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AN ELECTROCARDIOGRAPHIC STUDY OF NORMAL GOATS AND CATTLE USING A MODIFIED TECHNIQUE

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ABSTRACT

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An electrocardiographic technique, developed in sheep in the standing position, was applied to normal cattle and goats. Recordings were made with Einthoven's triangle in the sagittal plane and with the electrodes in rigidly fixed positions in relation to the heart. Waves of high amplitude and reproducible configurations were obtained in 22 goats and 15 cattle.

INTRODUCTION

Cardiac disorders of domestic animals caused by the ingestion of plants containing heart poisons are common in South Africa. Such syndromes can be properly investigated only if the electrocardiographic (ECG) properties of normal animals are known. Uniform ECG recordings could not be demonstrated in normal cattle (Alfredson & Sykes, 1942) and goats (Szabuniewicz & Clark, 1967; Pretorius & Terblanche, 1967) using standard limb and unipolar leads. For this reason Schultz, Pretorius & Terblanche (1972) developed a modified ECG recording technique in unanaesthetised standing sheep that gave more reproducible results. To reduce the large ECG variations obtained when recordings are made with Einthoven's triangle in the ventral plane, the triangle was moved to the sagittal plane in this investigation.

MATERIALS AND METHODS

Daily ECG and phonocardiographic recordings were made for 5 days on 22 clinically normal goats. Their ages, sexes and masses were as follows: 10 four-tooth and over ewes between 22 and 39 kg and 12 four-tooth to full mouth wethers between 20 and 49 kg.

In addition daily ECG recordings were made for 6 days on 15 clinically normal cattle. Their ages and sexes were as follows: five four-tooth and over cows, four milk-tooth heifers, one milk-tooth and one two-tooth bull and four milk-tooth steers.

Before making a recording of a goat it was placed in a wooden crate with a wooden floor and its head was fixed by means of a leather strap and buckle. Lateral movement was controlled by a horizontal metal pipe on each side of the crate. The cattle stood in a wooden crush with their feet on wooden slats. Subcutaneous needle electrodes were positioned according to Schultz *et al.* (1972) so as to place Einthoven's triangle on a sagittal plane. The electrodes were placed on the head between the ears, on the sacrum and medially in the sternal region, in goats 2 cm anterior to the infrasternal angle and in cattle midway between the two olecranons when the animal's front legs were in the normal standing position.

An Elema Mingograph 81 multichannel recorder at a sensitivity of 1 cm = 1 mV was used. The paper speed was 100 mm/s. The heart rate, various time intervals, wave forms and wave amplitudes were determined from these registrations. The sagittal plane QRS electrical axes were calculated by determining the algebraic sum of the deflections on leads I and II as described by Rushmer (1961).

The QRS configuration for each ox and goat was determined in all six leads. The nomenclature used for the QRS wave shapes followed that of Szabuniewicz & Clark (1967), where the first and second downward waves were successively denoted as Q and S and the first upward wave as R. The relative amplitudes of the different waves were indicated by the use of small and capital letters.

The QT times were corrected according to Bazett's formula: corrected QT = measured QT/$\sqrt{RR}$ (Alfredson & Sykes, 1942).

An Elema microphone was used for phonocardiographic recordings. The duration of mechanical systole was calculated as being the time interval between the beginning of the first and the beginning of the second heart sounds.

The data were processed by computer to determine the mean values and standard deviation for each individual animal (within-animal) as well as those of all the goats and cattle when regarded as distinct groups (between-animal).

STUDIES ON GOATS

Results

A. *Heart rate and time intervals*

The heart rate of the 22 goats varied between 70 and 137 beats/min with a mean of 102 and a standard deviation of 16 (Table 1). The values of the minimum, maximum, mean and standard deviation of the heart rate and time intervals for all leads are also shown in Table 1. In Tables 2, 3 and 4 the same parameters from three goats (random samples) are given. For example, in lead II of Goat 571 the mean durations of the PR, QRS and QT intervals were 0,139; 0,050 and 0,408s respectively (Table 2), whereas the same means for all the goats were 0,127; 0,048, and 0,380s (Table 1).

B. *Wave amplitudes and configurations*

P wave

The amplitudes of the P waves in leads I, II and aVR were of satisfactory height, with mean values of 0,122; 0,129 and 0,121 mV respectively, whereas those in leads III and aVL were unreliably small (Table 5). The configuration of the P wave in leads I and II showed daily variation between single and double positive waves (Fig. 1) in 9% of the goats (Table 6). Single positive wave forms, however, occurred more frequently than double ones (Table 6). The P waves in lead aVR always had a negative form. The configurations are given in Table 6.

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TABLE 1 The time intervals (s) of the PR, QRS and QT waves of the electrocardiogram of 22 goats[1]
Heart rate/min: 102 ± 16 (70 - 137)

Lead	PR	QRS	QT[2]
I	0,128 ± 0,016 (0,090 — 0,170)	0,035 ± 0,006 (0,020 — 0,050)	0,374 ± 0,033 (0,281 — 0,447)
II	0,127 ± 0,017 (0,085 — 0,170)	0,048 ± 0,008 (0,030 — 0,065)	0,380 ± 0,038 (0,275 — 0,455)
III	0,118 ± 0,017 (0,085 — 0,160)	0,048 ± 0,007 (0,030 — 0,070)	0,378 ± 0,037 (0,264 — 0,442)
aVR	0,128 ± 0,017 (0,075 — 0,170)	0,047 ± 0,007 (0,030 — 0,070)	0,380 ± 0,033 (0,287 — 0,470)
aVL	0,121 ± 0,016 (0,090 — 0,170)	0,033 ± 0,010 (0,010 — 0,065)	0,375 ± 0,033 (0,275 — 0,470)
aVF	0,124 ± 0,018 (0,070 — 0,170)	0,049 ± 0,007 (0,030 — 0,065)	0,381 ± 0,034 (0,271 — 0,470)

[1]Mean values of 110 recordings are expressed with ± standard deviation; minimal and maximal values are in parentheses
[2]Corrected

TABLE 2 The time intervals (s) of the PR, QRS and QT waves of the electrocardiogram of Goat 571[1] (six-tooth wether)
Heart rate/min: 91 ± 12 (76 - 103)

Lead	PR	QRS	QT[2]
I	0,136 ± 0,008 (0,130 — 0,150)	0,045 ± 0,005 (0,040 — 0,050)	0,414 ± 0,017 (0,395 — 0,447)
II	0,139 ± 0,012 (0,120 — 0,150)	0,050 ± 0,001 (0,050 — 0,053)	0,408 ± 0,013 (0,383 — 0,421)
III	0,119 ± 0,008 (0,106 — 0,130)	0,050 ± 0,001 (0,050 — 0,053)	0,414 ± 0,023 (0,372 — 0,437)
aVR	0,136 ± 0,004 (0,130 — 0,140)	0,046 ± 0,008 (0,040 — 0,060)	0,407 ± 0,012 (0,393 — 0,421)
aVL	0,123 ± 0,008 (0,110 — 0,130)	0,049 ± 0,007 (0,040 — 0,060)	0,398 ± 0,017 (0,372 — 0,421)
aVF	0,138 ± 0,012 (0,120 — 0,150)	0,051 ± 0,004 (0,050 — 0,060)	0,396 ± 0,016 (0,372 — 0,421)

[1]Mean values over a period of 5 days are expressed with ± standard deviation; minimal and maximal values are in parentheses
[2]Corrected

TABLE 3 The time intervals (s) of the PR, QRS and QT waves of the electrocardiogram of Goat 1537 (four-tooth wether)
Heart rate/min: 86 ± 7 (78 - 94)

