STUDIES ON APPLICATIONS OF ELECTROCARDIOGRAM IN HORSES

II. THE LEAD METHOD AND ELECTROCARDIOGRAM WITH SPECIAL REFERENCE TO CONFIGURATIONS AND MEASUREMENTS OF WAVES IN TWO BIPOLAR CHEST LEADS

Ryoichi NAKAMURA, Kimehiko TOO and Akira MATSUHASHI

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

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INTRODUCTION

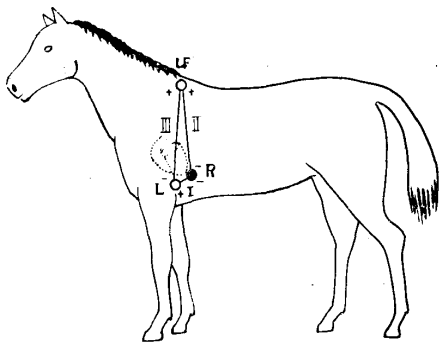
For the purpose of applying the electrocardiogram for the diagnosis of cardiac disorders in the horse, the authors have made electrocardiographic studies on the horse using several lead methods. In the previous paper[8], the authors described the results of their first study on the electrocardiogram of normal horses using the limb lead of which the electrodes were placed on the olecranons and the left pattelae. In an attempt to obtain additional information following that study, the authors conducted investigations using 2 types of bipolar chest lead. In such a lead, the electrodes were placed in 3 different positions on the skin of the frontal parts of the body.

There have been a few reports[3,4,5,9~12] publised on the horse electrocardiogram traced with the so-called bipolar chest lead, however, no lead method has yet been recommended as definitely superior. So, the values of the configurations and measurements of the waves in the bipolar chest lead are not evident. In the present paper, as a part of the undertaking, the results obtained with 2 bipolar chest leads are described.

MATERIALS AND METHODS

Ten horses were used for the experiments. They were pure bred or mongrel Percheron, 2~14 years old, including well nourished male, female and gelding. Their body temperature was 37.5°~38.5°C and cardiac functions were almost normal in auscultation. No hematological or pathological changes were found. Therefore, they were all regarded as entirely healthy. The equipment of the test room, the electrocardiograph and the electrodes used for the experiment were the same as those of the first experiment[8]. The method of measurements and the diacritical marks of the waves were also the same as in the first

CHART 1. *Lead Method of the Bipolar Chest Lead I*

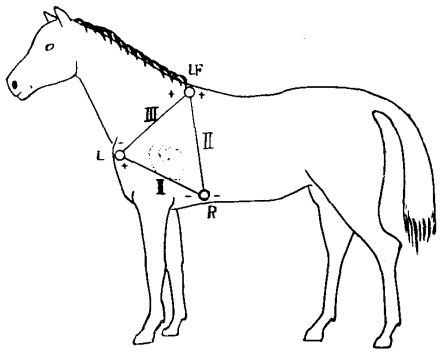


study.

In the experiment with bipolar chest lead I (hereafter abbreviated as the B. C. I), as was shown in chart 1, 3 points were selected on the skin of a standing horse for connecting the electrodes. The electrodes in lead I were placed on the skin of the left and right olecranons respectively. In lead II, the apexes of the withers and right olecranon were selected as connecting positions. In lead III, the apexes of the withers and left olecranon were connected by the electrodes. The wires were connected with the electrocardiograph so as to record the waves as an upward deflection under the following 3 conditions: (1) when the electric potential of the right olecranon shows relatively more negative than 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 more negative than that of the withers.

In the experiment with the bipolar chest lead II (hereafter abbreviated as the B. C. II), as indicated in chart 2, the electrode in lead I was connected with the left shoulder blade and the region of the apex of the 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 position. In lead III, points on the left shoulder blade and withers were connected with electrodes. The cables were connected with the electrocardiograph so as to record the waves as an upward deflection in the following conditions — the test must be conducted respectively under these condition: (1) when the electric potential of the region of the apex of the heart on the left side shows relatively more negative than that of the withers; (2) when the electric potential of the region of the apex of the heart on the left side is relatively more negative than that of the left shoulder blade; (3) when the electric potential of the left shoulder blade is more negative than that of the withers.

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



The waves obtained from the 2 lead methods were all measured in the same manner as that described in the first report.

