STUDIES ON APPLICATIONS OF ELECTROCARDIOGRAM IN CATTLE

THE LEAD METHOD AND ELECTROCARDIOGRAM WITH SPECIAL REFERENCE TO CONFIGURATIONS AND MEASUREMENTS OF WAVES IN LIMB LEAD, BIPOLAR CHEST LEAD I AND II, AND SEMI-UNIPOLAR CHEST LEADS

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INTRODUCTION

Since the electrocardiograph was introduced by EINTHOVEN nearly 45 years ago, studies on heart conditions in human subjects have been made to a great extent. In the veterinary field, the electrocardiogram has not yet been used for the clinical diagnosis of heart conditions.

There have been a few reports published on cattle electrocardiograms. ALFREDSON and SYKES[1] reported the bovine electrocardiogram by means of the limb lead which is similar to human standard lead, and also they[9] made an experimental bundle branch block of the heart on the bovine heart using LEW's method. The electrocardiogram of the bundle branch block on the bovine heart showed a typical configuration with the prolongation of QRS duration and changes of the ST-T waves. ALFREDSON and SYKES[2], using the limb lead, later reported the electrocardiogram on 78 dairy cattle, consisting of five different species. UESAKA[10~12] used several methods for recording the electrocardiogram of Japanese Black Breed cattle and suggested that the following three portions would be the best for taking the bipolar leads, viz., the left side of the neck, the portion anterior to the costal region, and the portion nearest to the apex of the heart on the left side of the body. GULLICKSON and CALVERLY made a report on the electrocardiogram taken on experimental cattle with vitamin E defficiency, using the same lead method of ALFREDSON and SYKES's. VACIRICA[13~15], using limb lead, reported the electrocardiogram of dairy cattle in three different stages: animals eating, animals in pregnant state and those with traumatic pericarditis. Especially in traumatic pericarditis the electrocardiogram showed characteristic changes of the ST-T waves. SUGANO et al. reported the electrocardiogram of dairy cattle using bipolar lead of which the electrodes were placed on the middle point of frontal edge of scapular bone, intercostal portion between the 9th and 10th costal bones on the left side and region of the apex of the heart on the left side of the body.

BROOIJMANS reported a three bipolar lead of which the lead method was similar to EINTHOVEN's, three augmented limb leads-aVR, aVL and aVF, and chest lead using WILSONS' central terminal technique for the indifferent electrode. Nine portions on the vertical plane and 4 on the horizontal plane were selected for installing of the different electrodes on the left and right sides of the body respectively.

As described above, the majority of investigators used the limb leads which resembled EINTHOVEN's standard limb lead. The present writers, reached a conclusion that fundamental data of heart conditions could not be obtained by using merely the method of limb leads.

However, in this experiment, use was made of three bipolar leads and a semi-unipolar chest one to register normal electrocardiogram. Judging from the results obtained in this experiment, the authors believe that the methods used here would be of use for clinical veterinary medicine.

MATERIALS AND METHODS

Forty head of normal cattle, 5~12 years old, mainly comprised of non-pregnant Holstein Breed of Hokkaido University Dairy Farm were employed for the experiment.

For recording the electrocardiogram, a battery driven electrocardiograph (the time constant of differential amplifier-1.5 second, type-UD-4 manufactured by the Fukuda Co. Ltd., Tokyo) was used. This apparatus registered 3 leads synchronously with vertical marks every 20 seconds regardless of the rate of the oscillograph. The sensitivity was so corrected as to make 1 millivolt correspond to an amplitude 10 millimeters. For recording the action current the metal clip electrodes were used for every lead. The registration was carried out with the cattle in a standing position. The cattle were given rest before the examination. The measurement of each wave was conducted in conformity with the manner recommended by the Committee of the American Heart Association.

The lead method in each experiment will be described in the later part of this paper.

The waves which appeared in the electrocardiogram were named P, Q, R, S and T according to EINTHOVEN's methods. The initial ventricular complex was always called QRS. All waves, however, were not always shown. As QRS manifested monophasic negative, the term QS which has been used was applied in this report. The second positive deflection which followed R was called R′. A negative deflection subsequent to S was named S′. LEPESCHKIN's method to identify small waves in the QRS complex with small letters and large waves with large capital letters has been universally accepted. To indicate the T waves, different types of waves such as monophasic positive and negative waves and diphasic waves consisting of the plus-minus and minus-plus type waves were used in this paper.

