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ELECTROCARDIOGRAM STUDIES IN LLAMAS

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Electrocardiograms (ECG) of 3 captive llamas (*Lama glama*) were recorded by a telemeter at a farm in Japan. The pattern of the ECGs was similar to the ruminant pattern in the AB lead position. QRS and T-waves were discordant in polarity except in one llama, where the polarity of the T wave changed according to the HR. In the quiet state, the HR varied between 60–80 / min depending on the nervousness of the llama. After running and after being held, the HR increased to more than 100 / min. During the recordings there were some variations of the HR which could be due to respiratory arrhythmia. Second-degree AV block and supraventricular premature complexes were also found in two llamas.

Key words: ECG, South American camels, llama

INTRODUCTION

There are four species of South American camels. Two are domesticated, the llama and the alpaca while the other two are wild, *i.e.* the guanaco and the vicuna. They live in the Andes Mountains at altitudes between 1000 and 3500 m (11). This makes their circulatory physiology interesting. One might anticipate that their electrocardiograms (ECGs) would differ from those seen in other ruminants (10).

In November 1988, the ECGs of three captive llamas (*Lama glama*) were taken at "Haidi Farm", Hokkido, which has an altitude of approximately 150m. The results were analyzed at the Faculty of Veterinary Medicine of the University of Hokkaido, Japan.

MATERIALS AND METHODS

The group of llamas consisted of two females and one male. One female (F1), 5 years old, was the dam of the second female (F2), 1 1/2 years old. The male (M), 4 years old, was the sire. The ECG was recorded by a telemeter (Fig. 1; DS–882,

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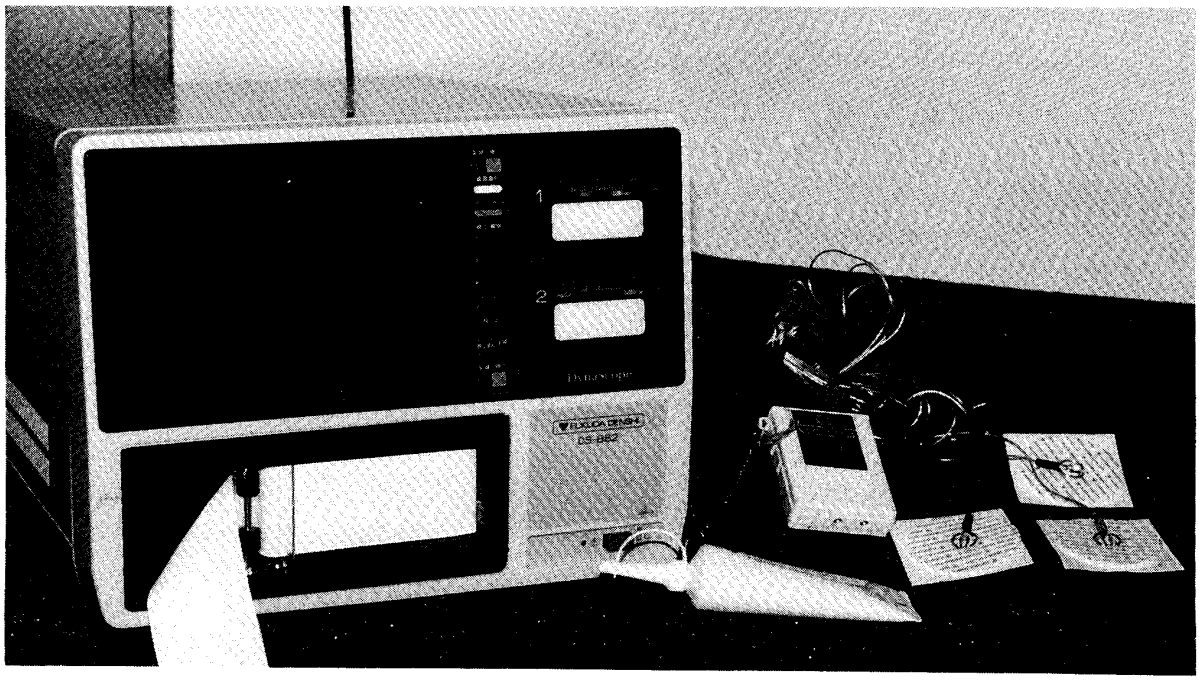

Fig. 1 Telemeter used during recording of the ECG

The electrodes were connected to a battery-operated transmitter which was small and light (5.5cm×9cm×2cm, 134g). The transmitter, attached to the wool on the back of the animal, transmitted electric signals to a receiver which decoded and inscribed them on paper. Because of the small size of the transmitter, the maximum distance allowed between the transmitter and the receiver was 30m.