Lead	PR	QRS	QT[1]
I	0,122 ± 0,013 (0,110 — 0,140)	0,030 ± 0,004 (0,025 — 0,035)	0,410 ± 0,009 (0,395 — 0,425)
II	0,119 ± 0,016 (0,100 — 0,140)	0,046 ± 0,004 (0,040 — 0,050)	0,405 ± 0,005 (0,397 — 0,412)
III	0,122 ± 0,014 (0,100 — 0,136)	0,050 ± 0,000 (0,050 — 0,050)	0,405 ± 0,005 (0,397 — 0,412)
aVR	0,114 ± 0,009 (0,105 — 0,125)	0,039 ± 0,003 (0,036 — 0,045)	0,404 ± 0,007 (0,390 — 0,412)
aVL	0,124 ± 0,009 (0,115 — 0,135)	0,038 ± 0,007 (0,030 — 0,050)	0,405 ± 0,007 (0,395 — 0,413)
aVF	0,117 ± 0,013 (0,100 — 0,130)	0,047 ± 0,004 (0,040 — 0,050)	0,413 ± 0,010 (0,400 — 0,425)

[1]Corrected

TABLE 4 The time intervals (s) of the PR, QRS and QT waves of the electrocardiogram of Goat 1542 (six-tooth ewe)
Heart rate/min: 123 ± 8 (113 - 131)

Lead	PR	QRS	QT[1]
I	0,121 ± 0,004 (0,120 — 0,130)	0,033 ± 0,004 (0,030 — 0,040)	0,372 ± 0,015 (0,358 — 0,402)
II	0,123 ± 0,005 (0,120 — 0,130)	0,050 ± 0,005 (0,045 — 0,060)	0,387 ± 0,011 (0,373 — 0,402)
III	0,105 ± 0,008 (0,100 — 0,120)	0,047 ± 0,004 (0,040 — 0,050)	0,391 ± 0,025 (0,368 — 0,441)
aVR	0,119 ± 0,007 (0,110 — 0,130)	0,050 ± 0,000 (0,050 — 0,050)	0,383 ± 0,017 (0,367 — 0,416)
aVL	0,116 ± 0,002 (0,115 — 0,120)	0,032 ± 0,006 (0,025 — 0,040)	0,366 ± 0,013 (0,352 — 0,388)
aVF	0,114 ± 0,007 (0,110 — 0,125)	0,048 ± 0,005 (0,040 — 0,055)	0,389 ± 0,006 (0,382 — 0,402)

[1]Corrected

The minimum, maximum, mean and standard deviation of the P wave amplitudes for all the goats are given in Table 5 and for the three individual goats are given in Tables 7, 8 and 9. In Fig. 2 the ECG recordings for one goat on 3 different days are given and in Fig. 3 the single recordings of three different goats.

QRS wave

Values of the minimum, maximum, mean and standard deviation of the QRS amplitude for all the goats are given in Table 5, and the values for three individual goats in Tables 7, 8 and 9. Except in lead aVL, where a small mean amplitude of 0,355 mV was recorded, the amplitudes of the QRS waves varied between 0,594 and 0,977 mV.

The configurations of the QRS waves of all the goats are given in Table 6. In Fig. 2 and 3 the daily within-goat and between-goats variations are illustrated. The configuration of the QRS wave in leads II, III and aVF were of the RS type though the amplitude of the R wave varied evenly between values smaller and bigger than 0,1 mV (rs and RS respectively). The same configurations were obtained in lead I except that the R wave was absent in 13% of the cases and that a qR configuration occurred in one goat.

Although they were uncommon, notched R and S waves occurred in leads I, II, aVR, aVL and aVF. Notched S waves in lead I are illustrated in Fig. I.

T wave

Except in lead aVL, where it commonly had a very low amplitude, T waves with satisfactorily large amplitudes were encountered in all the leads. In Table 5 the minimum, maximum, mean and standard deviation of the T wave of all the goats are shown and those of three individuals are reflected in Tables 7, 8 and 9. Much within-goat variation was encountered in the configuration of the T wave during consecutive days.

The T waves in leads I, II and aVL showed the smallest between-goats variation (Fig. 3 and Table 6), whilst the smallest within-goat variation encountered on different days occurred in lead I (Fig. 2 and Table 6). In Table 6 the T wave configurations of all goats are given.

C. *Electrical axis and mechanical systole*

The QRS electrical axis in the sagittal plane had a mean value of —110° ± 27° for all the goats (Table 10). This indicated that the mean vector was directed dorso-anteriorly (Fig. 4). These values varied from —43° to

TABLE 5 The amplitudes (mV) of the P, QRS and T waves of the electrocardiogram of 22 goats[1]

Lead	P	QRS	T[2]
I	0,122 ± 0,041 (0,050 — 0,200)	0,594 ± 0,177 (0,250 — 1,100)	0,245 ± 0,113 (0,050 — 0,600)
II	0,129 ± 0,046 (0,050 — 0,200)	0,977 ± 0,273 (0,400 — 1,750)	0,323 ± 0,176 (0,100 — 1,000)
III	0,058 ± 0,025 (0,000 — 0,150)	0,787 ± 0,269 (0,300 — 1,550)	0,181 ± 0,093 (0,050 — 0,550)
aVR	0,121 ± 0,039 (0,050 — 0,200)	0,739 ± 0,189 (0,400 — 1,300)	0,264 ± 0,141 (0,050 — 0,800)
aVL	0,064 ± 0,023 (0,050 — 0,150)	0,355 ± 0,198 (0,050 — 1,100)	0,098 ± 0,054 (0,000 — 0,300)
aVF	0,081 ± 0,031 (0,020 — 0,200)	0,859 ± 0,246 (0,350 — 1,600)	0,239 ± 0,127 (0,050 — 0,800)

[1]Mean values of 110 recordings are expressed with ± standard deviation; minimal and maximal values are in parentheses
[2]Corrected

TABLE 6 The configuration of the ECG waves of 22 goats in percentages

Wave	Lead	Configuration													Percentage showing variation from predominant configuration[1]
		+−	++	+	−+	−	RS	rS	R	qR	QR	QS	QRS	Qr	
P	I		*	100*											9
	II		14*	86*											9
	III			73*		27*									33
	aVR					100									0
	aVL			100											0
	aVF		9*	91*											9
QRS	I						41*	41*		5		13			5
	II						50*	50*							13
	III						50*	50*							9
	aVR								9*	55*	36*				13
	aVL						*		13*	33*	13*	9*	27*	5	33
	aVF						50*	50*							13
T	I			95*	5*	*									13
	II	*		91*	9*	*									27
	III	13*		61*	13*	13*									33
	aVR			18*		82*									13
	aVL	*		95*	5*	*									13
	aVF	9*		69*	13*	9*									45,5

[1]Percentage goats with intermittent daily variation from predominant configuration as indicated by *

TABLE 7 The amplitudes (mV) of the P, QRS and T waves of the electrocardiogram of Goat 571

Lead	P	QRS	T
I	0,100 ± 0,000 (0,100 — 0,100)	0,710 ± 0,082 (0,600 — 0,800)	0,279 ± 0,135 (0,100 — 0,450)
II	0,100 ± 0,000 (0,100 — 0,100)	0,889 ± 0,151 (0,700 — 1,000)	0,399 ± 0,254 (0,100 — 0,700)
III	0,050 ± 0,000 (0,050 — 0,050)	1,129 ± 0,148 (0,900 — 1,300)	0,219 ± 0,075 (0,100 — 0,300)
aVR	0,100 ± 0,000 (0,100 — 0,100)	0,659 ± 0,089 (0,600 — 0,800)	0,319 ± 0,175 (0,100 — 0,500)
aVL	0,050 ± 0,000 (0,050 — 0,050)	0,629 ± 0,083 (0,500 — 0,700)	0,139 ± 0,065 (0,100 — 0,250)
aVF	0,059 ± 0,022 (0,050 — 0,100)	1,009 ± 0,082 (0,900 — 1,100)	0,219 ± 0,175 (0,050 — 0,500)

—170°. The above values for three individual goats are shown in Table 10.

Mechanical systole is the time interval between the starting points of the first and second heart beats, as determined on the phonocardiogram. This was found to be 0,316 ± 0,024s (0,250 - 0,376). In Table 10 the data for three individual goats and for the group as a whole are given.

