escobar A, Thiesen R, Vitaliano SN, Belmonte EA, Werther K, Nunes N, Valadao CA:** Some cardiopulmonary effects of sevoflurane in crested caracara (*Caracara plancus*). *Vet Anaesth Analg*, 36, 436-441, 2009.
- Burtnick NL, Degernes LA:** Electrocardiography on fifty-nine anesthetized convalescing raptors. In, Redig PT, Cooper JE, Remple JD, Hunter DB (Eds): Raptor Biomedicine. 111-121, Chiron Publications Ltd, Keighley, 1993.
- Beebe W:** A Monograph of the Pheasants. Vol. I, p.XXI, Witherby&Co., London, 1918.
- Edwards NJ:** ECG Manual for the Veterinary Technician. 1<sup>st</sup> ed. p.111, WB Saunders Co, Philadelphia, 1993.
- Tilley LP:** Essentials of Canine and Feline Electrocardiography: Interpretation and Treatment. 3<sup>rd</sup> ed., Lea&Febiger, Philadelphia, 1992.
- Johnston DW:** Heart weights of some Alaskan birds. *The Wilson Bulletin*, 75, 435-446, 1963.
- Kasperska D, Kokoszynski D, Korytkowska H, Mistrzak M:** Effect of age and sex on digestive tract morphometry of Guinea fowl (*Numida meleagris* L.). *Folia biologica (Krakow)*, 60, 45-49, 2012.
- Uzun M, Yildiz S, Onder F:** Electrocardiography of rock partridges (*Alectoris graeca*) and chukar partridges (*Alectoris chukar*). *J Zoo Wild Med*, 35, 510-514, 2004.
- McKenzie B, Will BE, Hardien A:** The electrocardiogram of turkey. *Avian Dis*, 15, 737-744, 1971.
- Espino L, Suarez ML, Lopez-Beceiro A, Santamarina G:** Electrocardiogram reference values for the buzzard in Spain. *J Wildl Dis*, 37, 680-685, 2001.
- Hassanpour H, Hojjati P, Zarei H:** Electrocardiogram analysis of the normal unanesthetized green peafowl (*Pavo muticus*). *Zoo Biol*, 30, 542-549, 2011.
- Hassanpour H, Zarei H, Hojjati P:** Analysis of electrocardiographic parameters in helmeted guinea fowl (*Numida meleagris*). *J Avian Med Surg*, 25, 8-13, 2011.
- Machida N, Aohagi Y:** Electrocardiography, heart rates, and heart weights of free-living birds. *J Zoo Wild Med*, 32, 47-54, 2001.
- Cinar A, Bagci C, Belge F, Uzun M:** The electrocardiogram of the Pekin duck. *Avian Dis*, 40, 919-923, 1996.
- Lumeij JT, Ritchie BW:** Cardiology. In: Ritchie BW, Harrison GJ, Harrison LR (Eds): Avian Medicine: Principles and Application. 695-722, Wingers Publishing Inc, Lake Worth, Florida, 1994.