Because the llama has a wooly back, and shorter hair on its abdomen, it was unnecessary to clip the hair to place the electrodes (Red dot, 3M Co., U. S. A.). Three electrodes were fixed with "glue" in the AB lead position. They were placed on the left side of the thorax near the sternum, caudal to the forelimb (A), on the base of the neck (B), and on the left side of the lower abdominal or inguinal area (for the antenna) (Fig. 2). Working as quietly as possible to reduce the stress to the animals, the llamas were restrained around the neck and the electrodes placed quickly and easily in their respective positions. The animals were then left alone in the enclosure for the ECG to be recorded.

The ECG was recorded at two speeds: at 25 mm / sec, where the heart rate (HR) was calculated by measuring each SS interval as for instantaneous heart rate, and at 50 mm / sec, where the duration of P, QRS, T, QT, interval P-R and HR were calculated.

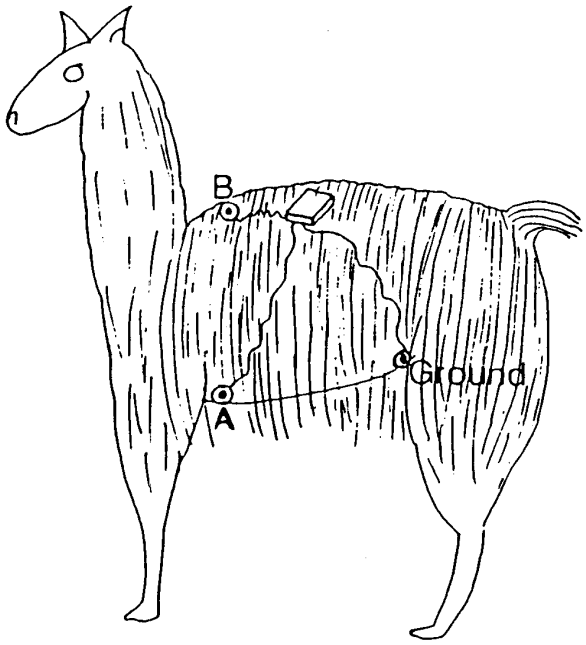

Fig. 2 Position of the electrodes for the AB lead

RESULTS

CONFIGURATION OF ECG :

The patterns of the ECGs were similar to the ruminant pattern in the AB lead as shows in Fig. 3. The values for each interval and duration of the ECG are shown in

