STUDIES ON APPLICATIONS OF ELECTROCARDIOGRAMS IN HORSES

III. THE LEAD METHOD AND ELECTROCARDIOGRAM WITH SPECIAL REFERENCE TO CONFIGURATIONS AND MEASUREMENTS OF WAVES IN SEMI-UNIPOLAR CHEST LEADS

Ryoichi NAKAMURA, Kimehiko TOO and Akira MATSUHASHI

Laboratory of Veterinary Internal Medicine,
Faculty of Veterinary Medicine,
Hokkaido University, Sapporo, Japan

(Received for publication, Jan. 6, 1956)

INTRODUCTION

In the previous two papers,[9, 10] studies were reported, respectively, on the normal horse electrocardiograms by means of the limb lead and on 2 kinds of bipolar chest leads placing the electrodes on the legs and frontal parts of the body. A background for experiments undertaken to develop a test for the functions in the heart disorders was established.

The method of taking the precordial leads was standardized in 1938 by the American Heart Association and the Cardiac Society of Great Britain and Ireland. The Committee also defined each type of precordial or chest lead. In the unipolar lead, different from the bipolar lead, 2 kinds of electrodes were used. The one placed on a part of the body far from the heart is called the indifferent electrode which would be less influenced by any electric forces of the cardiac region; the one placed over the pericardial region of the heart is the different or exploring electrode. When the electrode is placed on a portion distant from the heart, the potential variations of the distant electrode become weaker but they are not negligible in comparison with those of the precordial electrode. Therefore, this lead method must be designated as the "semi-unipolar lead". On the other hand, when the potential variations of the precordial electrode are large enough to cause similar variations in the distant electrode the potential of the distant electrode can be neglect in comparison with those of precordial. Consequently it may designated as the "unipolar lead".

There have been a few reports published on the horse electrocardiogram using the so called unipolar lead. LANNEK and RUTQVIST[7] adopted the central terminal and precordial leads, and UEDA et al.[11] used the semi-unipolar lead with the different electrode on the region near the heart and the indifferent electrode placed in the rectum. Recently, KUSACHI[5] reported the semidirect unipolar lead for tracing the horse electrocardiogram placing the different electrode on the region near the heart and indifferent electrode on the root of the tail.

In this paper, as the 3rd report on the clinical application of the electrocardiogram, the authors describe their investigations adopting the semi-unipolar chest leads with the indifferent electrode placed on the anus and the different electrode on 9 points peripheral to the heart region on both sides of the chest walls.

Materials and Methods

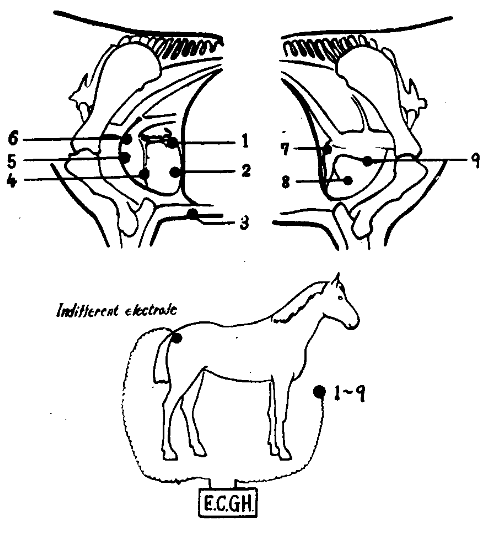
1. Materials

Five horses were used for the experiment. They were pure bred or mongrel Percheron, age between 4~14 years, including well nourished female and gelding. Body temperature was 37.4°~38.3°C and cardiac functions were almost normal in auscultations. In hematological findings, no changes were found. So, they were all regarded as entirely healthy.

2. Methods

The equipment of the test room, the electrocardiograph and electrodes were the same as those used in the experiments described in the first of these reports. In the present experiments with semi-unipolar chest lead, as indicated in chart 1, 9 points were selected on the skin of the standing horses for connecting the different electrodes. These points were indicated by arabic numbers which designate the electrode positions as follows: 1 is at the median portion of the 6th left costal space; 2 is at the low part of the 6th left costal space; 3 is at the back of the xiphoid; 4 is at the upper part of the left olecranon; 5 is at the median portion of the 2nd left intercostal space; 6 is at 20 cm above position 5; 7 is at the median portion of the 6th right costal space; 8 is at the low part of the 4th costal space at the right; 9 is at the median portion of the 2nd right intercostal space. The indifferent electrode was placed on the anus. The cables were connected so as to indicate downward deflection when the different electrodes indicate relatively negative. To record the electrocardiogram, the cables were connected as follows; 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, and then leads I and II were used.

