STUDIES ON CLINICAL APPLICATIONS OF ELECTROCARDIOGRAM ON DOGS I.

ELECTROCARDIOGRAM OF SHEPHERD DOGS AND KARAFUTO (SAGHALIEN) DOGS

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(Received for publication, October 12, 1959)

Introduction

Disturbances of the heart functions in dogs are frequently observed in daily clinics. To diagnose the heart disease of dogs, the stethoscope, and other methods, have been customarily used for a long time. Methods other than these have not been used.

The authors, recently have applied the electrocardiogram for diagnosing the heart functions of large domestic animals.

The lead methods and interpretation of electrocardiograms as used for cattle and horses can not be applied for dogs because the anatomical conditions of the dog heart differ from those of horse and cattle. The authors, therefore, concluded that the use of the electrocardiogram on dogs in daily clinic should take a different approach from that on large animals.

Many reports[2,4,6,7,8] have been published in the fields of experimental medicine in dogs. The electrocardiogram on dogs in experimental conditions under anesthesia, chest open, artificial respiration and nervous operation, etc. differs from that on dogs under normal conditions. Therefore, the electrocardiogram such as obtained under experimental conditions can not be applied in the veterinary clinic.

On the other hand, studies of the electrocardiogram on non-experimental dogs using limb lead, bipolar chest lead and unipolar chest lead were reported by Lannek. Ueda et al. and Takahashi reported as to electrocardiograms obtained by different form usual of lead methods. Alexander et al. and Powsner

et al. reported the distribution of the electric potential on the chest wall of dogs, where the portion showing the maximum value of R wave is that nearest to the apex of the heart and that of S wave is the position on the left elbow.

The authors, in this paper, described the results obtained from the use of 21 Shepherd dogs and 22 so-called Karafuto dogs employing limb lead, unipolar limb lead and unipolar chest lead.

MATERIALS AND METHODS

Experimental dogs were employed, as shown in tables 1 and 2, consisting of 21 Shepherd dogs (male 12, female 9) hereafter designated as "S dog", aged 1.5~13 year-old, and 22 Karafuto dogs (male 16, female 6) hereafter called "K dog", aged 0.5~11 year-old. The animals were born in Hokkaido and were all healthy. In addition, the animals were free from filariasis.

TABLE 1. *Materials* (Shepherd Dog)

CASE NOS.	AGE (year)	SEX	KIND OF ARRHYTHMIA	DEGREE OF ARRHYTHMIA	CLINICAL HEART SIGN
1	1.5	female		—	—
2	1.7	"		—	—
3	1.8	male		—	—
4	2	female	S.A. (R)	+	+
5	2	"	S.A.	++	+
6	2	"	S.A.	+++	+
7	2.5	male		—	—
8	2.5	"	S.A.	+++	+
9	2.6	"	S.A.	+++	+
10	3	"	S.A.	+	+
11	4	female	S.A. (R)	+	+
12	4	male	S.A.	+++	++
13	4	"	S.A.	+	+
14	5	female	S.A. (R)	+	+
15	5	"	S.A.	++	++
16	6	male	S.A.	+	+
17	6	"	—	—	—
18	6	"	S.A.	+	+
19	7	"	S.A.	+++	+
20	10	"	S.A.	+	+
21	13	female			

Notes: S.A.—Sinus arrhythmia. (R)—Respiratory arrhythmia.

First of all the dogs were placed on the table on the back side with their extremitis tied to the table. Sedative and pharmaceutical preparations were not used during the course of taking normal electrocardiogram. Prior to taking the electrocardiogram, the dogs were left quietly on the table in order to avoid any injurious currents.

Model 1-S electrocardiograph with the time constant of 2 seconds made by the Fukuda Medical Instrument Company was used. The needle electrode of diameter 1/2 mm was inserted approximately 10 mm subcutaneously.

Electrocardiograms were taken on K dogs in May and S dogs in August 1958; the recording of the electrocardiogram was conducted in the open air.

CHART 1. *Lead Method of the Limb Lead and the Electrocardiogram*

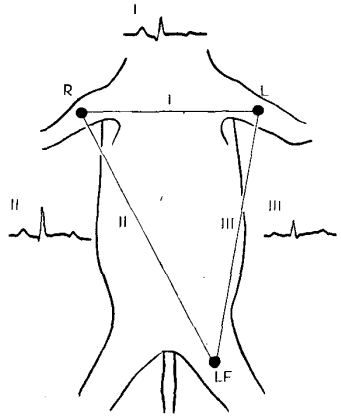


CHART 2. *Lead Method of Unipolar Limb Lead and the Electrocardiogram*

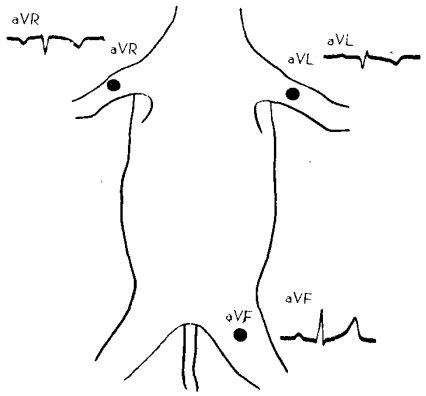
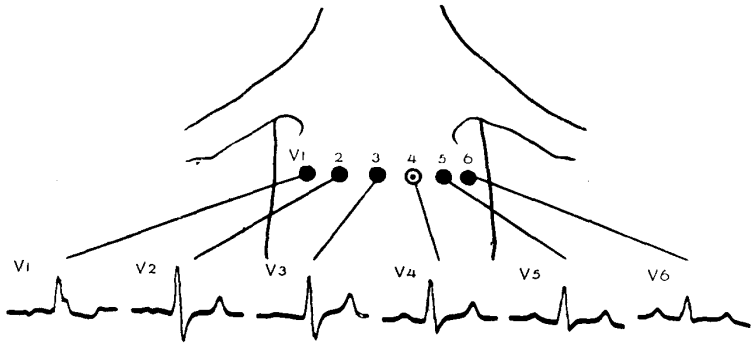


CHART 3. *Lead Method of the Unipolar Chest Lead and the Electrocardiogram*



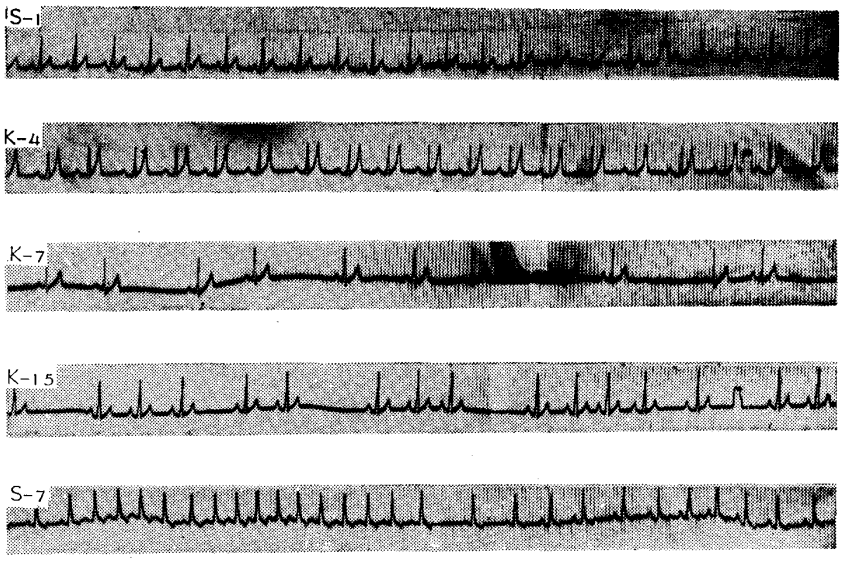
Three lead methods were used in this experiments. Firstly, in limb lead (I, II, III) as shown in chart 1, the electrodes were placed on the left and right arms and the left leg similar to Einthivens' standard limb procedure. Secondly in unipolar limb lead as shown in chart 2, the methods of augumented Goldberger lead was used. Finally, in unipolar chest lead as shown in chart 3, six points were selected for the position of the different electrodes, where point V4 is in position nearest to the apex of the heart; the Wilson central terminal was used as the indifferent electrode in that arrangement.

EXPERIMENTAL RESULTS

A. The Electrocardiogram of Shepherd Dogs

Twenty one Shepherd dogs were examined. The 3 kinds of lead positions just mentioned were used for taking the electrocardiograms. The electrocardiographic waves in each lead were classified and measured respectively.

FIG. 1. *Electrocardiogram of Arrhythmia (scale 1:4)*



Notes: All the tracings were taken in lead II and paper speed was 4 cm/sec.
S-1: Electrocardiogram of normal rhythm.
K-4, K-7 & K-15: Electrocardiogram of sinus-arrhythmia.
S-7: Electrocardiogram of respiratory arrhythmia.

1. Degree and character of arrhythmia (Fig. 1.)

The continuous waves which were traced on the paper from lead II of the limb lead were examined for study of arrhythmia. The results are shown in table 1. Fifteen out of 21 cases manifested sinus-arrhythmia and 3 out of 15 which showed sinus-arrhythmia had respiratory arrhythmia also. Seven out of those 15 cases indicated severe arrhythmia but the other 8 were slight cases. The cases of arrhythmia in those 15 cases may be explained as the abnormal rise of the nerve impulses in terms of its duration in the S-A node. In comparison of electrocardiograms which showed arrhythmia and sinus-rhythm, no particular difference was noticed. In all the cases showing arrhythmia abnormalities in the heart sounds were observed. In the Shepherd dog cases under the age of 1.8 year-old, arrhythmia was not observed, but the opposite indication was observed in the dogs in the 2~5 year-old group inclusive. No close relations between the arrhythmia and sex were recognized in this experiment.