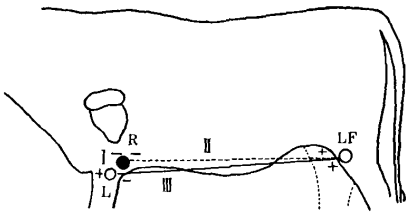
RESULTS OF EXPERIMENTS

1. Experiment No. 1—Limb Lead

Ten cattle were examined. In the experiment with limb lead, as shown in chart 1, 3 points were selected on the skin of standing cattle for the connecting of electrodes. The

electrodes in lead I were placed on the skin of the left and right olecranons respectively. In lead II, the right olecranon and left patella were selected as connecting positions. In lead III, the left olecranon and left patella were connected with the electrodes. The wires were connected to the electrocardiograph so as to record waves showing upward deflection under the following 3 conditions: (1) When the electric potential of the right olecranon is rather negative as compared to that of the left olecranon; (2) when the electric potential of the right olecranon is rather more negative than that of the left patella; (3) when the electric potential of the left olecranon is more negative than that of the left patella.

CHART 1. *Lead Method of the Limb Lead*



1) Configuration of waves

Configuration of typical wave in this lead is indicated in Fig. 1.

P wave: The most important findings of the waves were as follows. In P_{II} and P_{III}, the waves revealed flat shape and in P_{I} the peaked and M shaped waves were normally observed.

Q wave: The Q wave was observed in every case in lead I, but in leads II and III, it was not traced.

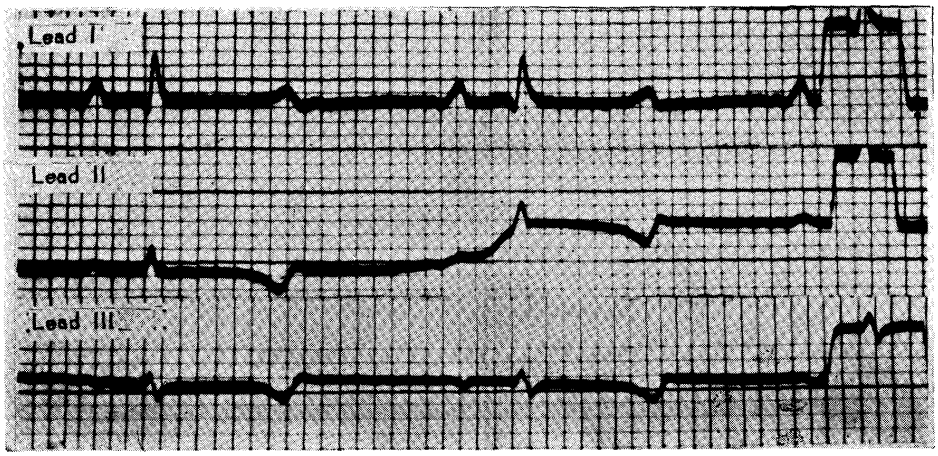
R wave: The configuration of the R wave in lead I showed the r type wave. In leads II and III, the configuration indicated peaked positive which is R type wave.

S wave: The S wave was observed in only 1 case of lead I and 2 cases in leads II and III respectively.

ST segment: The ST segment indicated downward deflection to the base line in lead I, but was parallel to the base line in leads II and III.

T wave: The T wave in lead I mostly showed monophasic negative waves, but two types of waves were observed in leads II and III which showed positive monophasic and

FIG. 1. *Electrocardiogram Recorded by the Limb Lead*



diphasic (minus-plus type) waves.

2) Measurement of waves

Measurement of the amplitudes was conducted for P, Q, R, S and T waves in each lead. The maximum, minimum and average values are shown in table 1. Records were 0.173 mv in P_I, 0.121 mv, −0.100 mv in P_{II} and 0.111 mv, −0.207 mv in P_{III}, and they were 0.239 mv, 0.173 mv and 0.133 mv in Q_I, Q_{II} and Q_{III} respectively. R_I, R_{II} and R_{III} indicated all positive deflections with the mean values of 0.230 mv, 0.344 mv and 0.245 mv respectively.