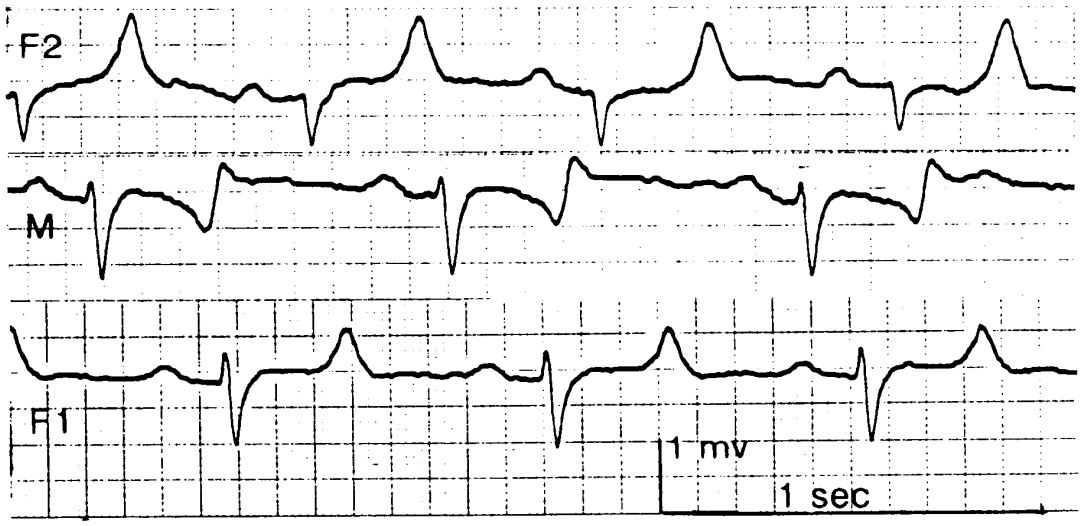

Fig. 3 ECG patterns of the three llamas

TABLE 1. The values for each interval and duration of the ECG

sec	F1 (n=134)	F2 (n=118)	M (n=134)
P	0.11±0.1400	0.096±0.010	0.10±0.010
P–R	0.19±0.1400	0.170±0.017	0.17±0.010
QRS	0.10±0.0070	0.090±0.012	0.10±0.008
T	0.14±0.0100	0.130±0.010	0.14±0.020
QT	0.40±0.0008	0.380±0.010	0.37±0.050

Table 1. The P wave positive and usually had a monophasis pattern. The main QRS deflection was negative, being of the rS QS type. The T wave was monophasic and positive in both females, but in the male it changed its polarity according to the HR.

CHANGES OF HR:

The HR of llama F1 moved between 60 and 100 / min, excluding the extremes values. This is a relatively short range and could be due to the fact that she was very tame, and did not appear to be restless; however, any movement from our part did provoke an alert reaction from her. Llama F2 was restless and nervous. It was difficult to restrain her, and we made her run. In the beginning of the recording the HR was between 100 and 140 / min; after some minutes the HR decreased, as the animal got quiet, staying between 70 and 100 / min. At the end of the recording, F2 went out of the enclosure, and ran a little; this resulted in an increase of the HR to higher than 100 / min.

Llama M was less nervous, but not as tame as llama F1. It was also difficult to restrain her, resulting in a high HR in the beginning of the recording, more than 100 / min. After a moment the HR decreased, reaching about 60 / min for a long period. At the end of the recording, this llama went out of the enclosure and the HR increased up to 141 / min (Tab. 2 and Fig. 4).

HR AND T-WAVE PATTERN:

Llama F1 and F2 consistently had the same discordant pattern that characterized the ruminants, a negative QRS and a positive T wave (Fig. 3). In the case of llama M, the T wave changed its polarity according to the HR. For an HR of 114–122 / min, the T wave was posittve. For an HR of 111 to 97 / min, the T wave changed its

TABLE 2. Changes of the heart rate in llamas

HR/min	F1	F2	M
$\bar{x}$±SD	73.93±8.72	93.85±17.88	81.86±19.29
max.	111.94	169.49	141.50
min.	50.0	51.37	55.76