TABLE 3. *Classification of P, PQ, ST and T waves*

WAVES	TYPES OF WAVES	LIMB LEAD			UNIPOLAR LIMB LEAD			UNIPOLAR CHEST LEAD					
		I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
P	Positive	17	21	21	1	14	18	4	13	19	21	21	21
	Negative	4			20	5	2	16	6	1			
	Flat					2	1	1	2	1			
PQ	O-line	21	18	21	19	21	21	21	21	21	21	21	21
	Upward		1		2								
	Downward		2										
ST	O-line	10	10	8	18	18	17	11	7	6	5	10	15
	Upward	5	4	3		1	2	6	13	14	15	9	2
	Downward	4	6	7	2	2	2	4				1	4
	Arc ↓	2		3						1			
	Arc ↑		1		1				1		1	1	
T	Positive	14	14	12	5	13	12	14	21	21	21	20	15
	Negative	7	4	6	15	6	7	7					5
	Minus-plus		3	3		2	2					1	1
	Plus-minus				1								

2. Configurations of the electrocardiograms

P wave: P waves as shown in table 3, may be classified into 3 types, viz., positive, negative and flat waves. In the limb lead positive P waves were observed in almost every cases lead. In the unipolar limb lead, P waves of lead aVR showed a negative deflection, but those of aVL and aVF indicated mainly a positive deflection. Furthermore, in the unipolar chest lead, negative form of P waves were traced in lead V1, but positive in V2~V6. P waves of flat type were found in a few cases of leads aVL, aVF and V1~V3.

PQ segment: PQ segment tracings were classified into 3 types, which are 0 (zero)-line type, upward and downward deflection types. For the PQ section in table 3 are shown the number of cases of each lead and each type. From this classification it will be seen that the PQ segment of most cases showed 0-line type except one case of lead II and 2 of aVR which indicated the upward deflection and 2 cases of lead II which showed downward deflection.

QRS complex: For classifing the QRS complex, in this paper the authors indicated the small waves by small letters and large waves by capital letters. Configurations of QRS complex may be classified into 12 types as shown in table 4. 3~8 kinds of different types of QRS complex in each lead were found. Eight different types in leads I, aVL and V1, 6 kinds in V6, 5 kinds in V2, 4 kinds in aVR and V5, and 3 kinds in II, III aVF, V3 and V4 were classified respectively. In lead I, II and III of the limb lead, qR type of QRS complex was found in most often. In the unipolar limb lead, rS and QS types in aVR, rS, QS and qR types in aVL, and qR type in aVF were mainly observed respectively.

TABLE 4. *Classification of QRS complex*

TYPES OF WAVES	LIMB LEAD			UNIPOLAR LIMB LEAD			UNIPOLAR CHEST LEAD						TOTAL
	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6	
qR	6	18	17	1	4	18	1	1			4	12	82
R	5	2	3		2	2	7	3	3	9	9	5	50
Rs	2				2		5	7	12	9	7	1	45
RS	2							9	6	3	1		21
rS	2			9	5		2	1				1	20
QS	1			8	4		1					1	15
Qr	2			3	1	1	2						9
qr							2					1	3
rs					2		1						3
QR	1	1											2
qRs			1										1
qs					1								1
Number of occurrences of types	8	3	3	4	8	3	8	5	3	3	4	6	252

Furthermore in the unipolar chest lead, R and Rs types in V1, RS and Rs types in V2, Rs and RS types in V3, R and Rs in V4 & V5, and qR & R types in V6 were observed largest numbers of cases respectively.

ST segment: Configurations in the ST segment as shown in table 3, may be classified into 5 types as upward, downward, arc curve wave faced downward, arc curve wave faced upward and 0-line types. From this classification, 0-line and upward types were most frequently observed respectively through all the leads. In the limb lead, 0-line and downward types were found in most cases. In the unipolar limb lead, 0-line type was mainly traced. In the unipolar chest lead, upward type in V2~V4 and 0-line type in V1, V5 and V6 were often found respectively. Arc curve type was found rarely in each lead tracing in this segment.

T wave: T wave, as shown in table 3, may be classified into 4 types as monophasic positive wave, monophasic negative wave, plus-minus type, and minus-plus type. Through the entire recording from in lead the positive wave was observed in most cases and secondarily negative one. In the limb lead, positive waves were found in about half of all cases while remaining cases indicated negative and diphasic waves. In the unipolar limb lead recordings, the negative T waves were observed in 15 out of 21 cases of aVR, but in aVL and aVF the positive waves were found mostly. In the unipolar chest lead, positive T waves were found in most cases of each lead except showing negative waves in some cases of V1 and V6, but diphasic waves were not recorded.

3. Frequency of appearance of Q, R and S waves recorded by each lead

As described above in the paragraph on QRS complex, various forms of QRS complex

TABLE 5. *Frequency of Q, R and S waves (%)*

LEADS		Q	R	S
Limb Lead	I	47.6	95.4	33.4
	II	90.5	100	0
	III	85.8	100	4.7
Unipolar Limb Lead	aVR	57.2	69.0	81.0
	aVL	47.6	76.3	66.7
	aVF	90.5	100	0
Unipolar Chest Lead	V1	19.1	100	42.9
	V2	4.7	100	81.0
	V3	0	100	85.8
	V4	0	100	57.2
	V5	19.1	100	38.2
	V6	62.0	95.4	14.3

were found in this experiment. The percentages of the frequency of appearances of Q, R and S waves respectively in each lead, as shown in table 5, are as follows: In the limb lead, the Q in lead I was present in 47.6%, in lead II in 90.5% and lead III in 85.8% respectively. R wave was present in 95.4~100% on each lead recordings. S wave was present in 33.4% in lead I and in 4.7% on lead III, but in lead II the S wave was not observed. In the unipolar limb lead, Q wave was recorded at the rate of 57.2% on aVR, 47.6% on aVL and 90.5% on aVF. R wave was present in 69~100%. S wave of aVR was seen at the rate of 81.0% and in 66.7% on aVL, but in aVF the S wave was not seen. In the unipolar chest lead, the Q wave of leads V3 and V4 were not observed. R waves of V1~V5 were present in 100% and of V6 they occurred in 95.4% of the records. S wave of leads V1, V5 and V6 were present in 14.3~42.9%, but the wave in V2~V4 was present in 57.2~85.8%.

4. Notchings on QRS complex

In each lead, notching formation in the recordings was observed on the deflection of the Q, R and S waves. The result of classification of those notchings is shown in table 6. The method of classification was based on the positions of notching; 6 different types or different positions may be listed as upward deflection of R, on top of R and on downward deflection of R, on downward deflection of Q and S, on bottom of Q and S and on upward deflection of Q and S. The notching formations were mostly observed on the downward deflections of R and secondary ones on upward deflections of R. The differences of notching formation recorded from each lead were slightly observed. The percentages of notching formations of leads III, V3 and V5 showed slightly greater than those of other leads.

TABLE 6. *Notching of QRS complex*

TYPES OF WAVES	LIMB LEAD			UNIPOLAR LIMB LEAD			UNIPOLAR CHEST LEAD						TOTAL
	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6	
	3	1	2		2		2	1	5	4	1	2	23
	2	7	6		2	2	2	1	1		3	4	30
	6	6	8		5	10	5	6	10	10	15	6	87
	1		1	7	2			1	3	1	1		17
	1			1			5	2	2			1	12
	2		1	7	5			2					17
Total	15	14	18	15	16	12	14	13	21	15	20	13	186

5. The relation between ST segment and T wave

As described in the section on ST under QRS complex, the form of ST segment is influenced by the direction of deflection of T wave. Table 7 records that when the ST segment shows upward deflection the T wave shows positive wave, when the ST shows downward the T wave indicates negative and when the ST shows 0-line one half of the cases of T wave indicated positive while the remaining ones are negative.

6. Measurement of the wave

Measurements were made on each wave in each lead concerning the amplitudes, intervals and durations. The minimum, maximum and average values were calculated.

a) Amplitudes of waves

Table 8 records the minimum, maximum and average values of P, Q, R, S and T waves in each lead.

P wave: In the limb lead, the average value of −0.104 mv as negative P and 0.152 mv as positive in lead I, 0.288 mv in lead II and 0.232 mv in lead III were obtained respectively. In the unipolar limb lead, −0.147 mv and 0.100 mv in aVR, −0.225 mv and 0.236 mv in aVL and −0.100 mv and 0.192 mv in aVF were gotten respectively as average values. Further, in the unipolar chest lead, −0.100 mv and 0.194 mv in V1, −0.112 mv and 0.137 mv in V2, −0.120 mv and 0.177 mv in V3, 0.230 mv in V4, 0.252 mv in V5 and 0.310 mv in V6 were respectively measured. The maximum value of amplitudes of P wave through all leads was 0.800 mv in V6 and the minimum was 0.030 mv in aVL.