DISCUSSION

The mean heart frequency of 102 beats/min obtained in 22 goats during this investigation is comparable with the results of Jha, Lumb & Johnston (1961) working with seven goats and those of Szabuniewicz & Clark (1967) working with 100 goats. The same holds true for the time intervals recorded. These authors, however, respectively found a slightly shorter QT interval

TABLE 8 Amplitudes (mV) of the P, QRS and T waves of the electrocardiogram of Goat 1537

Lead	P	QRS	T
I	0,069 ± 0,027 (0,050 — 0,100)	0,769 ± 0,044 (0,700 — 0,800)	0,139 ± 0,096 (0,050 — 0,300)
II	0,059 ± 0,022 (0,050 — 0,100)	1,035 ± 0,047 (0,980 — 1,100)	0,299 ± 0,070 (0,200 — 0,400)
III	0,053 ± 0,028 (0,020 — 0,100)	0,889 ± 0,108 (0,750 — 1,000)	0,219 ± 0,057 (0,150 — 0,300)
aVR	0,059 ± 0,022 (0,050 — 0,100)	0,870 ± 0,044 (0,800 — 0,900)	0,229 ± 0,057 (0,150 — 0,300)
aVL	0,050 ± 0,000 (0,050 — 0,050)	0,449 ± 0,070 (0,350 — 0,500)	0,073 ± 0,037 (0,020 — 0,100)
aVF	0,050 ± 0,000 (0,050 — 0,050)	0,939 ± 0,054 (0,900 — 1,000)	0,249 ± 0,079 (0,150 — 0,350)

TABLE 9 Amplitudes (mV) of the P, QRS and T waves of the electrocardiogram of Goat 1542

Lead	P	QRS	T
I	0,129 ± 0,027 (0,100 — 0,150)	0,369 ± 0,044 (0,300 — 0,400)	0,229 ± 0,027 (0,200 — 0,250)
II	0,139 ± 0,041 (0,100 — 0,200)	0,879 ± 0,083 (0,800 — 1,000)	0,270 ± 0,057 (0,200 — 0,350)
III	0,050 ± 0,000 (0,050 — 0,050)	0,689 ± 0,119 (0,550 — 0,850)	0,179 ± 0,044 (0,150 — 0,250)
aVR	0,129 ± 0,027 (0,100 — 0,150)	0,600 ± 0,035 (0,550 — 0,650)	0,229 ± 0,027 (0,200 — 0,250)
aVL	0,050 ± 0,000 (0,050 — 0,050)	0,259 ± 0,054 (0,200 — 0,350)	0,129 ± 0,044 (0,100 — 0,200)
aVF	0,070 ± 0,027 (0,050 — 0,100)	0,759 ± 0,054 (0,700 — 0,800)	0,219 ± 0,057 (0,150 — 0,300)

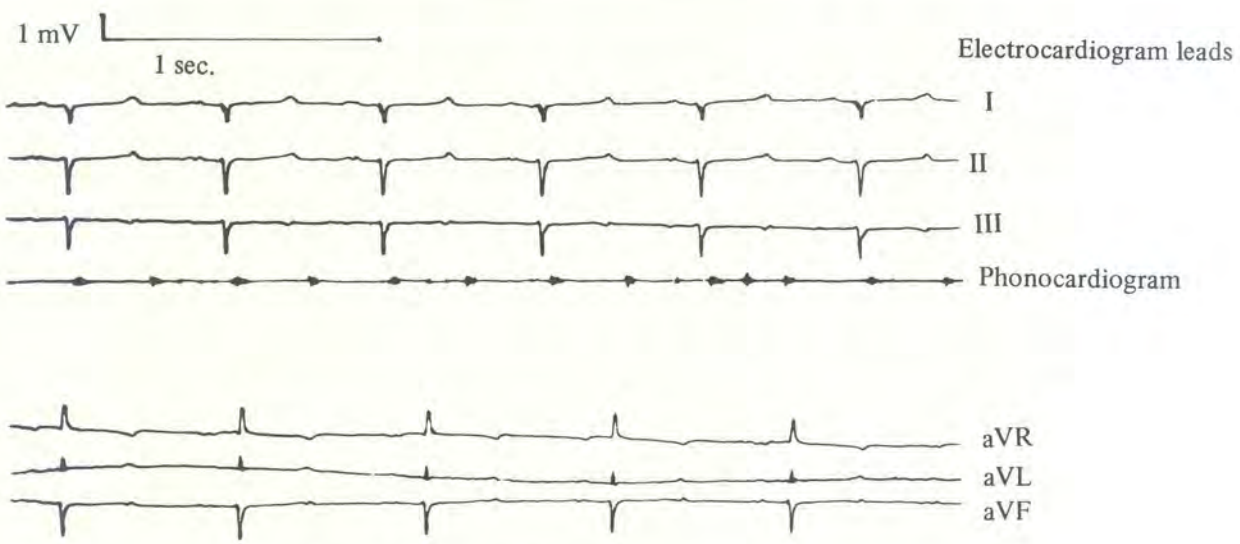

FIG. 1 The QRS configuration and double P wave of Goat 26716

and shorter PR and QT intervals. However, QT intervals they obtained were not corrected for heart rate; in the present investigation this was done according to the formula of Bazett (Alfredson & Sykes, 1942). Platner, Kibler & Brody (1948) obtained longer QRS and QT intervals but a shorter mean PR interval in comparison with the present investigation.

Except for lead aVL, where all the wave amplitudes were small and lead III, where only the P waves were small, satisfactorily larger amplitudes were obtained