TABLE 1. *Amplitudes of P, Q, R, S and T Waves of the Limb Lead* (mv)

WAVES	LEADS			MIN.	MAX.	AVER.
P	I			0.076	0.271	0.173
	II		(+)	0.010	0.323	0.121
			(−)	0.050	0.150	0.100
	III		(+)	0.030	0.270	0.111
			(−)	0.030	0.910	0.207
Q	I			0.067	0.500	0.239
	II			0.100	0.300	0.173
	III			0.009	0.213	0.133
R	1			0.076	0.350	0.230
	II			0.054	0.700	0.344
	III			0.065	0.522	0.245
S	I			·	·	0.162
	II			0.121	0.169	·
	III			0.135	0.272	·
T	I	T^1	(+)	0.112	1.020	·
			(−)	0.042	1.020	0.279
		T^2	(−)	·	·	0.028
	II	T^1	(+)	0.083	1.000	·
			(−)	0.007	0.690	0.249
		T^2	(+)	0.010	0.320	0.141
	III	T^1	(+)	0.135	0.364	0.212
			(−)	0.031	0.272	0.116
		T^2	(+)	0.032	0.163	·

In the S waves, S_I in one case was 0.162 mv; S_{II} and S_{III}, were 0.121 mv~0.169 mv and 0.135 mv~0.272 mv. In the T waves, there are found diphasic deflections of which the first one was named T^1 and the second T^2. From this classification in lead I, 0.112 mv~1.020 mv and −0.279 mv in T^1, 0.028 mv in T^2 were given. The values of 0.083 mv~1.00 mv and −0.249 mv in T^1, 0.141 mv in T^2 were observed in lead II and 0.212 mv and −0.116 mv in T^1, 0.032 mv~0.163 mv in T^2 were recorded in lead III respectively.

TABLE 2. *Duration of P, QRS and T Waves and Intervals of PQ (PR), RS-T, QT and PP of the Limb Lead* (Second)

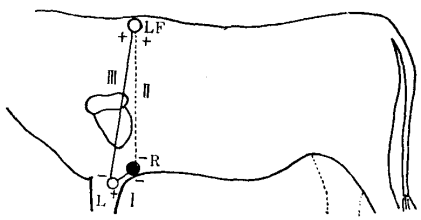
LEAD	WAVES	MIN.	MAX.	AVER.
	P	0.10	0.15	0.13
	QRS	0.07	0.12	0.09
	T	0.13	0.20	0.17
II	PQ (PR)	0.24	0.42	0.29
	RS-T	0.35	0.49	0.39
	QT	0.40	0.54	0.47
	PP	0.84	2.44	1.32

The duration of P, QRS and T respectively and the intervals of PQ (PR), RS-T, QT and PP (RR) were measured in order to obtain the minimum, maximum and mean values in lead II. Each value is shown in table 2. The duration of P waves in lead II was at 0.13 (0.10~0.15) sec. on an average, that of QRS waves was 0.09 (0.07~0.12) sec., further in T waves 0.17 (0.13~0.20) sec. was recorded. Pertaining to the intervals of PQ, RS-T, QT and PP were measured at 0.29 (0.24~0.42) sec., 0.39 (0.35~0.49) sec., 0.47 (0.40~0.54) and 1.32 (0.84~2.44) sec. respectively.

2. Experiment No. 2—Bipolar Chest Lead I

In this experiment, 10 normal cattle aged 5~12 were used. In the bipolar chest lead I, as indicated in chart 2, the electrode in lead I was connected with the right and the left olecranons. In lead II, the right olecranon and withers were chosen for the connecting positions. In lead III, points on the left olecranon and withers were connected to the electrodes. The wires were connected with the electrocardiograph so as to show an upward deflection under the following 3 conditions: (1) When the electric potential of the right olecranon is rather negative as compared to that of the left olecranon; (2) when the electric potential of the right olecranon is more negative than that of the withers; (3) when the electric potential of the left olecranon is rather negative compared to that of the withers.

CHART 2. *Lead Method of the Bipolar Chest Lead I*

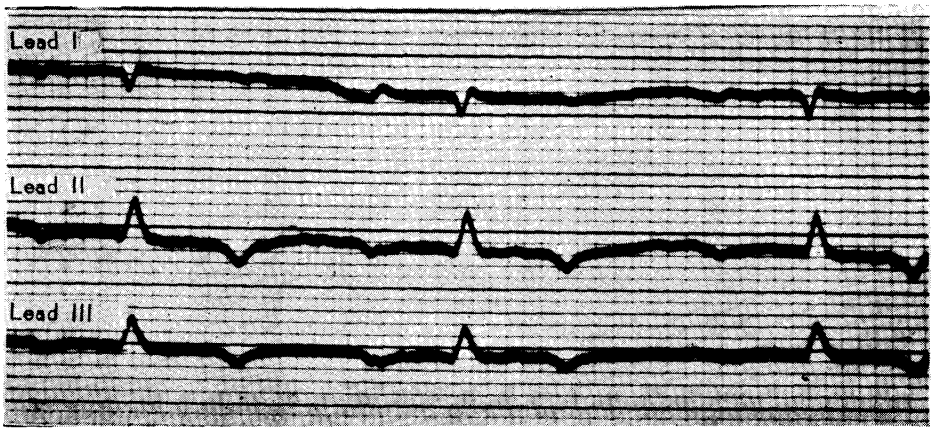


1) Configuration of waves

Typical configurations in this lead are shown in Fig. 2.

