

Change of Diurnal Heart Rate Patterns During Pregnancy and Lactation in Dogs (*Canis familiaris*)

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Olsson K, Lagerstedt A-S, Bergström A, Häggström J: Change of diurnal heart rate patterns during pregnancy and lactation in dogs (*canis familiaris*). Acta vet. scand. 2003, 44, 105-110. – Pregnancy and lactation involve great demands on the cardiovascular system. The purpose of this study was to investigate how the heart rate and diurnal heart rate pattern change when dogs become pregnant or lactate. Five clinically healthy female beagle dogs were mated, and delivered three to seven healthy puppies. The heart rate was investigated with 24-h ECG (Holter) once during anoestrus, at 3, 5, 7 and 9 weeks of pregnancy, and at week 4 postpartum (lactation). However, at 9 weeks, the ECG could not be recorded for the fully 24 h in 4 of 5 dogs, because labour started and the dogs then appeared disturbed by the recordings. The results at this date are not included in the statistical comparison. The heart rate increased progressively during pregnancy and was still elevated at 4 weeks of lactation. During late pregnancy the difference in heart rates between daytime and nighttime became smaller, but the heart rate was significantly higher in daytime in all periods. In conclusion, the increased heart rates during pregnancy and lactation reflect increased demands on the cardiovascular system and may be important to consider in clinical practice.

dog; pregnancy

Introduction

Heart rate changes in response to both external and internal stimuli, but diurnal variations during the reproductive cycle appear not to have been studied in dogs. During pregnancy extra blood is needed to meet the demands of the fetoplacental unit, leading to an increased blood volume and increased cardiac output. The rise in cardiac output is predominantly due to an increase in heart rate or in stroke volume or a combination of both. For example, in the guinea pig the increase has been found to be due to increased stroke volume (Hart *et al.* 1985, Peeters *et al.* 1980), but in ruminants there is predominantly an increase in heart rate (Olsson *et al.* 1998). Elevated cardiac output has been reported in late pregnant dogs (Moore

& Reeves 1980), but the authors gave no details of heart rate and stroke volume. Wegner & Dröge (1975) reported that the heart rate, measured by auscultation, was increased during the last 3 weeks of pregnancy in dachshunds.

Beagle dogs reach peak lactation 3 to 4 weeks after parturition, when they produce a daily milk volume of 14% to 17% of their body mass with a comparatively high energy content (Ofstedal 1984). Thus, lactation also involves a considerable strain on the cardiovascular system in the dog, but lactating dachshunds showed no increase in heart rate (Wegner & Dröge 1975).

The purpose of this study was to investigate how the diurnal heart rate changes in relation to reproductive period in the female dog. We de-

cided to follow the same dogs with ambulatory ECG (Holter) recordings for 24 h at pre-determined intervals during anoestrus, pregnancy and lactation. Such recordings would give important information to use in the clinic when evaluating the cardiovascular system of a pregnant or lactating dog.

Materials and Methods

Animals

The study sample comprised 5 clinically healthy female beagles (Table 1). They were born and housed at the Department of Small Animal Clinical Sciences, Swedish University of Agricultural Sciences, Uppsala. Dogs nos. 2 and 3 were sisters, dog no. 5 had the same mother as these 2, and dog no. 4 was the daughter of dog no. 2 (Table 1). They lived together until shortly before parturition and had outdoor exercise every day. Food (Pedigree Advanced Adult Formula[®] and Pedigree Pal[®], Waltham, UK) was provided daily between 6:45 a.m. and 8:00 a.m. Water was freely available. The dogs were mated one to 3 times, and pregnancy was confirmed by ultrasound examinations. When parturition was close, the dog in question was moved to an adjacent room and given access to a whelping box. The dogs delivered between 3 to 7 puppies (Table 1). From the age of 3-4 weeks, the puppies were given food (Pedigree Advanced Adult Formula[®], Pedigree Pal[®] and Pedigree Pal Advanced Formula Puppy Milk[®],

Waltham), and they were weaned at the age of 8 weeks. The technicians had taken care of the dogs already before the study began and were well known to the dogs. The care of the animals and the experimental design were approved by the Local Ethical Committee in Uppsala, Sweden.