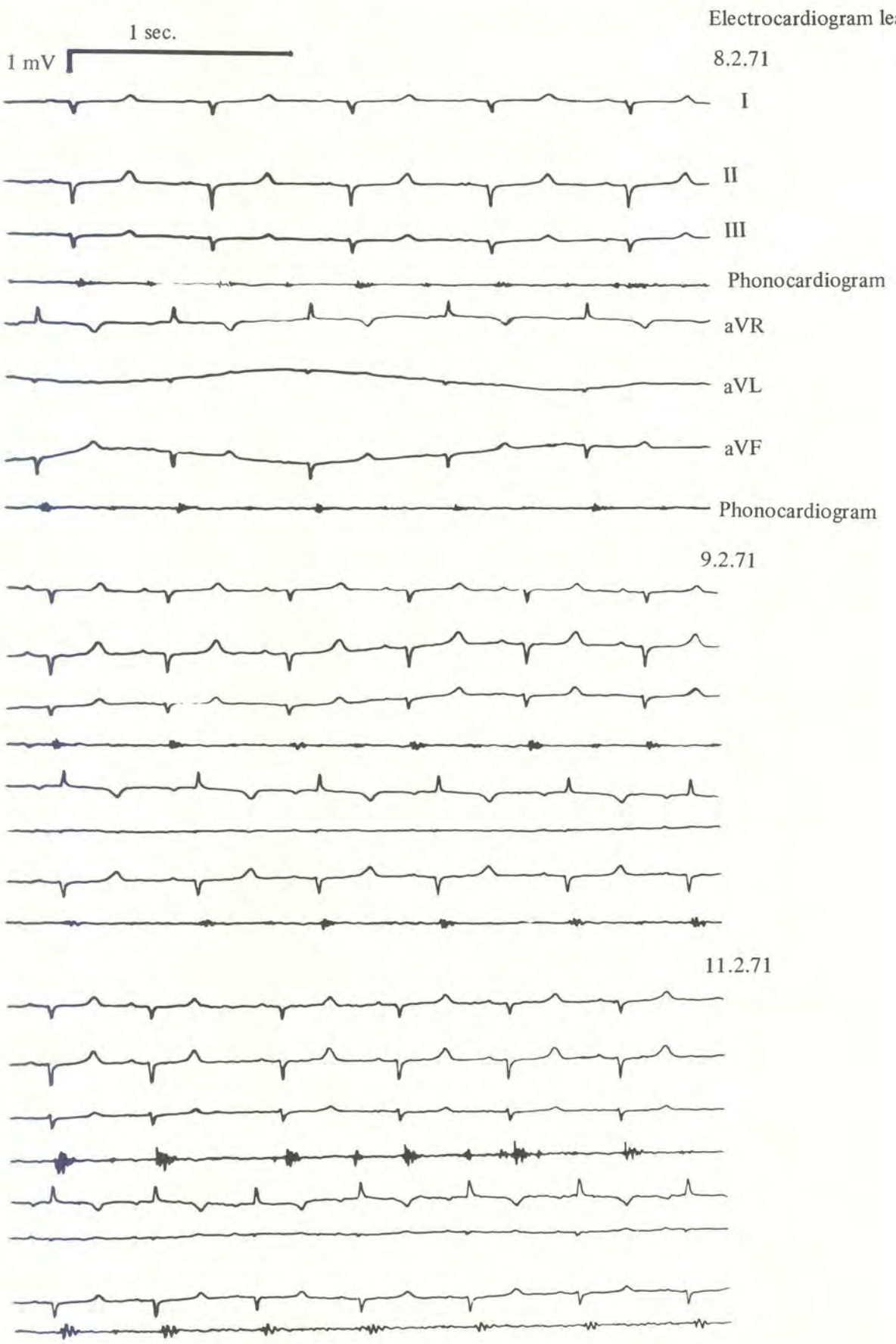

FIG. 2 The ECG of Goat 1541 on 3 different days

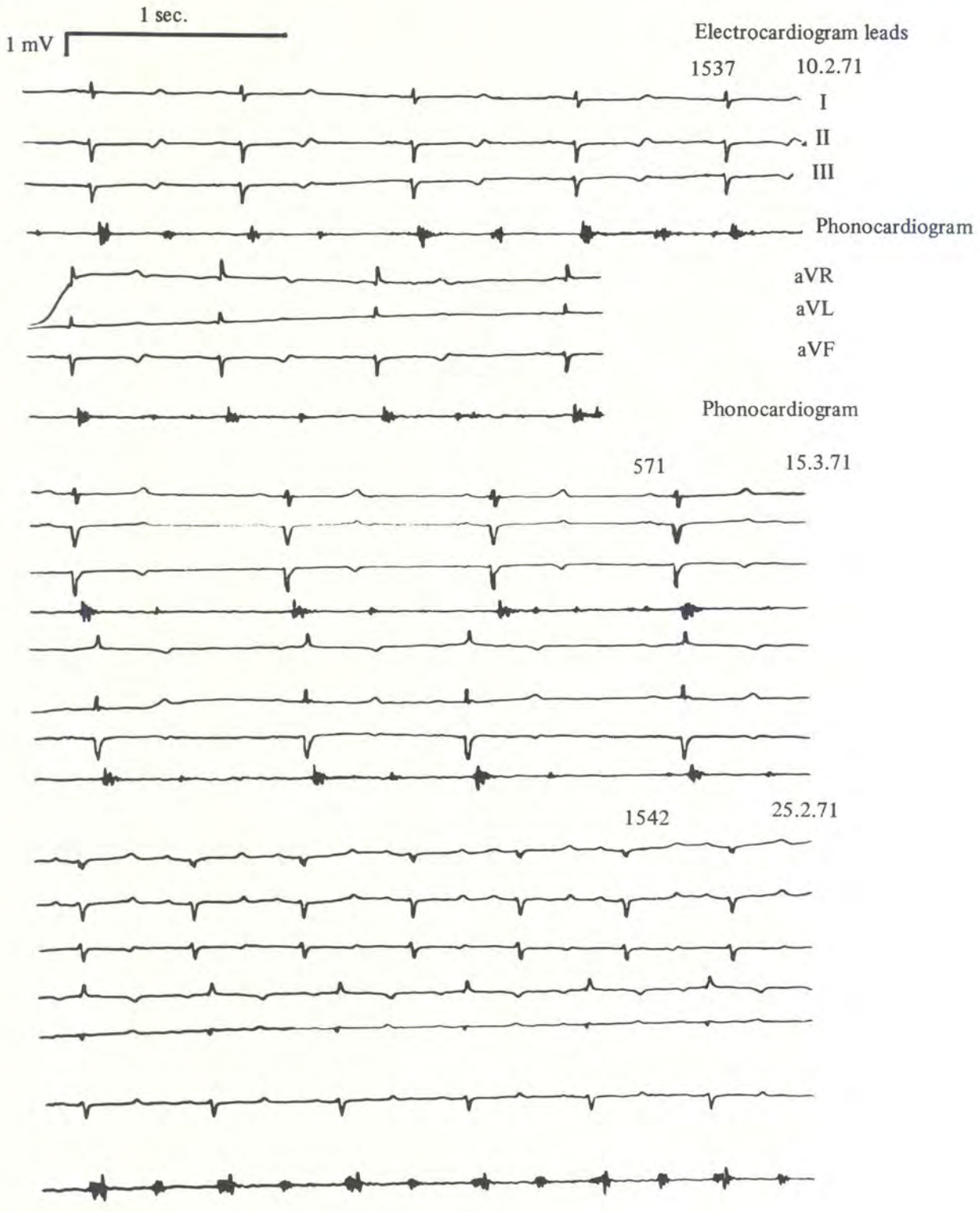

FIG. 3 The ECG of three different goats

TABLE 10 The mean values of the electrical axes and mechanical systoles for 22 goats and three individual goats

	Mean	Goat 571	Goat 1537	Goat 1542
Electrical axes	—110° ± 27° (—43 — — 170°)	—95° ± 3° (—90 — — 100°)	—84° ± 7° (—76 — — 95°)	—133° ± 8° (—122 — — 147°)
Mechanical systoles in s	0,316 ± 0,024 (0,250 — 0,376)	0,340 ± 0,108 (0,320 — 0,366)	0,355 ± 0,011 (0,340 — 0,370)	0,293 ± 0,011 (0,280 — 0,310)

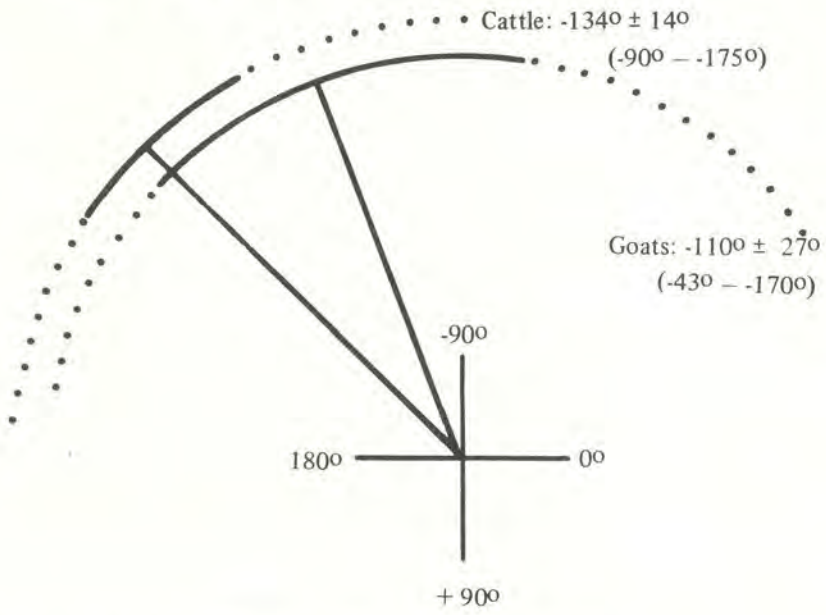

FIG. 4 The mean sagittal plane vectors of the QRS complex (degrees) for goats and cattle

TABLE 11 The time intervals (s) of the PR, QRS and QT waves of the electrocardiogram of 15 cattle[1]
Heart rate/min: 88 ± 14 (62 — 138)

Lead	PR	QRS	QT[2]
I	0,169 ± 0,025 (0,115 — 0,220)	0,059 ± 0,011 (0,035 — 0,080)	0,385 ± 0,027 (0,329 — 0,446)
II	0,166 ± 0,027 (0,115 — 0,225)	0,074 ± 0,009 (0,060 — 0,100)	0,389 ± 0,028 (0,327 — 0,438)
III	0,158 ± 0,026 (0,100 — 0,210)	0,070 ± 0,011 (0,050 — 0,100)	0,376 ± 0,029 (0,314 — 0,424)
aVR	0,169 ± 0,026 (0,120 — 0,230)	0,073 ± 0,010 (0,050 — 0,100)	0,397 ± 0,028 (0,329 — 0,448)
aVL	0,169 ± 0,027 (0,045 — 0,210)	0,048 ± 0,013 (0,030 — 0,090)	0,389 ± 0,030 (0,329 — 0,443)
aVF	0,160 ± 0,025 (0,100 — 0,210)	0,073 ± 0,010 (0,050 — 0,093)	0,391 ± 0,031 (0,353 — 0,441)

