# Electrocardiographic evolution in cats from birth to 30 days of age

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**Abstract —** Further knowledge of feline physiology and neonatology is needed because the number of cats being kept as pets and used as experimental animals has increased. Few studies have been published on feline sequential electrocardiography. This study was conducted to determine the values of normal waves, complexes, and intervals of the electrocardiogram in clinically healthy feline neonates. Serial electrocardiography was performed in 15 female and 15 male neonates at 30 days of age. Parameters analyzed were heart rate and rhythm, duration and amplitude of electrocardiographic waves, duration of intervals, and the electrical axis of the heart. The results did not show differences between males and females. During the neonates' first 30 days of life, migration of the electrical axis from right to left was observed. There was a progressive increase in the R wave amplitude, while the S wave amplitude showed a progressive decrease. A sinus heart rhythm was predominant in the feline neonates.

**Résumé — Évolution électrocardiographie chez les chats, de la naissance jusqu'à l'âge de 30 jours.** Une connaissance plus approfondie de la physiologie et de la néonatalogie félines est nécessaire puisque le nombre de chats gardés comme animaux de compagnie et utilisés pour la recherche ont augmenté. Peu d'études ont été publiées sur l'électrocardiographie successive. Cette étude a été effectuée afin de déterminer les valeurs normales des ondes, des complexes et des intervalles de l'électrocardiogramme de chatons nouveau-nés et cliniquement sains. Des électrocardiographies en série ont été effectuées chez 15 femelles et 15 mâles nouveau-nés âgés de 30 jours. Les paramètres mesurés étaient le pouls et le rythme cardiaque, la durée et l'amplitude des ondes électrocardiographiques, la durée des intervalles et l'axe électrique du cœur. Les résultats ne révèlent pas de différence entre les mâles et les femelles. Pendant les 30 premiers jours de vie des chatons, une migration de l'axe électrique du coté droit vers le gauche a été observée. Il y a eu une augmentation progressive de l'amplitude de l'onde R, alors que celle de l'onde S a diminué progressivement. Un rythme cardiaque sinusal était prédominant chez les chatons nouveau-nés.

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## Introduction

The cardiac physiology of cats at birth differs from that of adults, and only a few studies have focused on sequential electrocardiographic examinations in felines (1). Therefore, the objective of this study was to determine the evolution of the electrocardiogram in clinically healthy kittens during the neonatal period by attempting to define normality in the neonatal age group, since there is no established pattern of normal electrocardiographic values for neonatal or young felines (1). In addition, it would serve as a model in understanding cardiac physiology in other species (2).

## Material and methods

Thirty newborn kittens (15 males, 15 females) of no defined breed and from 7 different litters were used. The average weight of their dams was 3.5 kg. All kittens were submitted to a physical examination and appeared to be normal and healthy.

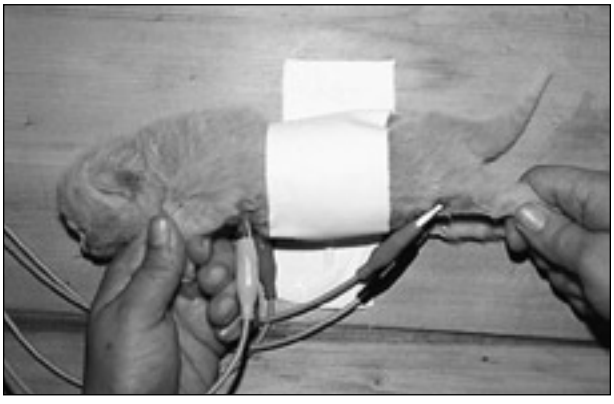

**Figure 1.** Restraint of the kitten for electrocardiographic exam

The electrocardiographic tests of the 30 unanesthetized kittens were started within the first 24 h after birth and

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**Table 1. Values of the electrocardiogram examination in neonates kittens**

| Parameters | Days of age | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 16 | 23 | 30 |
| Heart rate | 250 | 250 | 247 | 240 | 250 | 230 | 227 | 227 | 230 | 230 | 233 | 237 |
| P wave duration (s) | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| P wave amplitude (Mv) | 0.1 | 0.1 | 0.1 | 0.11 | 0.12 | 0.13 | 0.13 | 0.12 | 0.12 | 0.12 | 0.11 | 0.12 |
| PR interval duration (s) | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| QRS duration (s) | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.04 |
| R wave duration (s) | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.09 | 0.06 | 0.09 | 0.10 | 0.20 | 0.15 | 0.20 |
| S wave duration (s) | 0.16 | 0.2 | 0.14 | 0.16 | 0.17 | 0.17 | 0.16 | 0.16 | 0.15 | 0.11 | 0.12 | 0.15 |
| R/S amplitude (Mv) | 0 | 0.18 | 0 | 0 | 0 | 0.23 | 0 | 0.3 | 0 | 0 | 0 | 0 |
| QT interval duration (s) | 0.11 | 0.11 | 0.12 | 0.11 | 0.12 | 0.11 | 0.11 | 0.11 | 0.12 | 0.11 | 0.11 | 0.12 |
| Score electrical axis | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 5 | 5 | 5 |

s — seconds; mv — millivolt

were continued once a day until day 9 of age. Thereafter, the tests were performed at weekly intervals, that is, on days 16, 23, and 30 after birth.