CHART 1. *Lead Method of the Semi-Unipolar Chest Lead*



The method of measurement of the waves was the same as that described in the first report. The amplitudes of all waves were measured in millivolts (mv) in comparison with calibration curves. Durations and intervals in the waves of position 3 were measured in seconds. In this paper, the diacritical mark of each lead is indicated by the subscript which shows the different electrode position numbers after letter CA (CA stands for chest and anus). For instance, CA_1 and CA_2 indicate the leads on positions 1 and 2 respectively, and so on. Each wave is marked as follows; P_1 and P_2 indicate the P waves of CA_1 and CA_2 respectively, and so on.

RESULTS OF THE EXPERIMENTS

1. The Configurations of the Waves

The configurations of the waves obtained from the semi-unipolar chest lead in 5 horses are summarized in table 1. The findings were compared with the classification system described in the 1st report. Typical electrocardiograms are shown in charts 2~3.

The P wave: The findings of the P waves in each lead are as follows. Positive P waves were observed in 20~100% in P_1~P_6, but P_7~P_9 always showed the negative wave. In the classification of the P waves, types I, II and V were mostly found in each lead, but types III, IV and VI were rare.

The PQ (PR) segment: In each lead, types II and III which indicated the descending and the isoelectric curves were found in 40% and 80% respectively.

The Q wave: In CA_1 and CA_9, the Q waves were observed in 20% whereas the Q waves of CA_2~CA_8 showed type I in 40%.

The R wave: In the classification of the R wave, type I was found in 40~100% in each lead except R_2, and the R_2 indicated type V in 100%.

The S wave: Type I was observed in 20~80% in CA_1~CA_3, CA_8 and CA_9. No S waves were found in CA_4~CA_7.

The beginning point of the arc curved S: The recordings obtained from each lead curve which do not have deflection in the S wave may be classified into 3 types, namely I, II and III. In the present experiment, type III showed 20~60% in each lead; type I in each lead except CA_2 and CA_9 was observed in 20~40%, and type II was only observed in 20% in CA_4~CA_6 respectively.

The arc curved S: The arc curved S which has been no deflection in the S waves was classified into 2 types, namely I and III. In this respect, type I in 20% in CA_1 and CA_7, type II in 20~100% in each lead were noted.

The QRS complex: The occurrence of this configuration was classified into 7 types, namely IV~X. The results are shown in table 1. From 1 to 4 different types of waves were observed in each lead respectively.

The RS-T segment: The RS-T segment was classified into 4 types, namely I~IV. The most frequently observed forms in each lead are as follows: Type III in 20~100% in each lead and type I in 20~60% in each lead except CA_2 were recorded. Types II and IV were only observed in 20% in CA_3 and CA_6 respectively.

The T wave: Four types, I~IV, were found in the T waves. The negative monophasic wave of type II was indicated in 40~80% in each lead, and the positive monophasic wave

TABLE 1. *Classification of the Waves*

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

Note: *···Negative waves.