[1]Mean values of 90 recordings are expressed with ± standard deviation; minimal and maximal values are in parentheses
[2]Corrected

TABLE 12 The time intervals (s) of the PR, QRS and QT waves of the electrocardiogram of Cow 7123 (full-mouth)
Heart rate/min: 79 ± 5 (71 — 86)

Lead	PR	QRS	QT[1]
I	0,186 ± 0,005 (0,180 — 0,190)	0,073 ± 0,004 (0,070 — 0,080)	0,417 ± 0,017 (0,398 — 0,440)
II	0,184 ± 0,004 (0,180 — 0,190)	0,079 ± 0,002 (0,075 — 0,080)	0,416 ± 0,014 (0,398 — 0,435)
III	0,184 ± 0,004 (0,180 — 0,190)	0,080 ± 0,000 (0,080 — 0,080)	0,397 ± 0,011 (0,381 — 0,413)
aVR	0,188 ± 0,007 (0,180 — 0,200)	0,087 ± 0,002 (0,085 — 0,090)	0,424 ± 0,012 (0,409 — 0,446)
aVL	0,190 ± 0,002 (0,186 — 0,195)	0,050 ± 0,008 (0,045 — 0,065)	0,417 ± 0,007 (0,409 — 0,424)
aVF	0,179 ± 0,008 (0,170 — 0,195)	0,080 ± 0,000 (0,080 — 0,080)	0,413 ± 0,013 (0,386 — 0,424)

[1]Corrected

with Einthoven's triangle in the sagittal plane than those reported by Platner *et al.* (1948) and Szabuniewicz & Clark (1967), who used the conventional technique.

In leads I, II, aVR and aVF the P and QRS wave configurations were reproducible. In the case of lead III only the QRS waves were reproducible and in lead aVL only the P waves could be reproduced. The P waves in these leads were positive (I, II, aVL and aVF) and negative (aVR). Double peaks were sometimes recorded. Except in lead aVR where the QRS waves were of the QR type with Q absent or variable in size (R, qR, QR), the QRS waves in these leads were mainly of the RS type with R absent or variable in size (QS, rS, RS). Little within-goat variation was encountered on different days.

The T wave configurations were predominantly positive in lead I. They were rarely biphasic and little within-goat variation occurred on different days.

Thus, except for the T wave, which was only reliable in lead I, large wave amplitudes with reliable configurations were obtained in four leads (I, II, aVR and aVF). In this investigation all the waves were bigger, and in addition the P and QRS waves were less variable than those obtained by Platner *et al.* (1948) and Szabuniewicz & Clark (1967). However, with the standard lead method they obtained a more reliable T wave configuration.

The vector study of the QRS complex in the sagittal plane indicated that the electrical axis had a mean value of —110° during total depolarisation of the ventricles (Table 10). This is in agreement with the observations of Hamlin & Scher (1961), who concluded that the activation of the goat ventricles occurs chiefly in a dorsal and slightly cranial direction, i.e. from the apex to the base of the heart.

Studies on Cattle

Results

A. *Heart rate and time intervals*

The heart rate of the 15 cattle varied between 62 and 138 beats/min with a mean of 88 and a standard deviation of 14. The minimum, maximum, mean and standard deviation of all the time intervals are given in Table 11. The same parameters for a randomly selected cow, bull, heifer and steer appear in Tables 12 to 15. For example in lead II of Heifer 8211, the mean durations of PR, QRS and QT intervals were respectively 0,153; 0,070 and 0,380s (Table 14), while the same means for all the cattle were 0,166; 0,074 and 0,389s (Table 11).

Bazett's formula was used to correct the QT times.

Table 13 The time intervals (s) of the PR, QRS and QT waves of the electrocardiogram of Bull 8099 (two-tooth)
Heart rate/min: 99 ± 16 (79 — 125)

Lead	PR	QRS	QT[1]
I	0,180 ± 0,022 (0,150 — 0,210)	0,071 ± 0,004 (0,070 — 0,080)	0,360 ± 0,011 (0,348 — 0,379)
II	0,179 ± 0,020 (0,150 — 0,210)	0,074 ± 0,008 (0,070 — 0,090)	0,353 ± 0,012 (0,338 — 0,380)
III	0,169 ± 0,017 (0,140 — 0,190)	0,066 ± 0,010 (0,050 — 0,080)	0,330 ± 0,011 (0,319 — 0,348)
aVR	0,174 ± 0,020 (0,150 — 0,200)	0,076 ± 0,008 (0,070 — 0,090)	0,365 ± 0,012 (0,348 — 0,380)
aVL	0,169 ± 0,021 (0,140 — 0,200)	0,060 ± 0,000 (0,060 — 0,060)	0,365 ± 0,014 (0,350 — 0,391)
aVF	0,176 ± 0,023 (0,150 — 0,210)	0,069 ± 0,002 (0,065 — 0,070)	0,349 ± 0,012 (0,337 — 0,362)

[1]Corrected

Table 14 The time intervals (s) of the PR, QRS and QT waves of the electrocardiogram of Heifer 8211 (milk-tooth)
Heart rate/min: 82 ± 8 (73 — 95)

Lead	PR	QRS	QT[1]
I	0,153 ± 0,013 (0,140 — 0,170)	0,043 ± 0,005 (0,040 — 0,050)	0,374 ± 0,014 (0,353 — 0,393)
II	0,153 ± 0,013 (0,140 — 0,170)	0,070 ± 0,000 (0,070 — 0,070)	0,380 ± 0,021 (0,341 — 0,405)
III	0,145 ± 0,012 (0,130 — 0,160)	0,059 ± 0,006 (0,050 — 0,070)	0,365 ± 0,028 (0,324 — 0,400)
aVR	0,155 ± 0,011 (0,140 — 0,170)	0,066 ± 0,005 (0,060 — 0,070)	0,386 ± 0,019 (0,353 — 0,417)
aVL	0,154 ± 0,012 (0,140 — 0,170)	0,058 ± 0,004 (0,050 — 0,060)	0,380 ± 0,020 (0,353 — 0,417)
aVF	0,152 ± 0,010 (0,140 — 0,170)	0,065 ± 0,004 (0,060 — 0,070)	0,376 ± 0,018 (0,353 — 0,405)

[1]Corrected

TABLE 15 The time intervals (s) of the PR, QRS and QT waves of the electrocardiogram of steer 8301 (milk-tooth)
Heart rate/min: 84 ± 9 (71 — 100)

Lead	PR	QRS	QT[1]
I	0,133 ± 0,008 (0,120 — 0,140)	0,054 ± 0,006 (0,045 — 0,060)	0,391 ± 0,018 (0,361 — 0,422)
II	0,129 ± 0,006 (0,120 — 0,140)	0,069 ± 0,006 (0,060 — 0,080)	0,394 ± 0,017 (0,373 — 0,422)
III	0,127 ± 0,007 (0,120 — 0,140)	0,060 ± 0,000 (0,060 — 0,060)	0,380 ± 0,016 (0,349 — 0,398)
aVR	0,131 ± 0,004 (0,130 — 0,140)	0,070 ± 0,006 (0,060 — 0,080)	0,393 ± 0,015 (0,373 — 0,422)
aVL	0,121 ± 0,037 (0,045 — 0,140)	0,037 ± 0,004 (0,030 — 0,040)	0,387 ± 0,021 (0,349 — 0,422)
aVF	0,121 ± 0,007 (0,110 — 0,130)	0,063 ± 0,005 (0,060 — 0,070)	0,385 ± 0,015 (0,361 — 0,410)

[1]Corrected

B. *Wave amplitudes and configurations*

P wave

Except in lead aVF, where the mean value was 0,079 mV, P waves with high amplitudes were obtained in all leads. The mean values of all the other leads varied between 0,114 and 0,205 mV (Table 16). The mean, minimum, maximum and standard deviations of the P wave amplitudes for four cattle are given in Tables 17 to 20.