Kittens were positioned in right lateral recumbency, with the fore and hind limbs at right angles to the long axis of the body, and held in position with adhesive tape (Figure 1). The electrodes were attached proximal to the olecranon on the caudal aspect of the appropriate forelimb and over the patellar ligament on the cranial aspect of the appropriate hind limb (Figure 1), as described previously (2). The recording was performed in silence, at normal room temperature.

The 12-channel electrocardiograph (ECG module for Computer Module ECG-PC TEB; Tecnologia Eletronica Brasileira, São Paulo, Brazil) was connected directly to an automatic microcomputer. The recording velocity used was 50 mm/s, the sensitivity was 1 mv (1 mv = 1 cm). All readings were obtained simultaneously in order to reduce the time of kitten restraint (Figure 1).

The following parameters were analyzed: P waves, QRS complexes, and the PR and QT intervals, in lead II to measure amplitude (mv) and duration (s). These parameters were calculated manually, even though they were generated automatically, to avoid artifacts in automatic ECG evaluation. The mean electrical axis was calculated by using multiple leads (hexaxial lead system formed by the 6 limb leads — I, II, III, $aV_R$, $aV_L$, $aV_F$) to obtain multiple orrientations to the average wavefront, keeping these leads at a constant distance from the heart.

Nonparametric statistical analyses (Friedman test and Mann-Whitney test) were performed: the Friedman test for the analysis of any possible effects of time (d) on each sex for each of the parameters evaluated, and the Mann-Whitney test for analysis of possible effects at each time, with the level of significance set at 5% (3). For the electrical axis variable, it was necessary to associate the scores with the original values.

## Results

There were no significant differences in the median heart rates (range 190 to 250 bpm) during the first 30 d of age (Table 1). Gender had no effect on any of the parameters studied.

Data recorded of P wave, PR intervals, duration of QRS complexes, and duration of the QT interval were similar to those established for adult cats (2,4–6), in terms of both amplitude and duration, and did not change during the 30 d of observation (Tables 1 and 2). However, there was a progressive increase in R wave duration (Table 1).

**Table 2. Values of the electrocardiogram examination in adult cats**

| Parameters adult cats | Normal range |
|---|---|
| Heart rate | 100–240 |
| P wave duration (s) | 0.04 |
| P wave amplitude (Mv) | 0.2 |
| PR interval duration (s) | 0.05–0.09 |
| QRS duration (s) | 0.04 |
| R wave duration (s) | 0.09 |
| S wave duration (s) | not reported |
| R/S amplitude (Mv) | not reported |
| QT interval duration (s) | 0.07–0.20 |
| Score electrical axis | 0 -+160 |

s — seconds; mv — millivolt

The vector of axis in the frontal plane showed a right deviation from -150º to +180º on the 1st d of life. During the following 30 d, the axis moved progressively to the left, and by day 30, it was between +180° and +120° (Figure 2).

The morphology of the QRS complexes differed markedly from that seen in the adult cat, with predominance of the S wave, as demonstrated in Figures 3 and 4 for cats at 1 and 30 d of age, respectively.

## Discussion

The heart rate obtained in this study was higher than that previously reported (3,5,6), but it was still within average heart rate values during the first 30 d of age of neonate cats (7,8). The values were similar to those obtained in feline neonates by Pagel (1). Compared with the adult, the kitten has a lower blood pressure, stroke volume, and peripheral vascular resistance. The young animal, however, has a higher heart rate, cardiac output, plasma volume, and central venous pressure (9). Autonomic innervation of the heart and vasculature is incomplete in newborn kittens, providing them with little baroreflex control of circulation (10,11).