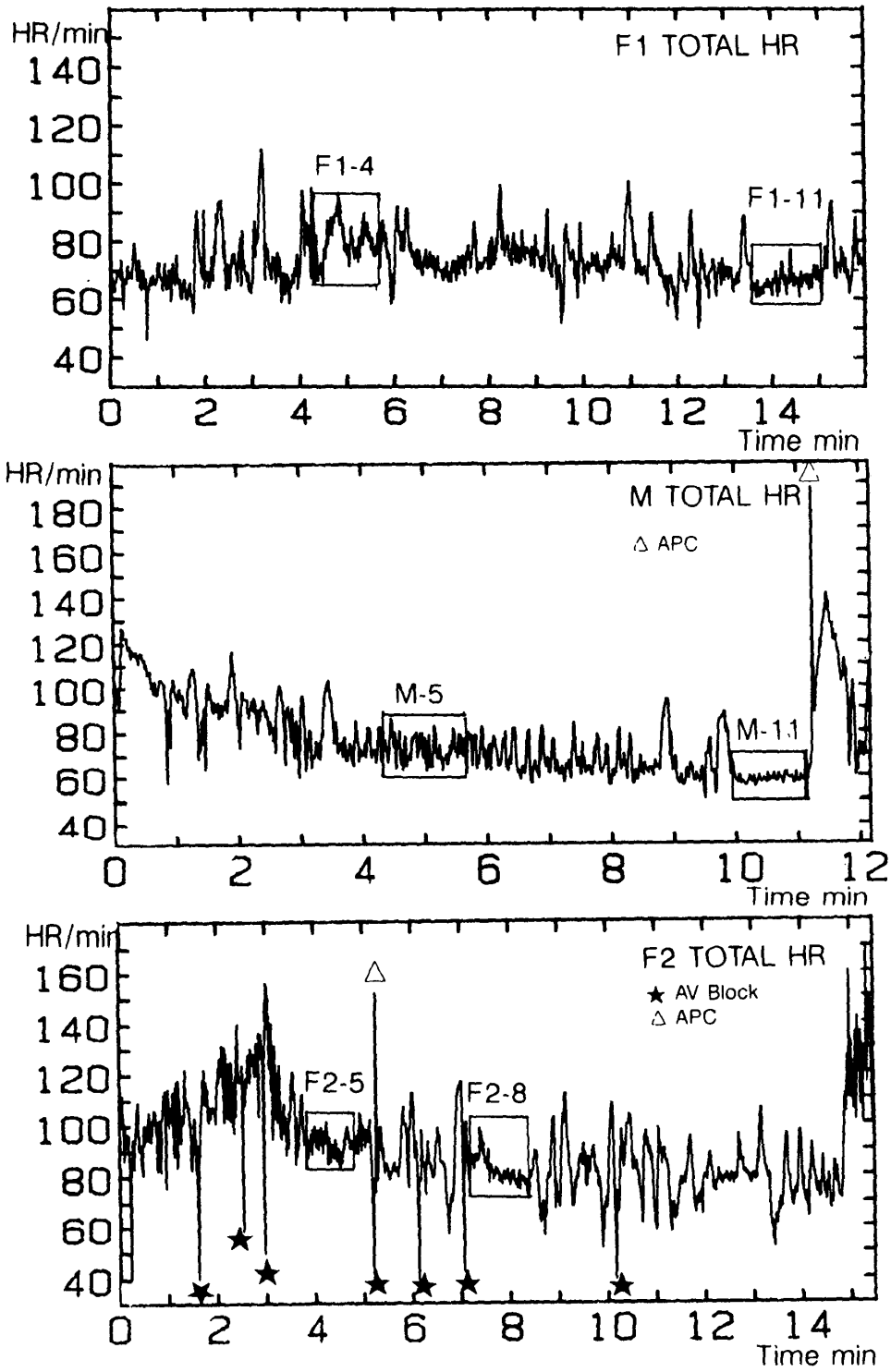

Fig. 4 Total HRs for llamas F1, M and F2

polarity from positive to biphasic: the first portion of the T wave going gradually under the baseline to form a negative deflection of the new biphavlc T wave, for an HR of 95–84 / min. Sometimes, the second portion of the T wave gradually decreased and formed a completely negative deflection. However, for the HR of 97–60 / min the T wave was continuously biphasic (Fig. 5).

Fig. 5 Changes of T-wave polarity according to the HR

A: T-wave polarity positive for HR: 114–122 / min

B: Change of T-wave polarity from positive to biphasic HR: 97–111 / min

C: Change of T-wave polarity from biphasic to negative HR: 84–95 / min

D: Change of T-wave polarity from negative to biphasic HR: 63–96 / min

RESPIRATORY ARRHYTHMIA:

The respiratory rate (RR) was not measured simultaneously with the recording of ECG. The RR was taken when the animals were feeding, and varied from 11 to 18 / min. Figure 6 shows portions of the total HR shown in Fig. 4. In these figures we can see variations of th HR drawn like waves, if we count the number of waves in one minute, the values are similar to the RR found separately (Tab. 3).