Q wave: Q wave was measured at the first negative deflection just before the R wave of the QRS complex. The average values for each lead are as follows: In the limb lead, −0.307 mv in lead I, −0.169 mv in lead II and −0.171 mv in lead III were measured

TABLE 7. *Relation of ST segment and T wave*

LEAD		TYPE OF ST	T WAVE			
			Positive Wave	Negative Wave	Minus-plus	Plus-minus
Limb Lead	I	Upward	5			
		Downward		3		
		Zero-line	7	3		
		Arc ↔	2			
	II	Upward	4			
		Downward		4	2	
		Zero-line	8	1		
		Arc ↑	1			
	III	Upward	3			
		Downward	1	5	1	
		Zero-line	6	1	1	
		Arc ↓	2		1	
Unipolar Limb Lead	aVR	Downward		2		
		Zero-line	5	12	1	1
		Arc ↑		1		
	aVL	Upward	1			
		Downward		2		
		Zero-line	12	4	2	
	aVF	Upward	2			
		Downward		1		
		Zero-line	10	5	2	
Unipolar Chest Lead	V 1	Upward	6			
		Downward	1	3		
		Zero-line	6	4		
	V 2	Upward	13			
		Zero-line	7			
		Arc ↑	1			
	V 3	Upward	14			
		Zero-line	6			
		Arc ↓	1			
	V 4	Upward	15			
		Zero-line	5			
		Arc ↑	1			
	V 5	Upward	10			
		Downward			1	
		Zero-line	8			
		Arc ↑	2			
	V 6	Upward	2			
		Downward		3	1	
		Zero-line	12	2		

TABLE 8. *Minimum, Maximum and Average Values of the Electrocardiographic Waves (in milli-volts) in Shepherd Dogs*

LEAD		P			Q			R			S			T		
		Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.
Limb Lead	I	−0.012	0.250	0.104	0.030	1.050	0.307	0.080	0.750	0.495	0.050	0.800	0.325	+0.030	0.650	0.176
		+0.030	0.250	0.152										−0.120	0.550	0.305
	II	+0.090	0.430	0.288	0.100	0.730	0.169	0.500	2.150	1.160			0.180	+0.100	0.650	0.211
	III	+0.100	0.400	0.232	0.050	0.320	0.171	0.300	2.280	0.891				+0.100	0.600	0.227
														−0.100	0.300	0.283
Unipolar Limb Lead	aVR	−0.050	0.400	0.147	0.100	1.400	0.495	0.050	0.400	0.156	0.100	0.951	0.660	+0.050	0.300	0.256
		+0.100	0.100	0.100										−0.003	1.200	0.329
	aVL	−0.150	0.300	0.225	0.100	0.700	0.273	0.050	0.900	0.500	0.100	0.951	0.521	+0.050	0.600	0.180
		+0.030	0.400	0.236										−0.005	0.300	0.215
	aVF	−		0.100	0.050	0.450	0.154	0.100	2.320	1.150				+0.030	0.520	0.259
		+0.100	0.300	0.192										−0.050	0.350	0.174
Unipolar Chest Lead	V 1	−		0.100	0.100	0.450	0.241	0.100	1.950	0.548	0.100	0.700	0.383	+0.100	0.720	0.343
		+0.050	0.500	0.194										−0.050	0.100	0.075
	V 2	−0.050	0.200	0.112			0.020	0.700	2.300	1.150	0.100	1.400	0.657	+0.200	1.500	0.765
		+0.040	0.200	0.137												
	V 3	−		0.120				0.751	2.550	1.480	0.090	1.450	0.535	+0.350	1.900	0.989
		+0.050	0.320	0.177												
	V 4	+0.100	0.350	0.230			0.050	0.650	2.900	1.810	0.100	1.600	0.420	+0.250	1.180	0.801
	V 5	+0.150	0.400	0.252	0.050	0.100	0.075	0.170	2.900	1.180	0.100	0.450	0.211	+0.150	1.800	0.559
	V 6	+0.100	0.800	0.310	0.035	0.300	0.113	0.050	2.000	0.650	0.080	0.650	0.365	+0.030	1.120	0.204
														−0.080	0.800	0.295

respectively. In the unipolar limb lead, −0.459 mv in aVR, −0.273 mv in aVL and −0.154 mv in aVF were obtained. Further, in the unipolar chest lead, −0.241 mv in V1, −0.020 mv in V2, 0.050 mv in V4, 0.075 mv in V5 and −0.113 mv in V6 were respectively recorded. The Q wave of lead V3 was not measured because the wave was not recognizable. The maximum value of Q wave was −1.400 mv in aVR and the minimum was −0.020 mv in V2.

R wave: Amplitudes of R wave of each lead showed much difference from one another. In the limb lead, 0.459 mv in lead I, 1.16 mv in lead II and 0.891 mv in lead III were measured respectively. In the unipolar limb lead, 0.156 mv in aVR, 0.500 mv in aVL and 1.15 mv in aVF were obtained respectively. In the unipolar chest lead, 0.548 mv in V1, 1.15 mv in V2, 1.48 mv in V3, 1.81 mv in V4, 1.18 mv in V5 and 0.650 mv in V6 were recorded respectively as average values. The maximum value of R wave was 2.90 mv of V4 and V5, and that of minimum was 0.050 mv of aVR, aVL and V6.

S wave: The negative wave just after of R wave was measured as the S wave. In the limb lead, −0.325 mv in lead I and −0.180 mv in lead III were obtained. But S wave of lead II was not measured because the wave was not traced. In the unipolar limb lead, −0.660 mv in aVR and −0.521 mv in aVL were gotten, but the S wave of aVF was not observed. In the unipolar chest lead, −0.383 mv in V1, −0.657 mv in V2, −0.535 mv in V3, −0.42 mv in V4, −0.211 mv in V5 and −0.365 mv in V6 were measured respectively. The maximum value of S wave was −1.600 mv in V4 and the minumum was −0.050 mv in lead I.

T wave: In order to indicate the positive deflection of T wave the sign + (plus) was used and for negative one the sign − (minus) was applied. In the limb lead, −0.305 mv and +0.176 mv in lead I, +0.211 mv in lead II, and −0.283 mv and +0.277 mv in lead III were obtained respectively as average values. In the unipolar limb lead, −0.329 mv and +0.256 mv in aVR, −0.215 mv and +0.180 mv in aVL, and −0.174 mv & +0.259 mv in aVF were gotten. Further, in the unipolar chest lead, −0.075 mv and +0.343 mv in V1, +0.765 mv in V2, +0.989 mv in V3, +0.801 mv in V4, +0.559 mv in V5, and −0.295 mv & +0.204 mv in V6 were recorded respectively. The maximum value of positive T was +1.900 mv in V3 and the minimum was +0.03 mv in leads I and V6. On the other hand, the maximum value of negative T was −1.200 mv in aVR and minimum −0.003mv in aVR.

b) Intervals and durations of waves

Table 9 shows the results of measurements of the intervals of PQ, QT, ST and durations of P, QRS and T waves.

P wave: In leads I, II and III the average values of 0.046 sec, 0.046 sec and 0.058 sec were obtained respectively. In the unipolar limb lead, 0.048 sec in aVR, 0.046 sec in aVL, and 0.045 sec in aVF were measured respectively. Further, in the unipolar chest lead, 0.047 sec in V1, 0.041 sec in V2, 0.058 sec in V3, 0.063 sec in V4, 0.060 sec in V5, and 0.048 sec in V6 were respectively recorded. The maximum value of duration of P was 0.15 sec in recordings from lead II and minimum was 0.005 sec in aVL.

QRS complex: From the beginning point of Q until the end of S wave was measured as the duration of QRS complex. In the limb lead, 0.042 sec in lead I, 0.051 sec in lead II and 0.052 sec in lead III were gotten. In the unipolar limb lead, average value of 0.051 sec in aVR and aVF, and 0.045 sec in aVL were obtained. Further, in the unipolar chest lead,

TABLE 9. *Minimum, Maximum and Average Values of the Duration and Interval of the Waves (in second) in Shepherd Dogs*

	LEAD	P			QRS			T			PQ			QT			ST		
		Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.
Limb Lead	I	0.020	0.060	0.046	0.030	0.065	0.042	0.025	0.280	0.054	0.065	0.140	0.121	0.110	0.305	0.183	0.025	0.210	0.074
	II	0.035	0.150	0.046	0.040	0.075	0.051	0.025	0.100	0.050	0.075	0.150	0.110	0.130	0.200	0.165	0.025	0.190	0.079
	III	0.020	0.075	0.058	0.040	0.075	0.052	0.025	0.175	0.066	0.065	0.140	0.104	0.150	0.225	0.170	0.010	0.090	0.063
Unipolar Limb Lead	aVR	0.020	0.100	0.048	0.030	0.065	0.051	0.030	0.100	0.054	0.065	0.140	0.114	0.160	0.215	0.180	0.050	0.125	0.071
	aVL	0.005	0.060	0.046	0.035	0.065	0.045	0.030	0.175	0.056	0.100	0.150	0.117	0.150	0.210	0.171	0.015	0.110	0.074
	aVF	0.020	0.075	0.045	0.030	0.075	0.051	0.020	0.075	0.051	0.075	0.145	0.109	0.110	0.190	0.170	0.050	0.140	0.074
Unipolar Chest Lead	V 1	0.035	0.065	0.047	0.030	0.075	0.045	0.025	0.110	0.057	0.090	0.175	0.120	0.150	0.225	0.175	0.025	0.125	0.074
	V 2	0.025	0.055	0.041	0.035	0.075	0.055	0.030	0.150	0.097	0.075	0.150	0.111	0.170	0.225	0.191	0.005	0.100	0.036
	V 3	0.025	0.075	0.058	0.035	0.075	0.056	0.050	0.175	0.142	0.095	0.150	0.108	0.160	0.250	0.190	0.005	0.060	0.027
	V 4	0.040	0.110	0.063	0.035	0.095	0.049	0.025	0.150	0.103	0.075	0.150	0.114	0.180	0.225	0.203	0.001	0.125	0.047
	V 5	0.040	0.110	0.060	0.030	0.060	0.047	0.040	0.125	0.087	0.090	0.125	0.106	0.150	0.225	0.200	0.025	0.110	0.064
	V 6	0.040	0.075	0.048	0.030	0.055	0.041	0.040	0.150	0.049	0.100	0.150	0.112	0.160	0.250	0.180	0.075	0.125	0.103

the values of 0.045 sec in V1, 0.055 sec in V2, 0.056 sec in V3, 0.049 sec in V4, 0.047 sec in V5 and 0.041 sec in V6 were respectively measured. Maximum value of QRS was 0.095 sec in V4 and minimum was 0.030 sec in leads I, aVR, aVF, V1, V5 and V6.