CHART 2. *Electrocardiograms in Each Position on Horse No. 1*

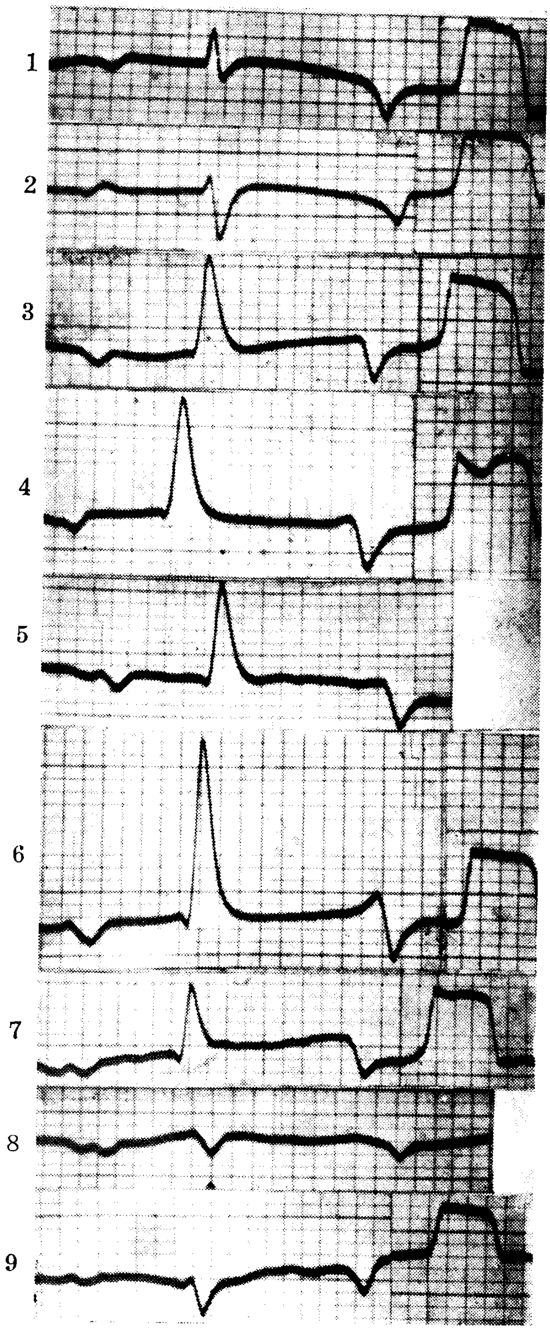
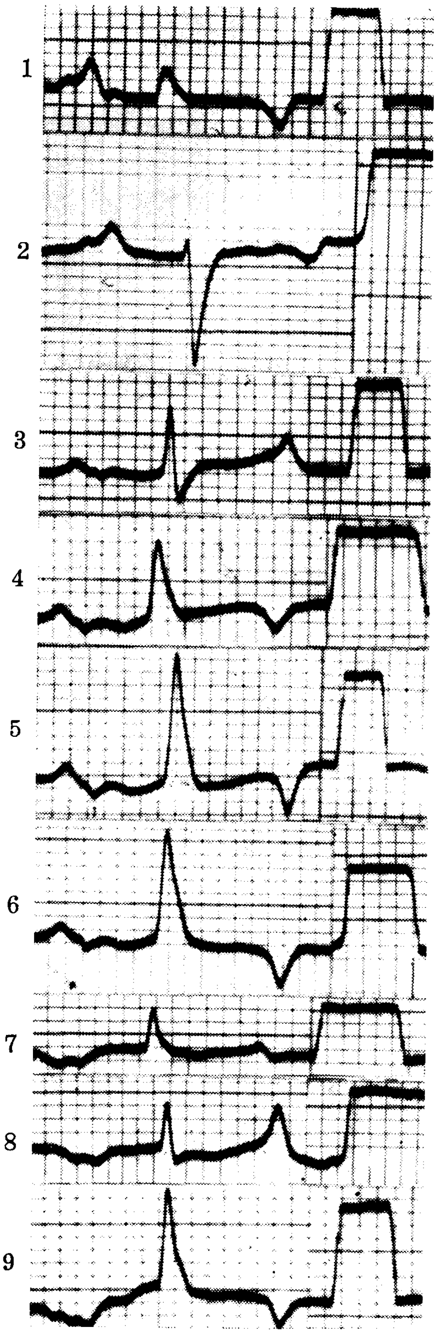


CHART 3. *Electrocardiograms in Each Position on Horse No. 4*



of type I was observed in 20% in $CA_1 \sim CA_4$, CA_8 and CA_9 respectively. The diphasic wave of type III was found in 20~60% in CA_1, CA_5 and CA_9, and diphasic wave of type IV was marked only in 20% in CA_2.

