ADAPTATION OF RADIOTELEMETRY TO EQUESTRIAN GAMES AND HORSE RACING

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Obscurely diagnosed as cases of cardiac ailment, many race horses have been put out of commission or retired. This term of disease itself decides the fate of such animals. Furthermore, horses trained for a long time for equestrian games have been absent from competitions due to cardiac ailment or some unaccountable sort of fatigue. Such horses are considered to amount to not less than 10% of all the racing and gaming horses in Japan. The present method of auscultation and palpation has shown such high percentage of horses with cardiac disturbance, but if any more minute diagnostic method is employed, the number of ailing animals will be greater than hitherto reported. On the other hand, the adaptation of such minute diagnostic method will put to light animals which are in the initial stage of disorder, thus being of help in planning the fundamental daily training and exercise, and will greatly decrease the rate of attrition.

This is why introduction of electrocardiography (ECG) and other methods for the examination of cardiac function is deemed necessary.

The advantage of application of the presently employed radiotelemeter to these purpose should be clear from the statement above. The first trial product (1957) of the ECG telemeter was designed for the purpose of use in the basic study of kinetic physiology³⁾. Although its visual recording was somewhat unfaithful, the elimination of connecting wires between the subject and the recording equipment was considered to be successful. However, the reach of this equipment was barely 20 meters and even the aid of antenna, the equipment made it possible to carry out only limited experiments. In the trial product No. 2 (1959), a carrier of 20 Mc/s short wave was employed and secured a reach twice as long as that of the preceding product. However, as miniature electric tubes were used in it, several obstacles were experienced. It was effectively used only for recording in indoor tests, such as a treadmill exercise. While several problems were rising about the experimental apparatus, the aforementioned disturbances came in lime light as an important problem to be solved by this method. Then product No. 3 (1961) was devised for the major purpose of checking an electrocardiographic change in healthy and ailing animals in outdoor locomotion. With this equipment over forty human beings in indoor and outdoor exercise, as well as over fifty racing and riding horses, were monitored electrocardiographically while they were in exertion.

From the results obtained, the method of ECG telemetry seemed to be of practical use, except for the strenuous exertion test. This method is reported here for further criticism.

COMPOSITION AND ADAPTABILITY OF THE EQUIPMENT

Fig. 1 presents the block diagram of the radio transmitter and receiver of the author's test equipment, product No. 3. Two 22.5 volt dry cells used to supply power

Fig. 1. Diagram of FM Radioelectrocardiograph System of the Author's Trial Apparatus No. 3

The transmitter consists of all the elements from the subject to the transmitting antenna.

The receiver consists of all the elements from the receiving antenna to the system out put.

to the circuit of transmitter are self-contained. The transmitter is $16 \times 9 \times 3$ cm in size and approximately 600 g in weight, with a metallic case, batteries, and a 1-meter transmitting antenna. (Later, the equipment was improved into a two-channel transmitter. It was halved in size and weighed 250 g. Still it had two batteries, and a 30-cm antenna.)

The incoming signal, after being amplified, modifies a 4,000 c/s subcarrier signal, and further modulates a 27.2 Mc/s main carrier as radio frequency (RF) to the antenna. The adaptation of subcarrier modulation is for the aim of transmitting two or multiple signals in near future. The subcarrier is of frequency modulation principle. The incoming ultra frequency signal is accomplished by changing the base voltage by the astable-multivibrator. The oscillator and the modulator of high frequency signal generate and modify the main carrier of 13.6 Mc/s. The modulated signal is emitted after frequency multiplication and power amplification as RF signal with an approximate reach of 100 meters.