Results

1. Results of the B. C. I Tests

(1) The Configurations of the Electrocardiograms

The classification of the waves obtained from the B. C. I in 10 horses is summarized in table 1. The findings were compared with the classification system described in the previous paper. Typical electrocardiograms are shown in plate I (Figs. 1~3).

TABLE 1. *Classifications of the Waves of the Bipolar Chest Lead I*

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

Note: * ··· Negative waves.

The P wave: The most important findings in the P waves are as follows. Type IV was found in 70% in P_I, and type VI was observed in 50 and 60% in P_{II} and P_{III} res-

pectively. Each of leads II and III in type II traced the negative wave.

The PQ segment: In each lead, type III which indicated the isoelectric curve was found in 70~80%.

The Q wave: The Q waves were found in 10% of the cases in lead I and 100% in leads II and III.

The R wave: In the classification of the R waves, type I was observed in 70% in R_I and 100% in R_{II} and R_{III}. One case of lead I showed the negative wave. Types IV and V were found in 10 and 20% respectively in only R_I.

The S wave: Type I in the S waves was observed in 30% in S_I, but leads II and III had no S wave. On the contrary, type II was found in both leads II and III and in 70% in lead I.

The beginning point of the S wave: The recordings obtained from each lead curve which do not have deflections in the S waves may be classified into 2 types, namely, I and III. In the present experiment, 50% in lead I, 90% in lead II and 70% in lead III all corresponded to type III, and other cases showed type I.

The arc-curved S: The arc-curved S which has no deflection in the S waves was classified into 2 types, namely, I and III. In this respect, 50% in lead I, 100% in lead II and 90% in lead III showed type III, and other cases of leads I and III indicated type I.

The QRS complex: Occurrences of this configuration were classified into 6 types, namely, IV, VI, VII, IX, X and XIV. Type IX was found in 90% in lead II and 60% in lead III, however, other types were observed in 10~40% or never in each lead.

The RS-T segment: The RS-T segments were classified into 3 types, I~III. In the RS-T_I, type II having the descending curve was observed in 80%. However, type III showing the isoelectric curve was found in 70 and 50% in RS-T_{II} and RS-T_{III} respectively. While 20~50% showed type I as the ascending curves in RS-T_{II} and RS-T_{III}.

The T wave: The T waves were classified into 4 types. Leading findings are as follows: type II which indicated the monophasic negative wave was found in 80 and 70% in T_I and T_{II} respectively; type I corresponding to the monophasic positive wave was observed in 60% in T_{III}. However, no types I and III in T_I nor type IV in T_{II} and T_{III} were recorded.

(2) Measurements of the Waves

Table 2 provides a tabulation of data of the amplitudes based on the calculations of the maximum, minimum and mean values of each wave. In addition, table 3 presents the results of the measurements of the intervals and durations for each wave in lead II. The records of 0.198 mv in P_I, 0.129 mv in P_{II} and 0.192 mv in P_{III} were given, while in Q_I, Q_{II} and Q_{III}, they were 0.05 mv, 0.13 and 0.31 mv respectively. Nine cases out of 10 R_I indicated positive deflections which measured 0.505 mv, but 1 case having negative deflection was -0.30 mv. R_{II} and R_{III} indicated all positive deflections which were measured as having values of 2.10 and 1.21 mv respectively. In the S waves, only S_I indicated 0.651 mv. Further, as to the T waves in each lead, they were found as diphasic deflections. So, they were named T^1 for the first deflection and T^2 for the second. Under this classification, recordings were made of -0.597 and 0.099 mv in T_I and 0.25 mv, -0.34 and -0.08 mv in T_{II}, further in T_{III}, 0.602 mv, 0.505 and -0.293 mv, respectively. On the other hand, the durations of the

TABLE 2. *Amplitudes of P, Q, R, S & T Waves of the Bipolar Chest Lead I (mv)*

WAVES	LEADS		MINIMUM	MAXIMUM	AVERAGE	CALCULATED NUMBERS
P	I		0.086	0.300	0.198	10
	II		0.062	0.180	0.129	10
	III		0.100	0.500	0.192	10
Q	I				0.050	1
	II		0.055	0.930	0.130	10
	III		0.130	0.512	0.310	9
R	I	(+)	0.150	1.150	0.505	9
		(−)			0.300	1
	II	(+)	0.105	3.230	2.100	10
	III	(−)	0.750	2.590	1.210	10
S			0.450	0.750	0.651	3
T	I	T^1 (−)	0.111	1.290	0.597	10
		T^2 (+)	0.086	0.111	0.099	3
	II	T^1 (+)	0.183	0.320	0.250	2
		T^1 (−)	0.210	0.575	0.340	8
		T^2 (−)			0.080	1
	III	T^1 (+)	0.240	0.900	0.602	8
		T^1 (−)	0.443	0.649	0.505	2
		T^2 (−)	0.118	0.500	0.293	3

