STUDIES ON APPLICATIONS OF ELECTROCARDIOGRAM IN HORSES

I. THE LEAD METHOD AND ELECTROCARDIOGRAM WITH SPECIAL REFERENCE TO CONFIGURATIONS AND MEASUREMENTS OF WAVES IN THE LIMB LEAD

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INTRODUCTION

It has been known for many years that a measurable amount of electric current is associated with the activity of the heart. Since EINTHOVEN (1897) registered the action current of the heart with a string galvanometer, in the human clinic, the electrocardiograph has been used in connection with examination of cardiac disorders. However, in the veterinary field, it has not yet been applied to daily clinical use. As for the diagnosis of cardiac disturbances, no accurate methods have been found except for the adoption of the electrocardiograph. So, studies on its use for animals are now being conducted by the present writers for the lead methods and for the calculation of waves.

There have been a few report published on horse electrocardiograms. KAHN led from the region of the apex of the heart on the left side and from the base of the right side in the neck when a bipolar chest lead was used. NÖRR reported that he used the limb and bipolar chest leads from the region of the apex of the heart on the left to the right shoulder blade. NEUMANN-KLEINPAUL & STEFFAN suggested that the most reasonable arrangement in horses was the 3 leads by means of leads I, II and III from the region of the apex of the heart on the left to the right shoulder blade and the anus. DUKES & BATT used 3 methods of limb, bipolar chest and unipolar chest leads and YASUDA et al. registered the horse electrocardiogram by the same method as was done by NEUMANN-KLEINPAUL & STEFFAN. UEDA et al. examined the use of chest leads from the anus to several points of the chest wall around the heart, and further, LANNEK & RUTQVIST conducted the 3 tests using the extremity lead, bipolar chest lead and the unipolar chest lead respectively. Recently, KUSACHI & NISHIDA used a bipolar lead from 2 points on the skin which were parallel to the long axis of the heart.

In the above worked reports, no definite lead methods for horses were recommended. Therefore, several examinations aimed at discovery of the most appropriate lead method for use in horses were conducted by the writers. As a part of that undertaking, for the first report, the results obtained with the bipolar lead of which the electrodes were placed on the legs, are described in this paper.

Materials and Methods

1. Materials

Ten horses were used for experiments. They were pure bred or mongrel Percheron, 3~15 years old, including female and gelding and all were well nourished. Temperature was 37.5°~38.3°C and cardiac functions were almost normal in auscultations. In hematological findings, pathological changes were not found. So, they were all regarded as entirely healthy.

2. Methods

1) For the elimination of alternating 50 cycle currents, the room was equipped rubber flooring and wire netting.

2) For recording the electrocardiograms, a differential amplifier electrocardiograph (UD-4 made by FUKUDA ECG Co. Ltd.) was used. This apparatus registers 3 leads synchronously.

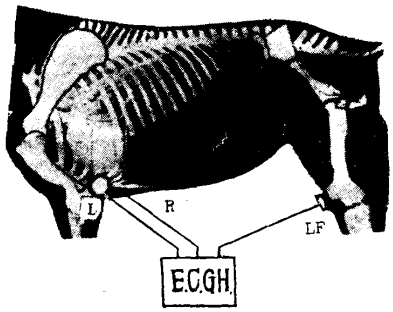
3) Concerning its sensitivity, 1 millivolt (mv) was adjusted to correspond to an amplitude of 10 millimeters (mm). The time recordings were made each 0.05 (1/20) second on the film.

4) The electrodes were made of the stainless splay mouth type clips in connection with the terminal end of the cable and they were adopted to the skin moistened with saline liquids.

5) In the limb lead, as shown in chart 1, 3 points were selected on the skin in standing horses for connection with electrodes. The electrodes in lead I were connected with left and right olecranons. In lead II, points on left patellae and right olecranon were taken for the connection positions. In lead III, points on left patellae and left olecranon were connected with electrodes.