P wave: The P wave in lead I usually showed upward deflection and the peaked form of the configuration was mostly observed. In lead II, flat and W type waves were traced. Most of waves inclined to be negative and the configuration indicated waves of negative

FIG. 2. *Electrocardiogram Recorded by the Bipolar Chest Lead I*



peaked and W type in lead III.

QRS complex: The QRS complex in the bipolar chest lead I showed the following configurations. In lead I, the types of qRs, QR, QS and R waves were observed; qR and R types in lead II and qR, QR and R types in lead III were traced respectively.

ST segment: The ST segment in lead I showed mostly downward deflection and an isoelectric pattern was observed in leads II and III.

T wave: The configuration of the T waves in lead I showed monophasic negative T wave in 9 out of 10 cases. The remaining one case, however, showed monophasic positive wave. T wave mostly manifested monophasic negative in leads II and III.

2) Measurement of waves

The results obtained from the measurement of the amplitudes, the durations and intervals in each lead wave are listed in tables 3 and 4. The mean values of the amplitudes recorded were as follows: 0.187 mv in P_I, −0.142 mv in P_{II} and −0.117 mv in P_{III}, 0.239 mv, 0.144 mv and 0.220 mv in Q_I, Q_{II} and Q_{III} respectively. R_I, R_{II} and R_{III} indicated all positive deflections with the mean values of 0.129 mv, 0.649 mv and 0.541 mv respectively. In the S waves, the amplitudes were recorded only in S_{III}, where the values were 0.118 mv on an average. In the T waves, there were found diphasic deflections. Accordingly they were named T^1 for the first deflection and T^2 for the second deflection as described in limb lead. In this classification, 0.116 mv and −0.283 mv in T_I^1, and 0.130 mv and −0.116 mv in T_I^2 were recorded. In T_{II}, 0.011 mv~0.130 mv and −0.336 mv in T^1, and 0.245 mv~0.376 mv in T^2. Further in T_{III} 0.058 mv~0.190 mv, −0.301 mv in T^1, −0.035 mv~−0.232 mv in T^2 were obtained.

The durations of the P waves were recorded at the average of 0.14 (0.10~0.20) sec. Those of QRS were 0.11 (0.07~0.15) sec., and 0.17 (0.13~0.24) sec. in T. Concerning the intervals, 0.28 (0.23~0.37) sec. in PQ, 0.34 (0.29~0.42) sec. in RS-T, 0.46 (0.39~0.55) sec. in QT and 1.32 (0.81~2.44) sec. in PP were measured respectively.

TABLE 3. *Amplitudes of P, Q. R, S and T Waves of the Bipolar Chest Lead I* (mv)

WAVES	LEADS			MIN.	MAX.	AVER.
P	I			0.130	0.250	0.187
	II		(−)	0.045	0.200	0.142
	III		(−)	0.093	0.270	0.177
Q	I			0.043	0.540	0 239
	II			0.046	0.200	0.144
	III			0.144	0.297	0.220
R	I			0.070	0.480	0.219
	II			0.386	1.135	0.694
	III			0.175	1.220	0.541
S	III			·	·	0.118
T	I	T^1	(+)	·	·	0.116
			(−)	0.087	0.513	0.283
		T^2	(+)	·	·	0.130
			(−)	·	·	0.116
	II	T^1	(+)	0.011	0.130	·
			(−)	0.101	0.600	0.336
		T^2	(−)	0.245	0.376	·
	III	T^1	(+)	0.058	0.190	·
			(−)	0.120	0.648	0.301
		T^2	(−)	0.035	0.232	·

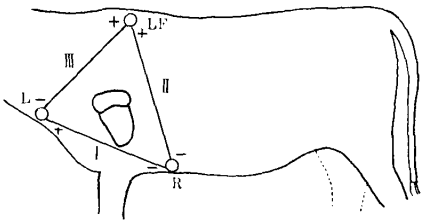
TABLE 4. *Duration of P, QRS and T Waves and Intervals of PQ (PR), RS-T, QT and PP of the Bipolar Chest Lead I* (Second)