2. Measurements of Waves

The variations in the amplitudes with positional changes of the different electrodes on the P, Q, R, S and T waves are shown in charts 4~8. The results

CHART 4. *Amplitudes of P Waves*

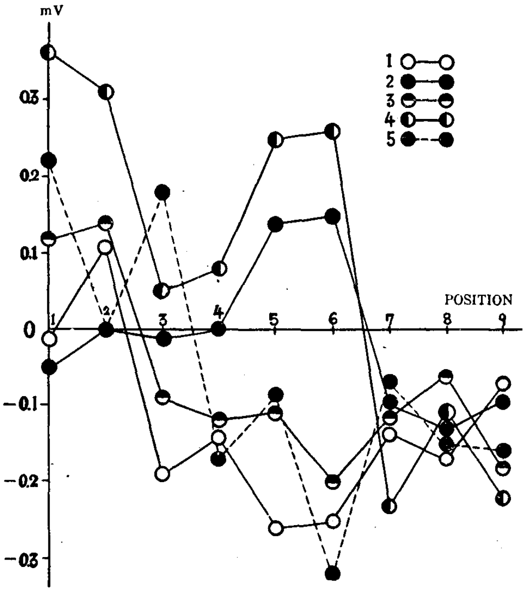


CHART 5. *Amplitudes of Q Waves*

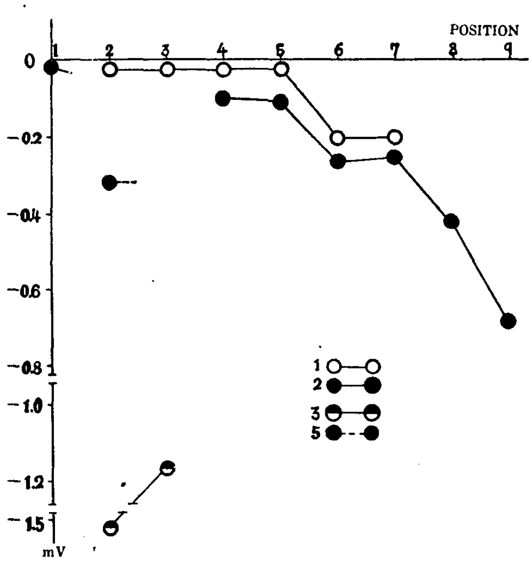


CHART 6. *Amplitudes of R Waves*

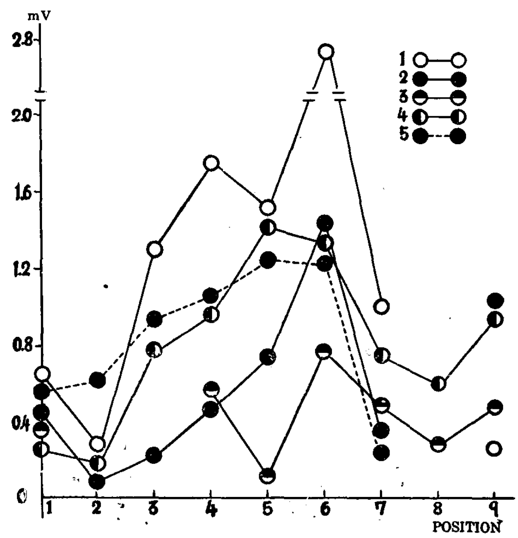


CHART 7. *Amplitudes of S Waves*

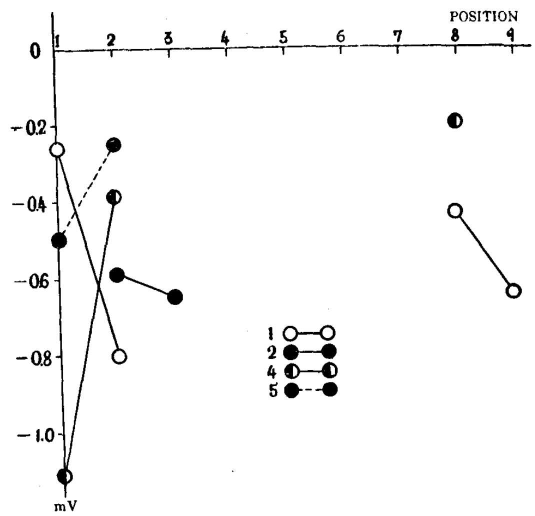
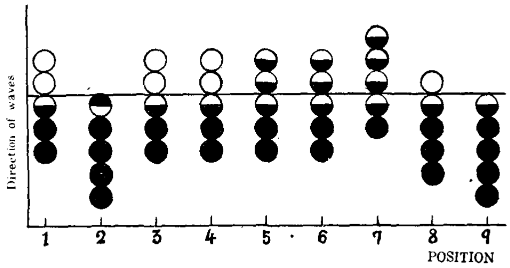