TABLE 3. *Durations of P, QRS & T Waves and Intervals of PQ (PR), RS-T, QT & PP of the Bipolar Chest Lead I (Second)*

LEAD	WAVES	MINIMUM	MAXIMUM	AVERAGE
II	P	0.140	0.200	0.17
	QRS	0.125	0.170	0.15
	T	0.100	0.200	0.15
	PQ (PR)	0.260	0.390	0.31
	RS-T	0.150	0.275	0.23
	QT	0.475	0.630	0.51
	PP (RR)	1.020	1.850	1.56

P waves averaged 0.17 (0.14~0.20) sec., and that of QRS was 0.15 (0.125~0.17) sec.; further in T, 0.15 (0.10~0.20) sec. was noted. Concerning the intervals, 0.31 (0.26~0.39) sec. in PQ (PR), 0.23 (0.15~0.275) sec. in RS-T and 0.51 (0.475~0.63) sec. in QT and 1.56 (1.02~1.85) sec. in PP were measured respectively.

2. Results of the B. C. II Tests

(1) The Configurations of the Electrocardiograms

The configurations of the electrocardiograms in the B. C. II were studied and classified

in the same manner as in the B.C.I. The classifications of the waves are shown in table 4: Characteristic electrocardiograms are reproduced in plate II (Figs. 4~6).

TABLE 4. *Classifications of the Waves of the Bipolar Chest Lead II*

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

The P wave: Six types were observed of the P waves. Leading findings in each lead were type VI. The appearances of type VI were 40% in P_I, 70% in P_{II} and 60% in P_{III}. Other types were 10~30% or zero.

The PQ segment: The PQ segments may be classified into 4 types. Type III presenting the isoelectric curve was most frequently observed in each lead.

The Q wave: The Q waves were classified into 2 types. Type I was observed in 70%

in Q_I, 80% in Q_{II} and 90% in Q_{III}, however, type II showed 10~30%.

The R wave: The positive deflections found in all cases of R_I and R_{II} corresponded to type I. In R_{III}, 50% indicated type I, however, no R deflections were found in the other cases. They were included within the Q or S waves (also spoken of as QS type).

The S wave: Type I was observed in 30% only in S_{III}. But type II was found in 100% in leads II and III and 70% in lead III.

The beginning point of the S wave: On the classification findings, as shown in table 4, no extraordinary variations were marked in the beginning point of the S waves.

The arc-curved S: The arc-curved S was classified into 2 types, called I and II. Both types were observed almost half and half in each lead.

The QRS complex: The results of the classifications of the QRS complex are set out in table 4. In each lead, there were found from 4 to 5 types of waves respectively.

The RS-T segment: The RS-T segments were classified into 4 types, named I, III, IV and V. The leading form in each lead is as follows: 80 and 60% of type I in RS-T_I and RS-T_{II} were found; 80% of type III was observed in RS-T_{III}. Type IV in RS-T_I and RS-T_{II} and type V in RS-T_{III} were not recorded.

The T wave: In the T waves, 4 types, I~IV, were observed. The diphasic wave of type III was indicated in 70 and 80% in T_I and T_{II}, but 90% in T_{III} corresponded to the monophasic negative wave of type I.

(2) Measurements of the Waves

The results obtained from the measurements of the amplitudes, durations and intervals in each lead wave are recorded in tables 5 and 6.