The receiver has an ability of receiving $27.12 \text{ Mc/s} \pm 20 \text{ Kc/s}$ RF signals, and a minimum field strength of about 10 db. The high frequency amplifier is employed to increase the selectivity and signal noise ratio (S/N). The mixer is equipped for production of 10.7 Mc/s intermediate frequency signal by mixing the 37.8 Mc/s high frequency produced by the local oscillator. The automatic frequency control (AFC) is used for control of local oscillation; the phase discriminator detects a frequency modulation (FM) component from a 10.7 Mc/s signal for pick up of $4,000 \text{ c/s}$ subcarrier signal; the amplitude limiter is employed to protect the detection of amplitude modulated signal from the discriminator. The squelch is employed to subside the noise when there is no input. The audiofrequency amplifier amplifies the modulated subcarrier. The band pass filter (BPF) is for separation of the subcarrier. The shaper is employed for the constant amplitude of subcarrier pulse width. The shaper is an integrating circuit for detection of the signal component in the pulse; amplification of output is conducted by the paraphase amplifier, which converts an unbalanced type signal to a balanced type. This receiver shows a frequency response of 0.5 to $1,000 \text{ c/s}$. When the input from the transmitter is 1 mV , it has a signal noise ratio of about 46 db. Furthermore, when a certain condition is maintained, it has a distortion percentage of less than 3%.

The received ECG signal is delivered by a lead cable plugged into the conventional ECG apparatus. The signal separated from the last-stage output circuit and amplified by the direct current amplifier is recorded simultaneously on the ink-writing oscillograph. The former signal is for detection of the ECG configuration distortion, and the latter for measurement of the heart rate and heart beat interval. It should be noted that when the critical level of the imbed batteries in the transmitter runs down, ECG distortion occurs, resulting in continuous operation for about 3 hours.

ELECTRODE

In order to pick up the cardiac action potential during muscular exertion, the electrode must imply with the surface motion of the skin. As the horse is an animal which sweats easily, the electrode must be secured in place by a reliable adhesive agent so that it will not be disengaged from the skin.

The electrode used is a round silver plate, 2 cm in diameter and about 0.3 mm in thickness. One of its sides is insulated with enamel. This is secured to the inside roof of a flanged rubber cap 2.5 cm in inside diameter and 1.0 cm in depth. The cup section acts as the electrode jelly reservoir. The adhesive agent is applied to the flange which adheres to the skin. The area to which the electrode is applied is shaven and washed thoroughly with ether or alcohol to ensure a minimum electric resistance of the skin. A small drop of electrode jelly is applied on and rubbed well into the skin area with the tip of a finger. The cup is filled with electric jelly and attached to the prepared area with an adhesive agent also applied to the skin. This method will ensure the electrode to be attached fairly securely, in resistance to the dermal motion and/or respiration and used for a sufficient long time.

The electrode applied to a human subject is similar in mode to that to a horse, but it is half the size of the latter.

SITE OF ELECTRODE FOR PICKING UP CARDIAC ACTION POTENTIALS, I. E., ECG SIGNALS IN MAN AND HORSES

Man: An exploring electrode is placed over the apex of the heart in the sixth

intercostal space and an other remote electrode over the manubrium of the sternum. The earth electrode is adhered to an almost middle point of the left flank at a level of the umbilicus. These sites are comparatively free of muscular interference at all times, except during vigorous exertion. The ECG tracing obtained from this bipolar chest lead has a configuration similar to that of the limb lead II (Fig. 2). The ECG signal received during exertion is recorded simultaneously with conventional electrocardiograph and ink-writing oscillograph.

Fig. 2. Comparison of ECG Configuration by Apex-Base Bipolar Chest Lead (1) and Standard Limb Lead ECG (2)

Horses: Judging from the distribution of ECG patterns on the surface of the body, the exploring electrode is placed over the apex of the heart, i.e., on the left chest side, 10 cm posterior to the olecranon, and the remote electrode at the base of the heart, i.e., the upper one quarter location of the middle longitudinal axis of the right scapula. The earth electrode is placed near the center of the lumbar region. The tracing derived from this bipolar chest lead easily discerns the variation of configuration of each deflection due to its high amplitude. In the case of horse exertion with a rider, the electrode placements are slightly modified; the exploring electrode is placed on the median line of the sternum at a point one-fifth to the posterior, and the remote electrode at the top of the spine of the fourth thoracic vertebra. When this bipolar lead is used, the P wave, QRS complex and T wave in the ECG show far more prominent amplitude than when any other lead is employed and the base line scarcely wanders.