Heart rate recordings

Long-term ambulatory ECG (Holter) recordings took place over 24 h, once during anoestrus, once at 3, 5, 7 and 9 weeks of pregnancy, and once during lactation (4 weeks postpartum). The recordings were done according to a method described previously (Calvert *et al.* 2000). Electrodes (Silver Trace AG/AgCl Electrodes, No 900703-130, GE Marquette Medical Systems, Milwaukee, WI, USA) were hidden inside a jacket designed to fit the dogs and firmly attached to the thorax. Holter recordings were performed with cassette recorders (8.500 Holter recorder, GE Marquette Medical Systems) placed inside the jacket pocket. The tapes were analysed by a prospective, technician-interactive Holter analysis system (Marquette Series 8000 Laser Holter System, GE Marquette Medical Systems). Holter tape data were transferred to a hard drive, and technician-selected normal and abnormal PQRST morphology was programmed by computer algorithms for template-matching criteria and artefact rejection level. Technician-supervised chronological ECG analysis with on-line tuning for accuracy was then performed. Retrospective technician validation of each cardiac cycle and editing were provided for each recording. The technician in question did not know the stage of reproduction of the dogs.

Statistical analyses

Statistical analyses were made with the General Linear Model (GLM) of the SAS program (SAS 1996). For each recording, the mean heart

Table 1. Characteristics of the 5 beagle dogs included in the study.

Dog	Age (years)	Length of gestation	Puppies (No.)	Whelping
1	8	61	3	3 rd
2	3	62	7	2 nd
3	2	61	6	1 st
4	3	62	6	1 st
5	2	61	7	1 st

Table 2. Hourly heart rates (means \pm SEM) in 5 Beagle dogs during each reproductive period.

Time of day	Anoestrus	3-week	5-week	7-week	9-week*	Lactation
0:00-1:00	71 \pm 9.2	89 \pm 4.3	104 \pm 4.0	122 \pm 4.9	136 \pm 14 (2)	94 \pm 5.8
1:00-2:00	66 \pm 4.8	84 \pm 6.5	103 \pm 4.6	122 \pm 3.0	146 \pm 20 (2)	92 \pm 2.1
2:00-3:00	62 \pm 4.0	85 \pm 7.0	101 \pm 4.8	125 \pm 4.4	134 \pm 19 (2)	86 \pm 2.5
3:00-4:00	65 \pm 2.7	83 \pm 6.4	99 \pm 5.7	131 \pm 4.3	130 \pm 16 (2)	85 \pm 3.7
4:00-5:00	61 \pm 3.5	89 \pm 5.5	102 \pm 5.2	113 \pm 2.1	141 \pm 25 (2)	79 \pm 3.6
5:00-6:00	66 \pm 3.2	92 \pm 6.4	103 \pm 3.1	113 \pm 4.8	152 \pm 18 (2)	89 \pm 2.6
6:00-7:00	107 \pm 5.0	132 \pm 3.3	124 \pm 7.2	144 \pm 3.5	139 \pm NA (1)	113 \pm 3.2
7:00-8:00	120 \pm 4.3	123 \pm 4.3	144 \pm 3.7	150 \pm 4.2	137 \pm NA (1)	122 \pm 4.2
8:00-9:00	102 \pm 6.6	114 \pm 6.2	135 \pm 8.4	144 \pm 3.6	137 \pm NA (1)	110 \pm 4.5
9:00-10:00	114 \pm 3.9	115 \pm 7.2	136 \pm 3.7	143 \pm 3.8	153 \pm 5.5 (3)	115 \pm 5.9
10:00-11:00	114 \pm 5.9	112 \pm 9.4	133 \pm 2.4	148 \pm 5.0	141 \pm 5.9 (3)	110 \pm 5.4
11:00-12:00	98 \pm 8.8	110 \pm 6.3	128 \pm 3.7	127 \pm 4.5	145 \pm 6.3 (4)	108 \pm 5.1
12:00-13:00	101 \pm 8.1	129 \pm 15	128 \pm 3.7	124 \pm 3.9	153 \pm 7.0 (5)	110 \pm 3.5
13:00-14:00	97 \pm 9.1	111 \pm 7.3	127 \pm 4.1	132 \pm 6.2	149 \pm 7.6 (4)	120 \pm 7.6
14:00-15:00	108 \pm 6.5	115 \pm 7.2	130 \pm 2.7	139 \pm 8.2	150 \pm 7.5 (4)	122 \pm 4.8
15:00-16:00	101 \pm 8.5	110 \pm 3.7	124 \pm 3.4	136 \pm 9.6	139 \pm 9.5 (3)	112 \pm 5.3
16:00-17:00	105 \pm 11	107 \pm 5.3	122 \pm 4.2	130 \pm 7.4	136 \pm 8.6 (3)	109 \pm 4.1
17:00-18:00	104 \pm 17	97 \pm 7.4	123 \pm 5.7	136 \pm 12	144 \pm 12 (3)	104 \pm 6.5
18:00-19:00	91 \pm 13	95 \pm 7.7	122 \pm 8.2	133 \pm 11	142 \pm 11 (3)	106 \pm 5.3
19:00-20:00	97 \pm 15	101 \pm 4.1	120 \pm 8.2	127 \pm 10	149 \pm 16 (3)	110 \pm 2.1
20:00-21:00	89 \pm 8.5	96 \pm 6.2	119 \pm 7.4	124 \pm 7.5	151 \pm 13 (3)	111 \pm 2.9
21:00-22:00	96 \pm 14	94 \pm 4.0	117 \pm 7.3	127 \pm 5.3	148 \pm 18 (2)	104 \pm 3.6
22:00-23:00	80 \pm 9.3	95 \pm 7.0	119 \pm 8.2	122 \pm 7.8	144 \pm 19 (2)	95 \pm 4.5
23:00-24:00	72 \pm 5.9	95 \pm 4.4	116 \pm 7.7	123 \pm 5.3	132 \pm 10 (2)	97 \pm 3.1