6) The cable were connected with the electrocardiograph so as to record the waves as an upward deflection in the following conditions. The tests must be conducted respectively on the following occasions: when the right olecranon's electric potential is relatively more negative than that of the left patellae; when the left olecranon's electric potential is more negative than that of the left

CHART 1.



The electrodes were applied in the following ways. On the right olecranon (R), on the left olecranon (L) and on the point of left patellae (LF).

patellae; when the right olecranon's electric potential is more negative than that of the left olecranon.

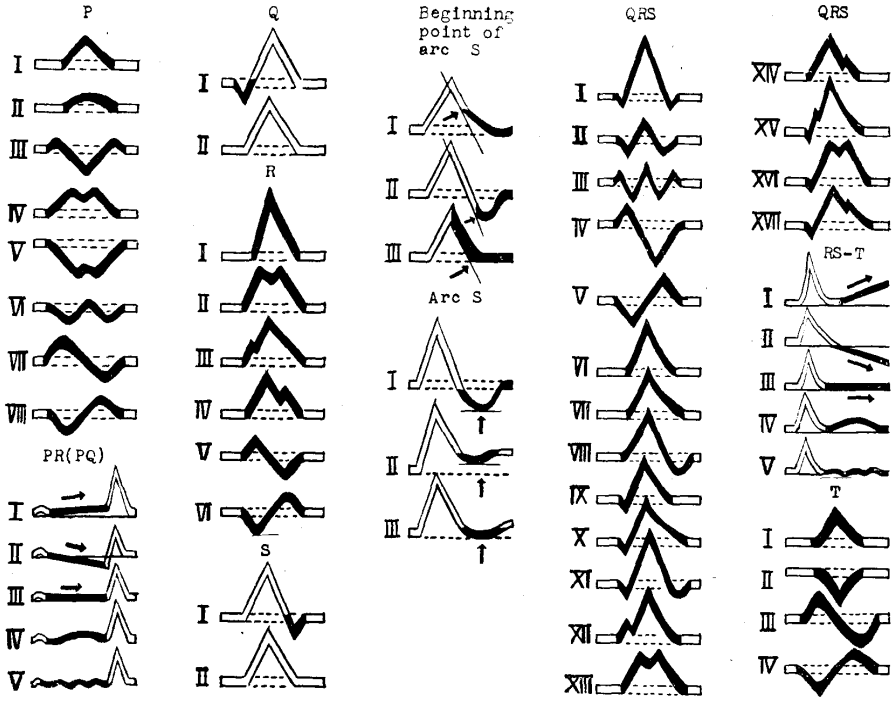
7) The measurements of each wave were conducted in the manner recommended by the Committee of Amer. Heart Ass.[1] Amplitudes were indicated in millivolt in comparison with calibration curves. Durations and intervals were measured in lead II by seconds. In the present paper, the diacritical marks were designated as P_I, P_{II}, and P_{III} in lead I, II and III and so on.

RESULTS OF EXPERIMENTS

1. The Configurations of Electrocardiograms

The authors classified the waves obtained in the use of several lead methods, as indicated in table 1, chart 2 and figs. 1~10, to I~VIII types. So, in the present paper, comparisons of the results in limb lead were made among those types.

CHART 2. *Classifications of the Waves*



The P wave: Five types of waves were found. Leading findings in P waves were as follows; 7 cases or 70% in P_I indicated triphasic wave with small deflections which corresponded to type III; 6 cases or 60% of type IV in P_{II} and 5 cases or 50% of type IV in P_{III} were found. No waves were found of types I and VI of lead I, of types III and V of lead II and of type V of lead III.

The PQ segment: The PQ segment may be classified into 5 types numbered I~V which showed descending, ascending, round, isoelectric and vibratory. In the present experiment, type III was found in the largest number. These were 8 cases or 80% in PQ_I, 7 cases or 70% in PQ_{II} and 8 cases or 80% in PQ_{III}. Types I and IV in PQ_I, types II and V in PQ_{II}, and types II and IV in P_{III} were not found.