CHART 8. *Changes of T Waves*



Note:

- ○ Monophasic positive wave
- ● Monophasic negative wave
- Diphasic wave (± type)
- Diphasic wave (∓ type)

obtained from the measurements of the durations and intervals are recorded in table 2. The durations of the waves in P_3 (P_3 indicates the P wave of the CA_3) was 0.12 (0.10∼0.20) sec. on the average and that of the QRS was 0.121 (0.075∼0.15) sec. and 0.169 (0.12∼0.20) sec. in T. Concerning the intervals, 0.229 (0.225∼0.385) sec. in PQ (PR), 0.496 (0.43∼0.602) sec. in QT, 0.206 (0.14∼0.253) sec. in RS-T and 1.211 (0.975∼1.37) sec. in PP were measured respectively.

TABLE 2. *Durations and Intervals of Each Wave in Lead CA_3 (Second)*

WAVES	MINIMUM	MAXIMUM	AVERAGE
P	0.100	0.200	0.120
QRS	0.075	0.150	0.121
T	0.120	0.200	0.169
PQ (PR)	0.225	0.385	0.229
RS-T	0.140	0.253	0.206
QT	0.430	0.602	0.496
PP (RR)	0.975	1.370	1.211

DISCUSSION

On the basis of the results obtained by using the lead method as described above, the influence of the electric motive forces of the heart to the anus is very weak because the heart is distant from the anus. The lead method applied in this experiment was consequently regarded as the semi-unipolar lead. UEDA et al. and KUSACHI reported about the horse electrocardiogram using the semi-unipolar chest lead. They pointed out that these positions of the indifferent electrode would be less influenced by the electric motive forces of cardiac region, and the central terminal lead could not be applied for the animal because the eccentric position of the heart differs from that of the human as was pointed out by KIMURA. On the contrary, LANNEK and RUTQVIST reported the horse electrocardiogram using the central terminal and precordial leads with the right foreleg chosen as the position for the indifferent electrode. Those methods are similar to those in human electrocardiography.

Concerning the position of the different electrodes, UEDA et al. selected peripheral positions of the heart on the left and right chest walls. LANNEK and RUTQVIST selected the positions of the different electrode as follows: Leads CR_1 and CT_1 were placed on the right side of the thorax, 3 to 5 cm above a horizontal line of the highest point of the olecranon which are located above the right ventricle. Leads CR_2 and CT_2 were placed on the left side of the thorax as high as the horizontal line of the highest point of the olecranon, of which locations are consequently above the left ventricle. As for the positions of the different electrodes in the presently described experiment, the positions of 1~3 and 7 are on the left ventricle as may be seen from chart 1, and 4~6 and 8~9 are toward the right ventricle. From the results, the lead points in this experiment are essentially the same as those of other investigators and at the same time those positions are variable to a great extent in recording the electrocardiogram with small displacements of the electrode. It is accordingly necessary to select a precise location in order to avoid any serious error.

The configurations of the P waves almost always showed the triphasic or diphasic wave. The positive waves in P_1 and P_2, the negative waves in P_7~P_9 and the negative and positive waves in P_3~P_6 were observed respectively. Considering these facts, it appears that the directions of conduction in auricle were the same as those reported by UEDA et al. and KUSACHI. The type of QRS complex is generally influenced by the position of the different electrodes. UEDA et al. reported that the QRS deflection shows upward on the basic portion of the left and right ventricles. On the contrary, at the apex of the ventricle the deflection indicates downward; furthermore, on the middle portion of the left ventricle the QRS complex traced large R and S deflections. LANNEK and RUTQVIST reported that the QRS complex shows downward deflection on the left ventricle, but on the right side the QRS complex traced the positive R deflection and the large S wave appeared. Comparing the presently obtained type of QRS complex with their results, the form of the QRS on the base of the ventricles are similar to that of UEDA et al. The opposite relation may be found on the apex of the ventricle, namely, the present results show positive R deflections. It is considered that this difference is due to the changes of positions of the different electrodes. The general configuration of the T wave is characterized by 2 types; they are negative and diphasic (± type) waves. UEDA et al. stated that the most of the subjects indicated negative monophasic waves, therefore they maintained that, when some abnormality of the ventricular muscle is present, the T wave always shows the positive monophasic or diphasic wave. KUSACHI reported that the T wave mostly indicates the diphasic waves in semidirect unipolar lead. It is considered that the form of the T wave shows the negative and diphasic waves (± type) in the horse electrocardiogram using the semi-unipolar chest lead.