*The number in brackets at 9-week denote number of dogs, which were recorded.

rate for each hour of the day was used in the statistical analyses. The model for analysing the data included the effect of the individual, the effect of the period of pregnancy or lactation, sampling time and the interaction term between period of pregnancy and sampling time. The difference in heart rate between day and night was evaluated by substituting sampling time in the model for the dichromatised variable day (6:00 to 24:00 h) or night (0:00 to 6:00 h). Owing to the lack of complete data sets at 9 weeks of pregnancy, this period was not included in the statistical analyses. Values are presented as means and standard error of the mean (SEM). Significance was set at $p < 0.05$.

Results

All pregnancies were normal. The dogs whelped 61-62 days after the first mating. Also during the lactation period, all dogs were healthy. They had no problems with lactation and took good care of their puppies.

The heart rate changed in relation to reproductive period and time of day (Table 2 and Fig. 1). In all 5 dogs the heart rate increased in the morning when the technicians arrived and the dogs were fed. The heart rate gradually decreased throughout the day to reach the lowest value after midnight. Overall the heart rates were already increased at 3 weeks of pregnancy compared to anoestral values ($p < 0.001$). The heart rates were further increased at 5 and at 7

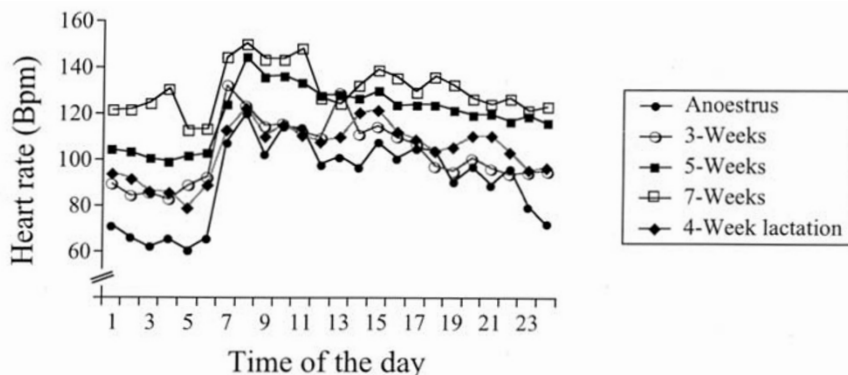


Figure 1. Diurnal changes of heart rate obtained by continuous 24 h (Holter) ECG in 5 beagle dogs during anoestrus, pregnancy and lactation. For simplicity only the means are shown (for means and SEM, see Table 2). The heart rate was significantly ($p < 0.001$) increased already at 3 weeks of pregnancy compared to anoestral values and was further increased at 5 and 7 weeks of pregnancy. At 4 weeks of lactation, the heart rate had decreased to a level similar to that at 3 weeks of pregnancy. Bpm = beats per minute.

weeks of pregnancy ($p < 0.001$ compared to 3 weeks of pregnancy). At 9 weeks of pregnancy, heart rate was recorded during 1 to 24 h (Table 2). The Holter equipment was removed after the birth of the first puppy in two dogs and at 1 or 2 h before the birth of the first puppy in two other dogs. The mean hourly heart rate was higher in each of the five dogs close to parturition compared to values obtained at 7 weeks of pregnancy at the same time of the day. However, this difference was not statistically evaluated as a complete data set was only obtained in one dog. At 4 weeks of lactation, the heart rates had decreased to a level similar to that at 3 weeks of pregnancy, that is lower than at 5 and 7 weeks of pregnancy but higher than during anoestrus (Table 2 and Fig. 1).

Although the relative difference between daytime (6:00 a.m.-12:00 p.m.) heart rates decreased with the course of gestation, they were higher than nighttime (12:00 p.m.-6:00 a.m.) rates for all periods ($p < 0.001$). When daytime and nighttime heart rates were analysed discretely as independent variables, the values were separated for all periods with the excep-