The R wave: The R waves were also classified into 5 types numbered I~V. In 7 cases or 70% in R_I apparently positive deflections were shown. Four cases or 44% out of 9 cases in R_{II} and 7 cases or 70% out of 10 cases indicated respectively negative deflections in R_{III}.

The S wave: Small negative deflections in S waves corresponded to type I; type II was the curve from the downstroke of the R wave to the zero (base)

TABLE 1. *Classifications of the Waves*

KINDS OF WAVES	TYPES OF WAVES	LEADS I	LEADS II	LEADS III
P	I	0	2	3
	III	7	0	1
	IV	1	6	5
	V	2*	0	0
	VI	0	1	1
Q	I	1*	5*	2*
	II	9	4	8
PR (PQ)	I	0	1	1
	II	1	0	0
	III	8	7	8
	IV	0	1	0
	V	1	0	1
R	I	7	3 (1*)	5 (4*)
	II	0	2*	1*
	III	2	0	2*
	IV	0	1*	0
	V	1	3	2
S	I	2	3	1
	II	8	6	9
Beginning point of Arc S	I	1	1	1
	III	7	5	8
Arc S	I	2	4	4
	III	6	2	5
RS-T	I	0	1	1
	II	4	1	1
	III	6	6	8
	V	0	1	0
T	I	0	6	9
	II	10*	0	0
	IV	0	3	1

Note: *…Negative waves

line. In this classification, 8 cases or 80% in S_I, 6 cases or 60% in S_{II} and 9 cases or 90% in S_{III} showed type II. All others were type I.

The beginning point of arc S: In the recordings obtained in each lead curve which do not have deflections in S may be classified, as indicated in chart 2, into the 2 types or I and III. In the present experiment, 7 cases in lead I, 5 cases in lead II and 8 cases in lead III, all corresponded to type III, and 1 case in each lead was type I.

The arc curved S: The arc curved S in which were found no deflections of S waves were classified into 2 types that is I and III. Six out of 9 cases in lead III showed type III, however, 4 out of 6 cases in lead II corresponded to type I. There were no cases of type II.

The QRS complex: The various configurations of the QRS complex, as shown in chart 2, were synthetic forms of Q, R, S and arc curved S. They were classified into 17 types.

The RS-T segment: The intervals between the end of the QRS complex and the beginning of the T wave had been designated as to the RS–T junction or RS–T segment; 5 types of ascending, descending, vibratory, isoelectric and slight round up above zero line were observed. In RS–T_I, 6 of type III and 4 of type II out of 10 cases were found respectively. In RS–T_{II} and RS–T_{III}, type III was frequent occurring in 6 and 8 cases respectively.

The T wave: The T waves were classified into 3 types. All 10 cases in T_I showed monophasic negative waves which were categoried to type II. In T_{II} 6 cases indicated positive monophasic of type I, but 3 cases were diphasic of type IV. Further in T_{III}, 9 cases of type I and 1 case of type IV were observed.

2. Measurement of the Waves

Measurements of amplitudes were conducted for P, Q, R and T waves in each lead. Although minimum, maximum and average values, as indicated in table 2, were taken for each wave, in the present paper, they were recorded as the mean values. The records of 0.087 mv in P_I, 0.257 mv in P_{II} and 0.229 mv in P_{III} were given, and in Q_I, Q_{II} and Q_{III} they were 0.09 mv, 0.194 and 0.075 mv respectively. R_I indicated all positive deflections which were measured as 0.412 mv. Five cases with positive deflections in R_{II} were 0.377 mv, but 4 cases with negative deflections were −0.574 mv. In R_{III}, 3 positive cases out of 10 were 0.23 mv and 7 negative cases were −0.597 mv. In the T waves, all negative monophasic T_I showed −0.253 mv. In T_{II} and T_{III} there were found diphasic deflections. So, they were named T^1 for the 1st deflection and T^2 for the 2nd deflection. From this classification, 0.386 mv, −0.176 and 0.45 mv in T_{II}, further in T_{III}, 0.384 mv, −0.20 and 0.40 mv were recorded respectively.