LEAD	WAVES	MIN.	MAX.	AVER.
	P	0.10	0.20	0.14
	QRS	0.07	0.15	0.11
	T	0.13	0.24	0.17
II	PQ (PR)	0.23	0.37	0.28
	RS-T	0.29	0.42	0.34
	QT	0.39	0.55	0.46
	PP	0.84	2.44	1.32

3. Experiment No. 3—Bipolar Chest Lead II

In the experiment with the bipolar chest lead II, as indicated in chart 3, the electrodes in lead I were connected with the left shoulder blade and the region of the apex of the

CHART 3. *Lead Method of the Bipolar Chest Lead II*

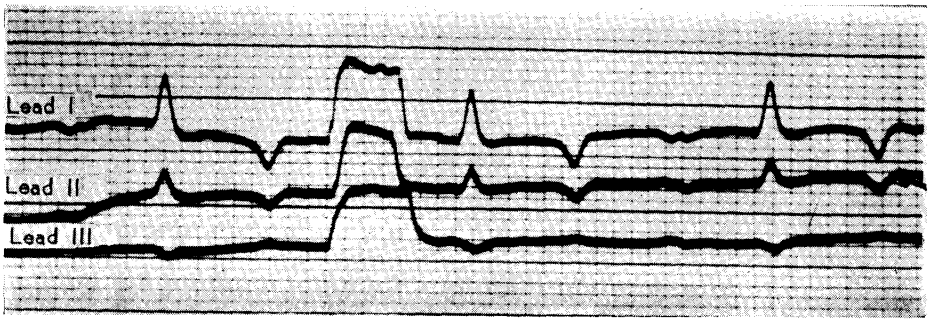


heart on the left side. In lead II, the region of the apex of the heart on the left side and withers were chosen for the connecting positions. In lead III, the points on the left shoulder blade and withers were connected with the electrodes. The cables were connected to the electrocardiograph with adjustment to record the waves with an upward deflection when the potential of the electrodes of the R, L and LF showed a relationship as R<L<LF.

1) Configuration of waves

The typical electrocardiogram is shown in Fig. 3.

FIG. 3. *Electrocardiogram Recorded by the Bipolar Chest Lead II*



P wave: The P wave which usually shows a configuration of W form in leads I and II, was normally less flat in lead III and accordingly showed a constant downward trend in every lead.

QRS complex: The first downward wave of the rapid ventricular initial complex was designated by EINTHOVEN as the Q wave, the first upright wave as the R wave, and the second negative wave as the S wave. In short, the present writers have named the ventricular initial complex as QRS, regardless of the presence of all three waves. From this point of view, the configuration of QRS in this lead can be described as follows: In lead I and II, small Q wave was shown and subsequent large upright R wave so-called R type were noticed in most cases. In lead III variable forms were observed; e.g., qr, QS and R forms.

S wave: The second negative one, the S wave, was not shown in this lead.

T wave: Monophasic negative waves were usually observed in leads I and II. On the contrary, the T wave showed monophasic positive or diphasic (plus-minus type) waves in lead III.

2) Measurement of waves

Table 5 provides a tabulation of the amplitudes based on the calculations of the maximum, minimum and mean values of each wave. In addition, table 6 presents the results of the

TABLE 5. *Amplitudes of P, Q, R and T Waves of the Bipolar Chest Lead II* (mv)

WAVES	LEADS		MIN.	MAX.	AVER.
P	I		0.154	0.167	•
		(−)	0.092	0.167	0.119
	II	(−)	0.073	0.158	0.095
			•	•	0.080
	III	(−)	0.064	0.154	0.118
Q	I		0.007	0.227	0.076
	II		0.036	0.167	0.118
	III		0.009	0.307	0.156
R	I		0.346	1.310	1.238
	II		0.160	1.210	0.550
	III		0.085	0.428	0.274
T	I T^1	(+)	0.089	0.397	•
		(−)	0.246	1.470	0.727
	I T^2	(−)	0.182	0.832	•
	II	(−)	0.144	0.885	0.332
	III T^1	(+)	0.008	0.305	0.219
	III T^2	(−)	0.009	0.196	0.132

TABLE 6. *Duration of P, QRS and T Waves and Intervals of PQ (PR), RS-T, QT and PP of the BipolarChest Lead II* (Second)

LEAD	WAVES	MIN.	MAX.	AVER.
II	P	0.11	0.20	0.15
	QRS	0.09	0.15	0.12
	T	0.09	0.25	0.16
	PQ (PR)	0.24	0.39	0.30
	RS-T	0.33	0.42	0.36
	QT	0.43	0.55	0.47
	PP	0.84	2.44	1.32