Except for leads III and aVF, where between-cattle and within-cattle variations occurred, the configuration of the P wave was fully reliable in all the leads. In leads I, II and aVL positive monophasic P waves were always obtained whilst in lead aVR it was always negative (Table 21). Within-cattle and between-cattle recordings are given in Fig. 5 and 6.

TABLE 16 The amplitudes (mV) of the P, QRS and T waves of the electrocardiogram of 15 cattle

Lead	P	QRS	T
I	0,205 ± 0,045 (0,150 — 0,300)	0,868 ± 0,167 (0,500 — 1,200)	0,439 ± 0,152 (0,200 — 0,800)
II	0,148 ± 0,046 (0,100 — 0,250)	1,265 ± 0,268 (0,700 — 1,800)	0,618 ± 0,229 (0,200 — 1,800)
III	0,114 ± 0,031 (0,050 — 0,200)	0,627 ± 0,176 (0,400 — 1,100)	0,340 ± 0,176 (0,100 — 0,900)
aVR	0,176 ± 0,045 (0,100 — 0,300)	1,031 ± 0,194 (0,650 — 1,500)	0,487 ± 0,183 (0,200 — 0,900)
aVL	0,149 ± 0,039 (0,100 — 0,250)	0,431 ± 0,127 (0,200 — 0,800)	0,280 ± 0,100 (0,100 — 0,600)
aVF	0,079 ± 0,037 (0,050 — 0,200)	0,898 ± 0,213 (0,500 — 1,400)	0,461 ± 0,153 (0,200 — 1,000)

TABLE 17 Amplitudes (mV) of the P, QRS and T waves of the electrocardiogram of Cow 7123

Lead	P	QRS	T
I	0,208 ± 0,020 (0,200 — 0,250)	0,999 ± 0,089 (0,900 — 1,100)	0,441 ± 0,066 (0,350 — 0,500)
II	0,116 ± 0,025 (0,100 — 0,150)	1,161 ± 0,063 (1,100 — 1,200)	0,641 ± 0,080 (0,500 — 0,700)
III	0,116 ± 0,025 (0,100 — 0,150)	0,424 ± 0,027 (0,400 — 0,450)	0,408 ± 0,091 (0,300 — 0,550)
aVR	0,183 ± 0,025 (0,150 — 0,200)	1,116 ± 0,081 (1,000 — 1,200)	0,516 ± 0,051 (0,450 — 0,600)
aVL	0,166 ± 0,025 (0,150 — 0,200)	0,533 ± 0,060 (0,450 — 0,600)	0,274 ± 0,052 (0,200 — 0,350)
aVF	0,050 ± 0,000 (0,050 — 0,050)	0,774 ± 0,041 (0,700 — 0,800)	0,483 ± 0,068 (0,400 — 0,550)

TABLE 18 Amplitudes (mV) of the P, QRS and T waves of the electrocardiogram of Bull 8099

Lead	P	QRS	T
I	0,158 ± 0,020 (0,150 — 0,200)	0,799 ± 0,063 (0,700 — 0,900)	0,224 ± 0,041 (0,200 — 0,300)
II	0,149 ± 0,044 (0,100 — 0,200)	1,083 ± 0,116 (0,900 — 1,200)	0,383 ± 0,093 (0,250 — 0,500)
III	0,100 ± 0,000 (0,100 — 0,100)	0,529 ± 0,040 (0,500 — 0,600)	0,233 ± 0,025 (0,200 — 0,250)
aVR	0,149 ± 0,031 (0,100 — 0,200)	0,924 ± 0,088 (0,800 — 1,000)	0,283 ± 0,068 (0,200 — 0,400)
aVL	0,100 ± 0,000 (0,100 — 0,100)	0,424 ± 0,041 (0,400 — 0,500)	0,183 ± 0,025 (0,150 — 0,200)
aVF	0,074 ± 0,027 (0,050 — 0,100)	0,774 ± 0,088 (0,700 — 0,900)	0,283 ± 0,025 (0,250 — 0,300)

TABLE 19 Amplitudes (mV) of the P, QRS and T waves of the electrocardiogram of Heifer 8211

Lead	P	QRS	T
I	0,174 ± 0,027 (0,150 — 0,200	0,999 ± 0,089 (0,900 — 1,100)	0,416 ± 0,098 (0,300 — 0,500)
II	0,133 ± 0,040 (0,100 — 0,200)	1,291 ± 0,128 (1,100 — 1,500)	0,516 ± 0,098 (0,400 — 0,700)
III	0,108 ± 0,048 (0,050 — 0,150)	0,625 ± 0,088 (0,500 — 0,750)	0,174 ± 0,027 (0,150 — 0,200)
aVR	0,141 ± 0,020 (0,100 — 0,150)	1,049 ± 0,077 (1,000 — 1,200)	0,408 ± 0,066 (0,300 — 0,500)
aVL	0,141 ± 0,037 (0,100 — 0,200)	0,458 ± 0,091 (0,350 — 0,600)	0,233 ± 0,040 (0,200 — 0,300)
aVF	0,073 ± 0,027 (0,050 — 0,100)	0,799 ± 0,063 (0,700 — 0,900)	0,333 ± 0,075 (0,200 — 0,400)

TABLE 20 Amplitudes (mV) of the P, QRS and T waves of the electrocardiogram of Steer 8301

Lead	P	QRS	T
I	0,283 ± 0,025 (0,250 — 0,300)	1,133 ± 0,075 (1,050 — 1,200)	0,699 ± 0,094 (0,600 — 0,800)
II	0,183 ± 0,025 (0,150 — 0,200)	1,666 ± 0,121 (1,500 — 1,800)	0,999 ± 0,414 (0,700 — 1,800)
III	0,116 ± 0,025 (0,100 — 0,150)	0,841 ± 0,128 (0,700 — 1,000)	0,399 ± 0,260 (0,100 — 0,800)
aVR	0,241 ± 0,020 (0,200 — 0,250)	1,324 ± 0,154 (1,050 — 1,500)	0,799 ± 0,089 (0,700 — 0,900)
aVL	0,183 ± 0,040 (0,150 — 0,250)	0,458 ± 0,159 (0,200 — 0,650)	0,308 ± 0,066 (0,200 — 0,400)
aVF	0,083 ± 0,025 (0,050 — 0,100)	1,124 ± 0,194 (0,800 — 1,300)	0,566 ± 0,136 (0,400 — 0,800)

QRS wave

Except in lead aVL where the mean value was 0,431 mV, high QRS wave amplitudes were obtained in all the leads. The maximum, minimum, mean and standard deviation of the QRS amplitudes for all the cattle are given in Table 16 and those for four individuals in Tables 17 to 20.

In lead II the QRS configurations were very reliable with little daily within-cattle and between-cattle variation (Fig. 5 and 6). The configurations were always of the RS type although the size of the R wave varied (RS and rS). The same configurations were obtained in leads I and aVF though daily variation occurred (RS, rS and QS). The wave configurations in lead aVR were always of the QR type with the Q wave varying in size (R, qR and QR). Daily variation in the same animal occurred only in 13% of the cases (Table 21).

Notched Q, R and S waves occurred in leads I, II, aVR and aVL. Notched S waves in lead I are illustrated in Fig. 7.

TABLE 21 The configuration of the ECG waves of 15 normal cattle in percentages

Wave	Lead	Configuration													Percentage showing variation from predominant configuration[1]
		+−	++	+	−+	−	RS	rS	R	qR	QR	QS	QRS	RSR	
P	I			100											0
	II			100											0
	III			7*		93*									7
	aVR					100									0
	aVL			100											0
	aVF	*	7*	80*		13*									40
QRS	I						20*	73*				7*			33
	II						67	33							0
	III						67	20*				6,5*	6,5*		20
	aVR								7*	40*	53*				13
	aVL						20*	20*			7*	20*	20*	13*	33
	aVF						67*	33*							13
T	I			100*	*										13
	II			100											0
	III			100											0
	aVR					100									0
	aVL			40*	53*	7*									13
	aVF			100											0

[1]Percentage cattle with intermittent daily variation from predominant configuration as indicated by *

T wave

Except for lead aVL, where the between-animal variation was high (Fig. 6), the T waves of the 15 cattle had a conspicuously high amplitude with a constant wave configuration. In lead I daily variations occurred in 13% of the animals. A positive T wave was predominantly present (Table 21 and Fig. 5).