TABLE 2. *Amplitudes of P, Q, R & T Waves*

WAVES	LEADS		MIN.	MAX.	AVER.
P	I		0.03	0.17	0.087 (10)
	II		0.02	0.43	0.257 (9)
	III		0.02	0.46	0.229 (10)
Q	I				0.09 (1)
	II		0.08	0.49	0.194 (5)
	III		0.06	0.09	0.075 (2)
R	I	(+)	0.17	0.75	0.412 (10)
	II	(+)	0.04	0.73	0.377 (5)
		(−)	0.44	0.74	0.574 (4)
	III	(+)	0.14	0.32	0.23 (3)
		(−)	0.13	1.16	0.597 (7)
T	I	(−)	0.05	0.39	0.253 (10)
	II	T^1 (+)	0.04	1.26	0.386 (6)
		T^1 (−)	0.14	0.24	0.176 (3)
		T^2 (+)	0.32	0.69	0.45 (3)
	III	T^1 (+)	0.15	1.00	0.384 (9)
		T^1 (−)			0.20 (1)
		T^2 (+)			0.40 (1)

Note: ( )···indicates calculated numbers.

TABLE 3. *Durations of P, QRS & T Waves and Intervals of PR (PQ), RS-T, QT & PP (RR)*

	WAVES	MIN.	MAX.	AVER.
LEAD II	P	0.08	0.17	0.14
	QRS	0.10	0.15	0.12
	T	0.05	0.19	0.13
	PR (PQ)	0.20	0.34	0.28
	RS-T	0.16	0.46	0.22
	QT	0.38	0.73	0.50
	PP (RR)	0.84	1.70	1.28

The durations of P, QRS and T and intervals of PR (PQ), RS-T, QT and PP (RR) were measured in lead II but 1 case was measured in lead III. Minimum, maximum and mean values were taken. The duration of P was averaged at 0.14

(0.08~0.17) sec. and that of QRS was 0.12 (0.10~0.15) sec., further in T, 0.13 (0.05 ~0.19) sec. was noted. Concerning the intervals, 0.28 (0.20~0.34) sec. in PR (PQ), 0.22 (0.16~0.46) sec. in RS-T, 0.50 (0.38~0.73) sec. in QT and 1.28 (0.84~1.70) sec. in PP were measured respectively.

DISCUSSION

As for the lead method, the nomenclature of limb lead in this paper resembles that of extremity or limb lead used by DUKES & BATT and by LANNEK & RUTQVIST. When the electrodes, in the present experiment, were placed on the right and left olecranons and on the left patellae, the electrocardiograms were registered smoothly and all were observed to possess similar characters.

The limb lead used in the present experiment is a bipolar lead. From the considerations for lead II and III, the electrodes which were placed on the two forelegs were closed to the heart. So the influences of the electromotive forces may be more apparent in comparison with the electrode placed on the posterior leg. It may be regarded to show a likeness to unipolar lead. When the electric potentials in different electrodes are more positive than those of indifferent electrodes, in unipolar lead, the electrodes may be connected with electrocardiograph for indications of curves to upwards. It has been interpreted that a recording wave indicates an upward deflection when the stimulation wave approaches to the different electrode and indicates downward deflection when getting away. In the present experiment, the opposite relations in electrodes were found. Considering from these facts in lead II and III, R deflections trend downward when the heart is placed as dropped heart and show upward when it is placed transversely.

Since no works have been published concerning the curve classifications in equine electrocardiograms, the authors classified the wave into many forms, as indicated in chart 2, based on the experiments with several leads. LANNEK & RUTQVIST observed usually notchings and diphasic P waves. TAKAYASU reported that triphasic P waves appeared in the human electrocardiogram when stimulation spread from sinus node to the left and right auricles and to Tawara's node. The intricate triphasic P wave may always be seen in horses.