The amplitudes of the waves in each lead could not be compared with others' reports because of the change in position of the electrodes as has been recorded by each worker. As for the durations and intervals of the waves, the present recordings were almost the same as those of UEDA et al., consequently they may be useful in investigations of electrocardiogram.

SUMMARY

Studies were made on the electrocardiogram of the semi-unipolar chest lead in which the anus was selected for the position of the indifferent electrode in the normal horse as a part of the authors' project of electrocardiographic studies. The results obtained are summarized as follows:

1. Concerning the position of the indifferent electrode, the authors considered that the anus is the suitable position, for the clinical application, when the semi-unipolar chest lead is used.

2. The different electrode positions on the region near the heart must be chosen at least on the left and right sides.

3. Intricate positive or negative diphasic and triphasic waves were found mostly in the P wave. The appearance of this intricate type is usually recognized in the normal horse electrocardiogram using the semi-unipolar lead.

4. Most of the PQ (PR) segments showed descending and isoelectric curves.

5. The Q wave was generally observed in each lead.

6. The variation of the QRS complex being caused by the positional changes of the different electrode is as follows: On the position 2 the wave showed the negative deflection or diphasic; on the positions 3 and 4 the QRS complex takes the form of the positive wave with high amplitude; on the positions 5 and 6 the upward deflection was observed.

7. The S wave was found in the $CA_1 \sim CA_3$, CA_8 and CA_9. The other leads almost always showed the arc curved S.

8. Diphasic wave with negative deflection after positive and negative monophasic waves was mostly observed in T wave.

9. The position which indicated the highest amplitude and the measurement values in each wave are as follows: That is, 0.36 mv in P_1 and -0.32 mv in P_6, -1.72 mv in Q_2, 1.37 mv in R_6, -1.112 mv in S_2 and 1.44 mv in T_7^1 with -0.22 mv in T_7^2.

10. The values of the durations and intervals approach closely to the results

listed in the report of UEDA et al.

11. It is suggested that the semi-unipolar chest lead herein described may be of value for clinical application in diagnosing heart disorders.

CONSIDERATIONS FOR THE CLINICAL USE OF LEAD METHOD IN THE HORSE

As described in this series of 3 papers, the authors experimented with several lead methods in connection with the recording of the horse electrocardiogram. The clinical value of the several lead methods may be commented upon as follows.

Depending upon the experiment, the limb lead may not be suitable for the clinical use in the horse because the variation of the electrical changes of the heart is not completly traced. In the bipolar chest leads I and II, the angles of the direction of the electric motive forces of the heart indicated the parallel direction against the plane of those leads. Therefore, the variation of the electrical changes of the heart was apparently registered on the electrocardiogram. The authors considered that the bipolar chest leads I and II may be applicable for daily clinic as KUSACHI has already reported. The semi-unipolar chest lead, for the clinical as well as for the experimental purposes, should be employed alone for the elucidation of the heart functions. So, the electrocardiogram of the semi-unipolar chest lead may be useful for diagnosing the damaged region in the heart disorder, whereas in the bipolar chest lead those damages may not be discovered definitely. For the above described reasons, it may be considered that, for the purpose of the daily clinical diagnosis of the heart disorder, the use of the bipolar chest leads I and II together with semi-unipolar chest lead are valuable.

The authors would like to express their gratitude to Prof. K. HONMA and Assist. Prof. R. KUSACHI (Laboratory of Veterinary Physiology of Hokkaido University) for their kind advice. This study is indebted also to the Department of Education for a subsidy. Thanks are extended to the authorities concerned.

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