C. *Electrical axes*

The QRS electrical axis in the sagittal plane had a mean value of —134° ± 14° for all the cattle (Table 22). This indicated that the mean vector was directed dorso-anteriorly (Fig. 4). These values varied from —90° to —175°. The above values for four individual cattle are shown in Table 22.

DISCUSSION

The mean heart rate of 88 beats/min is comparable with that obtained in dairy calves by Alfredson & Sykes (1942) but was much higher than that reported in dairy cattle by Platner *et al.* (1948) and in cattle by Too, Nakamura & Hirao (1958). This might partly explain why the PR and QRS intervals in this investigation were shorter than those obtained by other workers. Platner *et al.* (1948), however, reported similar time intervals in a study of dairy calves. The higher mean heart rate in the present study might be due to the relatively younger age of the animals used. The QT time intervals are comparable with those obtained by Alfredson & Sykes (1942) in dairy cattle, by Platner *et al.* (1948) in calves, by Sander (1968) in cattle and by Spörri (1954) in young cattle. In all these studies the QT time intervals were corrected with Bazett's formula.

Except for lead aVR, where the P waves were small, and in lead aVL, where the QRS and T waves were small, large P, QRS and T wave amplitudes were found in all leads. The mean values were of the same order as those obtained by Too *et al.* (1958) using bipolar chest leads, and by Enhörning (1962) and Platner *et al.* (1948), using standard limb leads. Smaller standard limb lead amplitudes were, however, obtained by Too *et al.* (1958).

Thus, except in the P waves in leads III and aVF, the QRS waves in leads III and aVL, and the T wave in lead aVL, reproducible wave configurations and amplitudes were obtained for all waves.

The mean and standard deviation of the QRS wave vector obtained in this study were superior to those obtained by Alfredson & Sykes (1942).

These results were more reliable than those obtained with standard limb leads by Too *et al.* (1958), by Alfredson & Sykes (1942), by Enhörning (1962) and by Platner *et al.* (1948).

SUMMARY

Electrocardiograms and phonocardiograms were recorded from 22 normal goats and 15 normal cattle.

In this investigation Einthoven's triangle was moved

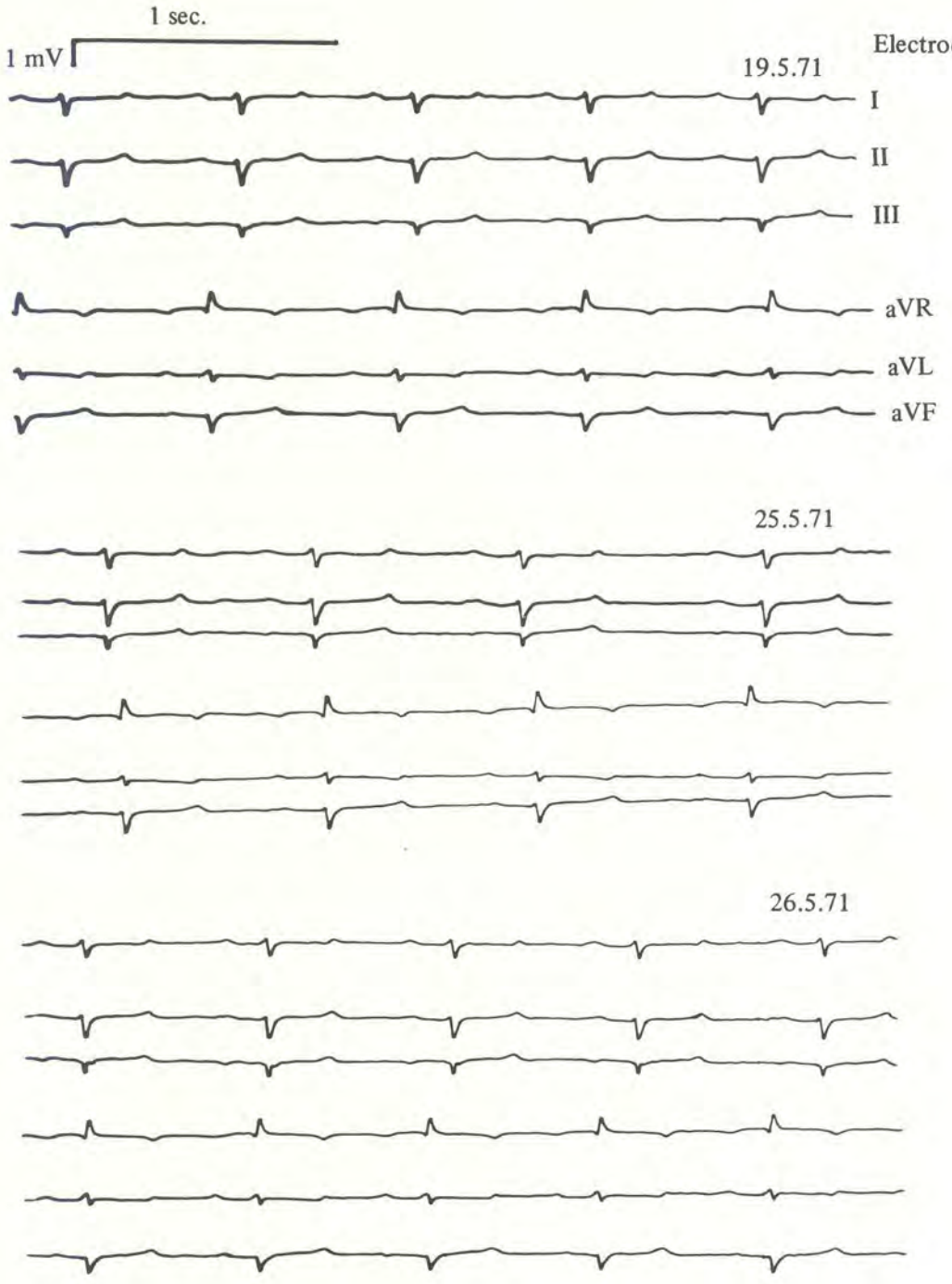

FIG. 5 The ECG of Bull 8099 on 3 different days

TABLE 22 The mean values of the electrical axes of 15 cattle and four individual cattle

Mean	Cow 7123	Bull 8099	Heifer 8211	Steer 8301
—134° ± 14° (—90 — — 175°)	—43° ± 5° (—134 — — 150°)	—122° ± 6° (—115 — — 129°)	—105° ± 9° (—90 — — 115°)	—141° ± 7° (—129 — — 150°)

to a sagittal plane in an attempt to obtain reproducible recordings. Recordings were made on leads I, II, III, aVR, aVL and aVF. Heart frequencies, time intervals, wave amplitudes, QRS electrical axes and durations of mechanical systoles were measured.