T wave: In the limb lead, the average values of 0.054 sec in lead I, 0.050 sec in lead II and 0.066 sec in lead III were measured respectively. In the unipolar limb lead, 0.054 sec in aVR, 0.056 sec in aVL, and 0.051 sec in aVF were recorded respectively. In the unipolar chest lead, 0.057 sec in V1, 0.097 sec in V2, 0.142 sec in V3, 0.103 sec in V4, 0.087 sec in V5, and 0.049 sec in V6 were respectively obtained. Maximum value of duration of T was 0.280 sec in lead I and the minimum was 0.020 sec in aVF.

PQ: The segment from the beginning point of P wave until the beginning point of QRS complex was measured as PQ (PR) interval. In the limb lead, values of 0.121 sec, 0.110 sec and 0.104 sec respectively in leads I, II and III were measured. In the unipolar limb lead, 0.114 sec in aVR, 0.117 sec in aVL, and 0.109 sec in aVF were recorded respectively. In the unipolar chest lead, 0.120 sec in V1, 0.111 sec in V2, 0.108 sec in V3, 0.114 sec in V4, 0.106 sec in V5, and 0.112 sec in V6 were obtained respectively. Maximum value of PQ was 0.175 sec in V1 and minimum was 0.065 sec in leads I, III and aVR.

QT: The interval extending from beginning of Q to the end of T wave was measured as QT interval. In the limb lead, 0.183 sec in lead I, 0.165 sec in lead II, and 0.170 sec in lead III were respectively measured as average value. In the unipolar limb lead, 0.180 sec in aVR, 0.171 sec in aVL and 0.170 sec in aVF were gotten. In the unipolar chest lead, 0.175 sec in V1, 0.191 sec in V2, 0.190 sec in V3, 0.203 sec in V4, 0.200 sec in V5, and 0.180 sec in V6 were obtained respectively. Maximum value of QT interval was 0.305 sec in lead I and minimum was 0.110 sec in aVF.

ST: The ST interval between the terminal point of S and beginning point of T was measured. In the limb lead, values of 0.074 sec, 0.079 sec and 0.063 sec in leads I, II and III were recorded respectively. In the unipolar chest lead, 0.071 sec in aVR, 0.074 sec in aVL and aVF were obtained. In the unipolar chest lead, 0.074 sec in V1, 0.036 sec in V2, 0.027 sec in V3, 0.047 sec in V4, 0.064 sec in V5, and 0.103 sec in V6 were measured respectively. Maximum value of ST was 0.210 sec in lead I and minimum was 0.001 sec in V4. As described above, each ST interval indicated definitely different values, because the ST segment was influenced by the form of T wave. In some cases, the authors could not decide where the beginning point of T or terminal point of ST occured, therefore, it was not possible to measure the ST interval very correctely.

7. The quotient of R/S in the unipolar chest lead

The general configurations of QRS complex in the unipolar chest lead are characterized by the R-S complex. As the elctrode is moved from V1 to V6, the deflection of amplitudes of R wave increases steadly, that of S wave decreases slowly. The quotient of R/S shows the degree of relationship between the R and S deflection. The quotient of R/S in human subjects has been used for an indication in the diagnosis of the heart damage. Table 10 provides the value of the quotient of R/S in S dogs. "0=%" means the percentage of cases which were not calculated because either the R or S were absent. From V1 to V4 the R/S quotient increases in value and then decreases in V5 and V6. The quotients are as follows: 0.47 in V1, 3.20 in V2, 5.39 in V3, 7.85 in V4, 7.82 in V5, and 1.91 in V6.

TABLE 10. *The Quotient of R/S in Unipolar Chest Lead*

LEAD	MIN.	MAX.	AVER.	0=(%)
V 1	0.20	0.8	0.47	31.8
V 2	0.106	8.0	3.20	18.9
V 3	0.675	16.1	5.39	13.2
V 4	0.84	20.3	7.85	45.0
V 5	0.37	11.6	7.82	63.7
V 6	0.07	3.75	1.91	86.5

8. Sub-conclusion regarding electrocardiograms in S dogs

Sinus arrhythmia was observed in almost all cases; and the ages of the dogs were 2~5 years old. The cases which indicated arrhythmia showed the abnormalities of the heart sounds in clinical examinations.

Most of the P waves showed positive except the negative one of aVR and V1. The amplitudes of P wave ranged at 0.152~0.288 mv and the duration was 0.046~0.058 sec. PQ segment mostly showed 0-line waves except the few cases of leads II and aVR, and the interval was 0.104~0.121 sec. QRS complex may be classified into 12 types. In the limb lead, qR and R types were mostly observed. In unipolar limb lead rS and QS in aVR lead, Rs, QS and qR in aVL, and qR in aVF were respectively traced in most cases. In the unipolar chest lead, Rs and qR types were mostly seen. The S wave was not traced as parts of the QRS of lead II and aVF. No Q wave in V3 and V4 was seen. The amplitudes of Q were −0.020~−0.445 mv, that of R was 0.156~1.48 mv and S wave was −0.180~−0.660 mv. The duration of QRS was 0.041~0.056 sec. ST segment showed 0-line and upward types in most cases, and the duration of ST was 0.027~0.103 sec. T wave may be classified into 4 types. Positive wave of T was observed in most cases, but diphasic type was rare. The negative waves were observed in aVR and V1. Amplitude of T was 0.176~0.989 mv and −0.075~−0.305 mv. Duration of T was 0.049~0.142 sec.

Notching of the wave was observed on the deflection of QRS complex. In most cases, the notching was placed on downward stroke of R, and secondary notching occurred at top of R. Close relation was observed between the form of ST segment and direction of T in each lead. The quotient of R/S in the unipolar chest lead showed that the value was increased from V1 to V4 steadly and then decreased from V5 to V6 slowly.

B. The Electrocardiogram of Karafuto Dogs

Twenty-two cases of Karafuto dogs were examined in this experiment. The lead methods in this experiment were the same as used on Shepherd dogs.

1. Degree and character of arrhythmia

On 20 out of 22 cases, the heart rhythm showed sinus-arrhythmia. In 3 out of 20 cases, respiratory arrhythmia was observed. In 10 cases, high degrees of arrhythmia were seen and the cases showed heavy stopping of pulse beat in clinical examinations. In another 10 cases, moderate degrees of arrhythmia were observed. In the cases of under 1 year-old

TABLE 2. *Materials* (Karafuto Dog)

CASE NOS.	AGE (year)	SEX	KIND OF ARRHYTHMIA	DEGREE OF ARRHYTHMIA	CLINICAL HEART SIGN
1	0.5	male	S.A.	++	—
2	0.7	"	S.A.	++	+
3	0.75	"	S.A.	++	+
4	0.75	"	S.A.	++	+
5	0.75	"	S.A.	+	+
6	1	female	S.A. (R)	+	+
7	2	"	S.A.	+	+
8	3	"	—	—	—
9	4	"	S.A.	+	—
10	4	male	S.A. (R)	+	+
11	4	female	S.A.	+	—
12	4	"	S.A. (R)	+	—
13	5	male	—	—	—
14	5	"	S.A.	+	+
15	5	"	S.A.	++	+
16	6	"	S.A.	+	+
17	6	"	S.A.	++	+
18	6	"	A.S.	++	+
19	7	"	S.A.	++	+
20	8	"	S.A.	+	+
21	8	"	S.A.	++	+
22	11	"	S.A.	++	+

Notes: S.A. –Sinus Arrhythmia. (R) –Respiratory Arrhythmia.

and over 6 year-old dogs, high degrees of sinus arrhythmia were observed. But in over 1 year to 5 year-old experimental animals, slight degree arrhythmia were recorded. There was no fundamental difference between the electrocardiograms showing the definite arrhythmia and sinus rhythm.

2. Configuration of the waves

Classification were made of the waves in recordings from each lead as follows.

P wave: P wave may be classified into 3 types as positive wave, negative wave and flat wave as shown in table 11. In the limb lead, the P wave showed mostly positive type. In the unipolar limb lead, negative P wave in aVR, negative and positive waves in aVL, and positive wave in aVF were observed. In the unipolar chest lead, in V1 and V2 the P wave showed negative in most cases, but in V3~V6 the positive P waves were observed mostly.

TABLE 11. *Classification of P, PQ, ST and T waves*

WAVES	TYPES OF WAVES	LIMB LEAD			UNIPOLAR LIMB LEAD			UNIPOLAR CHEST LEAD					
		I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6
P	Positive	22	22	20	1	8	22	9	13	17	21	22	21
	Negative				21	8		12	9	5	1		1
	Flat			2		6		1					
PQ	0-line	22	13	14	9	20	15	15	11	14	12	13	15
	Downward		5	3			5	4	11	8	10	9	6
	Upward			1	10	1		2					1
	Arc ↓		4	2	1	1	2	1					
	Arc ↑			2	2								
ST	Upward	10	14	9		2	15	9	19	22	21	15	12
	0-line	8	4	9	9	7	5	9	1		1	7	10
	Downward	1	1	2	9	12	1	4					
	Arc ↑				4	1	1		2				
	Arc ↓	3	3	2									
T	Position	16	22	21	2	3	21	13	22	22	22	22	20
	Negative	6		1	20	19		7					2
	Plus-minus						1	2					

PQ segment: PQ segment can be classified into 5 types as 0-line, upward, downward, ascending arc curve and descending arc curve as shown in table 11. In the limb lead, PQ segment showed 0-line type in most cases and others were downward wave. In the unipolar limb lead, upward type in aVR, 0-line type in aVL and aVF were respectively observed. In the unipolar chest lead, PQ segment showed 2 different types, they are 0-line and downward types.