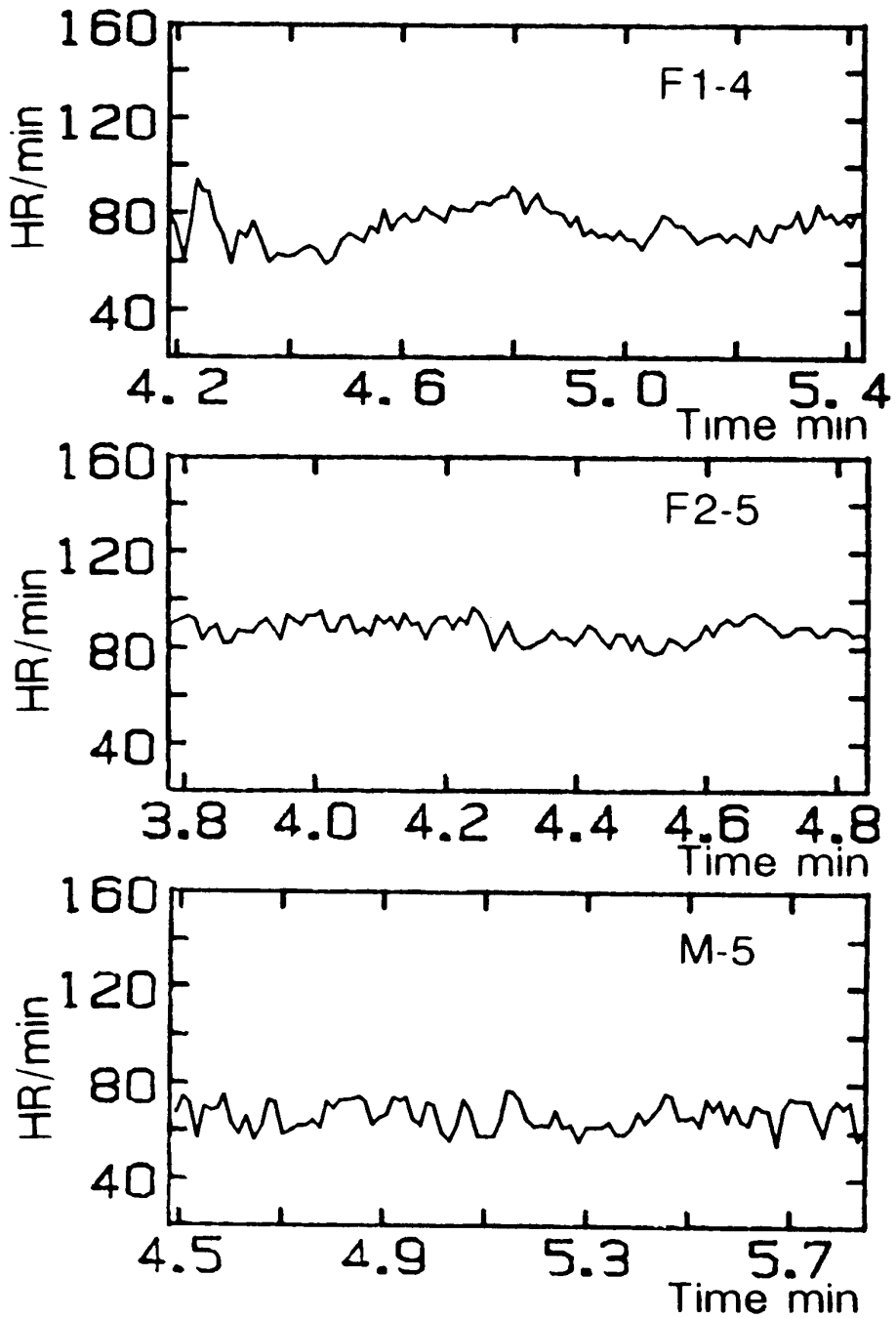

Fig. 6 Respiratory arrhythmia

Portions of the total HR of each llama. The frequency of the waves could be compared to the respiratory rate.