The PR (PQ) corresponded to intervals of conduction of activity from the sinus node to the ventricles. From 70 to 80 % of them showed isoelectric and approached the results of DUKES & BATT and LANNEK & RUTQVIST.

Considering from the configurations of QRS which indicated the spread of activity in the ventricles, 40% of negative R deflections were taken to indicate a dropped heart and 30 % of positive R deflections were taken to indicate transversed heart. Remaining 30% did not correspond to any types.

The RS-T junctions and segments showed the intensity of activity of the

ventricles reaching its summit. The results obtained in the present experiments were descending, ascending and isoelectric waves as LANNEK & RUTQVIST had reported. Although such results are thought to be normal, the further experiments will be needed.

Positive and negative monophasic and diphasic T were reported by DUKES & BATT and by LANNEK & RUTQVIST similar to those obtained in the present experiment. But no definite statements can be made as to thier significance.

As for the amplitudes of waves except for that of R_I, P was higher but Q and R were lower than those reported in the work of LANNEK & RUTQVIST. This discrepancy is considered to be caused by differences in the electrode positions.

Calculations of durations and intervals were almost same in average values as those of DUKES & BATT and LANNEK & RUTQVIST, so they may be applicable to investigations of electrocardiograms.

SUMMARY

Configurations and calculations in the limb lead were conducted in normal horses as a part of project in electrocardiographic studies.

The results thus obtained are summarized as follows.

1. Cardiac displacement may be observed in the limb lead by the directions of recordings of R_{II} and R_{III} waves. Although 40% of dropped heart and 30% of transversed heart were observed, 30% could not be classified to any types.

2. The intricate triphasic waves in P wave were found in from 70 to 80%. Appearance of this type was found usually in normal horses in the limb lead.

3. Isoelectric waves in the PR (PQ) were shown in from 70 to 80%, but other cases indicated descending, ascending and vibratory. No appearances of isoelectric waves were ever found in the latter cases, except for the presence of disturbances, in the results of calculations of PR (PQ) intervals. Therefore, it will be thought that the measurement of PR (PQ) intervals in disturbances of auriculoventricular conduction has an important significance.

4. Notchings on the down or upstroke were found 20% in R_I, 10% in R_{II} and 20% in R_{III}, and then, notchings of the apex of R waves in R_{II} and R_{III} were seen 20 and 30% respectively. The appearance of notching in negative R, except for R_I, seemed to have some correlations with the cardiac displacement.

5. Arc curved S waves were found in 80% in lead I, 66% in lead II and 90% in lead III. They appeared on the terminal part of the downstroke of R and succeeded to RS–T segments.

6. In RS–T segments or junctions, each 60% in leads I and II, and 80% in lead III indicated isoelectric types. In other cases were found the types of

descending, ascending and slight vibratory to the zero line.

7. Monophasic negative waves were always observed in the T wave of lead I. In leads II and III, 66 and 90% of them indicated monophasic positive waves. Other cases were the diphasic which showed positive deflections after negative.

8. The amplitudes in each wave were higher in the mean values than those of LANNEK & RUTQVIST. The authors considered that such results may be ascribed to the position differences of electrodes.

The mean values of durations and intervals nearly approached the results reported by DUKES & BATT and by LANNEK & RUTQVIST.