QRS complex: As shown in table 12, QRS complex may be classified into 12 kinds of different wave types through all the leads. Seven types in leads I and V1, 6 in V5 and V6, 5 in aVRLF, 4 in lead II, III, V2 and V4, and 3 in V3 were respectively observed. In the limb lead, the QRS complex showed R, Rs, qR and qRs types. In the unipolar limb lead, Qr, QS and rS waves in aVR and aVL were observed. On the other hand, qRs and Rs waves were mostly traced from lead aVF. In the unipolar chest lead, RS and Rs waves were mainly observed in each lead, but the QRS complex with Q deflection was very rare and Q wave from V3 was not seen.

ST segment: ST segment may be classified into 5 types as 0-line, upward, downward, descending arc curve and ascending one. Table 11 shows the classification. In the limb lead, upward type was mostly observed and secondary one was 0-line type. In the unipolar limb lead, downward type was mostly observed in leads aVR and aVL, but ST segment of aVF showed upward type. In the unipolar chest lead, ST segment of all cases, except V1 and

TABLE 12. *Classification of QRS complex*

TYPES OF WAVES	LIMB LEAD			UNIPOLAR LIMB LEAD			UNIPOLAR CHEST LEAD						TOTAL
	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6	
Rs	5	9	8	1		7	4	4	5	7	11	8	69
RS	3			2			8	16	16	12	5	5	67
qRs		5	7			8		1		2	1		24
qR	4	7	3			3					2	5	24
Qr				10	11								21
R	5	1	4			3	2				2	2	19
rS				5	3		4	1	1	1	1		16
QS				4	4		1					1	10
qr					2		2					1	5
QR	2				2								4
r	2						1						3
rs	1					1							2
Number of occurrences of types	7	4	4	5	5	5	7	4	3	4	6	6	264

V6, showed upward type. In V1 and V6 the ST showed downward type in about half cases.

T wave: T wave, as shown in table 11, may be classified into 3 types as positive wave, negative and diphasic waves. In the limb lead, positive T waves were observed in leads I, II and III, and negative T was observed in lead I and II. In the unipolar limb lead, negative waves were observed in most cases of aVR and aVF, but positive one was seen in aVL. In the unipolar chest lead, positive waves were observed in almost all cases of V2~V5, and in V1 and V6; the positive waves were observed in more often cases than the negative waves.

3. Frequency of appearance of Q, R and S waves in each lead

As described above, many types of QRS complex were observed. In this section, the degree of frequency of each Q, R and S wave in each lead was indicated by the percentage values, as shown in table 13. In the limb lead, Q waves were present in 27.3~54.5% of the tracings. R waves were present in 100% and S wave indicated in the ratio of 36.4~68.2%. In the unipolar limb lead, Q waves were present in 45.0~81.8%, R waves in 77.3~100% and S waves in 31.8~72.8%. In the unipolar chest lead, characteristic inclinations were observed. They are, Q waves were present in 0~13.2% in V1~V5, but S waves were seen in 100% in V2~V4. R waves appeared in 100% in V2~V5.

4. Notchings on QRS complex

Notchings were found on QRS complex in tracings from each lead. Based on the position of the notching formation on QRS deflections, 6 types of notchings were observed. The results of observations are shown in table 14. On the most, the notching was traced

TABLE 13. *Frequency of Q, R and S waves (%)*

LEAD		Q	R	S
Limb Lead	I	27.3	100	36.4
	II	54.5	100	63.7
	III	45.0	100	68.2
Unipolar Limb Lead	aVR	63.7	81.8	54.5
	aVL	81.8	77.3	31.8
	aVF	45.0	100	72.8
Unipolar Chest Lead	V1	13.2	95.5	77.3
	V2	4.54	100	100
	V3	0	100	100
	V4	9.08	100	100
	V5	13.2	100	81.8
	V6	31.8	95.5	63.7

TABLE 14. *Notching of QRS complex*

TYPES OF WAVES	LIMB LEAD			UNIPOLAR LIMB LEAD			UNIPOLAR CHEST LEAD						TOTAL
	I	II	III	aVR	aVL	aVF	V1	V2	V3	V4	V5	V6	
	3	1					4	5	3	3	3	3	25
	1	2	2	1	1	1	1	2		3	3	2	19
	5	7	9			9	4	3	7	5	8	2	59
				1			1	1	2		2	2	9
				2	1		1	3		2			9
				4	5			1		2	1		13
Total	9	10	11	8	7	10	11	15	12	15	17	9	134

on down-stroke of R deflection and secondarily on up-stroke and top of R wave. Notching on the Q and S waves were rarely seen. In the unipolar chest lead, notching was more frequently observed than in other leads.

5. The relation between ST segment and T wave

As mentioned above, the form of ST segment was influenced by the direction of T

TABLE 15. *Relation of ST segment and T wave*

LEAD		TYPE OF ST	T WAVE		
			Positive wave	Negative wave	Minus-plus
Limb Lead	I	Upward	10		
		Downward		1	
		Zero-line	6	2	
		Arc ↓		3	
	II	Upward	14		
		Downward	1		
		Zero-line	4		
		Arc ↓	3		
	III	Upward	9		
		Downward	1	1	
		Zero-line	9		
		Arc ↓	2		
Unipolar Limb Lead	aVR	Downward		10	
		Zero-line	1	7	
		Arc ↑	1	3	
	aVL	Upward	2		
		Downward		12	
		Zero-line	1	6	
		Arc ↑		1	
	aVF	Upward	15		
		Downward			1
		Zero-line	5		
		Arc ↑	1		
Unipolar Chest Lead	V1	Upward	8		1
		Downward		4	
		Zero-line	5	3	1
	V2	Upward	19		
		Zero-line	1		
		Arc ↑	2		
	V3	Upward	22		
	V4	Upward	21		
		Zero-line	1		
	V5	Upward	15		
		Zero-line	7		
	V6	Upward	12		
		Zero-line	8	2	

deflection. Table 15 shows that relationship between the ST segment and T waves to exist. When ST shows upward the T wave indicates positive; when ST shows downward the T wave indicates negative wave; when ST shows 0-line type the T wave more frequently indicates the positive wave than negative.

TABLE 16. *Minimum, Maximum and Average Values of the Electrocardiographic Waves (in milli-volts) in Karafuto Dogs*

LEAD		P			Q			R			S			T^1			T^2
		Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Aver.
Limb Lead	I	+0.040	1.000	0.173	0.024	0.421	0.381	0.025	1.818	0.586	0.090	0.320	0.186	+0.004	1.500	0.302	
	II	+0.050	1.000	0.350	0.002	0.400	0.144	0.550	4.200	1.998				+0.160	1.500	0.638	
	III	+0.071	0.545	0.227	0.050	0.660	0.109	0.090	3.090	1.520	0.010	1.320	0.250	+0.100	1.050	0.422	
Unipolar Limb Lead	aVR	−0.025	1.600	0.184	0.054	1.950	1.062	0.048	1.780	0.314	0.100	1.560	0.663	−0.100	0.900	0.342	
		+		0.210										+0.320	0.350	0.335	
	aVL	−0.018	0.300	0.136	0.150	1.000	0.560	0.050	0.400	0.217	0.050	0.600	0.276	−0.050	0.320	0.194	
		+0.050	0.100	0.060										+0.200	0.250	0.233	
	aVF	+0.100	0.500	0.224	0.050	0.350	0.144	0.250	2.650	1.507				+0.200	1.250	0.613	0.100
														−		0.100	
Unipolar Chest Lead	V1	−0.050	0.200	0.130	0.050	0.200	0.110	0.050	1.350	0.546	0.050	1.650	0.513	−0.010	0.550	0.267	0.100
		+0.100	0.200	0.143										+0.060	0.850	0.340	
	V2	−0.050	0.150	0.087			0.050	0.250	1.900	0.980	0.200	1.850	0.796	+0.200	3.500	0.967	
		+0.100	0.250	0.150													
	V3	−0.025	0.100	0.063				0.400	2.180	1.226	0.110	1.900	0.960	+0.025	1.298	0.732	
		+0.050	0.280	0.077													
	V4	−		0.030				0.450	2.350	1.203	0.080	1.600	0.723	+0.040	1.750	0.761	
		+0.050	0.300	0.106													
	V5	+0.100	0.300	0.169	0.036	0.100	0.077	0.130	2.500	1.339	0.100	1.900	0.637	+0.300	1.850	0.757	
	V6	−		0.100	0.010	0.500	0.170	0.100	2.800	1.437	0.100	1.689	0.721	+0.050	1.800	0.644	
		+0.080	0.400	0.190										−		0.150	

6. Measurement of the waves

Measurements were made on the amplitudes, intervals and durations in each wave in each lead. Maximum, minimum and average values were recorded.

a) Amplitudes of P, Q, R, S and T waves of each lead were tabulated in table 16.

P wave: In the limb lead, average value of 0.173 mv in lead I, 0.35 mv in lead II, and 0.227 mv in lead III were respectively obtained. In the unipolar limb lead, −0.184 mv and 0.210 mv in aVR, −0.136 mv and 0.06 mv in aVL, and 0.244 mv in aVF were recorded. In the unipolar chest lead, average values of −0.130 mv and 0.143 mv in V1, −0.087 mv and 0.15 mv in V2, −0.063 mv and 0.077 mv in V3, −0.030 mv and 0.106 mv in V4, 0.169 mv in V5, and −0.100 mv and 0.19 mv in V6 were respectively recorded. Besides, the maximum value of P amplitude was −0.160mv in aVR, the minimum was −0.018 mv in aVL.