HUMAN RADIOELECTROCARDIOGRAMS DURING EXERCISE

Materials and methods: The subjects used were five healthy men 23 to 35 years of age. ECGs were recorded at the supine, sitting, and standing position prior to exercise. They were monitored continuously in the mark time at walking, running and full-speed running pace; during walk, moderate running and vigorous running; during

passing hurdles one meter high at a run in the yard and track; and in the pre-exercise and post-exercise for a fixed period of time.

Results: (1) Mark time. The subjects were monitored continuously in the 2-minute standing position before exercise, during the 6-minute mark time, and in the standing position for 5 minutes in the post-exercise period. Before the exercise test was started, the subjects had been instructed to shake the arms alternatively, maintaining such quiet respiratory exercise as in ordinary walk.

Fig. 3 shows an example of the normal ECG recording obtained at 1-minute intervals during the practice of the above-graded task. As already cited, the ECG at rest recorded from this bipolar chest lead, like that from the limb lead II, had a positive P wave, a QRS complex of qRs type, and a positive T wave.

During exercise, the P-P interval became short and the T wave increased in height slightly, maintaining no indication of pathological changes in ECGs. There was no marked distortion of ECG tracing produced by shaking arm, stamping with the feet, twisting the upper half of the body, and/or breathing exercise nor wandering of the base-line from jarring movements of the radio transmitter. Technically satisfactory ECGs without noise interference were recorded in all the subjects throughout the period of exercise.

Fig. 4.
Human Radio ECGs
during Ordinary Walk
Shown at 1-Minute
Intervals

Fig. 3. Human Radio ECGs during
Mark Time Exercise Shown
at 1-Minute Intervals

The heart rate ranged from 70 to 90 in the standing repose and increased to about 120 during the mark time exercise. This increase occurred rapidly at the beginning of stamping exercise and a plateau was reached gradually within 30 to 60 seconds. Sometimes changes occurred in the pulse rate a little slowly and it took about 3 minutes to reach the plateau. The time required for the pulse rate to return to its pre-exercise value varied in a wide range from about 2 to 5 minutes after exercise, depending upon the condition of the individual.

(2) Ordinary walk. The subjects were requested to walk in a circle 15 meters in radius, keeping the same pitch as during the above-cited mark time. ECG signal were received 40 meters away from the location of exercise. Distortion of ECGs and/or external interference did not occur, as shown in Fig. 4.

Radiotelemetry of cardiac action potential was considered to be capable of detecting detailed changes in the ECG during such light exercise as mark time and walk.

(3) Mark time at running pace. The subjects were monitored continuously in the 2-minute erect standing repose, during the 5-minute stationary stamping at a run with full arm shaking and

Fig. 5. Human Radio ECGs during Running Mark Time Exercise Shown at 1-Minute Intervals

ment of the exercise, when a steady state was entered. After termination of the exercise the heart beat became uniform in a few minutes. In comparison with the heart rate before the exercise, it was about twenty in excess. It took approximately 15 minutes for the heart beat to come back to the value shown in the initial stage.

(4) Light running. At a distance of 30 to 40 meters away from the receiver, the subject was forced to run in a circle for 2 minutes at the same pace as in the case of stationary running mark time. In that case, essentially the same ECGs were depicted as in the latter. No configuration distortion nor noise mixture was noted. This result proves the adaptability of radio ECG to light running exercise (Fig. 6).

thigh lifting, in the 4-minute stationary standing repose, and in the 4-minute sitting position of rest thereafter (Fig. 5).