With the exception of the T wave configuration, large wave amplitudes with reliable configurations were obtained in four leads (I, II, aVR and aVF) in goats. The T wave was only reliable in lead I. Except for leads III and aVF where the P wave varied; leads

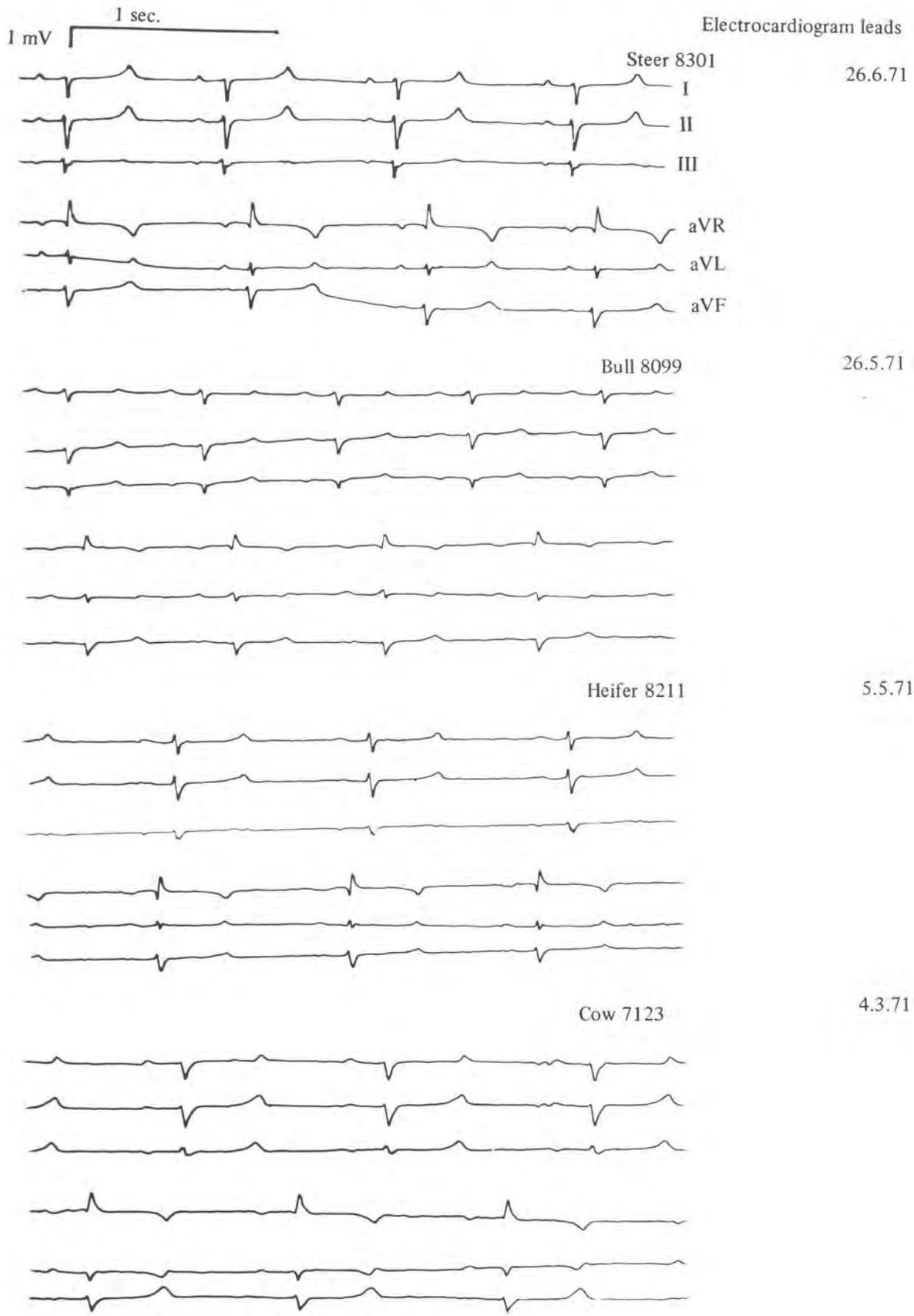

FIG. 6 The ECG of four different cattle

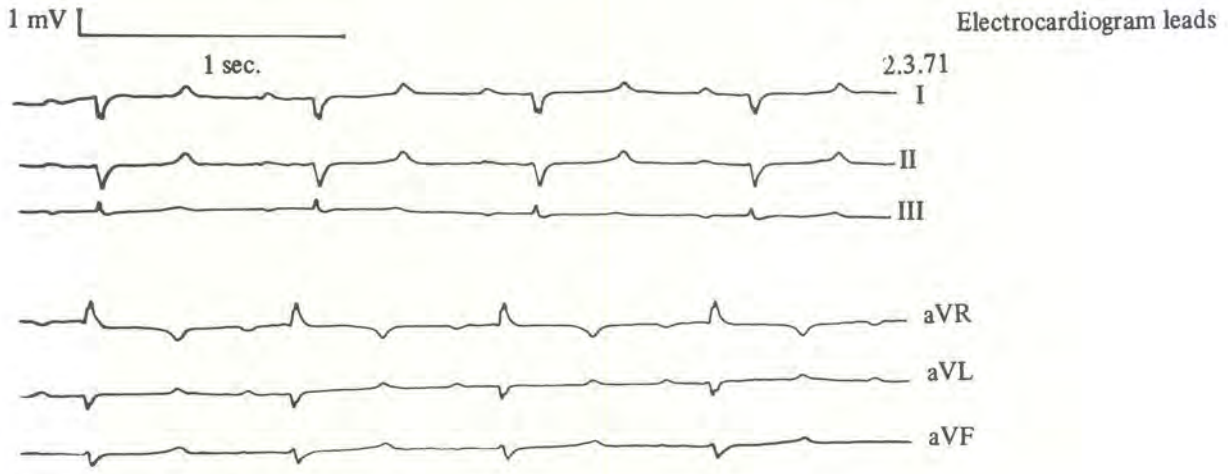

FIG. 7 The QRS configuration of the ECG of Cow 7122

III and aVL where the QRS wave was variable and lead aVL where the T wave was variable, uniform recordings were obtained in cattle, in all leads. The QRS wave of both species could be roughly divided into two configuration groups.

This investigation, therefore, proved that in goats and cattle the mean value of the sagittal plane vector of the QRS complex falls within the same limits as it does for sheep, namely —90° to —180°.

The method used in this study is superior to the standard lead method when used in standing cattle and goats that are not tranquilized. Although variations were encountered with this method, where the electrodes were placed in rigidly fixed positions in relation to the heart, they could be ascribed to inherent electrical cardiac variations and were not due to limb movements, as is often the case with the standard limb lead method.

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REFERENCES

ALFREDSON, B. V. & SYKES, J. F., 1942. Electrocardiograph studies in normal dairy cattle. *J. agric. Res.*, 65, 61-87.

ENHÖRNING, G., 1962. Das Elektrokardiogramm der Rinder. *Dt. tierärztl. Wschr.*, 69, 242-246.

HAMLIN, R. L. & SCHER, A. M., 1961. Ventricular activation process and genesis of QRS complex in the goat. *Am. J. Physiol.*, 200, 223-228.

JHA, S. K., LUMB, W. V. & JOHNSTON, R. K., 1961. Some physiologic data on goats. *Am. J. vet. Res.*, 22, 912-914.

PLATNER, W. S., KIBLER, H. H. & BRODY, S., 1948. Electrocardiograms of mules, horses, cattle, sheep and goats. *Res. Bull. Mo. agric. Exp. Stn.*, 419, 1-12.

PRETORIUS, P. J. & TERBLANCHE, M., 1967. A preliminary study on the symptomatology and cardiodynamics of gousiekte in sheep and goats. *Jl S. Afr. vet. med. Ass.*, 38, 29-53.

RUSHMER, R. F., 1961. Cardiovascular dynamics. 2nd ed. London: W. B. Saunders Co.

SANDER, W., 1968. Das Elektrokardiogramm des Rindes. Klinische und pathologisch-anatomische untersuchungen an leukosekranken Rindern. *Zentbl. Vet. Med.*, Reihe A, 15, 587-634.

SCHULTZ, R. ANITRA, PRETORIUS, P. J. & TERBLANCHE, M., 1972. An electrocardiographic study of normal sheep using a modified technique. *Onderstepoort J. vet. Res.* 39, 97-106.

SPÖRRI, H., 1954. Warum ist das Schwein für den Herztod prädisponiert? *Zentbl. Vet. Med.* 1, 799-809.

SZABUNIEWICZ, M. & CLARK, D. R., 1967. Analysis of the electrocardiograms of 100 normal goats. *Am. J. vet. Res.*, 28, 511-516.

TOO, K., NAKAMURA, R. & HIRAO, K., 1958. Studies on the application of electrocardiogram in cattle. *Jap. J. vet. Res.*, 6, 230-244.

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