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

WAVES	LEADS			MINIMUM	MAXIMUM	AVERAGE	CALCULATED NUMBERS
P	I			0.13	0.38	0.240	10
	II			0.08	0.31	0.180	10
	III			0.04	0.21	0.090	10
Q	I			0.05	0.18	0.130	7
	II			0.06	0.20	0.140	8
	III			0.02	0.61	0.290	9
R	I			0.68	2.22	1.030	10
	II			0.42	2.18	1.210	10
	III			0.07	0.23	0.210	4
S	III			0.02	0.92	0.340	3
T	I	T^1	(+)	0.08	0.67	0.350	7
			(−)	0.20	0.30	0.260	3
		T^2	(+)	0.05	0.20	0.125	2
			(−)	0.20	0.48	0.310	8
	II	T^1	(+)	0.10	3.33	0.680	10
		T^2	(−)	0.04	1.83	0.330	10
	III	T^1	(+)	0.12	0 32	0.180	7
			(−)	0.01	0·10	0.050	3
		T^2	(−)	0.14	0·30	0.220	3

TABLE 6. *Durations of P, QRS & T Waves and Intervals of PQ (PR), RS-T, QT & PP (RR) of the Bipolar Chest Lead II (Second)*

LEAD	WAVES	MINIMUM	MAXIMUM	AVERAGE
II	P	0.120	0.170	0.130
	QRS	0.100	0.175	0.103
	T	0.150	0.230	0.180
	PQ (PR)	0.290	0.450	0.330
	RS-T	0.145	0.310	0.220
	QT	0.480	0.560	0.520
	PP (RR)	1.230	2.010	1.030

The mean values of the amplitudes are as follows; recordings of 0.24 mv in P_I, 0.18 mv in P_{II} and 0.09 mv in P_{III} were obtained, and in Q_I,Q_{II} and Q_{III}, they were 0.13 mv, 0.14 and 0.29 mv respectively. R_I and R_{II} indicated all positive deflections which were measured as 1.03 and 1.21 mv respectively. In R_{III}, 4 cases out of 5 were 0.12 mv but 1 case could not be measured because the wave was so small. In the S waves, the amplitudes were observed only in S_{III}, where the average value was 0.34 mv. In the T waves, there were found diphasic deflections. So, they were named T^1 for the first deflection and T^2 for the second as in the B.C.I. In this classification, 0.35 mv, −0.26 mv in T^1_I, and 0.125 mv, 0.31 mv in T^2_I were recorded. In T_{II}, 0.68 and −0.33 mv were measured. Further in T_{III}, 0.18 mv −0.05 and 0.22 mv were noted. The durations of the P waves were averaged at 0.13 (0.12~0.17) sec., those of QRS were 0.103 (0.10~0.175) sec., further in T, 0.18 (0.15~0.23) sec. was noted. Concerning the intervals, 0.33 (0.29~0.45) sec. in PQ, 0.22 (0.145~0.31) sec. in RS-T, 0.52 (0.48 ~0.56) sec. in QT and 1.03 (1.23~2.01) sec. in PP were measured respectively.

DISCUSSION

The 2 lead methods described as above are for the bipolar chest lead placing the electrodes on the three points as it was shown in charts 1 and 2. Some workers[2,4,5,9~12] have reported about the bipolar chest lead in the horse. In comparison of the present results with those of them, D_9 and D_{10} which were demonstrated and named by YACOËL & SPITZ seem similar to leads II and III of the B. C. I. The other works all describe methods different from that of the present writers' in selection of the position for the connection of the electrode.

The relationship between the position of the connection of the electrode and influence upon the heart electric potential has been reported by HECHT. With regard to his work, it may be said, that in the B. C. I, the changes of the electric potential on the part of the left and right ventricles act upon the electrode placed on the left and right olecranons, and changes in that of the part of the endocardium have influence upon the electrode connecting the withers. Considering these facts,

the electrocardiogram in lead I indicates the difference between the changes of the electric potential in the left and right ventricles. The same judgment may be applied to leads II and III of the B. C. I; the traced electrocardiogram indicates the difference between the electric potential changes in ventricles and in the endocardium. Furthermore, in B. C. II, the same point will be considered; that is, the electrocardiogram traced in lead I indicates the difference between the changes of the electric potential in the left and right ventricles, and in leads II and III, it shows the difference between the changes in that of the ventricles and endocardium. Therefore, it may be suggested that, when a cardiac disorder occurs, electrocardiographic changes may be found in the waves in conformity with each lead.