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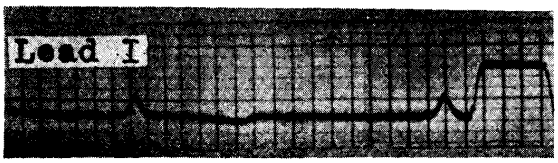
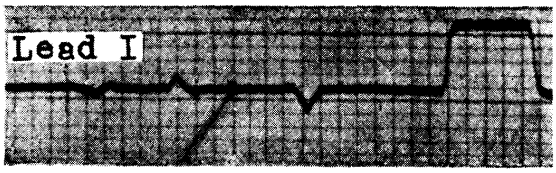
FIG. 1



Positive peaked R. Negative T. Isoelectric of PR (No. 1)

FIG. 2

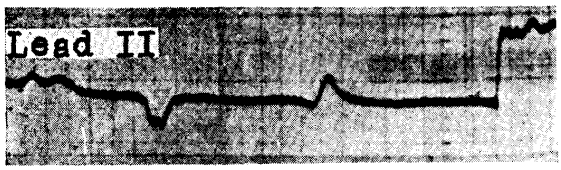


Triphasic P. Monophasic negative T (No. 2)

FIG. 3

Peaked P in both leads, negative peaked R in lead III. Negative and marked notching at the apex of R in lead II. Arc curved S in leads II and III (No. 3)

FIG. 4

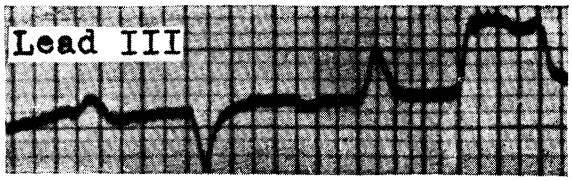


Triphasic P. Negative and marked notching at the apex of R. Diphasic T (No. 4)

FIG 5

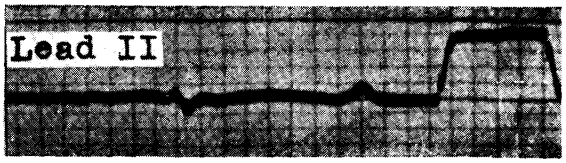
Triphasic P. Marked notching of R. Monophasic positive T (No. 5)

FIG. 6



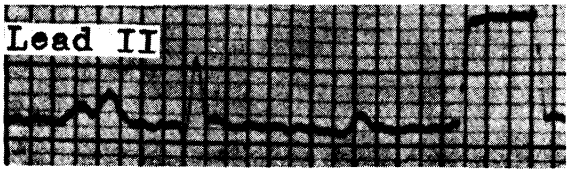
Negative peaked R. Arc curved S. Monophasic positive T (No. 6)

FIG. 7



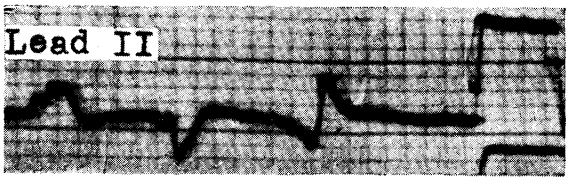
Diphasic R (No. 7)

FIG. 8



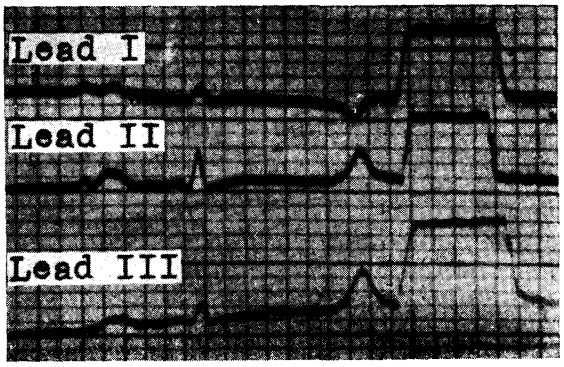
Triphasic P. Vibratory of PQ and ST. Positive peaked R with Q and S (No. 8)

FIG. 9



Triphasic P. Negative and marked notching of R. Diphasic T (No. 9)

FIG. 10



Positive peaked R in all leads. Triphasic P and isoelectric of PQ in lead II. Descending of RS-T in lead I. Ascending of RS-T in leads II and III. Negative T in lead I and positive T in leads II and III (No. 10)