tion of those at 3 weeks of pregnancy and 4 weeks of lactation. This was similar to the overall results.

A few (<5 per 24 h) isolated supraventricular and ventricular beats were found sporadically in all dogs at various stages of pregnancy.

Discussion

This study involves, to our knowledge, the first serial measurements of heart rate in the same dogs, both day and night, throughout all reproductive periods. The findings show that the increase in heart rate during pregnancy is substantial in these beagle dogs from 3 weeks of pregnancy onwards.

Every morning the dogs became excited when the technicians arrived and fed them. The heart rate increased, which was expected both considering the excitement and the increased activity. It could be argued that 4 of the dogs were related and that this had influenced the results. This cannot be excluded, but our findings are in agreement with other reports in non-pregnant beagle dogs in which the heart rate was measured either by Holter recordings (*Ulloa et al.*

1995) or by telemetry (Miyazaki *et al.* 2002).

Our results illustrate that the marked difference between daytime and nighttime heart rates are comparatively small during late pregnancy. The mean hourly values over 24 h (between 120 and 130 beats per min) obtained during late pregnancy are considered to be quite high and are within the range found by auscultation at daytime in late pregnant dachshunds (Wegner & Dröge 1975).

It is well known that healthy non-pregnant dogs may have episodes of heart rates well above 200 heartbeats per min during exercise or excitement, but these episodes are usually limited in time. This makes it less likely that an acute stress episode caused such drastic and consistent increases in mean hourly values as found during late pregnancy in this study. The decreased difference between values obtained during the day and those obtained during the night in late pregnancy could possibly be attributed to the fact that the dogs already had such a high resting heart rate that movement during the day could not bring it much higher. Furthermore, because of abdominal distension and movement of the foetuses it is likely that the pregnant dogs could not rest comfortably during this period.

The heart rate increased progressively during pregnancy and was elevated also at lactation in our study. This is at variance with the report by Wegner & Dröge (1975), who did not find an elevated heart rate in lactating dogs. However, it is not clear from their study at which stage of lactation their investigations were done. Around 4 weeks after parturition the energy demands from the puppies are the greatest (Scantlebury *et al.* 2000). There is reason to suppose that there is a high demand for extra blood flow to the mammary gland until the time at which the puppies start to eat more food from other sources.