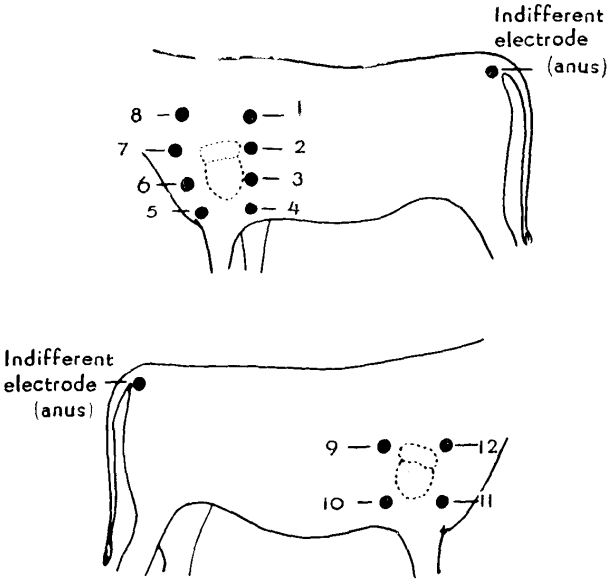
measurement of the intervals and durations of each wave in lead II. Values of 0.154 mv, 0.167 mv and −0.119 mv in P_I, 0.080 mv and −0.095 mv in P_{II} and −0.118 mv in P_{III} were given, while mean values were 0.076 mv, 0.118 mv and 0.156 mv in Q_I, Q_{II} and Q_{III} respectively. R_I, R_{II} and R_{III} indicated positive deflections which were measured at 1.238 mv, 0.550 mv and 0.274 mv respectively. Values of 0.089 mv∼0.397 mv, −0.727 mv in T_I^1 and −0.182 mv ∼−0.832 mv in T_I^2, −0.332 mv in T_{II} and 0.219 mv in T_{III}^1 and 0.132 mv in T_{III}^2 were recorded.

On the contrary, the durations of the P waves were recorded at the average of 0.15 (0.11~0.20) sec., those of the QRS were 0.12 (0.09~0.15) sec., and 0.16 (0.09~0.25) sec. in T. Pertaining to the intervals, 0.30 (0.24~0.39) sec. in PQ (PR), 0.36 (0.33~0.42) sec. in RS-T and 0.47 (0.43~0.55) sec. in QT and 1.32 (0.84~2.44) sec. in PP were measured.

4. Experiment No. 4—Semi-Unipolar Chest Lead

Ten healthy non-pregnant cattle were used in the experiment. Use was made of semi-unipolar chest lead; as indicated in chart 4, 12 points were selected on the skin of the standing cattle for connecting the different electrodes, and such points were indicated by arabic numbers. The different electrode was placed near the anus. The cable was connected so as to indicate downward deflection when the different electrode was rather negative. To record the electrocardiogram, the indifferent electrode was connected to the R cable and the different electrode on each point was connected to the L and LF cables respectively. Leads I and II were used subsequently.

CHART 4. *Lead Method of the Semi-Unipolar Chest Lead*



1) Configuration of waves

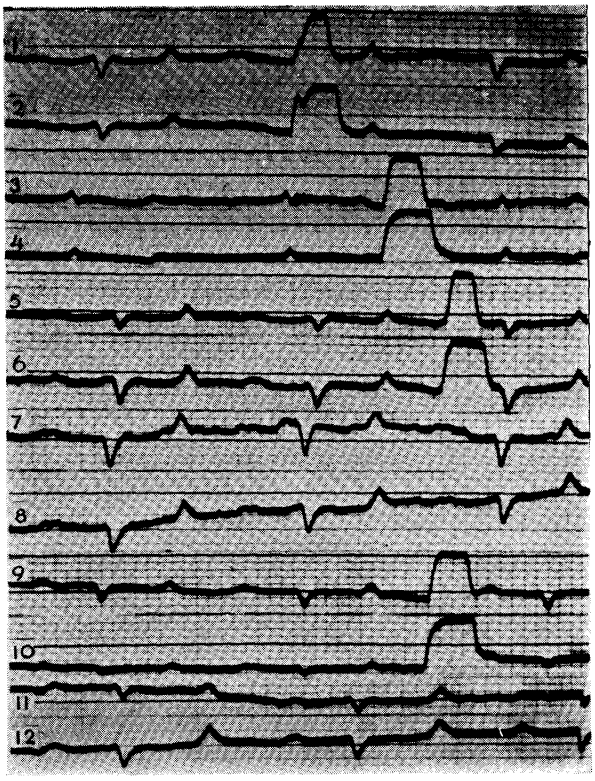
The typical electrocardiogram obtained from the semi-unipolar chest lead is shown in Fig. 4.