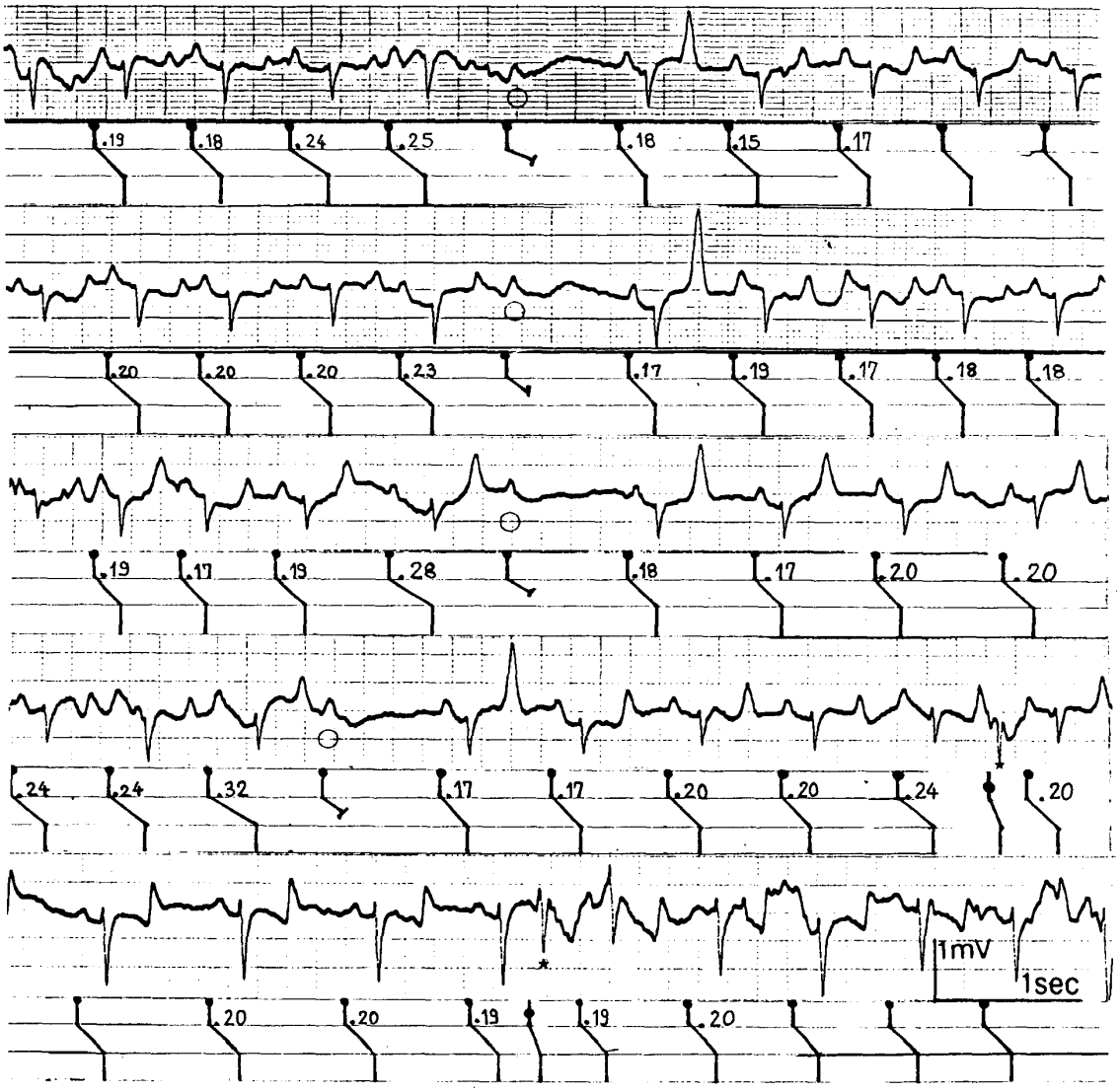

Fig. 7 Arrhythmias

Second-degree AV block (○) and supraventricular premature complex (*) of llama F2 and llama M.

TABLE 3. The values of the respiratory rate in llamas

Part of * Total HR	HR median for each part	duration of each part(sec)	number of waves	waves/min or possible RR
F1–4	81±7.0	73.81	18	14.6
F1–11	66±3.0	89.73	24	16.0
F2–5	93±4.0	64.15	19	17.7
F2–8	82±5.0	72.89	19	15.6
M–5	73±5.0	81.93	15	11.0
M–11	59±2.5	99.21	15	9.0

* see Fig. 4

ARRHYTHMIA :

In the case of llama F2, a second-degree AV block was found (Fig. 7). There was a prolongation of the P-R interval one or two complexes before the second-degree AV block occured, possibly the Wenckebach phenomenon (9). Supraventricular premature complexes were found in llamas F2 and M, with no compensatory pause (9) (Fig. 7).