Conclusion

Our study shows that pregnancy and lactation cause marked increases in heart rate in the beagle dog indicating considerable physiological demands on the cardiovascular system. This may be important to consider in clinical practice.

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References

- Calvert CA, Jacobs GJ, Smith DD, Rathbun SL, Pickus CW: Association between results of ambulatory electrocardiography and development of cardiomyopathy during long-term follow-up of Doberman pinschers. *J. Am. Vet. Med. Ass.*, 2000, 216, 34-39.
- Hart MV, Hosenpud JD, Hohimer AR, Morton MJ: Hemodynamics during pregnancy and sex steroid administration in the guinea pig. *Am. J. Physiol.*, 1985, 249, R179-R185.
- Miyazaki H, Yoshida M, Samura K, Matsumoto H, Ikemoto F, Tagawa M: *Exp. Anim.*, 2002, 51, 95-98.
- Moore LG, Reeves JT: Pregnancy blunts pulmonary vascular reactivity in dogs. *Am. J. Physiol.*, 1980, 239, H297-H301.
- Oftedal OT: Lactation in the dog: Milk composition and intake by puppies. *J. Nutr.*, 1984, 114, 803-812.
- Olsson K, Hydbring E, Cvek K: Cardiovascular and fluid regulatory mechanisms during pregnancy and lactation in small ruminants. *Trends Comp. Biochem. Physiol.*, 1998, 5, 283-296.
- Peeters LL, Grutters G, Martin CB Jr: Distribution of cardiac output in the unstressed guinea pig. *Am. J. Obstet. Gynecol.*, 1980, 138, 1177-1184.
- Scantlebury M, Butterwick R, Speakman JR: Energetics of lactation in domestic dog (*Canis familiaris*) breeds of two sizes. *Comp. Biochem. Physiol. Part A.* 2000, 125, 197-210.
- SAS Institute. User's Guide: Statistics, version 6.12. 1996. SAS Institute Inc, Cary, NC, USA.
- Ulloa HM, Houston BJ, Altrogge DM: Arrhythmia prevalence during ambulatory electrocardio-

graphic monitoring of Beagles. *Am. J. Vet. Res.*, 1995, 56, 275-281.

Wegner Von W, Dröge P: Zur Statistik und zur endogenen und exogenen Komponente der Vitalfunktionswerte bei Teckeln (The endogenous and exogenous components of the vital functions of Dachshunds). *Berl. Münch. Tierärztl. Wschr.*, 1975, 88, 354-358. (In German).

Sammanfattning

Förändringar i hjärtfrekvensmönstret under dräktighet och laktation hos hund.

Dräktighet och laktation innebär att kardiovaskulära omställningar måste ske för att tillfredsställa fostren/valparnas behov. Syftet med föreliggande studie var att undersöka hur hjärtfrekvensmönstret påverkas under dräktighet och laktation. Eftersom hundar har en dygnsrytm med långa lugna perioder under dygnets mörka timmar var det av speciellt intresse att un-

dersöka hur dygnsvariationerna i hjärtfrekvensen påverkades. Fem kliniskt friska beaglar betäcktes och fick mellan 3 och 7 valpar. Hjärtfrekvensen registrerades under 24 timmar med Holter bandspelare en gång under anoestrus, en gång vid 3, 5, 7 och 9 veckors dräktighet samt 4 veckor efter förlossningen (laktation). Vid 9 veckors dräktighet kunde inte 24 timmars registrering genomföras hos 4 av tikarna eftersom förlossningen startade och västen med Holter bandspelaren då syntes irritera dem. Data vid denna tidpunkt ingår därför ej i statistiska jämförelsen. Hjärtfrekvensen ökade kontinuerligt under dräktigheten och var högre under laktation än under anoestrus. Skillnaden i hjärtfrekvens mellan natt och dag minskade allteftersom dräktigheten framskred, men hjärtfrekvensen var hela tiden högre under dagen än under natten. Sammanfattningsvis visar denna studie att dräktighet och laktation innebär en betydande påfrestning på det kardiovaskulära systemet hos hund, vilket bör beaktas i den kliniska verksamheten.

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