P wave: The shape of the P waves in P_1~P_3 generally showed the negative flat form. In P_4~P_{12} unidentified waves were traced on the paper, which resembled flat W type waves.

QRS complex: The configuration of the QRS complex varied depending on the lead point, e.g.; qr type in lead point Nos. 1~3 and Nos. 6~10; R type in Nos. 6~10; QS type frequently observed in lead point Nos. 3 and 4.

T wave: Four types were observed in the T waves in lead point Nos. 1~12, which were monophasic positive, negative deflection and diphasic waves with plus-minus and

FIG. 4. *Electrocardiogram Recorded by the Semi-Unipolar Chest Lead*



minus-plus types. Most of T waves showed monophasic negative form in lead point Nos. 1~3. It, however, showed monophasic positive pattern in lead point Nos. 4 and 5, and showed the same types in lead point Nos. 6~12 as well as in lead point Nos. 1~3. There was a relationship between the direction of the T waves in these lead points and that of QRS complex: when the QRS complex showed qR, the T waves were monophasic negative or plus-minus type. On the other hand, when the QRS complex showed the qrS or QS types, the direction of T waves was recorded as monophasic positive wave or minus-plus type waves.

2) Measurement of waves

Measurement of the amplitudes of the waves were conducted on P, QRS and T waves in every lead. The duration of P, QRS and T were recorded as well as the intervals of PQ, RS-T, QT and PP in lead point No. 3. The results of the measurement of the amplitudes in lead point Nos. 1~12 are recorded in table 7 while durations and intervals are shown in table 8.

The amplitude of the waves in P_3 was 0.08 mv on an average and 0.164 mv in R_3, 0.386 mv in S_3 and 0.279 mv and 0.146 mv in T_3^1; 0.112 mv was recorded in T_3^2. The duration of the waves was 0.14 sec. in P_3 on an average; they were 0.12 sec. in the QRS_3 and 0.13 sec. in T_3.

As for the intervals, they were 0.29 sec. in PQ (PR), 0.44 sec. in QT, 0.31 sec. in RS-T and 1.32 sec. in PP (RR).

TABLE 7. *Average Values of Amplitudes of P, Q, R, S and T Waves of the Semi-Unipolar Chest Lead* (mv)

WAVES		LEADS POSITIONS											
		1	2	3	4	5	6	7	8	9	10	11	12
P		0.115	0.048	0.080	0.080	0.098	0.076	0.130	0.100	0.110	0.068	0.158	0.154
	(−)	0.075	0.224	·	0.073	0.118	0.159	0.125	0.117	0.117	0.159	0.118	0.331
Q		0.127	0.096	0.080	0.161	0.136	0.152	0.248	0.250	0.261	0.106	0.226	0.188
R		0.202	0.282	0.164	0.424	0.609	0.318	0.601	0.429	0.336	0.272	0.470	0.344
S		0.356	0.226	0.386	0.278	0.413	0.620	0.800	0.504	·	0.202	0.391	0.290
T	T^1	0.116	0.153	0.279	0.207	0.205	0.232	0.327	0.221	0.181	0.181	0.191	0.211
	(−)	0.369	0.419	0.146	0.522	0.611	0.276	0.469	0.502	0.385	0.393	0.710	0.625
	T^2	0.080	0.120	0.112	0.077	·	·	·	·	·	·	0.200	0.263
	(−)	·	·	·	0.100	0.241	0.174	0.080	0.077	0.225	0.063	·	·

TABLE 8. *Duration of P, QRS and T Waves and Intervals of PQ (PR), RS-T, QT and PP of the Semi-Unipolar Chest Lead* (Second)

LEAD	WAVES	MIN.	MAX.	AVER.
Position No. 3.	P	0.11	0.15	0.14
	QRS	0.06	0.19	0.12
	T	0.10	0.24	0.13
	PQ (PR)	0.24	0.40	0.29
	RS-T	0.26	0.37	0.31
	QT	0.36	0.50	0.44
	PP	0.95	1.45	1.32