Q wave: In the limb lead, Q wave was measured at −0.381 mv in lead I, −0.144 mv in lead II, and −0.109 mv in lead III were respectively recorded. In the unipolar limb lead, −1.062 mv in aVR, −0.56 mv in aVL, and −0.144 mv in aVF were obtained. Further, in the unipolar chest lead, −0.110 mv in V1, −0.05 mv in V2, −0.077 mv in V5 and −0.17 mv in V6 were measured. But the Q waves of V3 and V4 were not seen. Maximum value of Q wave was −1.95 mv in aVR and minimum one was −0.002 mv in lead II.

R wave: Amplitudes of R waves in lead I, aVR, aVL and V1 showed low deflection, and the other leads showed high amplitude deflection. In the limb lead, 0.586 mv in lead I, 1.998 mv in lead II, and 1.52 mv in lead III were gotten as average values. In the unipolar limb lead, 0.314 mv in aVR, 0.217 mv in aVL, and 1.507 mv in aVF were recorded respectively. Further in the unipolar chest lead, gradual increase of R waves was observed at from V1 to V6. They are 0.546 mv in V1, 0.98 mv in V2, 1.226 mv in V3, 1.203 mv in V4, 1.339 mv in V5, and 1.437 mv in V6. Maximum value of R wave was 4.20 mv in lead II and minimum was 0.025 mv in lead I.

S wave: S waves of lead I, III and aVL indicated low amplitude deflection but S waves of leads II and aVF were not observed. In the limb lead, −0.186 mv in lead I and −0.250 mv in lead III were recorded. In the unipolar limb lead, −0.633 mv in aVR and −0.276 mv in aVL were gotten. In the unipolar chest lead, −0.513 mv in V1, −0.796 mv in V2, −0.96 mv in V3, −0.723 mv in V4, −0.637 mv in V5 and −0.721 mv in V6 were measured respectively. Maximum value of amplitude of S wave was −1.90 mv in V3 and V5, and minimum one was −0.01 mv in lead III.

T wave: In most cases, T wave showed positive and negative form, while diphasic type was rare. As the signs of diphasic wave, T^1 as first deflection and T^2 as second deflection were used in this paper. In the limb lead, 0.302 mv in lead I, 0.638 mv in lead II and 0.422 mv in lead III were recorded respectively. In the unipolar limb lead, −0.342 mv and 0.335 mv in aVR, −0.194 mv and 0.233 mv in aVL, −0.100 mv and 0.613 mv in T^1 and 0.100 mv in T^2 of aVF were measured respectively. In the unipolar chest lead, T^1 of V1 was recorded as −0.267 mv and 0.34 mv, T^2 of V1 was measured as −0.100 mv. Amplitude of V2 was 0.967 mv, V3 was 0.732 mv, V4 was 0.761 mv, V5 was 0.757 mv, and V6 were −0.150 mv and 0.644 mv as average values. Amplitude of positive T wave was showed greater deflection than that of negative T waves. Maximum value of positive T wave was 3.50 mv in V2 and that of negative wave was −0.90 mv in aVR. Minimum value of

TABLE 17. *Minimum, Maximum and Average Values of the Duration and Interval of the Waves (in second) in Karafuto Dogs*

	LEAD	P			QRS			T			PQ			QT			ST		
		Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.
Limb Lead	I	0.020	0.075	0.041	0.020	0.063	0.037	0.025	0.110	0.054	0.065	0.190	0.118	0.100	0.250	0.190	0.050	0.140	0.085
	II	0.030	0.090	0.057	0.030	0.045	0.038	0.025	0.125	0.072	0.100	0.180	0.141	0.100	0.225	0.180	0.025	0.100	0.073
	III	0.025	0.075	0.055	0.030	0.090	0.039	0.055	0.140	0.078	0.100	0.160	0.125	0.125	0.225	0.180	0.015	0.100	0.075
Unipolar Limb Lead	aVR	0.025	0.075	0.052	0.030	0.085	0.040	0.025	0.125	0.068	0.100	0.175	0.122	0.075	0.225	0.117	0.010	0.110	0.088
	aVL	0.015	0.075	0.040	0.005	0.080	0.038	0.015	0.100	0.050	0.050	0.150	0.118	0.075	0.215	0.178	0.050	0.170	0.090
	aVF	0.005	0.075	0.052	0.030	0.050	0.038	0.010	0.125	0.076	0.090	0.175	0.126	0.125	0.225	0.174	0.010	0.100	0.074
Unipolar Chest Lead	V 1	0.015	0.060	0.031	0.020	0.060	0.039	0.025	0.125	0.069	0.090	0.160	0.119	0.125	0.250	0.189	0.015	0.150	0.075
	V 2	0.025	0.125	0.052	0.030	0.060	0.052	0.050	0.115	0.082	0.085	0.175	0.131	0.125	0.240	0.190	0.025	0.125	0.065
	V 3	0.025	0.115	0.051	0.020	0.100	0.046	0.050	0.152	0.097	0.080	0.190	0.116	0.075	0.230	0.176	0.015	0.105	0.055
	V 4	0.015	0.125	0.049	0.035	0.060	0.045	0.015	0.190	0.093	0.075	0.200	0.138	0.100	0.225	0.118	0.015	0.115	0.062
	V 5	0.005	0.060	0.047	0.030	0.080	0.048	0.015	0.175	0.096	0.075	0.190	0.123	0.140	0.230	0.164	0.025	0.125	0.066
	V 6	0.020	0.075	0.047	0.025	0.055	0.038	0.050	0.125	0.081	0.075	0.175	0.120	0.160	0.224	0.175	0.025	0.150	0.078

positive T wave was 0.004 mv in lead I and that of negative one was −0.01 mv in V 1.

b) Intervals and durations of waves

Table 17 exhibits the results of measurements on durations and intervals in each lead.

P wave: In the limb lead, 0.041 sec in lead I, 0.057 sec in lead II and 0.055 sec in lead III were obtained as average values. In the unipolar limb lead, 0.052 sec in aVR and aVF, and sec 0.040 in aVL were recorded. In the unipolar chest lead average value of 0.031 sec in V 1, 0.052 sec in V 2, 0.051 sec in V 3, 0.049 sec in V 4, and 0.047 sec in V 5 and V 6 were measured respectively. Maximum value of P duration was 0.125 sec in V2 and V 4. Minimum was 0.005 sec in aVF and V 5.

QRS complex: Increase of duration in QRS complex was observed in the unipolar chest lead while decrease was seen in other leads. Average values are as follows. In the limb lead, 0.037 sec in lead I, 0.038 sec in lead II and 0.039 sec in lead III were recorded. In the unipolar limb lead, 0.040 sec in aVR, and 0.038 sec in aVL and aVF were measured respectively. In the unipolar chest lead, 0.039 sec in V 1, 0.052 sec in V 2, 0.046 sec in V 3, 0.045 sec in V 4, 0.048 sec in V 5, 0.038 sec and in V 6 were gotten. Maximum value of QRS was 0.100 sec in V 3 and minimum one was 0.005 sec in aVL.

T wave: Duration of T wave showed increase in value in the unipolar chest lead and showed decrease in other leads. In the limb lead, 0.054 sec in lead I, 0.072 sec in lead II and 0.078 sec in lead III were measured, In the unipolar limb lead, 0.068 sec in aVR, 0.050 sec in aVL, and 0.076 sec in aVF respectively were measured. Further, in the unipolar chest lead, 0.069 sec in V 1, 0.082 sec in V 2, 0.097 sec in V 3, 0.098 sec in V 4, 0.096 sec in V 5, and 0.081 sec in V 6 were obtained respectively. Maximum value of T duration was 0.19 sec in V 4 and minimum one was 0.010 sec in aVF.

PQ: PQ interval was measured on the segment of the recordings from the beginning point of P to the beginning point of QRS. In the limb lead, 0.118 sec in lead I, 0.141 sec in lead II, and 0.125 sec in lead III were respectively obtained as average values. In the unipolar limb lead, 0.112 sec in aVR, 0.118 sec in aVL and 0.126 sec in aVF were recorded. In the unipolar chest lead, 0.119 sec in V 1, 0.131 sec in V 2, 0.116 sec in V 3, 0.138 sec in V 4, 0.123 sec in V 5, and 0.120 sec in V 6 were gotten. Maximum value of PQ interval was 0.200 sec in V 4 and minimum value was 0.05 sec in aVL.

QT: QT interval was measured from the beginning point of QRS to the end of T wave, which means the activation time of ventricles. In the limb lead, 0.190 sec in lead I, 0.180 sec in leads II and III were obtained as average values. In the unipolar limb lead, 0.117 sec in aVR, 0.178 sec in aVL, and 0.174 sec in aVF were measured respectively. In the unipolar chest lead, 0.189 sec in V 1, 0.190 sec in V 2, 0.176 sec in V 3, 0.118 sec in V 4, 0.164 sec in V 5, and 0.175 sec in V 6 were recorded. Maximum value of QT interval was 0.25 sec in leads I and V 1, and minimum one was 0.075 sec in aVR, aVL and V 3.

ST: The interval between the end of QRS complex and the beginning point of T wave was measured as ST. In the limb lead, 0.085 sec in lead I, 0.073 sec in lead II, and 0.075 sec in lead III were gotten. In the unipolar limb lead, 0.038 sec in aVR, 0.090 sec in aVL and 0.074 sec in aVF were measured as average values. In the unipolar chest lead, 0.075 sec in V 1, 0.065 sec in V 2, 0.055 sec in V 3, 0.062 sec in V 4, 0.066 sec in V 5 and 0.078 sec in V 6 respectively were measured. Maximum value of ST interval was 0.17 sec in aVL

and minimum was 0.01 sec in aVF.