As for the relationship between the configurations of the waves and the electrode positions in the experiment, the following indications were observed. When the electrodes in leads II and III of the B. C. I and in leads I and II of the B. C. II were placed parallel with the longitudinal axis of the heart, high amplitudes and unvarying curves were recorded. On the contrary, when the electrode positions in lead I of the B. C. I and in lead III of the B. C. II were made at a right angle with the longitudinal axis of the heart, the electrocardiograms showed small amplitudes and variable configurations.

The P waves usually took diphasic and triphasic forms as was also found in the limb lead reported in the previous paper. The PQ segments mostly showed isoelectric waves with values ranging among the normal interval values. Such finding means that the conductivity from the sinus node to the auriculoventricular node is normal. In the classification of the QRS complexes in the B. C. I and II, variations of the wave types more frequently occurred in the former than the latter. The S waves were found in lead I of the B. C. I and in lead III of the B. C. II. From these results, it seems that the S wave may be recorded by these leads of which the electrodes were made at a right angle to the longitudinal axis of the heart. The T waves were the monophasic negative in character in leads I and II of the B. C. I and diphasic in character in leads I and II of the B. C. II. It is considered that the types of these waves are not abnormal because their appearance was related to the electrode positions.

It is impossible to compare the present results regarding the amplitudes with those of the other investigators, because they used different positions for placing the electrodes. The calculations of the durations and intervals were almost the same as in the average values reported in the previous work and in works of other investigators. Consequently, the values obtained in the experiments may be a useful contribution to the investigation of the electrocardiogram.

SUMMARY

Studies were made on the electrocardiograms and calculations of the two types of the bipolar chest lead in the normal horses as a part of the authors' project of electrocardiographic studies. The results thus obtained may be summarized as follows:

1. The changes of the electric potential of the ventricles and those of the endocardium caused by cardiac disorders may be recorded on the electrocardiograms in the bipolar chest lead.

2. The electrocardiograms in leads II and III of the bipolar chest lead I and in leads I and II of the bipolar chest lead II were marked by high amplitudes and unvarying curves. On the contrary, in lead I of the bipolar chest lead I and in lead III of the bipolar chest lead II, the electrocardiograms showed small amplitudes and variable waves. It seems that these interesting facts may be caused by the relationship between the position of the electrodes and the anatomical heart axis.

3. Intricate diphasic and triphasic waves were found in 80~90% of the P waves. The appearance of this intricate type is usually recognized in the normal horse in the bipolar chest leads I and II.

4. Most of the PQ (PR) segments showed isoelectric waves.

5. Variation in the QRS complex in the bipolar chest leads I and II occurs more frequently in the former than in the latter.

6. The S wave was observed in 30% of S_I of the bipolar chest lead I and in S_{III} of the bipolar chest lead II respectively. The other cases almost always showed the arc-curved S.

7. The monophasic negative T wave was observed in 70~80% in T_I and T_{II} of the bipolar chest lead I. Diphasic waves were found in 70~80% in T_I and T_{II} of the bipolar chest lead II. Further, monophasic positive waves were usually observed in T_{III} of the bipolar chest leads I and II.

8. It is impossible to compare the values of the amplitudes obtained in the experiment with those of the other investigators', because their selection of the electrode positions differed from that in our method.

9. The mean values of the durations and intervals approach nearly to the results listed in the writers' previous report, and in those of DUKES & BATT and LANNEK & RUTQVIST.