A progressive increase in R wave amplitude, which started about the 1st wk of life, may be related to the development of the left ventricle in relation to the right one during the neonatal phase, which corresponds with

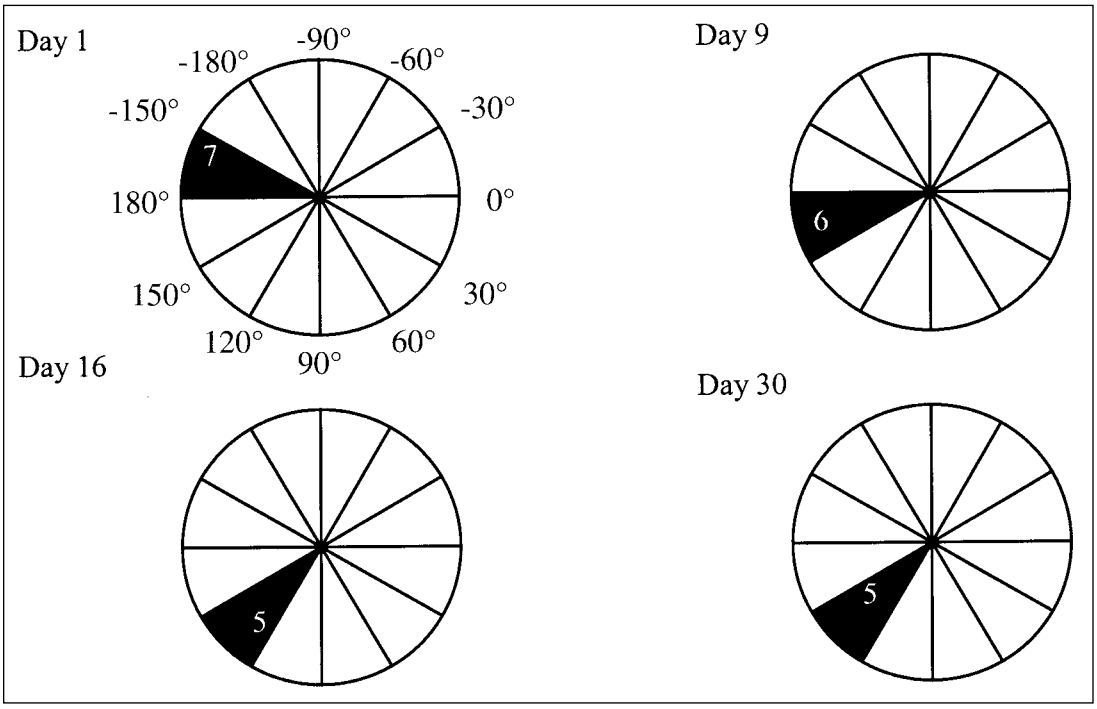


**Figure 2.** Mean position of score of electric cardiac axis in newborn kittens by age in days.


**Figure 3.** A sample of the most common QRS morphologies in the frontal planes in a cat at 1 d of age

the development of the left heart, as described previously (9,12,13).

The amplitude of the S wave showed a decrease during the 30 d of the recordings, probably resulting from progressive hypertrophy of the left ventricular mass rather than from a decrease in the right ventricular mass.

The R/S coefficient is expressed by the relation between the amplitude of the R wave and the amplitude of the S wave (Table 1). This coefficient could represent the development of the left ventricle in relation to the right. In the present study, although a marked alteration in the amplitude of the R and S waves occurred, the R/S relationship did not differ during the study period of 30 d. The amplitude of the R wave never exceeded that of the S wave, in contrast to what is observed in most adult cats. The R/S coefficient observed here showed that it probably happens with increasing age. Pagel (1) reported that the R/S coefficient is altered after the 6th wk of life in kittens. The leftward shift occurs physiologically due to the increase in the systemic blood pressure, the decrease in lung pressure, and the closing of the ductus arteriosus after birth (10,11,14). The differences in growth of the 2 ventricles can be considered to be a direct consequence of the alterations of the mechanical force


**Figure 4.** A sample of the most common QRS morphologies in the frontal planes in a cat at 30 d of age.

of heart work, in agreement with our results (11,12,15–17).

The migration of the mean electric axis is not completed at 30 d of age. This is based on the fact that although 120° to 150° is within the normal electric axis range for adults (0° to 160°), many adult cats are below 120° (5). This is because of a net positive QRS, due to the amplitude of the R wave in lead II being greater than that of the S wave. Since the R/S ratio never became positive in our study, it would be useful clinically to know when predominance of the left heart can be recorded in the electrocardiogram and how long it takes to reach the adult patterns.

In conclusion, the present study showed that the electrocardiographic parameters analyzed are not influenced by sex. The mean electric axis starts to deviate from the right to the left at birth and continues to do so during the 1st mo of life. In feline neonates, as well as in other species, there was a progressive increase in R wave amplitude and a progressive decrease in S wave amplitude during the first 30 d of life. The electrocardiographic values of heart rate, duration and amplitude of the P wave, and PR and QT intervals, as well as the duration of the QRS complex, in the feline neonates were within the normal patterns specified for adult cats. CVJ

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