Upon commencement of the exercise, the P-P interval fluctuated irregularly. Then the interval shortened. The T and P wave became close together. In a short time the interval between the T and P wave disappeared.

Immediately after the commencement of the stationary standing rest, the P wave notched on to the descent recording of the T wave, in such a manner as in the case of sinus tachycardia. This change of the P-P interval returned promptly to the control level within a few minutes. During this exercise neither configuration distortion nor noise interference in the ECG was detected.

The heart rate was 70 to 75 before exercise. It increased to 140 to 180 about 3 minutes after commence-

Fig. 6. Human Radio ECGs during Running Exercise Shown at 1-Minute Intervals

Fig. 7. Human Radio ECGs during Full-Speed Running Mark Time Exercise Shown at 1-Minute Intervals

(5) Mark time at a full-speed running pace. A consecutive radio ECG was recorded after 2-minute standing repose, 2-minute high thigh lifting and vehement arm waving at stationary position, 6-minute standing repose, and 5-minute standing (Fig. 7).

The heart rate exhibited the first summit, 35 to 40 seconds after the commencement, a subsequent slight decrease, and an increase to produce a plateau. Otherwise, it gradually stabilized in about 3 minutes. It took, however, 15 minutes for the heart rate to recover to the value shown before commencement of the whole exercise. The maximum heart rate was 200 to 220 during this period.

At the commencement of the exercise, ECG tracing recorded noise and distorted configuration, which disappeared in a short while and made clear recording possible. With an increase in the heart rate, the P wave became close to the T wave, denoting of sinus tachycardia. Upon suspension of the exercise, the P and T waves were gradually separated from each other, an isoelectric level reappeared between the both and change of ECG shifted to the repose period.

(6) Full-speed running. In the same exercise yard as mentioned above, an obstacle 1 meter high was installed. The subjects were monitored while they were running as fast as possible in a circle, jumping over the obstacle. In each hurdling the ECG configuration distorted. Furthermore, the base line showed wavy wandering along with respiratory exercise. The whole ECG tracing, however, was recorded clearly enough to study the wave forms. Fig. 8 shows such type of ECG.

The goal of radio telemetering is to obtain ECG tracing with no noise nor distortion in the midst of full-speed running and/or vigorous muscular exertion. The present equipment cannot get away from the distortion of wave-recording at the start of running or during jumping over an obstacle. It is presumed that the disturbance in ECG tracing may be the result of muscle interference, alterations in the condition of the electrode and skin surface relations, and changes in the electric resistance of the skin.

Fig. 8. Human Radio ECGs Continuously Traced during Full-Speed Running with 1-Meter High Hurdle Jumping

Arrows pointing downwards show the time of hurdle jumping. Arrows pointing upwards show the start or stop of full-speed running.

RADIOELECTROCARDIOGRAMS OF RIDER AND HORSE DURING MUSCULAR EXERTION

Materials and methods: The subjects used for the experiment were 10 riders and 36 riding horses for equestrian game, including 17 horses which had run in the race course.

Experiments were conducted in a riding-ground, 30×70 meters in size, and part of a race course, 1,000 meters per round. The transmitter was put in a bag attached to the belt of the rider in both case of ECG tracing on riders and horses. The receiver was placed on the second-floor balcony of a building 30 meters away from the riding-ground. Signals received were listened in by a speaker contained in the receiver, and

recorded simultaneously by the conventional ECG apparatus and ink-writing oscillograph. The ECG apparatus was employed for operation of 30 seconds to a minute at each change of gait to check the ECG configuration. The oscillograph was operated throughout the required task for calculation of the heart rate and measurement of the heart beat interval.

Results: (1) Radio ECGs of the rider during exercise. In a square riding-ground, both ends of which were located 30 and 100 meters far away from the receiver respectively, the radio ECG tracing was conducted in such instances as ordinary dressage from walk to extended canter and jumping obstacles 1.0 and 1.4 meters high at a light canter. The length of exercise for the whole period was about 20 minutes.