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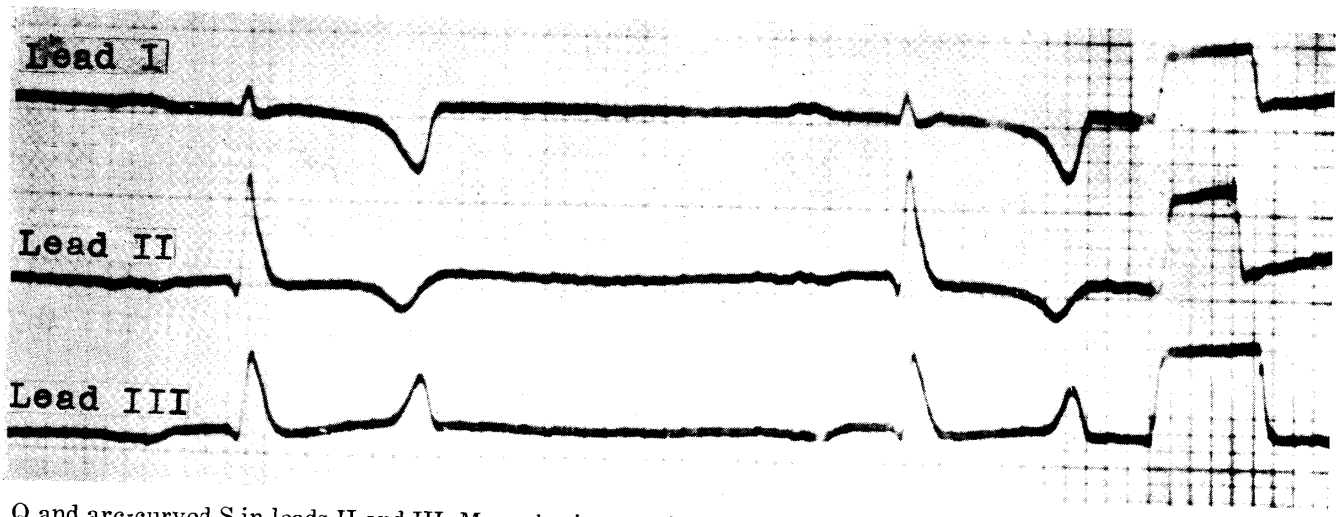
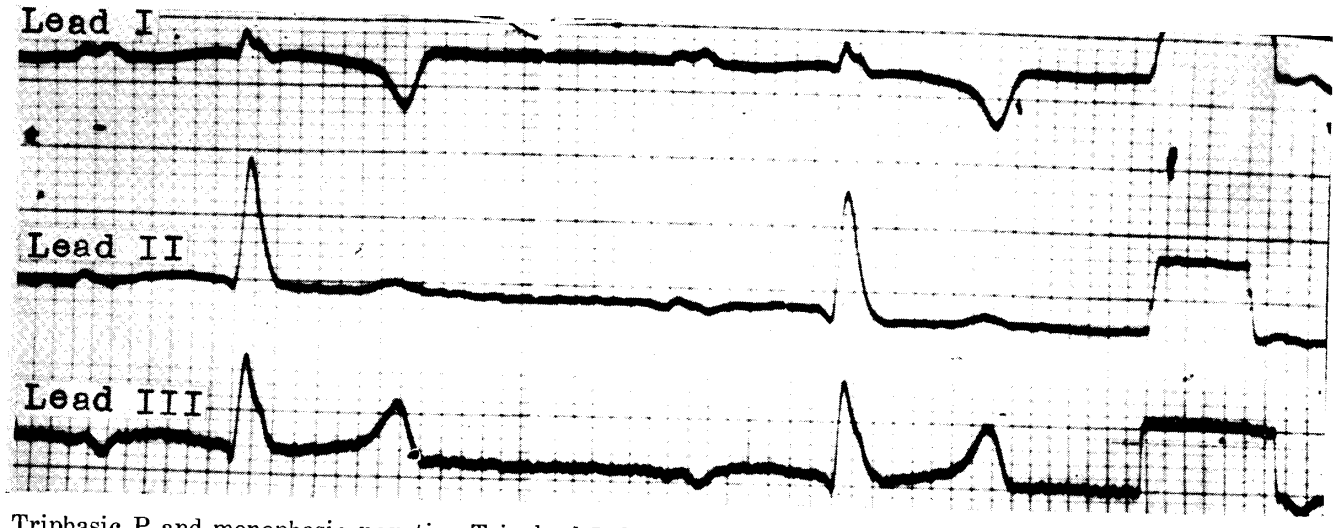
FIG. 1