7. The quotient of R/S in the unipolar chest lead

In the unipolar chest lead, according to the movements of the electrode position, the frequency of appearance of R and S waves and their amplitude were changed. This findings

TABLE 18. *The Quotient of R/S in Unipolar Chest Lead*

LEAD	MIN.	MAX.	AVER.	0=(%)
V 1	0.14	7.00	1.69	27.30
V 2	0.37	6.65	1.84	4.54
V 3	0.50	19.53	2.58	0
V 4	0.45	29.44	3.93	0
V 5	0.43	8.35	3.03	18.90
V 6	0.70	9.00	3.16	50.00

may be effected by the anatomical heart position and the position of electrode. In human electrocardiogram, when the electrode is moved from V 1 to V 6, the R wave increases in amplitude and S wave decreases. Those relations may be indicated by the quotient of R and S-R/S. By the same method as in human beings, the quotient of R/S of K dog, as shown in table 18, was measured. "=%" indicates the percentage of which the quotient was not obtained because either R or S were absent. The value of 1.69 in V 1, 1.84 in V 2, 2.58 in V 3, 3.93 in V 4, 3.03 in V 5, and 3.16 in V 6 were respectively recorded. The quotient of R/S shows gradual increase from V 1 to V 4, and maximum value was seen in the lead position of V 4 then decrease in V 5 and again slight increase in V 6.

8. Sub-conclusion as to the electrocardiogram in K dog

Cases of arrhythmia which were observed mostly in this experiment, were all sinus arrhythmia. The degree of arrhythmia in the animals of which the age was under 1 year and over 5 years showed heavy sinus arrhythmia with stopping of pulse. On the contrary, dogs of 1 to 5 years showed slight arrhythmia. Further, the abnormalities of the heart sounds were observed in high degree in the cases of arrhythmia.

P waves showed mostly positive deflection except negative waves of leads aVR and V 1. Amplitude of P was measured at 0.06~0.35 mv. Duration of P was 0.32~0.556 sec. The figure of PQ segment showed parallel with 0-line in the limb lead, aVL and aVF, but in the unipolar chest lead the wave showed upward type in half of the cases while the others were downward waves. Duration of this segment was recorded as 0.116~0.141 sec.

QRS complex in K dog may be classified into 12 different types. Rs and RS types were observed in most cases. But in aVR and aVL the complex showed QS type waves. Further in the unipolar chest lead, Q waves were seen rarely, especially the Q wave was not observed in V 3. Amplitude of Q waves was 0.05~1.062 mv, that of R was 0.21~1.998 mv, and S was 0.186~0.96 mv. Duration of QRS complex was measured as 0.033~0.052 sec.

In ST segment of the limb lead, 0-line type and upward types were mostly observed.

But in the unipolar limb lead, the wave showed downward type, and in the unipolar chest lead ST segment showed upward type. Duration of ST was calculated as 0.052~0.090 sec. T waves in most lead showed positive deflection except negative waves of aVR and aVL. Amplitude of positive T wave was 0.096~0.233 mv and that of negative wave was −0.100~−0.342 mv. Duration of T was 0.050~0.098 sec.

Notching formations on QRS complex were observed mostly on downward deflection of R and next more often at upward deflection of R. They were observed more frequently in the unipolar chest lead than in other leads. There are some relationships between the form of ST segment and direction of T deflection. When ST segment showed upward, the T wave indicated positive deflection. When ST showed downward the T indicated negative wave. Further, when ST segment showed 0-line type, the T wave showed positive waves in more cases than negative cases. Observations were made on the quotient of R/S of the unipolar chest lead. The R/S values increase gradually from the lead point of V1 to V4, decrease in V5, and then again increase in V6 over V5. The value of R/S in V1 was 1.69, V4 was 3.93 and V6 was 3.16.

C. Comparison of Observations on the Electrocardiogram in S Dog and K Dog

Electrocardiograms were recorded by above described three different kinds of leads methods. The records obtained from 21 S dogs and 22 K dogs, were studied concerning the configuration of waves and measurement values to ascertain the differences between the electrocardiograms of S and K dogs. The results are as follows.

Arrhythmia: The kind of arrhythmia in both sorts of dogs was almost always sinus arrhythmia. In K dogs, the arrhythmia was observed in young dogs under 1 year and old dogs aged over 5 years. On the contrary, the arrhythmia, in S dogs, was observed in the cases whose ages were between 2 and 5 years.

P wave: In S dogs, negative waves were observed in leads I and aVF, but in same leads of K dogs negative waves were not observed. Besides this, in the unipolar chest lead of K dogs negative P wave was observed in almost all tracings except from V3, but S dogs negative wave was seen at V1, V2 and V3.

PQ segment: PQ segment may be classified into 5 types in the worked cases of the K dog and 3 types in the S dog. In most cases of S dogs PQ segment showed 0-line type, but in K dogs PQ segment showed 0-line and downward types.

QRS complex: QRS complex of electrocardiograms from both sorts of dogs can be classified into 12 different types respectively. Not common types were qr and r, though the K dogs have r type and S dog have qr type. Through the all lead tracings Rs and RS types were mostly observed in the K dog, but in the S dog qR, R and Rs types were mainly recorded. Some differences were observed concerning the figure of each lead wave tracings of both kinds of dogs. In the limb lead, QRS of S dogs showed mostly qR type, but in K dogs R, Rs, qR and qRs types were seen. In the unipolar limb lead, QRS of aVR in both sorts of dog showed the same picture, but in aVL of K dogs the wave showed mostly Qr and QR types. On the other hand, in S dogs R, Rs and qR types were observed. Further, in aVF, the waves of S dogs showed qR while in K dogs they were qRs and Rs types. In the unipolar chest lead, there is no essential differences between the two sorts of dogs.

ST segment: ST segment of K dog recordings showed upward waves and in S dogs

the wave showed 0-line types. Especially, in the unipolar chest lead, ST segment trended to trace the upward wave.

T wave: T waves were generally observed to be positive on both dog groups except the negative T waves of aVL in K dogs and aVF in S dogs.

Notching formation on QRS complex: Notching in S dog electrocardiogram recordings was seen more often than in K dog recordings. The notching occurred on the downward deflection of R wave in most cases in both sorts of dogs. On both dog groups, the notching of the unipolar chest lead was more frequently seen than other lead recordings.

Measurement value: Amplitude and duration of P wave in the S dog showed higher and longer values than those of K dog. Amplitude of Q wave in K dogs was higher than that of S dogs. R wave of the limb lead and unipolar limb lead in K dogs were higher than that of S dogs. But in the unipolar chest lead, amplitudes of R waves of S dogs indicated higher voltage than that of K dogs. Amplitudes of S in K dogs showed higher voltage than that of S dogs. Duration of QRS complex in S dogs was longer than that of K dog. Amplitudes of T wave of the limb lead and the unipolar limb lead in K dogs indicated higher values than those of S dogs. On the other hand, in the unipolar chest lead, amplitudes of T waves in S dogs showed higher than that of K dogs. Duration of T wave in S dogs showed longer value than that of K dogs. Intervals of PQ and ST of K dogs were longer than that of S dogs. Further, intervals of QT of the limb lead and the unipolar limb lead in K dogs were longer than those of S dogs, but in the unipolar chest lead, the QT interval of S dogs was longer than that of K dogs. From these results, the authors concluded that the general tendency of measurement values is as follows: amplitudes and durations of P and QRS of S dogs indicates higher values than those of K dogs. Durations of PQ, QT, ST and T waves in K dogs indicated longer value than that of S dogs.

DISCUSSION

Several kinds of methods of arrangements for taking dog electrocardiogram have been reported by workers. According to the objects of taking electrocardiogram and experiments, different types of body position were chosen for herein reports experiments. Therefore, the position of the heart and the electric heart axis show different states according to the body position, and then configuration is influenced by the positional changes of the heart. LANNEK used the method, when taking the electrocardiogram of dog, of laying the animal on a wooden board on his left side. This method is useful for recording unipolar chest lead impulses but not for limb leads. On the other hand, the method of laying the dog on a table with his back position and the extremities fixed to a table was reported by other workers. This method may be favorable for taking the limb lead and the unipolar chest lead impulses. Moreover, this dog position is similar to that used for humans, therefore the explanations of the dog electrocardiogram are easy. Further to this, movement of dog may be prevented by using the method of fixing extremities on table; this method is in conformity with that used in operations

or experiments on the thorax organs—heart, lungs, etc. Concerning the influence on the electrocardiogram by positional changes of the heart which are caused by different fixing methods, it was reported by TAKAHASHI that in 25 out of 40 cases increase in amplitudes of QRS and T waves were observed on the electrocardiogram of back position compared with standing position.

For recording the electrocardiogram, the dog must keep his mind and body quiet during the experiment. For this purpose, drugs of anesthesia have been used usually, but this treatment does not bring good effects for electrocardiographic pictures because the drugs influence the heart functions. In the present experiments, the dog made rest for a while after fixing and then recording begins when the dog becomes quiet.

In regard to the electrode, those used in securing human electrocardiograph could not be applied because experimental animals have hair. Therefore, the present authors used a needle electrode of $^1/_2$ mm diameter like the venous injection needle, and the electrode was put into the skin under the lead position. The injury currents which are produced by using needle electrode disturbs the recordings of waves. To prevent the injury currents, in this experiment, the recordings were begun after some intervals from when the electrode was introduced into the skin.