Fig. 9. Rider's Radio ECGs during Riding Exercise and Practice of Various Gaits in Dressage

In riding trot and canter, the rider's body conducted a rather exaggerated performance. So that, from time to time the ECG configuration distorted. The ECG tracing, however, was generally accurate and clearly defined. As shown in Fig. 9, the rider's heart rate began to increase gradually when trot was commenced, and slight sinus tachycardia was manifested in the extended trot and ordinary canter. The heart rate became twice as high as the pre-exercise one. In canter, including jumps, there were intermixtures of muscular action potentials prior to take-off, also distortion arose in the configuration. Muscle interference occurred more frequently in the case of inexperienced riders.

When there was a shift to the action of take-off obstacle, the heart beat increased rapidly in many riders.

Besides, when a horse refused the obstacle, swerved or put up a defence, it was interesting to note that the heart beat showed actually a sudden increase. Horse riding was not considered to be so light a task for the rider as it looked from outside. The ECG tracing of the rider while riding could be more or less satisfactorily monitored by the method employed in this experiment.

(2) Radio ECGs of the horse in action. The ECG configuration derived from the bipolar chest lead attached to the apex and base of the heart has the following distinctive features: (a) the P wave is positive with one or two peaks, (b) the QRS complex is of rS type, and (c) the T wave is positive and either monophasic or diphasic.

Radio ECGs were recorded at a track 150 meters long during a 2-round walk, 3-round trot, 3-round canter, 3-round trot and 2-round walk, plus 5-minute repose prior to and after exercise.

Healthy horses in exercise showed such general variations in ECG as indicated in Fig. 10.

In the case of standing at rest, the ST segment appeared at the shoulder where the S wave shifted to the T, descending toward the spike-shaped T wave. At the commencement of exercise, this ST segment descending became horizontal. As the exercise continued,

it ascended to such extent that the shoulder part was transfigured to the ascending notch of the T wave. The amplitude of the T wave increased as the exercise was intensified, being above 1.5 mV at light canter. The amplitude of the T wave was about 0.6 mV at the time of repose. The potential amplitude and configuration of the P wave and QRS complex did not seem to vary.

The T to P interval corresponding to diastole of heart action gradually shortened. In strenuous exercise, the T and P wave closed in, till the P wave appeared like a notch in the T wave. Fig. 10 gives an example of actual ECG tracing. In this example the P-P interval at standing repose was 1.4 seconds, that is, the heart rate of which was about 10 more than that in the stall. The P wave had two peaks, the QRS complex was a rS type of 2-mV amplitude, ST segment possessed a prominent shoulder, and the T wave was monophasic. The interval between the T and P wave was not isoelectric, but slanted slightly. At the commencement of exercise, a mild agitation appeared in the base line, especially in the T to P position. This was considered to be the result of variation in location of the relative electrodes, which was accompanied the change in the body form during exercise. This agitation occurred concurrently with the strike-on and take-off of the foreleg. It was presumed that this variation could not avoided unless the placement of the electrodes was further investigated.

Moreover, there were occasions when noise entered the P-R, S-T, and/or T-P sections. The spike-like noise was a muscle action potential, while an irregular fluctuation noise appeared in the case where there was no contact between the electrodes and skin. The S and T wave amplitude being conspicuously large, there was practically no disturbance.

In trotting exercise, the T to P portion shortened to less than a half of that at repose, the shoulder of the ST segment was attached to the T wave, and the T wave amplitude was slightly enlarged.

In canter, the ST segment and the T-P interval were further shortened, and the T wave amplitude was extended to 1 mV. The shoulder of the ST segment became a notch in the T wave elevation.

In extended canter, the S wave moved smoothly into the T wave with no notch. The T wave amplitude increased to about 2 mV, without including variation in the S wave. The T and P wave became close to each other, but did not show such fusion as observed in sinus tachycardia. As the exercise slackened the T wave amplitude lessened, the shoulder of the ST segment via the notch in the T wave appeared with the extension of the T to P portion.