DISCUSSION

Based upon the results obtained from the limb lead, 2 bipolar chest leads and semi-unipolar chest lead, the authors made comparative consideration on the lead methods. In regard to the limb lead, firstly, ALFREDSON and other investigators recorded cattle electrocardiogram with the limb lead connecting wires to lead points different from those of the present writers. While the authors selected the olecranon of left and right legs for lead points, they picked the extremities of fore legs. The configuration of the waves particulary of QRS

pattern and the direction of T waves vary depending on the location of lead points. Through the present experiments, the amplitude of the waves was very low in the limb lead because of the direction of electric axis which was semi-vertical and not horizontal to the plane constructed by the 3 lead points. In consequence, changes of the heart action were not traced sufficiently. On the other hand, high amplitude of the waves was recorded in bipolar chest leads I and II for the reason that the lead points, particulary the lead point of the apex in the bipolar chest lead II, were so close to the heart. The electric changes on the heart, therefore, can be recorded clearly, which would make the bipolar chest lead available for the clinical use. As for the semi-unipolar chest lead, the anus was chosen for the connecting point of the different electrodes. The electromotive forces of the heart to the anus were very weak, for the heart was at a distance from the anus. Consequently, the lead method applied in this experiment can be regarded as a semi-unipolar chest lead.

The configuration of the waves observed in limb lead was composed of the following conspicuous points: low amplitudes of every wave; triphasic and diphasic P waves; various kinds of QRS. The fact that the configurations showed various kinds of waves in this lead can be traced to the relationship existing between the lead point and the electric heart axis as mentiond above. ALFREDSON et al., in this regard, described the QRS pattern classifying it into 4 types as R, QR, qR and QS, and clearly stated that R and qR types of electrocardiogram were observed mainly in limb lead in cattle. Comparing the results of present experiments and their conclusion, the authors obtained the same results from the point of view of the existence of R and qR type waves that were mainly observed in the limb lead.

Pertaining to the bipolar chest lead I, the method of lead I was the same as that used in lead I of limb lead. In leads II and III, the electrode was placed on the withers. The configuration of the electrocardiogram in leads II and III consequently showed electrical changes in the cavity and epicardium of the ventricles because the positions on the withers were faced toward the cavity of ventricles and the position of olecranon was faced toward the epicardium of the heart. As for the configuration of the waves of the bipolar chest lead I, in lead I low amplitude waves were shown, but in leads II and III high amplitude waves were recorded, because the electromotive forces on the withers which were influenced by the heart through internal organs were stronger than those on the olecranon. The action current of the cavity of the ventricles, therefore, had an influence upon the electrocardiogram in leads II and III.

Comparing the configuration of the electrocardiogram obtained by semi-unipolar chest lead in this paper and the results of BROOIJMANS' experiment, the

authors obtained the same results from the points of view of the existence of QS type of QRS complex and monophasic positive T wave in the lead from the portion of the apex of the heart and qR type and monophasic negative T wave in the lead from the upper portion of the heart.

Summary

In connection with the serial electrocardiogram recorded by means of the limb lead, bipolar chest leads I and II and semi-unipolar chest lead were obtained on one each of 40 normal dairy cattle. The data derived from the analysis of these records can be summarized as follows:

1. In the electrocardiogram of the limb lead when the left and right olecranons and left patella were chosen for the positions of lead points, the triphasic and diphasic P wave in each lead, r type of QRS complex in lead I and R type in leads II and III, and monophasic negative and positive T waves are observed, respectively.

2. In case of the use of the bipolar chest lead I in which the left and right olecranons and withers were selected for the lead points, the triphasic P wave, qR and R type of QRS complex and monophasic negative T waves were observed in each lead respectively.

3. When the bipolar chest lead II was employed using the withers, left shoulder blade and the apex of the heart on the left side for the lead points, W form of P wave in each lead, qR type in leads I and II, and qR, QR in lead III, and monophasic negative T wave in leads I and II, monophasic positive and diphasic waves in lead III were observed respectively.

4. In case of the use of the semi-unipolar chest lead, the waves in the lead at the upper portion of the heart showed negative P, and R type of QRS complex and negative T waves were also observed there. On the contrary in the lead at the apical portion of the heart, the positive P and QS type of QRS complex and positive T wave were traced.

5. On the basis of these experiments, the limb lead may not be suitable for clinical use in cattle because the variation of the electrical changes of the heart was not completely traced. The bipolar chest leads I and II, however, may be applicable for clinic use, for the variation of the electrical changes of the heart were apparentely registered on the electrocardiogram. The semi-unipolar chest lead may be of use in the diagnosis of disorders in the heart providing that different electrodes are placed close to the heart. From the findings described above, it may be considered that the use of bipolar chest leads I and II together with semi-unipolar chest lead is valuable for the clinical diagnosis of heart disorders.

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