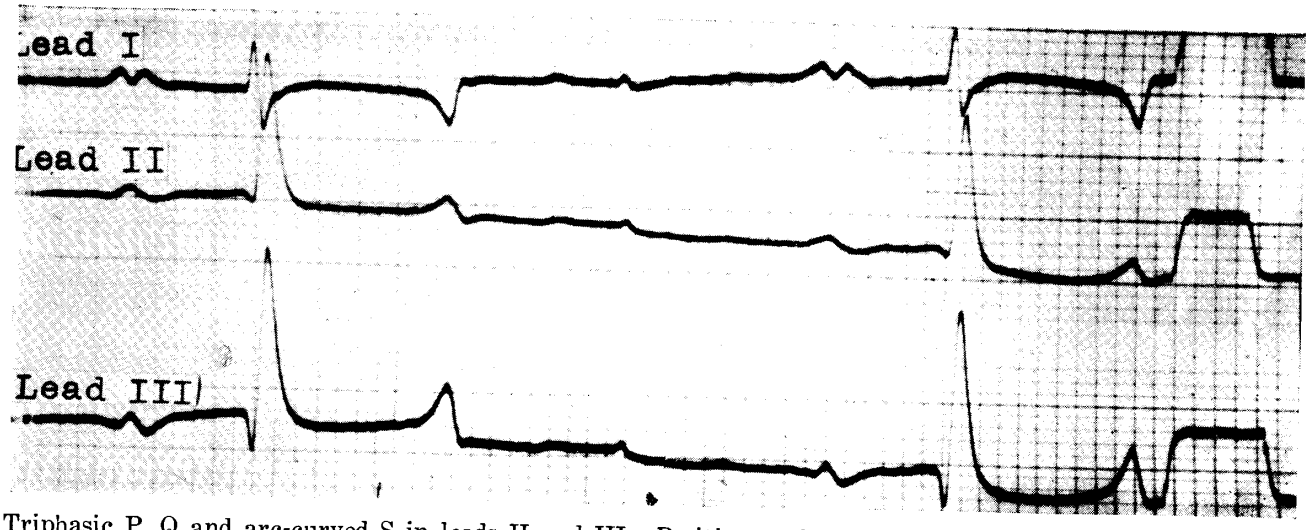
Q and arc-curved S in leads II and III. Monophasic negative T in leads I and II. Positive peaked R in each lead.

FIG. 2



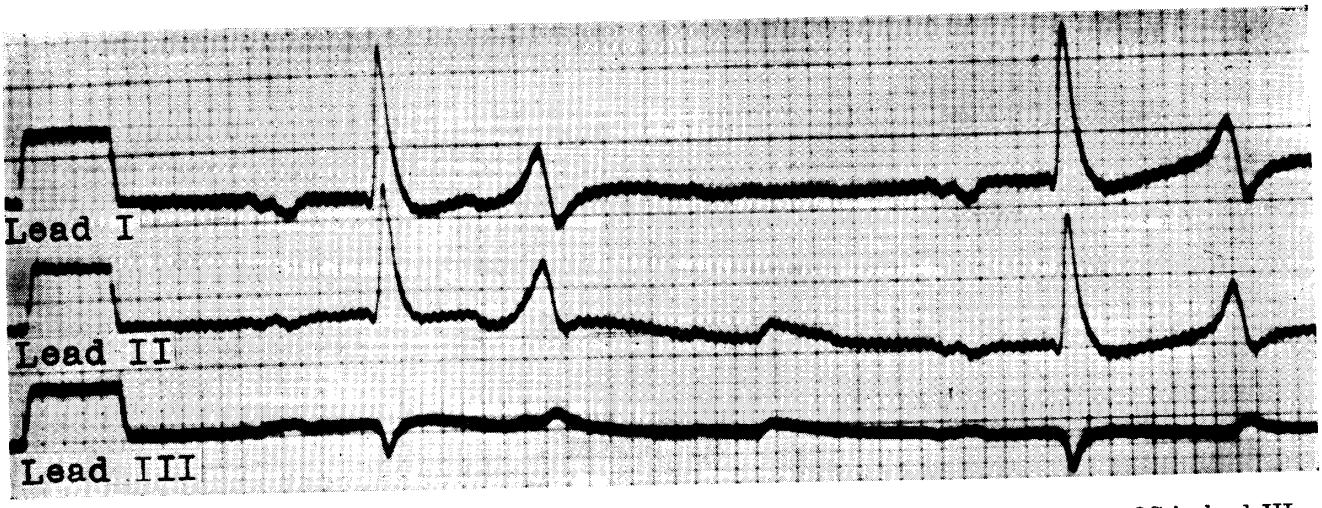
Triphasic P and monophasic negative T in lead I. Monophasic positive T in leads II and III.