At the cessation of the exercise, the varied wave immediately returned to its original state, and only the shortening of the T to P portion remained, but this portion presently returned to the complete state of repose.

(3) ECG tracing at racing gallop. On a 100-meter stretch of a 1,000-meter race track, racing gallop was repeated twice to record a radio ECG, which is shown in Fig. 11. In the ECG of this subject horse, the P wave was of monopeak and low amplitude,

Fig. 10. Horse's Radio ECGs during Dressage and Presentation of Different Gaits in a Series of School Exercise

Fig. 11. Horse's Radio ECGs during Repetition Twice of 100-Meter Racing Gallop, Traced Continuously

Arrows pointing downwards show the start of racing gallop, and one pointing upwards indicates the cease. The arrow with SS shows the end of exercise.

the QRS complex of rS type, and the T wave diphasic. In Fig. 11, the ECG tracing of the upper two rows is for the first stretch gallop, and that of the next two rows for the second stretch gallop.

At the start of full gallop, pointed out by an arrow in the figure, considerable intermixing of muscular interferences and irregular noises was presented in the ECG tracing, the increased altitude of the T wave being only discernible. In such extreme exertion, the horse was forced again to run at racing gallop. Furthermore, the rider's aiding performance reached its maximum and caused an inevitable displacement of the attachment of the electrodes. It was the motive of this great distortion of the ECG configuration.

As racing gallop was gradually declined to canter and to trot, an intermixed electromyogram quickly retired and the wave shape became clear.

The heart beat increased remarkably right after suspension of the racing gallop, being 240 per minute, or 6 to 7 times as high as the normal value. In the ECG tracing of this exercise, the elevation of the ST segment and the increase in altitude of the T wave were conspicuous. The P wave was attached onto the descent of the T wave, as it was typical sinus tachycardia.

The major changes of ECG configuration in the case of exercise were the increase in amplitude of the T wave, elevation of the ST segment, narrow interval between the T and P waves, diffusion of these waves, and reversible variation.

DISCUSSION

There is no need to stress the importance of human ECG in the field of sports medicine, and that of ECG tracing in sporting and racing horses during action in the field of animal physiology. As ECG tracing in clinical cardiac examination is occasionally of importance, detailed research has been conducted separately on ECG configuration at rest, that is, at non-exercise load. The present experiment was conducted to contribute to the detection of any abnormality in ECG for clinical diagnosis. Such abnormality was supposed to be identified when ECG was traced on loaded occasions or under muscular exertion. It was expected that some improvement would be made in the physiological technique for the study of animal locomotion from the results of the present experiment.

The conventional electrocardiograph can be utilized for restricted recording of ECG on human mark time exercise, or on running in the same place on a treadmill. It is not applicable, however, to check sporting and racing horses, particularly those moving outdoors when there is a considerable distance between the object and the observer. This is an essential point which has been taken into consideration in the present study.

This is the motive of the research which the author has performed for several years to develop a wireless conveying method of the cardiac action potential.

As mentioned above, this trial apparatus is the third of its kind ever produced..

Since the first two apparatus were scarcely able to transmit the ECG configuration, but R deflection accurately, they were used to count and measure the heart beat intervals in physiological experiments on motion⁵⁻⁸⁾.

The transmitter of the third trial apparatus is a battery operated and all transistorized, with a metal case weighing 600 g. In order that the broadcast signal of ECG radio transmission may be less susceptible to external interference, it is of frequency modulation principle¹⁾.

The range of the radio signal is limited to 100 meters. The previously elaborated radio electrocardiographic detection, however, is applicable to clinical diagnosis and physiological experiments on free moving sporting and racing horses. It is desirable that the transmitter be smaller in size and lighter in weight.