Various kinds of lead methods have been applied by many workers. The most common method is to use the limb lead; the method is similar to that used with human. Other methods are to use unipolar limb lead, unipolar chest lead and direct leads. LANNEK used limb lead (I, II & III), IV lead as a bipolar lead which lead from the base and apex of the heart, and chest leads named CR6U, CR6L and CR5, in which the indifferent electrode was placed on the right foreleg and different electrodes placed on 2 points of left chest wall and 1 point of right chest wall. UEDA et al. recorded the dog electrocardiogram by using the methods of I, II & III leads and aVRLF—so called Goldberger's lead. TAKAHASHI reported that KOBAYASHI et al. experimented with the bipolar lead in which the electrodes were placed on the armpit of right side, middle point of right cartilage and left chest wall, and also reported that SHINOHARA et al. based on vectorcardiography, selected for lead positions the upper portion of right scapule, the position between second and 4th costal bones of left side on armpit level and the right groin. Kobayashi's and Takahashi's methods make use of bipolar chest leads which are same type as limb lead of human electrocardiography in relation between position of the heart and position of lead points. TAKAHASHI made comparative research concerning the lead I of Kobayashi's and Shinohara's methods. The amplitude of QRS complex and T wave of Shinohara's lead I showed remarkable increase in voltages. TAKAHASHI reported that the direction of electric heart axis in dog differs from that of human's.

Comparative observations were made on the figure of electrocardiogram which obtained from the present experiments and the results of LANNEK and UEDA et al. Consequently, in limb lead, the inclinations of the figures of P and QRS were similar with those of them, but T wave of present cases indicates a trending for the T wave to show positive deflection. In the cases of negative T wave, no changes of ST were observed and also clinical symptoms could not be found. So the authors considered that the negative T wave of limb lead may be normally observed in some cases without showing abnormality of ST segment. But this problems must be left for further study. In unipolar limb lead, the data of dog have not published by other workers. So, in this paper, the authors compared with the figure of human electrocardiogram. In lead aVR, the electrode was placed in the position above the cavity of the ventricles. It is said that P wave shows negative, QRS complex indicates QS and rS type and T wave become negative in human's waves. In present experiments, the same results as human's picture were obtained except some cases which showed qR type of QRS wave and positive T waves. The authors considered that in the cases showing qR type and positive T wave the heart is placed in the vertical position. The recordings of aVL differ from those of aVR; the electrode is faced to the left ventricle of the heart. So, the P wave shows positive, QRS complex takes qR or QR type and T wave is positive in human's picture. In the present experiments, on the contrary, the QRS complex showed Qr, QS and rS types in K dogs, while R or QS types in S dogs were observed. T wave showed negative form. From these results, the authors considered that the heart is positioned vertical to the chest wall. Further in aVF, the electrode faces to the apex and left ventricle of the heart in human's. So, P wave shows positive, QRS complex indicates Rs, and T waves usually become positive. The results of the workers' experiments showed similar configurations for the most part to those of human picture. It is considered that the vertical heart position exerts influence upon the recordings of leads aVR and aVL, but does not cause change in the recordings of lead aVF.

In unipolar chest lead, the figures of V1 and V6 are different from those of V2～V5 because each electrode is faced toward different parts of the heart. Also, figures of V1 and V6 especially the QRS complex are influenced by the rotation of the heart to the heart axis. In leads V2～V5, the electrocardiogram recordings shows similar type to those of aVF because the electrode positions of leads V2～V5 are influenced by the left ventricle and apex of the heart. In leads V3 and V4, the amplitudes of QRS complex indicate the highest voltage compared with others. These facts agree with findings of POWSNER et al. described in report of electric potential distribution of body surface in the dog.

It is said that the PQ segment usually shows flat wave which is parallel

with the base line. On the contrary, in these experiments, the downward and arc curve waves were observed. But in the cases which showed no flat wave, the P wave showed normal pattern and prolongation of PQ time was not observed. The authors considered that those cases are normal, and that the changes of PQ segment are caused by the delays action currents of the auricles. The contour of ST segment has close relation with the direction of T wave. In the present experiments, abnormal ST waves just like a coronary insufficiency were not observed.

Concerning the notching formation of QRS complex, LANNEK reported that the notchings were observed on the upward deflection of R wave on limb lead in 42% of his experimental cases. In the recordings of the present experiments, notching formations were present in 66.7~85.8% on S dogs and in 45~50% on K dogs in the limb lead. The position of notching was mostly on the downward deflection of R and secondarily on upward deflection of R. When notching formation was seen the prolongation of duration of QRS was not observed.

Measurement values in these experiments were compared with the results of LANNEK concerning limb lead. With regard to amplitudes, the values of these experiment showed lower than those of LANNEK. Concerning the duration, the present results indicate longer time than those of LANNEK. It is considered that the differences occur because of difference of species of experimental dogs and of fixing methods. The quotient of R/S in the unipolar chest lead in the S dog and K dogs used, showed higher value than that of human's data. In regard to the relationship between the value of R/S and ventricle muscle injury in dog, the authors can not made any accurate explanation on the basis of their data.

Irregularity of the heart beat usually recognized in dog clinics and the degree of arrhythmia can be diagnosed by the use of stethoscopical examination. But the character of arrhythmia can not be decided. To apply electrocardiogram gives certain information for the degree and character of arrhythmia. In the present experiments, for study of arrhythmia, lead II of the limb lead was used. The finding was that the kind of arrhythmia was always sinus arrhythmia. Concerning the relationship between arrhythmia and age of dogs, LANNEK reported that in cases of 2~4 weeks old animals arrhythmia were not observed, but in all cases of over 4 weeks arrhythmia including respiratory types in some cases were observed. From present observations, 2~5 years old S dogs and K dogs under 6 months old and over 5 years old showed definite sinus arrhythmia, but respiratory types were rare.

The relationship between the figure of the wave and dilatation and hypertrophy of the ventricles of the heart has been well studied in human electrocardiography, but not in dog electrocardiogram. On the basis of the present experiments,

the authors can not discuss the relationship because the examination of the radiographical and anatomical analyses was not conducted.

SUMMARY

Twenty-one Shepherd dogs and 22 Karafuto dogs were examined. Limb lead (I, II & III), unipolar limb lead (aVR, aVL & aVF) and unipolar chest lead (V1～V6) were employed for these experiments. Classification was made of waves and measurements of each wave of each lead. The results are summarized as follows;

1. Arrhythmia was seen in 15 out of 21 cases in the S dogs and in 20 out of 22 cases in the K dogs. All of the arrhythmia were sinus arrhythmia including some cases of respiratory arrhythmia. The cases of sinus arrhythmia showed clinically abnormal heart sound.

2. Electrocardiogram of S dogs traced by three different kinds of lead methods are as follows. P wave mostly showed positive in each lead except for negative waves in leads aVR and V1. PQ segment always showed flat wave paralleled with 0-line except the waves in some cases of leads II and aVR. QRS complex may be divided into 12 types. Through out all lead recordings, qR type was mostly observed with R and Rs types being second. But the QRS complex which was constructed of only Q and S waves were observed in leads aVR, aVL and V1. Further, no S wave was seen in leads II and aVF, and no Q wave was observed in V3 and V4. ST segment mostly showed the flat wave and upward waves. T wave showed mainly positive form but diphasic type was sometimes seen. Notching formation on QRS complex was traced mostly on the downward deflection of R and secondly on top of R waves. Close relation may be recognized between the form of ST segment and direction of deflection of T wave.

3. Electrocardiogram of K dogs are characterized as follows. P wave in most cases showed positive wave excepting negative one in leads aVR and V1. PQ segment showed flat wave in limb lead, aVL and aVF, but in recordings from the unipolar chest lead the segment showed downward deflection. QRS complex may be classified into 12 types. Rs and RS types were mostly seen but the QRS in aVR and aVL was mainly constructed of Q and S waves. In the unipolar chest lead, Q waves were not observed in recording of V3. Upward deflection and 0-line type of ST in limb lead, downward in aVL & aVR, and upward in unipolar chest lead were respectively observed. Positive T waves were observed in most cases, but in aVR and aVL the T waves showed negative. Notchings on QRS were usually found on the downward deflection of R and next most frequently on upward deflection of R. In regard to the relationship between the forms of ST and T waves, same conclusions were reached as in the S dogs.

4. Some differences were observed between the electrocardiograms of S and

K dogs, which were concerned with figure and measurement value of each wave in each lead. But fundamental differences were not observed electrocardiographically.

5. In regard to the clinical application of the electrocardiogram on dogs, the authors considered that the electrocardiograph is a useful instrument for diagnose of the heart conditions. First of all fixing method is important: the writers consider it best to put the dog on his back with extremities bandaged to the table, because the movement of the dog may be prevented during the recording of the electrocardiogram. The needle electrode is useful. The electrode is applied to the subcutaneous area under the lead position, then for some time the electrode should be kept as it is, so the injury current may be destroyed and no influence of injury currents may be recognized in the traced wave.

It is needful for diagnosis of the heart condition that recording of the electrocardiogram should be made by many leads as possible. But in clinic many leads are not applied to the patient. Therefore, authors consider it practical and useful for clinical examination that diagnosis of arrhythmia be conducted by lead II of the limb lead, and then that unipolar lead be used to learn about the positional changes of the heart. Records from the unipolar chest lead are valuable for learning about the heart muscle condition especially to ascertain if there have been damages to the ventriclar muscles.

The authors are greatly indebted to the Ministry of Education for its finacical assistance. Likewise the assistance of the concerned authorities is highly appreciated. The authors express cordial thanks to Prof. R. NAKAMURA, the chief of this Department for his kind direction and review, and also to Mrs. R. HAGA and M. AMANAI for their helpful advices.

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