DISCUSSION

It is well known that pulmonary hypertension, and consequent right ventricular hypertrophy, occurs in humans and animal living at high altitudes (1, 6). But in the viscacha (Lagidium peruanum) and llama, there is anatomical evidence that this does not occur (quoted in 3). Harris et al. (1982) found slight pulmonary hypertension, which disagrees with the findings of Banchero et al. (1971). However, these llamas did not have right ventricular hypertrophy, and the walls of the pulmonary trunk and small pulmonary arteries were thin. This was probably due to slight pulmonary hypertension and other mechanisms of altitude adaptation such as elevated levels of oxidative enzymes (5).

The ECG pattern, QRS and T-wave discordance in polarity, were similar to those found in other ruminants such as the bovine (8). This was true of llamas F1 and F2. In the case of llama M, as the HR was decreasing, the T wave was changing its polarity from positive to biphasic, then to negative and biphasic again. The HR, sympathetic nervous system, electrolyte imbalance, gas level and pH of blood, can modify the polarity and amplitude of the T wave (9). Anyone of these factors could be the reason for the change in polarity of the T wave in llama M. However, in this study it seemed that the changes of the T wave pattern may have been correlated to the HR.

The P-R intervals, and durations of QRS and QT, described by Martinez et al. (1988) in llamas living at high altitude and at sea level were slightly different but not

statistically significant. At sea level, the P-R interval was 0.14±0.5 sec, the duration of QRS was 0.055±0.01 sec and that of QT was 0.347±0.03 sec. At high altitude the durations and the intervals were 0.188±0.03 sec for P-R, 0.067±0.013 for QRS and 0.371±0.036 sec for QT. The values of P-R and QT for llamas living at high altitude are similar to those found in our study in llama living at low altitude, but the duration of QRS was longer in our animals. This supports the observation that there is no electrocardiographical difference between animals at low and high altitude. In our study it was not possible to calculate the mean electrical axis deviation because of the recording method (AB lead). Martinez et al. (1988) described a positive cephalic axis deviation, which was the same for animals living at different altitudes. This was probably due to the ventricular vector, which has an apex-to-base direction and not due to an enlargement of the right ventricule.

ECG were taken without any kind of tranquilizer or anesthesia. The HR values are probably higher than values taken from medicated animals, since our presence interfered with their behavior. At the beginning of recording, the three llama were still afraid and excited because of our manipulation while placing the electrodes, resulting in an increase of the HR to more than 100 / min. During recording, when they were quieter, the HR decreased to 60 / min. F2, which was by far the most nervous, had the highest HR of the three, followed by M and F1, the latter being the calmest and friendliest, with the lowest HR. At the end of recording llama F2 and llama M went out of the enclosure, resulting in an increase of the HRs similar to the HRs just after they were held.

Martinez et al. (1988) found an HR 71±29.3 / min for sea level animals and 72.88 ±14.9 / min for high altitude animals, both taken while resting. Harris et al. (1982) found a median of 63 / min in 12 llamas at 4200m, after waiting one hour for stabilization of the HR. Banchero et al. (1971) reported that during exercise llama HRs increased more than 110 / min, up to 180 / min. All these values are in agreement with our findings.

It was not possible to measure the respiratory rate (RR) simultaneously with the ECG recordings. But there were slight variations of the HRs coincident with the RRs counted separately. These variations of the HR could be due to the respiratory movements, called respiratory arrhythmia.

Two kinds of arrhythmia were found: AV block and supraventricular premature complex. Llama F2 had both kinds of arrhythmia, but not often enough to cause any failure or any symptoms. The AV block was preceded by a prolongation of the P-R interval and followed by a normal QRS complex with a tall T wave. Llamas M and F2 had supraventricular premature complexes with no compensatory pauses.

Trying to interfere as little as possible with the normal life of the animals, in this study the ECG were recorded with a telemeter. The use of the telemeter is advisable for future research because of its ease of operation and the possibility of

observing changes in the HR without disturbing the animals.

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