FIG. 3



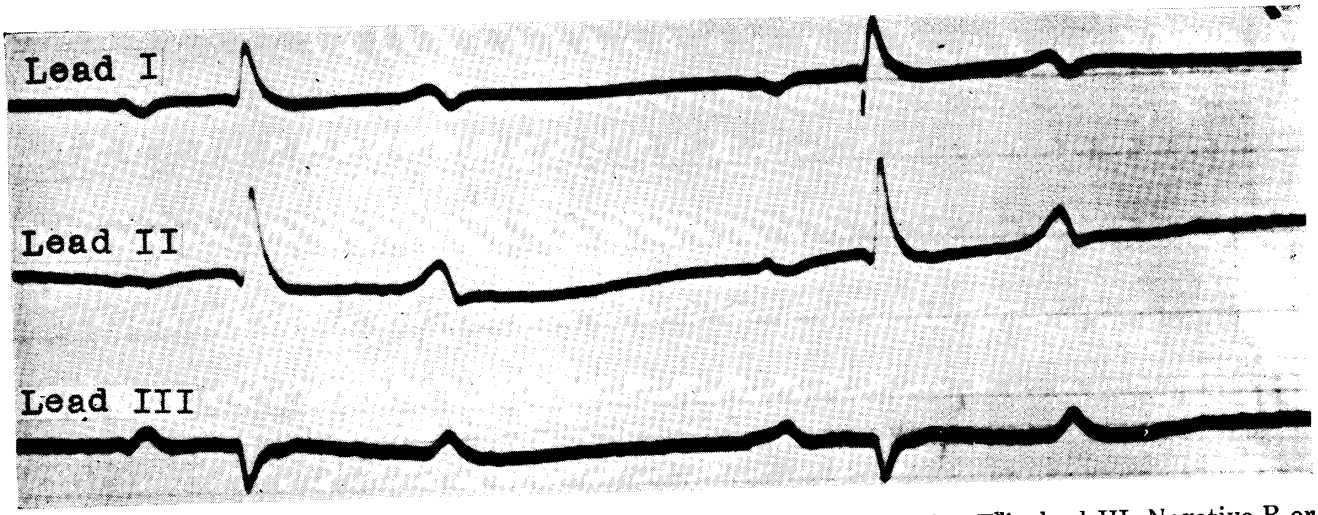
Triphasic P, Q and arc-curved S in leads II and III. Positive peaked R in each Lead. Large S in lead I.

FIG. 4



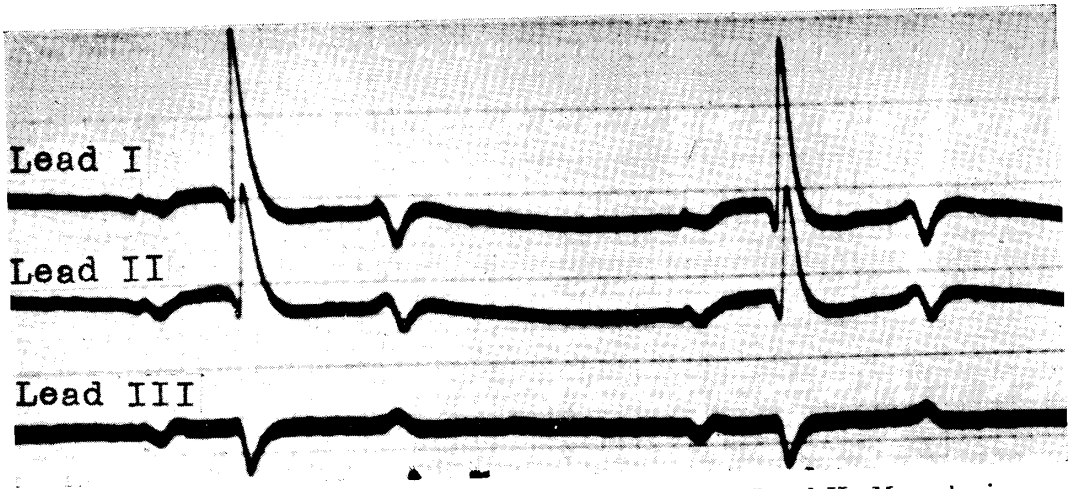
Triphasic P, Q and arc-curved S in leads I and II. Diphasic T in leads I and II. Negative R or QS in lead III.

FIG. 5



Peaked R, arc-curved S and Diphasic T in leads I and II. Monophasic positive T in lead III. Negative R or QS in lead III.

FIG. 6



Triphasic P, peaked R, arc-curved S and diphasic T in leads I and II. Monophasic positive T in lead III. Negative R or QS in lead III.

References

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