In radio electrocardiography, there is very little interference of muscle action potential during light and moderate exercise. The distortion of ECG configuration caused by bodily motion is slight. Diagnostic detection, however, is not yet possible in healthy or ailing horses under strenuous exertion. In order to attach the electrodes firmly to the skin, the hair at the location must be shaved. However, it is necessary to devise any pickup method for attachment, without shaving the location, so that no damage may be made in the outward appearance of riding and racing horses.

Radiotelemetry can be used to trace any change in the ECG of a horse faithfully when the horse is stationary or in slow action. When there is some change in position, from standing to sitting or from one phase of action to another, intermixing of noise frequently occurs from an unknown cause, and probably gives rise to great variances in the ECG tracing, making the results unreliable. In order to remedy this, further studies are needed to improve the electrodes themselves and the location of attachment. For instance, the electrode should be placed at such a point as related least to defecation during action and to the deflection brought about by a strong amplitude. Even when such a point is discovered, it must not disturb saddling, the rider's legs or the riding technique at all.

Furthermore, for accurate ECG tracing in a horse, the time constant of 1-second is too short as it is in the amplifier of this apparatus. In the case of a horse, it is desirable to be at least 2 to 2.5 seconds, in which the bodily motion and respiratory exercise must cause the base line to wander considerably. This is also related to the improvement of the location of attachment of the electrodes.

Even in the case of conducting the ECG alone, multiple transmission of two or more is desirable. Actually, for the purpose of multiplying the signal transmission in trial apparatus No. 3, an incoming signal modulates the subcarrier, which further modulates the radio frequency of the main carrier.

The simultaneous pickup of physiological events will be considered necessary in both kinetic physiology and clinical diagnosis^{2, 4, 9-11)}. For instance, the multiple transmission of respiration, body temperature, and electrocardiogram, or the simultaneous transmission of muscular action potential from two or more different muscles associated with one joint will further add something to the knowledge obtained from radiotelemetric exercise.

SUMMARY

A radiotelemeter was produced tentatively for electrocardiography (ECG). Its constitution was outlined. Experiments were conducted to make its actual adaptation possible by demonstrating its utility. The results obtained are summarized as follows.

1) The radio transmitter is a portable device, battery-operated and all transistorized. The signal is broadcast by frequency modulation on a 27.2 Mc/s signal carrier with a reach of approximately 100 meters. The receiver is of super heterodyne system, relaying the ECG signal simultaneously to a conventional electrocardiograph and to an ink-writing oscillograph.

2) The electrode is a silver plate attached to a rubber cap. It is adhered to the skin with an adhesive agent with precaution not to be dislocated by perspiration.

3) This apparatus was used to monitor human subjects in mark time, ordinary walk, stationary running action, actual fast running and hurdling, horses and riders on horseback in exercise, and horses with riders in various gaits. It gave technically satisfactory ECGs at all times, except in strenuous exertion. This apparatus was considered to be of use in functional investigation of cardiac activity, clinical diagnosis of cardiac ailment, and physiological study of locomotion.

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馬術競技および競馬におけるラジオ・テレメーターの応用

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著者が試作した心電図用ラジオ・テレメーターの構成の概要を説明し、実地の応用例をかかげて、その性能を証明した。

1. 送信器は電池式、オール・トランジスタ、携帯用である。送信は周波数変換方式、22.5 Mc/s の主搬送波を使用している。到達距離は約 100 m である。

受信器はスーパー・ヘテロダイン方式、記録は市販心電計とインク書きオッシログラフで同時におこなう。

2. 電極はゴム・キャップ内に装着した銀板で、皮膚に生ゴム・セメダインで固定し、発汗による脱落をさけるように工夫してある。

3. この装置を用いて、人、馬などの運動（足ふみ、かけ足、ハードル飛越における人、馬場運動における騎手と馬、競走駈歩における馬）中の心電図を記録した。

極めて激しい運動のほか、この装置は実用に供するという結果をえた。